Science Magazine for Students and Parents

OYLA AUSTRALIA

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12+

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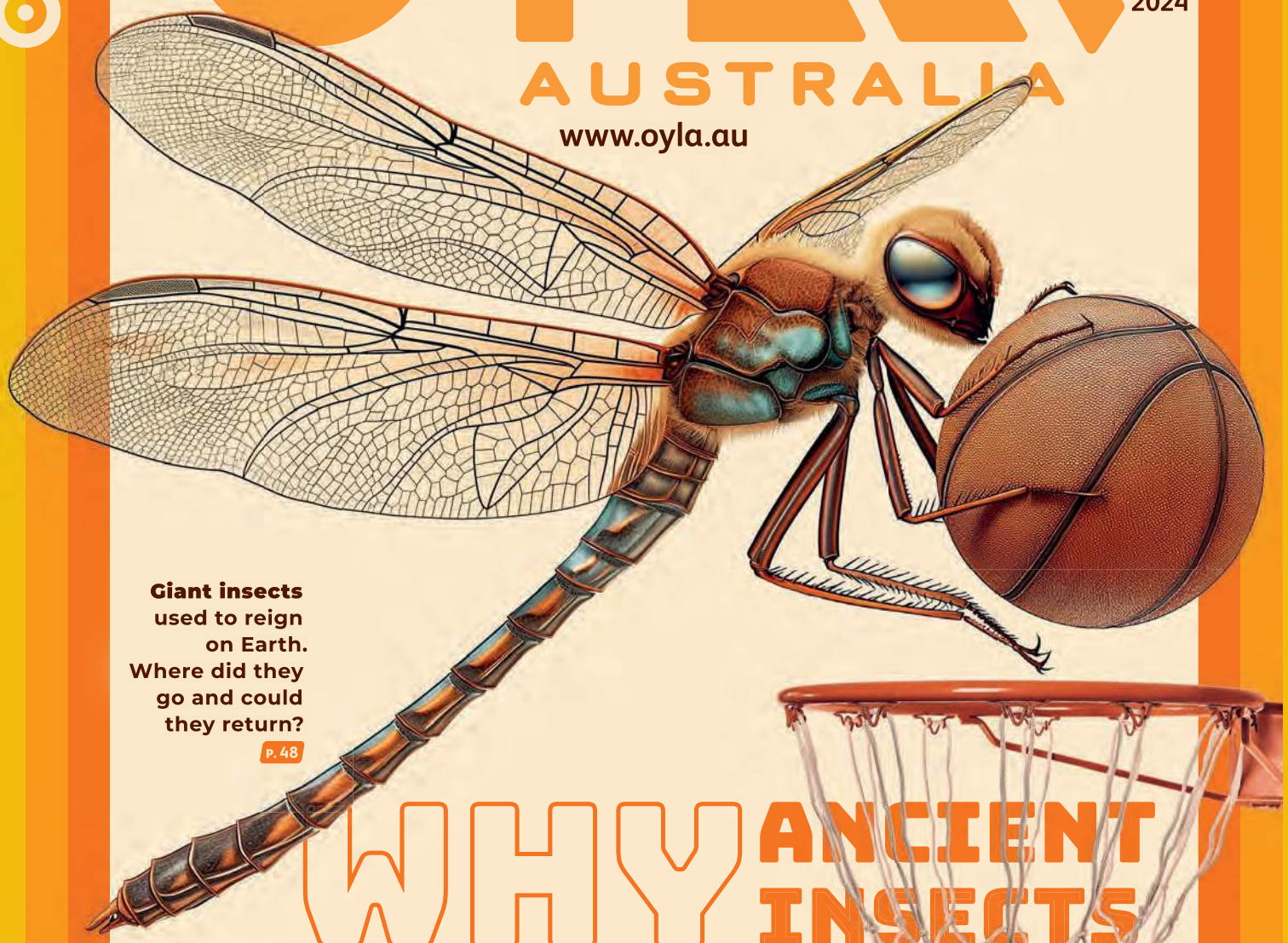
JUNE
2024



Giant insects used to reign on Earth. Where did they go and could they return?

P. 48

WHY ANCIENT INSECTS WERE SO BIG

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OYLA is a monthly popular science magazine for students (12+), as well as their parents. The focus of the magazine is based on the **STEM** (Science, Technology, Engineering, and Mathematics) concepts.

We break down **complicated topics** into **simple language** and supplement it with **informative graphics**. This makes OYLA magazine accessible to young readers.

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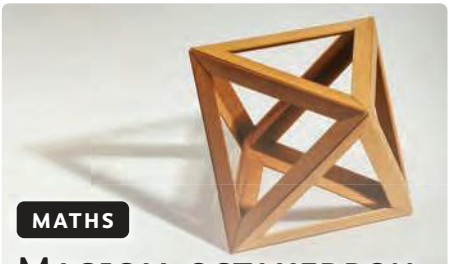

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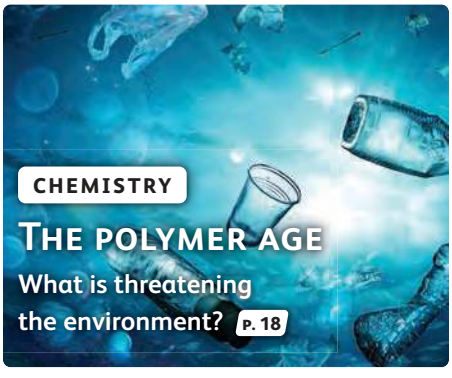

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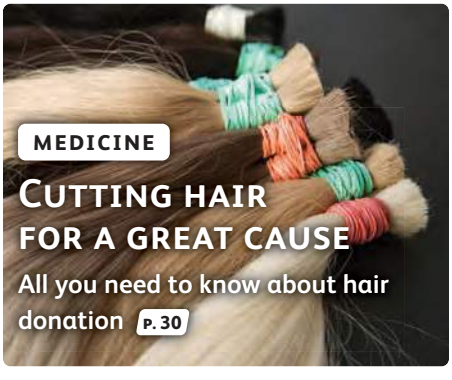

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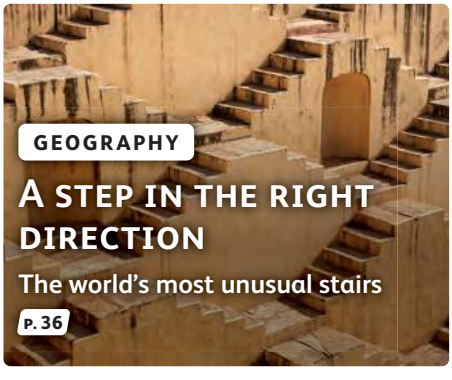

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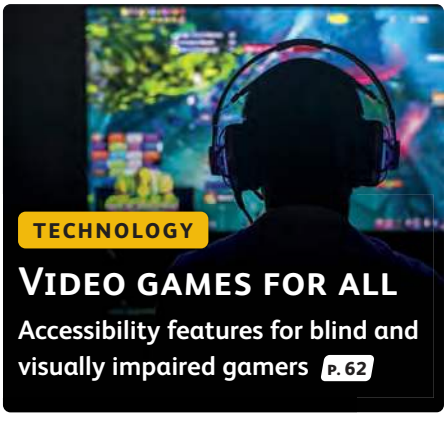

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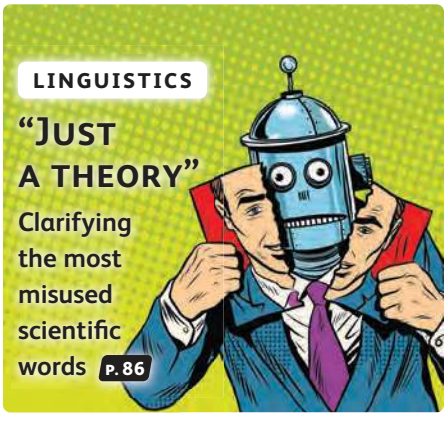

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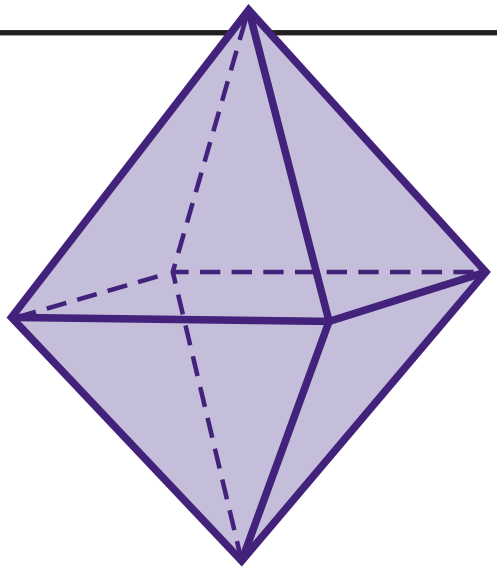
MAGIC TRICKS WITH AN OCTAHEDRON

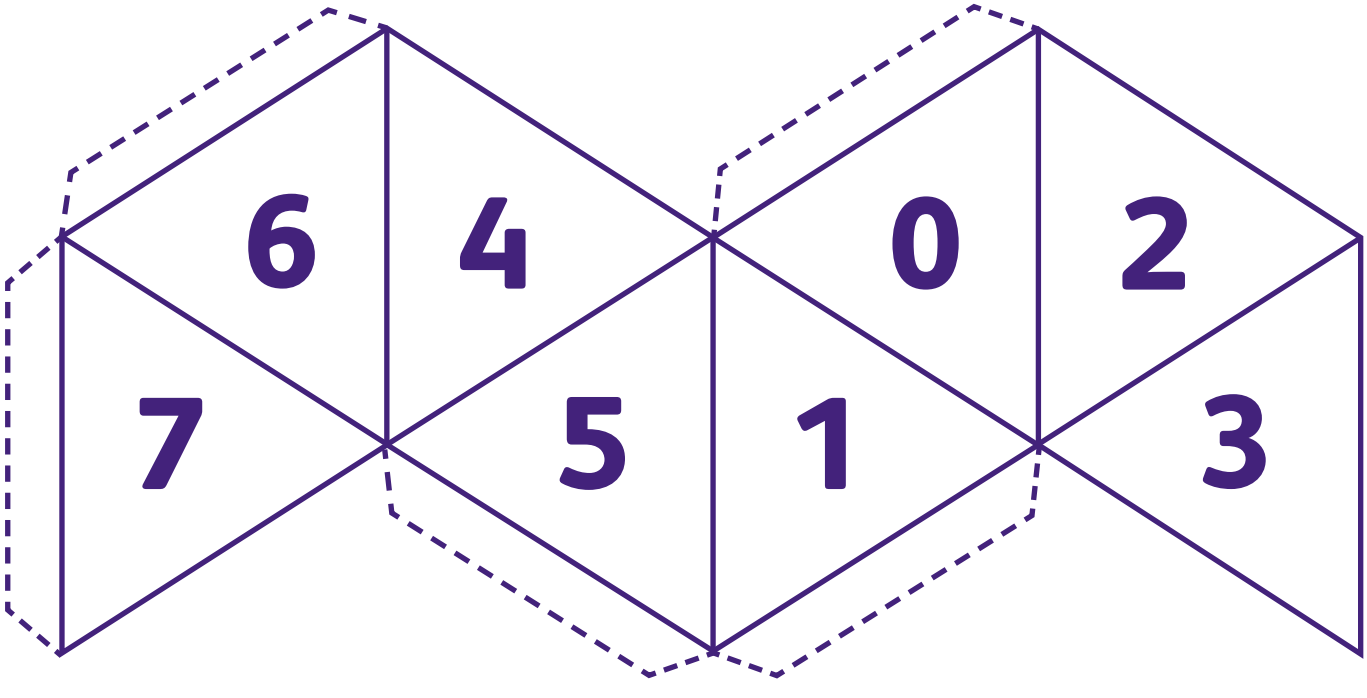
Want to surprise your friends with a spectacular trick? If so, then this article is for you!



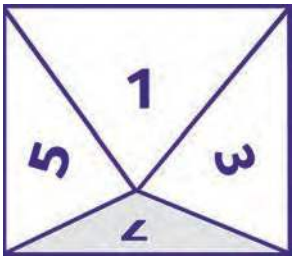
The illustration depicts an **octahedron**, one of the five regular polyhedra. An octahedron is a geometric object with eight faces (the name originates from the Greek word for "eight," οκτώ). Each face is an equilateral triangle, giving the shape twelve edges, six vertices, and four edges converging at each vertex.

You can make an octahedron from paper using a net (see below). Begin by cutting out one equilateral triangle. Then, using the triangle as a template, draw eight triangles on thick paper, as shown on the net.

Next, attach the areas of the net within the dotted lines (you will need those when gluing the octahedron) to the triangles.



You might be wondering, what does magic have to do with all this? Here's the fascinating part: by assigning the numbers indicated on the net to the faces of the octahedron, you can use it to perform a cool trick.



Ask someone to think of any number from **0** to **7**. Place the octahedron on the table or hold it in your hands, making sure that the person can only see the faces with numbers **1**, **3**, **5**, and **7**. Ask them if they see the number they had in mind. If the answer is yes, take note of number **1**.

Next, flip the octahedron so that the person only sees the faces with numbers **2**, **3**, **6**, and **7**, and ask the same question again. If the answer is affirmative, take note of number **2**.

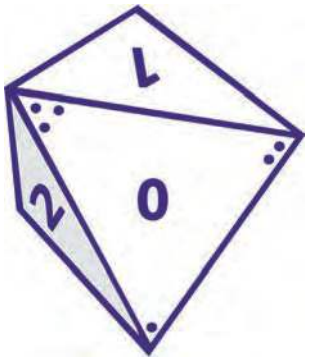
Repeat your question for the third (and last) time, turning the octahedron so that the person can only see the faces with numbers **4**, **5**, **6**, and **7**. If they answer "yes" this time, keep number **4** in mind. Now, mentally sum up all three numbers. You will get the number the person is thinking of (or **0**, if they answered "no" three times). For example, if the answers were "no," "yes," and "yes," then your number is **6 (2 + 4)**. If the responses were "yes," "yes," and "no," then the number is **3 (1 + 2)**. The trick lies in the fact that any number from **1** to **7** can be represented as a combination of the numbers **1**, **2**, and **4**:

1 = 1
2 = 2
3 = 2 + 1
4 = 4
5 = 4 + 1
6 = 4 + 2
7 = 4 + 2 + 1

This means that the four numbers that you show first (**1**, **3**, **5** and **7**) "contain" number **1**; the second set (**2**, **3**, **6** and **7**) has number **2**, while the third set (**4**, **5**, **6** and **7**) has **4**.

When the person answers your questions, they unintentionally give you a clue about whether you should account for **1**, **2**, or **4** in the total sum.

To make it easier to find the positions of the octahedron you need when demonstrating the trick, you can mark the three vertices that should be facing you when presenting the octahedron to the audience. For example, use one, two, or three dots as markings:

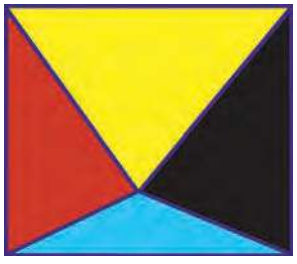


Place one dot at the vertex corresponding to the faces with numbers **0**, **2**, **4**, and **8**. Use two dots for the vertex with numbers **0**, **1**, **4**, and **5**, and three dots for the vertex with **0**, **1**, **2**, and **3**. When showing the numbers for the first time, turn the vertex with one dot towards yourself, then present the vertex with two dots facing you for the second display, and the one with three dots for the third.

Instead of marking the faces of the octahedron with numbers or points, you can paint them in different colours and guess the chosen colour. To do this, assign a separate colour to each number from **0** to **7** and show them to your audience, asking them to choose and remember one. You will then announce the chosen colour. For convenience, you can make the **0** face white and use the colours of the rainbow (except violet) and black for the remaining faces:

Number on the face	Colour
1	Red
2	Orange
3	Yellow
4	Green
5	Blue
6	Indigo
7	Black

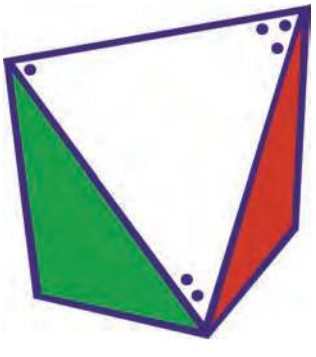
Of course, you will need to memorise the colours and their corresponding numbers.



When demonstrating the trick, you need to show the octahedron to the viewer three times and ask if they see "their" colour. Begin with the red, yellow, blue, and black faces, then move on to the orange, yellow, indigo, and black ones. Finally, display the green, blue, indigo, and black faces during the third round.

Using the total sum obtained from the responses (just like with the number trick), you can identify the hidden colour. For example, if the answers were "yes," "no," and "yes," then it's blue (the number of this colour is equal to **5**), and if they were "no," "yes," and "no," then it's orange (**2**).

In this version of the trick, you can also mark the three corresponding vertices to find the desired position of the octahedron:



And, of course, before demonstrating the trick to your friends, make sure to practise with someone at home. Good luck!

Einstein's Revolutions

REVOLUTION #1: THE SPECIAL THEORY OF RELATIVITY



At the end of the 19th century, physicists were fit to get bored very soon. It seemed that all the most important laws of nature were already known and that there were no more serious discoveries to be made. Science rested reliably on the fundamental theories that described all the known aspects of things: where classical Newtonian mechanics did not fit, Maxwell's electrodynamics equations were applied . . . It appeared that little work remained to be done. Scientists "just" needed to smooth out some discrepancies–not too serious, but somehow vexing. For starters, the speed of light was causing a few headaches.

THE FAMOUS VIOLINIST

Once, at his country house during a dinner party, Einstein entertained guests by playing the violin. One local journalist, unfamiliar with the host or his works, asked his neighbour, "Who's playing?" To which the astonished person answered, "Who?! It's Albert Einstein himself!" The following day, a note appeared in the local newspaper where the journalist worked that the famous violinist Albert Einstein played at a reception the day before. The scientist cut out the note, hung it on the wall, and pointed to it at any opportunity, saying to everyone, "There! As a matter of fact, I'm a famous violinist!"



Galileo Sails on a Ship

Relativity was invented by Galileo Galilei. "Imagine you are sailing on a ship, in a cabin without windows," argued the great Italian. "Water is dripping from the tap, papers are sitting on the table, and a pirate parrot is making a racket in its cage. Can you tell if the ship is docked or sailing smoothly on the sea, not speeding up or slowing down, not swaying or turning? No matter what you do, the water continues to drip, the papers stay put, and the parrot doesn't change its tune. You can conduct any experiments, drop a mug on the floor, measure the trajectory of falling drops—none of it will make any difference."

The Galilean principle of relativity became one of the cornerstones of Newtonian mechanics. The principle helped reveal that all laws of science act in the same way, both at rest and during rectilinear uniform motion—in the inertial frame of reference, as physicists say. To move from a resting system to a moving one, it is sufficient to consider the speed at which the ship moves. From Galileo's perspective, in the cabin, the parrot is frozen or motionless within the cage. From the point of view of those waving goodbye on the dock, the parrot simply moves at the speed of the ship. But it is not always this simple.

The phenomena of electricity and magnetism, discovered even later than Newton's mechanics, could only be described in the second half of the 19th century. The movement and interaction of electric charges and fields did not obey mechanics—they demanded their own formulas.

The equations of the Scottish physicist James Maxwell marked the pinnacle of this work. However, they introduced an element that did not add up with the previous formulas: the speed of light in a vacuum. According to Maxwell, the speed should be constant, regardless of who measures it or from where. If Galileo were to shine a light on us from the cabin with a flashlight, it wouldn't make a difference if the cabin was stationary or in motion. The light would shine out of a standing vessel at the same speed it would from a sailing vessel.

RELATIVISTIC TIME DILATION

The effect of the Special Theory of Relativity, in which all physical processes in a moving body are slower than in a stationary body (according to the clock of the stationary body):

$$\Delta t = \frac{\Delta t_0}{\sqrt{1 - v^2/c^2}}$$

Did you know that this effect is taken into account in GPS satellite clocks, which gain about 38 microseconds per day over clocks on the ground?

RELATIVISTIC MASS INCREASE

The faster an object is moving, the greater the mass of the object will be:

$$\Delta m = \frac{\Delta m_0}{\sqrt{1 - v^2/c^2}}$$

For example, at a speed of 260,000 km/s (87% of the speed of light), the mass of the object from the point of view of an observer, located in a resting frame of reference, will double!

Einstein Rides the Tram

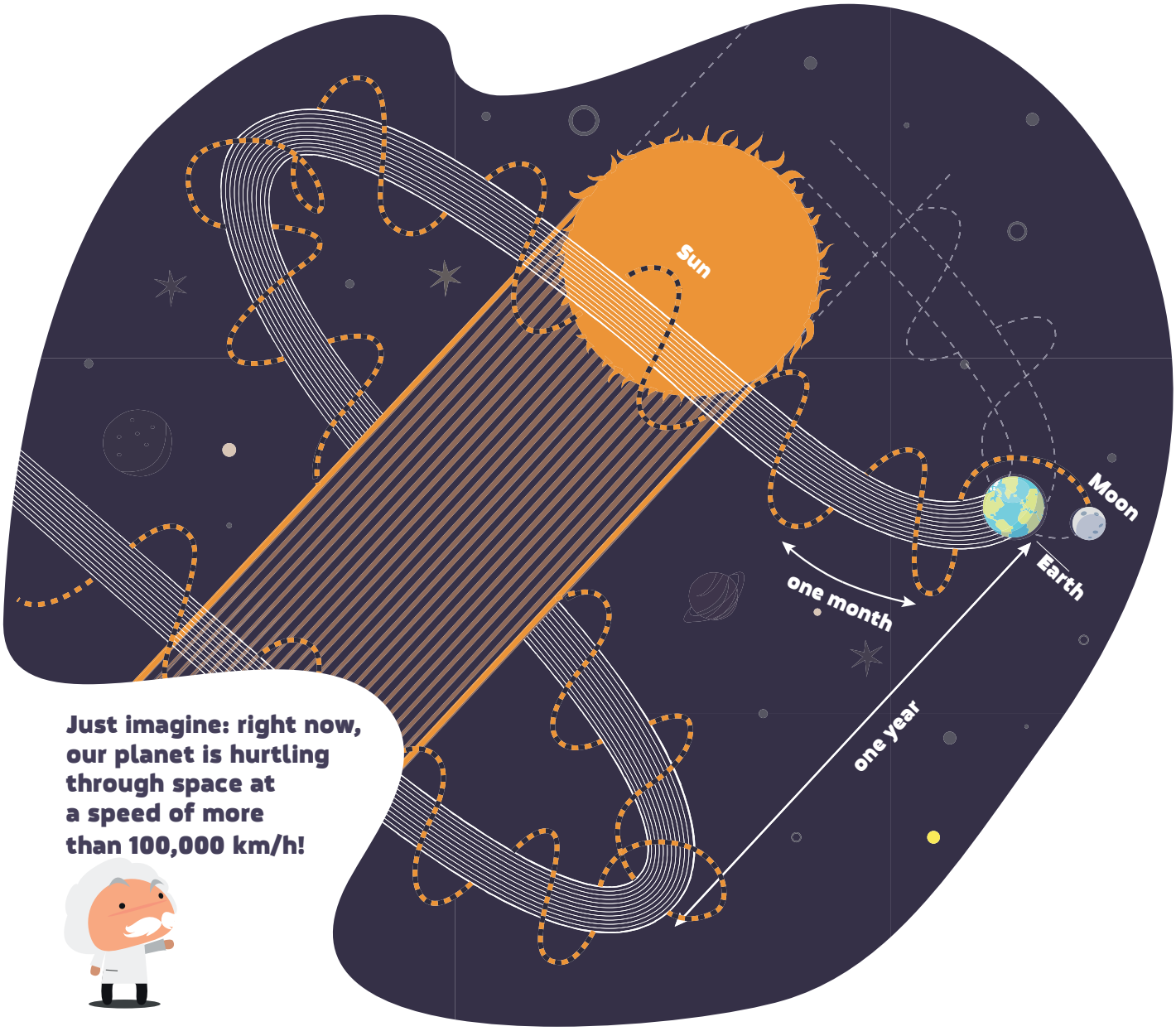
We, too, are in motion, given that we live on a planet that revolves around the Sun at a speed of more than 100,000 km/h. Perhaps this considerable speed could affect the speed of light? Alas, it doesn't: Albert Michelson and Edward Morley established this fact in the 1870s. The scientists measured, with utmost accuracy, the speed of the beam's motion in the direction of Earth's motion and perpendicular to it, but found no difference. The speed of light was indeed constant. This means that the speed of a bullet fired from a moving ship would be higher than if it were fired from a stationary pier, while light would always move at the same speed. Is this really possible?

The best minds of the time worked to resolve this "small contradiction." Newton's mechanics, having undergone centuries of practical testing, held a more established reputation compared to the relatively recent Maxwellian electromagnetism. Therefore, most scientists tried their best to "adjust" Maxwell's equations to the Newtonian "classics." The most exquisite mathematical games were played out, but a solution required a departure in the opposite direction.

RELATIVISTIC LENGTH CONTRACTION

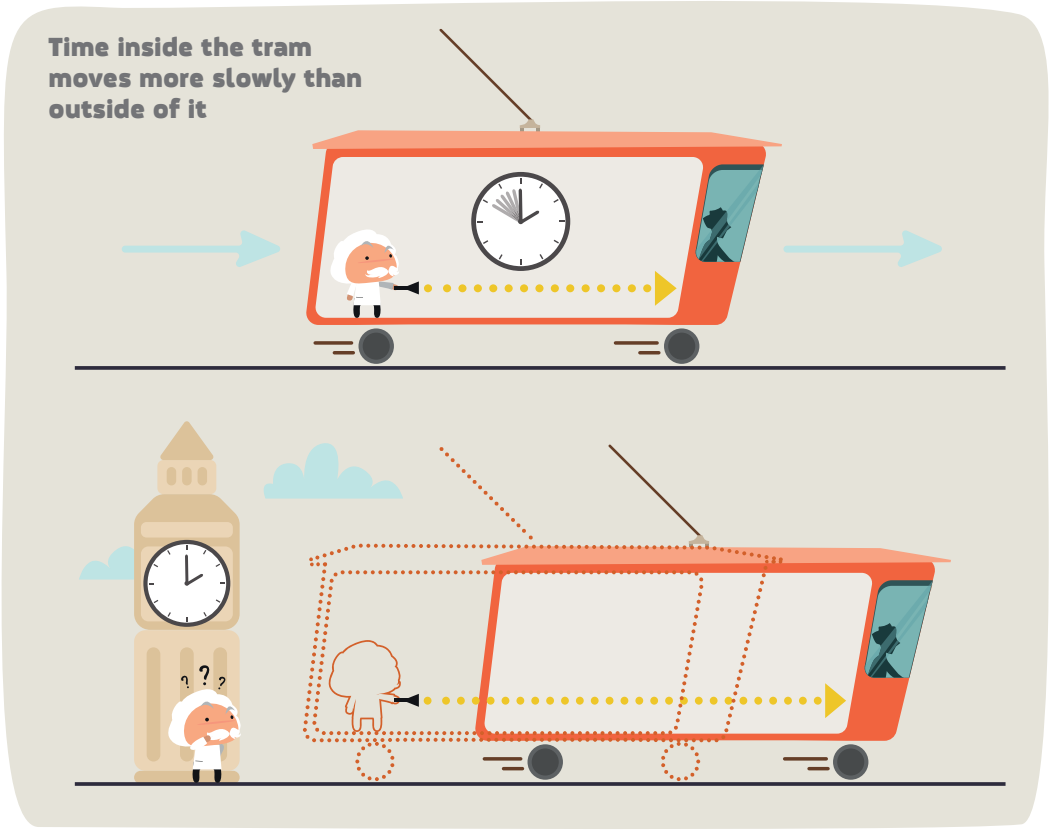
The length of the object moving with near-light speed decreases (along the direction of motion) relative to the observer. If the object reaches the speed of light, its size will equal 0.

$$l' = \sqrt{1-(v/c)^2}\,l$$



"Wait," thought Albert Einstein. "What if, in reality, Maxwell's electromagnetism is right and Newton's mechanics isn't at all? Maybe the speed of light really is constant in any inertial frame of reference? But how can this be? It implies...—they say that this realisation dawned on Einstein when he was riding in a tram and incidentally looked at a street clock.—This implies that if the system is in motion, then the time within it changes too." This discovery marked Einstein's first revolution.

The **Special Theory of Relativity** (STR), which Einstein described in 1905, crowned both classical mechanics and electromagnetism. In this theory, the laws of nature remain the same (or, as physicists say, invariant) in all inertial frames of reference. But the "background" on which they operate changes. To maintain the constancy of the speed of light, we will have to sacrifice the immutability of time.



The light from the flashlight will move past us at the same constant speed. While the light travels forward, the driver, having covered some distance, will have moved away, requiring extra time for the light to catch up. Therefore, the stop will be made not at all where Einstein wanted—and where he would disembark in reality.

The paradox can only be solved by slowing down time. If we perceive the time of the moving tramcar more slowly, then the light will be able to reach the driver at the right time according to our clock, and Einstein will exit precisely where he intended.

Revolution #1

Imagine Einstein's tram accelerating to a significant speed, and the scientist, sitting in the back seat, gives the driver a flashlight signal. As soon as the light reaches the driver at its usual speed, he will immediately stop, and the physicist will calmly exit and go about his business. But if we look at it from the side, standing on the pavement, paradoxes are unfolding.



This and other paradoxes of STR have been repeatedly confirmed in practical experiments. In one such experiment, physicists installed an ultra-precise atomic clock on an aeroplane that covered enormous distances at high speed. Then, the reading on the clock was checked—the experiments recorded a gap in the hours that were spent onboard the aircraft and those that elapsed on Earth. If we overlook the time difference between us and the navigation system satellites flying in orbit, a deviation of fractions of a second will accumulate daily. While seemingly small, this discrepancy is enough for coordinates, calculated by GPS, to stray by a few metres each day.

So, in 1905, Einstein achieved the first revolution, effectively "reconciling" Newton's mechanics and Maxwell's electromagnetics, while at the same time laying the first stone in the foundation of modern physics. Calculations carried out with the help of STR equations have been confirmed with remarkable precision. In everyday situations with speeds much lower than the speed of light, the equations of special relativity reduce to the classical Newtonian equations. The clock starts to lag ever so slightly even when we are riding a bicycle—just so weakly that we can't even notice it.

WHY DO HUMANS TAKE SO LONG to Grow Up?



Of all mammals, we have one of the longest periods of maturation. Mice are ready for independent life a month after birth, and lion cubs reach independence in the second year of life. But a person finally stops growing only at the age of 25. Why does this happen?

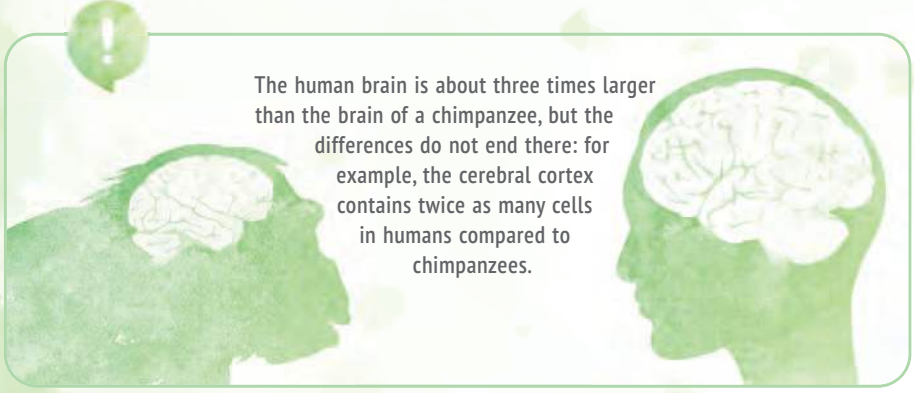
This phenomenon cannot be attributed solely to body size or life expectancy. Elephants, on average, live as long as humans but weigh much more. At 12–13 years old, an elephant calf becomes an adult, while a human child is just entering adolescence. This cannot be explained by specific characteristics of great apes, either: our closest relatives, chimpanzees and bonobos, develop quickly too—by the age of 8–10, these apes reach almost their adult size.

The reason lies in the brain. This large organ grows most rapidly after birth, when its size is no longer limited by the constraints of the birth canal. As a result, a significant portion of energy consumed by a human child is spent on the development of the brain rather than the body. By the age of 4–5, the brain's energy expenditure reaches its climax: up to 66% of all energy received by the body goes to the brain (in adults, the brain is much more modest and only uses about 20% of total energy).

These considerable "appetites" are associated with an active development of the **cerebellum**—an area of the brain housing roughly half of all neurons in the body. The cerebellum is primarily responsible for movement coordination, body positioning, and muscle tone, and it was recently discovered to play a significant role in the accumulation of experience, memory, and thinking. Cerebellar development is complete when a person is about 13 years old. This is the same age when children experience a major growth spurt, meaning they begin to grow quickly.

However, a long childhood is not all bad: during this time, a person accumulates valuable knowledge and learns many useful skills, from holding a spoon to solving integrals.





The human brain is about three times larger than the brain of a chimpanzee, but the differences do not end there: for example, the cerebral cortex contains twice as many cells in humans compared to chimpanzees.



VISITING THE FIERCE "SISTER"

In the 1960s–1980s, Venus was a hot topic for researchers. It became the first planet to host a human-made lander, and regular interplanetary station expeditions gave scientists a lot of invaluable data. However, in the 1990s, Mars entered the foreground instead.

On the Sidelines

Over the past three decades, only three space probes have gone to Venus, and only one of them is currently operating—the Japanese *Akatsuki* ("Dawn"). Mars, on the other hand, has been visited by 15 probes over the same timespan, equipped with rovers and even a helicopter.

During the first half of the 20th century, the prevailing belief was that life could exist on Venus's surface … Now we know better: it's a genuine inferno with a temperature close to 500°C, a pressure in the carbon dioxide atmosphere over 90 atmospheres, and with sulfuric acid rain to boot! No lander could survive on Venus for more than two hours.



Temperature near the surface
467°C



Atmospheric Pressure
90 bar



Distance to the Sun
108 million km

An image of Venus taken by the *Akatsuki* station in 2018



What to Look for on Venus?

Why spend exorbitant amounts of time and money to get to a planet whose surface is more sterile than an operating room? Let's try to figure it out.

Venus, oddly enough, **shares many similarities with Earth**. It has a similar size, identical average density, and gravitational acceleration of 8.9 m/s², suggesting a similar composition to that of Earth. It is very likely that our planets were formed under the same initial conditions from a single protoplanetary disc of gas and dust. Likely indeed—but not certain.



Rotation
in the opposite direction



Radius—
95%
of Earth's



Weight—
81.5%
of Earth's

It's still unclear **why Venus rotates in the opposite direction** to the rest of the planets (except for Uranus). If all the planets were formed from the same "blank slate" of gas and dust, then, according to the laws of conservation, they should rotate in the same direction, i.e. counterclockwise.

There have been numerous possible explanations for Venus's extravagant behaviour: the Sun's exerted tidal force, Mercury's orbital "escape," the braking effect due to Venus's very high atmospheric density, a collision with a very large protoplanet . . . Hypotheses abound, but so far not a single one has been fully accepted by the scientific community.

An illustration of the size ratio of Mercury, Venus, Earth, and Mars (from left to right)

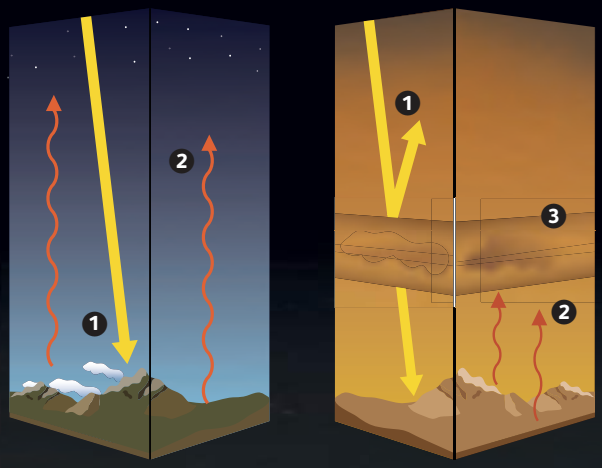


Research on Earth, Venus, and Mars is useful for specialists in **comparative planetology**. It can help clarify the history of terrestrial planets' formation and development, the evolution of their atmospheres, and differences in their tectonic activity. This, in turn, increases our chances of understanding **the future development of Earth**, especially its atmosphere and climate amidst ongoing global warming.

A Candidate for Terraforming

Despite its infernal surface conditions, Venus is the most suitable candidate for **colonisation** and **terraforming**. The "Morning Star's" mass helps it **contain its atmosphere** much better than Mars, which means that all the efforts that go into generating oxygen will not be wasted. Transforming Venus into a habitable place depends on whether we can resolve the **issue of carbon dioxide and water**. After all, the effect these two compounds have on one another is both fundamental and mutually dependent.

Since Venus and Earth were formed under similar conditions, their chemical compositions should be similar too. But is that really the case? The **mass** of Venus's atmosphere is **one hundred times that of Earth's**, and 96.5% of it is carbon dioxide. The pressure at its surface is 92 atmospheres (which is similar to being over 900 m underwater on Earth). Under such conditions, carbon dioxide becomes a supercritical fluid, exhibiting the properties of both a gas and a liquid at the same time. Again, our planets were formed under similar conditions. Consequently, the amount of carbon dioxide should be the same on Earth. However, there is only 0.04% of this gas in Earth's atmosphere.



^ The Sun's rays (1) reach Earth's surface, heat it and then escape in the form of infrared radiation (2). Meanwhile on Venus, clouds of sulfur dioxide and sulfuric acid (3) reflect about 75% of the Sun's rays and retain the absorbed heat, creating the greenhouse effect and the high temperatures on the surface.

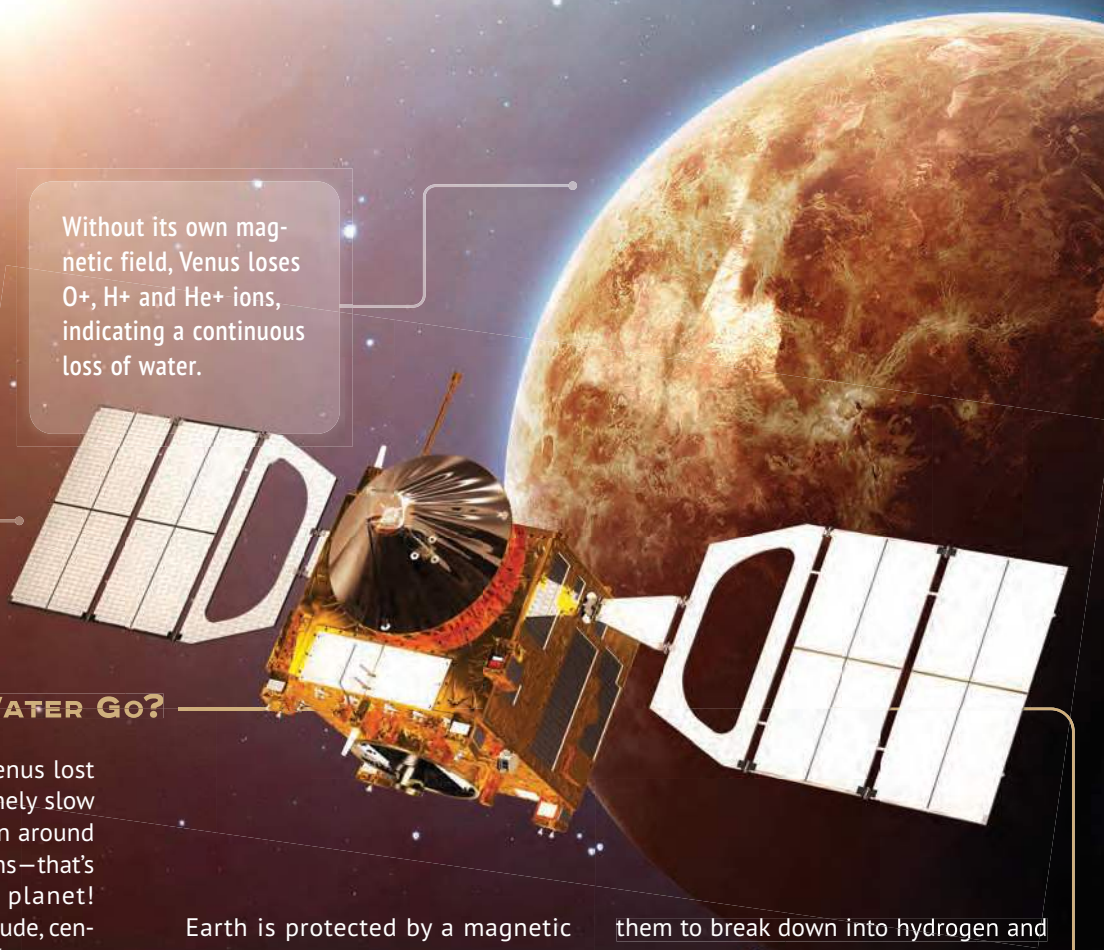
So why such a difference? Because of water!

Carbonic acid salts, or **carbonates**, formed in Earth's seas and oceans. These salts contained atoms of carbon and oxygen, that is, components of carbon dioxide molecules. Myriads of microorganisms began using carbonates to build their skeletons and shells, which turned into limestone millions of years later. From the atmosphere, carbon dioxide migrated into water, and was later "sealed" within solid rocks.



In 2009, with the help of the data collected by the Venus Express mission, hypotheses arose about Venus's past. Was there water there once? And what about tectonic activity?

Without its own magnetic field, Venus loses O+, H+ and He+ ions, indicating a continuous loss of water.

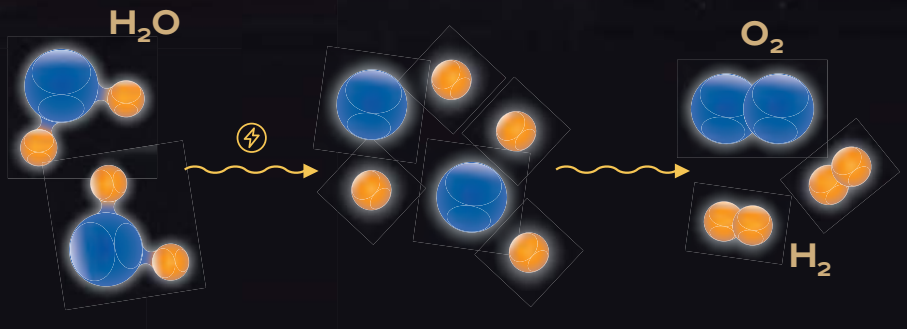


Where Did the Water Go?

It is currently believed that Venus lost its water because of its extremely slow rotation rate: it makes one turn around its axis every eight Earth months—that's 243 times slower than our planet! Because of such a leisurely attitude, centrifugal forces were unable to "squeeze" heavy elements (primarily iron) into the centre of the planet and form a metallic core. Venus has no magnetic field, and the solar "wind" reaches its surface without obstruction.

Earth is protected by a magnetic field, so bursts of high-energy particles only create nuisances for people in the polar regions, causing magnetic storms and auroras. But what would happen if there was no such shield? The Sun's bullet-like ions would break apart water molecules in the atmosphere, causing them to break down into hydrogen and oxygen. Lightweight atoms and molecules are prone to so-called **dissipation**, meaning they just fly into space forever. Earth lost its atmospheric helium through dissipation, while Venus lost its water due to this process. The Analyser of Space Plasma and Energetic Atoms (ASPERA) of the Venus Express station (2005–2015) discovered that there were two hydrogen atoms for every "escaping" oxygen atom, meaning it's highly likely that H_2O molecules are getting destroyed.

As a sad result, Venus, which initially had large reserves of water, lost them all due to solar wind, and carbon dioxide binding mechanisms were destroyed. The greenhouse effect began to work in full force, and the remaining water evaporated, turning Venus into the red-hot desert we know today.



^ The process of destruction of water molecules in Venus's atmosphere

What Should We Consider?

The most pressing tasks at hand are the detailed cartography of Venus and a systematic study of its atmosphere. Two NASA missions will begin work on these issues. The first mission, VERITAS (an abbreviation for Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy), is due to start in 2031. The spacecraft itself will be built by the Lockheed Martin Corporation, and the research equipment will be provided by NASA and its Jet Propulsion Laboratory in cooperation with aerospace agencies of Germany, Italy and France.

The mission leaders' idea is that VERITAS should be able to detect changes that have occurred since the expedition of the *Magellan* space probe (1989–1994), which photographed 98% of the planet's surface. If we're lucky, VERITAS will be able to observe **tectonic activity** in real time by periodically scanning the surface with an accuracy of up to 1.5 cm. If successful, this mission will provide scientists with comprehensive data on current geological activity on Venus. However, the main purpose of VISAR (Venus Interferometric Synthetic Aperture Radar) is to fill in "cells" on the map with a resolution of just 30 m (*Magellan* was able to "distinguish" details within a range of 115 to 280 m).

The multispectral imaging system VEM (Venus Emissivity Mapper) will be tasked with expanding and adding to the information received by VISAR. VEM will scan the surface in the infrared spectrum using so-called **"transparency windows"** (radiation within a certain range that is not absorbed by the atmosphere) and, based on the reflection spectra, determine the types of rocks present on the planet (basalts, granites, etc.). The end result of this scanning is an up-to-date geological picture of the surface. *JPL* Planetologist **Suzanne Smrekar**, director of the *VERITAS* project, said, "*To unwrap the mysteries of Venus we have to look under the hood at Venus's interior; it is the engine for global geologic and atmospheric evolution.*"

While VERITAS is set to orbit Venus at a safe altitude, the DAVINCI+ (Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging) descent probe will have to experience everything the hellish planet has to offer firsthand. The probe, enclosed in a titanium sphere 1 m in diameter, will begin its journey at an altitude of 120 km. When the module reduces its speed and reaches an altitude of 70 km, it will jettison its heat shield and begin a continual analysis of the atmosphere's composition with the help of the spectrometers VMS (Venus Mass Spectrometer) and VTLS (Venus Turntable Laser Spectrometer). When the probe emerges from the clouds at an altitude of 30 km and the descent speed drops to 11–12 m/s, a high-resolution heat-resistant camera will turn on. Special attention will be paid to the **tesserae**—elevated plateau-like areas broken up by cracks and faults. These tesserae occupy more than 7% of Venus's surface, while Earth has nothing of the kind. They are concentrated in several different regions of the



Artist's impression of the DAVINCI probe >

< The VERITAS spacecraft



planet, and the DAVINCI+ module will make its descent on one of them, called *Alpha Regio*.

In the hour before landing, the probe will be using the onboard weather station VASI (Venus Atmospheric Structure Investigation) to measure the temperature, pressure, and wind speed and direction to obtain a meteorological "baseline" of Venus's atmosphere. Armed with this information, scientists hope to better understand how the **super-rotation** works—that's a planetary hurricane that moves 60 times faster than the planet itself and reaches speeds of about 500 km/h! The DAVINCI+ mission is scheduled to launch in June 2029, and the investigation of the "Morning Star" should begin in 2031.

How Will Others Respond?

The European Space Agency (ESA) intends to launch the EnVision mission to Venus in 2031, which could be thought of as an addition to the American project VERITAS. The orbiter will have radars and spectrographs installed that are capable of conducting observations in both infrared and ultraviolet spectra. The scheduled research program will focus on studying Venus's atmospheric composition dynamics, monitoring climate change, searching for volcanic eruptions, and investigating surface mineralogy.

The directors at the ESA are hoping that EnVision, with an estimated cost of at least half a billion euros, will replicate the success of the Venus Express (2006–2014), whose contribution to the study of Venus was enormous.



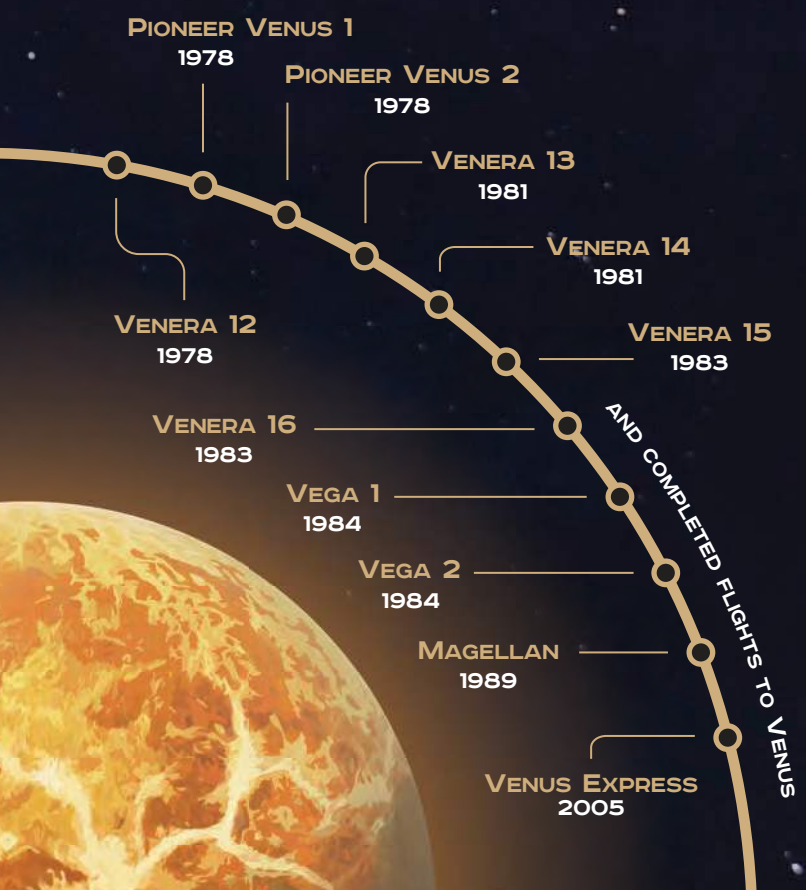
The EnVision orbiter ^

The Russian Venera-D program (with the "D" standing for "long-living") involves not only orbital research but also landing a research module on the surface. The module will take soil samples and analyse them with the help of a pulsed neutron generator (similar to the device installed on the Mars rover *Curiosity*). Around 300–500 MB of data will be transmitted to Earth until the radio equipment overheats and breaks down. The launch of the Venera-D spacecraft is scheduled for 2029.

Similarly, India is gaining increasing confidence as a spacefaring nation. The launch of the Shukrayaan-1 mission is scheduled for December 2024. The spacecraft will be launched using the *GSLV Mark III* rocket from the Satish Dhawan Space Centre (located on Sriharikota Island, Bay of Bengal) cosmodrome. The main goals of this four-year scientific program include exploring the stratigraphy of Venus's surface to determine the age of its rock layers, analysing the chemical and isotopic composition of its atmosphere, and studying the influence of solar wind. The total mass of scientific equipment for this mission will exceed 100 kg.

China has demonstrated remarkable progress in the space industry, extending its reach to Venus. In July 2022, the China National Space Administration announced the project VOICE (Venus Volcano Imaging and Climate Explorer) as part of the ambitious research program *Tianwen* ("Questions to Heaven"). The automatic station is scheduled for launch in 2026, with plans to enter Venus's circular polar orbit in 2027. The orbital module will be equipped with an infrared radar and "tailored" to search for active volcanoes.

Scientists have been looking for planets in other star systems and have achieved impressive results there, but we know disconcertingly little about our closest cosmic "neighbour," which happens to be much more similar to Earth than the vast majority of discovered exoplanets. Let's hope that this peculiar situation will soon be addressed and that, by exploring beneath Venus's thick veil, we'll better understand the inner workings of our own home planet.





THE POLYMER CENTURY:

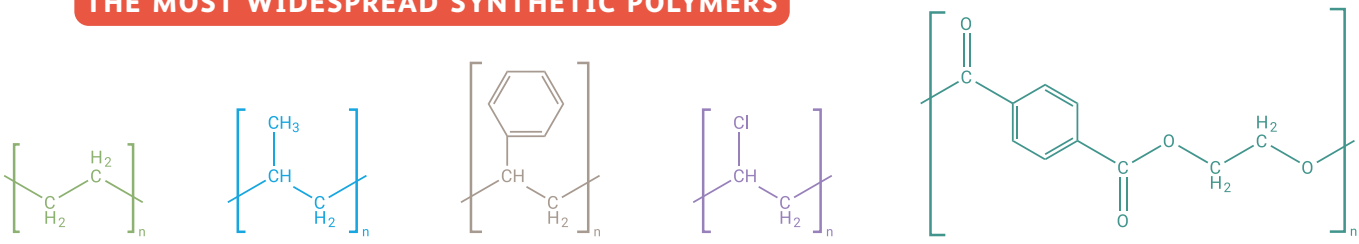
What's Threatening the Environment?

People have been using polymers since the Stone Age. Wool and leather are made of proteins, while the main component of many fabrics, papyrus, and paper is cellulose. These naturally derived polymers decompose relatively quickly. In the early 20th century, however, humankind learned how to produce synthetic polymers. Items made using these materials turned out to be light and durable. Still, the arrival of the polymer century was overshadowed by the discovery that nature cannot quickly decompose these compounds. As a result, our "handmade" polymers gather in enormous quantities in landfills, and scientists are looking for ways to save the Earth from being suffocated by plastic.

Chain Molecules

Polymers have a large molecular mass. In these compounds, certain elements are periodically repeated, forming structural links. Polymers are as old as life itself. Proteins, nucleic acids, and polysaccharides are fundamental building blocks of all living systems. These are called "natural polymers," while those that appeared as a result of human activity are human-made or **synthetic**.

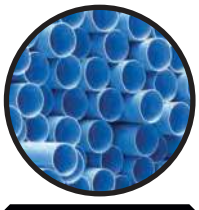
THE MOST WIDESPREAD SYNTHETIC POLYMERS





POLYETHYLENE (PE)

Frost- and impact-resistant. Used to make film, bags, pipes, containers, and even body armour.



POLYPROPYLENE (PP)

A tough, rigid plastic that is more sensitive to heat than PE. Used in the production of plastic films, bags, pipes, and containers.



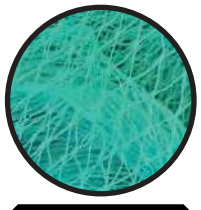
POLYSTYRENE (PS)

Water- and frost-resistant, cheap to produce, easy to process. Used to make plastic dishes and toys.



POLYVINYL CHLORIDE (PVC)

Resistant to corrosion by acids and alkalis. Used as a sealant and electrical insulation material.



POLYETHYLENE TEREPHTHALATE (PET/E)

Very durable, a good dielectric. Used to make plastic bottles, threads, and fibres.

2.11 million tonnes

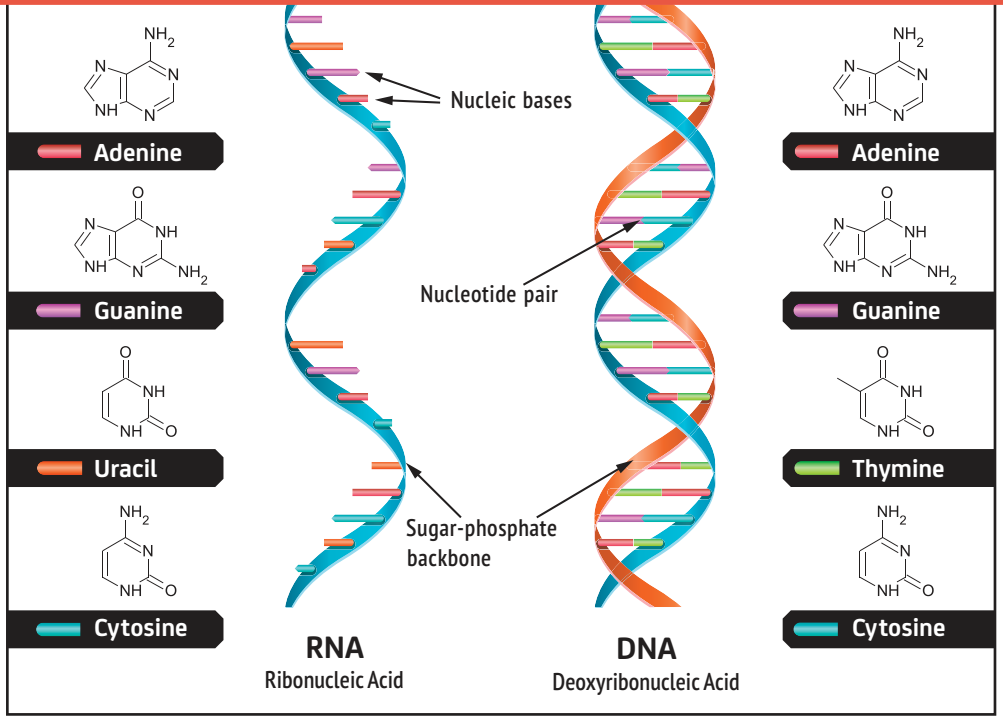
The projected global production of bioplastics in 2024



PLA **18.7%**
PBAT **13.5%**
PA **11.9%**
PE **10.5%**
PTT **9.2%**

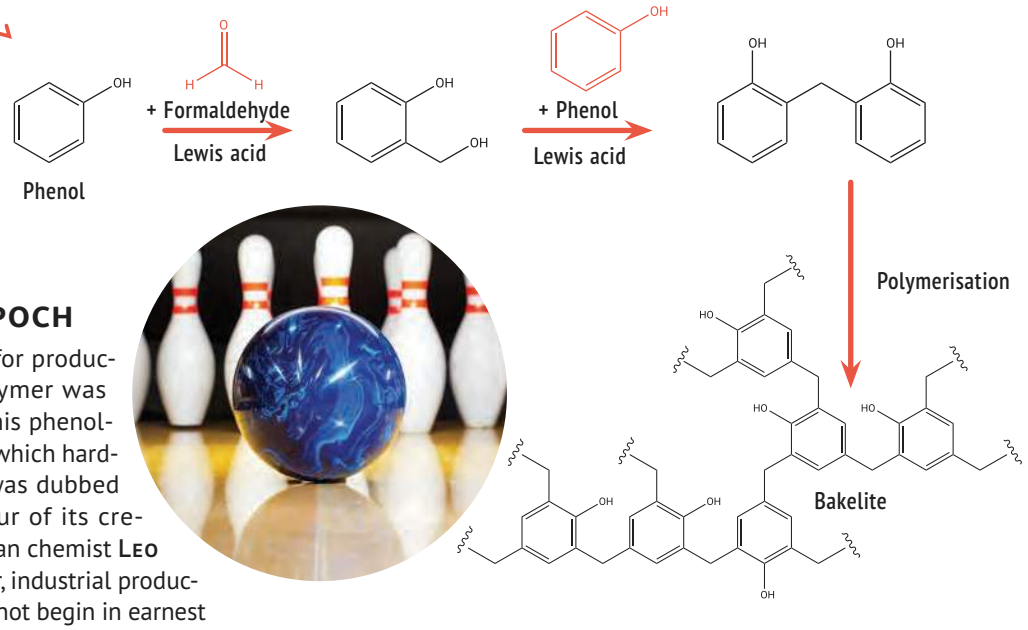
Source: Baghi et al., 2022

REPETITION OF MONOMERS IN THE STRUCTURE OF NUCLEIC ACIDS



Human-made polymers are created as a result of chemical modifications of naturally occurring ones. The first artificial polymer, **nitrocellulose**, was invented in 1846 by CHRISTIAN FRIEDRICH SCHÖNBEIN. At first, nitrocellulose was used to replace ivory products (such as billiard balls) and produce photo and movie film stock. Nowadays it's the basis for smokeless gunpowder.

Synthetic polymers are produced by the polymerisation or polycondensation of low molecular weight compounds (typically refined petroleum products). These are what we usually call "plastic" in everyday life. Five major synthetic polymers are produced on a massive scale: polyethylene, polypropylene, polystyrene, polyvinyl chloride, and polyethylene terephthalate.



Bakelite, the first human-made plastic ever produced on a large scale, is widely used for various purposes, including the manufacturing of items such as bowling balls.

Synthetic Epoch

The first technique for producing a synthetic polymer was patented in 1909. This phenol-formaldehyde resin, which hardens upon heating, was dubbed "**Bakelite**" in honour of its creator, Belgian-American chemist **Leo Baekeland**. However, industrial production of polymers did not begin in earnest until the 1950s, when **Karl Ziegler** and **Giulio Natta** developed catalysts that allowed polyethylene and polypropylene to be produced without high pressure or temperature conditions. Thanks to the Ziegler-Natta catalyst, the chemical industry quickly mastered the production of structural and packing materials. But less than ten years later, environmentalists began to sound the alarm. In the 1960s, it was already obvious that the increase in the production of single-use plastics and packaging posed a threat to the environment. Plastic that had served its purpose was strewn throughout cities, suburbs, and even the seas.

These fears were confirmed. If in the 1950s no more than 2 million tonnes of plastics were produced per year, in 2015, this number soared to 400 million tonnes. At least 4 billion tonnes have been shipped from factories over the past 13 years.

The simplicity and large volumes of production have caused plastics to become truly single-use products. Only 9% of all synthetic polymers produced are recycled, while another 12% are burned in the furnaces of industrial waste incinerators and thermal power stations. It's not difficult to calculate that the remaining 79% of plastic has ended up in landfills, garbage dumps, or just in the environment. Every year, over 8 million tonnes of synthetic polymers are dumped into the Pacific Ocean alone. Sea and ocean currents collect them in garbage patches which, over time, risk transforming into garbage continents. By 2050, the total mass of polymer waste in the ocean is expected to reach 12 billion tonnes.

What Dangers Do They Pose?

Synthetic polymers have no natural analogues. Therefore, they don't degrade like, for example, a fallen leaf or a piece of leather. There are no naturally occurring biochemical processes that can quickly destroy plastics. Degradation occurs only due to photochemical processes, temperature changes, contact with river or seawater, or mechanical pulverisation by winds, currents, and so on. All of these take a very long time. According to scientists' calculations, the total disintegration of plastic bottles made of PET takes 500 years in nature, and polyethylene plastic bags, up to 100.

Some chlorine-containing synthetic polymers (for example, PVC) demonstrate high levels of chemical reactivity due to the presence of chlorine atoms and, therefore, degrade faster. However, in this case, the products of this decomposition are volatile organochloride substances that are often very toxic, such as dioxins.

It's possible to find organisms that have evolutionarily adapted to attract trace elements from synthetic polymers. The list of bacteria that can digest these polymers (especially soft and waxy polyethylene) is growing. In 2016, a bacteria was discovered that consumes polyethylene terephthalate (*Ideonella sakaiensis*). Then, in 2017, the list of beings with uncommon food preferences expanded



Tanned leather could be considered the first human-made polymer. During its production, substances from the tanning solution react with proteins in the hide, causing the protein molecules to cross-link together, strengthening the durability of the leather. This technology emerged back in the Stone Age.



Over the past 60 years, global production of plastic reached 8.3 billion t, of which 6.3 billion t ended up in landfills.

to include a more highly-developed organism: the greater wax moth (*Galleria mellonella*). It digests polyethylene, turning it into ethylene glycol. Some scientists are now **bioprospecting** – looking for bacteria in the environment that could help digest plastics.

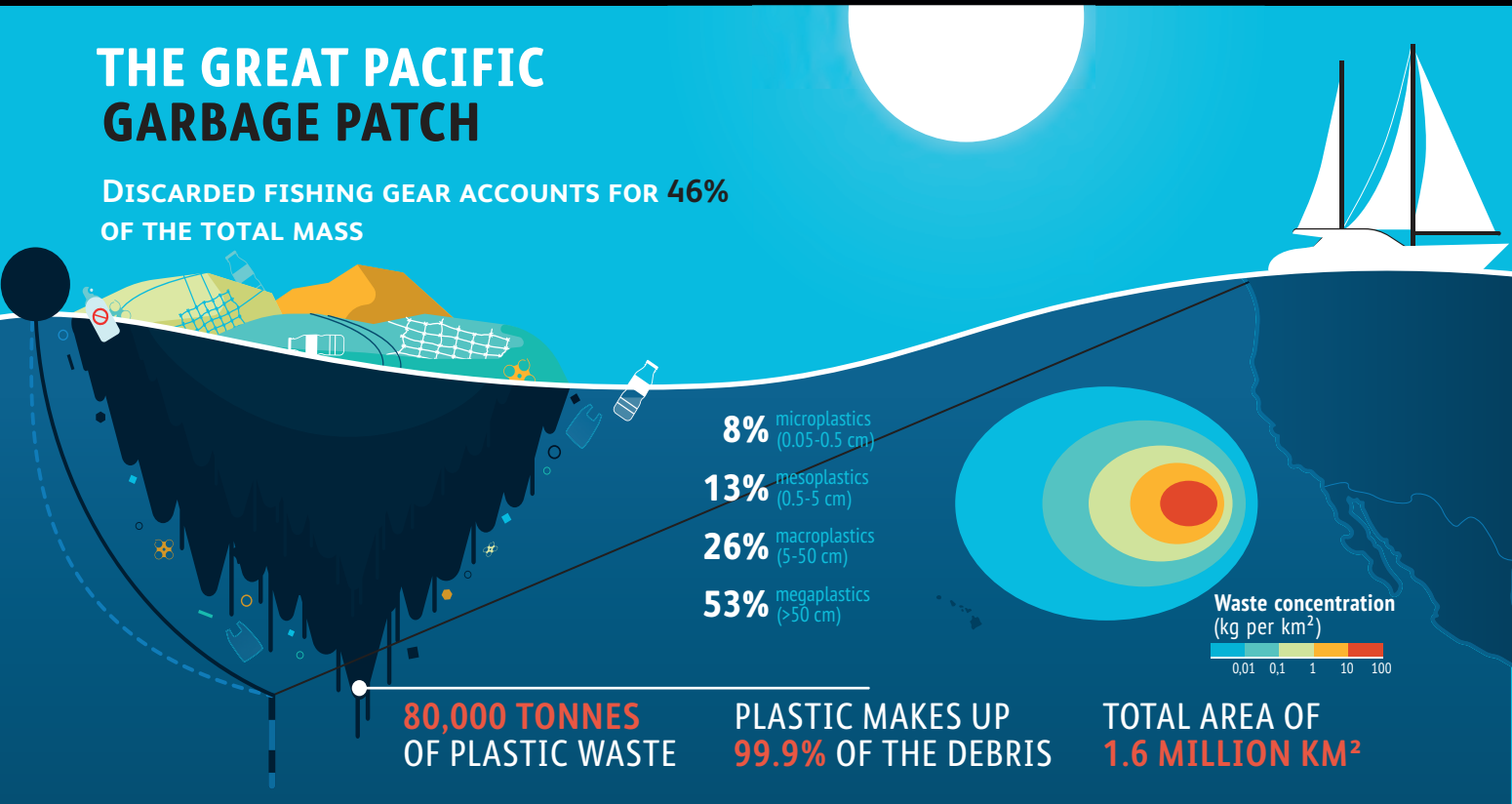
On the one hand, the emergence of the biological recycling of plastic is good. On the other hand, it poses new threats: waste might not be the only food for these organisms in the future. If they start to consume, for example, the polymer insulation of wires or supply pipelines for water, this could cause many accidents and human-made disasters.

OCEAN WASTE ACCUMULATION MAP

Source: NOAA

THE GREAT PACIFIC GARBAGE PATCH

DISCARDED FISHING GEAR ACCOUNTS FOR 46% OF THE TOTAL MASS



80,000 TONNES OF PLASTIC WASTE

PLASTIC MAKES UP **99.9%** OF THE DEBRIS

TOTAL AREA OF **1.6 MILLION KM²**

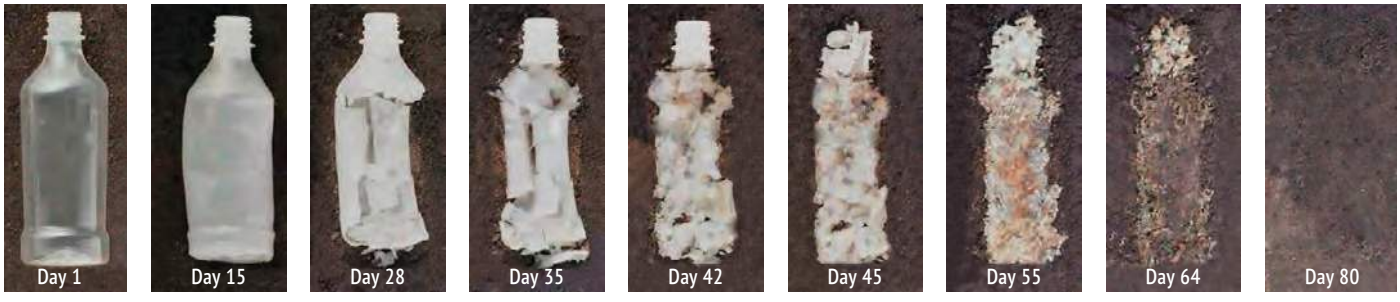
Friendly Alternatives

Biodegradable polymers are an effective solution to this challenge. Researchers are developing ways to produce polymer materials that will quickly be digested by microorganisms in soil and water. The raw materials for these polymers should also be derived from renewable sources. Polylactic acid (polylactide) is used to make plastic packaging for food and cling film. Bottles and bags made from this material take less than 100 days to degrade completely, almost the same rate as fallen leaves. Technologies to produce other biodegradable polymers are under development. These include, for example, polycarbonates, which are intended to replace polyethylene terephthalate (PET).

In the meantime, while most packaging and bags are still made of non-biodegradable materials, we can reduce the amount of plastic waste that we produce. You can do your part by bringing a reusable bag to the supermarket instead of taking a plastic one and wrapping foods in paper instead of plastic bags. And, of course, when you go out into nature with your friends, don't leave behind rubbish (even if it is biodegradable). Instead, make sure to throw it away somewhere specially designated for that purpose.



A grey seal caught up in pieces of a fishing net on the beach in Horsey, England. Luckily, this incident was reported to the local animal rescue services.



A polylactide bottle decomposes in the environment within 80 days. The resulting lactic acid is incorporated into the metabolism of land and aquatic microorganisms.



Between 500 billion and 1 trillion plastic bags are used every year. Their average usage span is only 15–25 minutes, and it takes 100–500 years for a plastic bag to fully decompose.



A turtle swims out to catch a breather in the middle of a garbage patch in the Atlantic Ocean.

WHY DO DUCKS HIDE FROM THE RAIN?

After all, they are always swimming and diving underwater!

Contrary to the popular saying, "like water off a duck's back," the plumage of waterfowl (anseriformes) is not completely waterproof.

Barbs—the tiny hair-like structures that make up duck feathers—are so tightly packed together that they let almost no water pass through. The sebaceous secretion from the preen (uropygial) gland also helps repel water: similar to shoe polish, it makes the feathers more elastic.

You may have noticed that adult ducks carefully preen themselves after swimming. This is necessary to restore the water repellency of the plumage. If the feathers are in constant contact with water, sooner or later they will clump together and begin to "leak." This is why spreading them out in the rain may not be effective.

Additionally, ducks have different types of plumage. The fuzzy "suits" of ducklings and the coloured, iridescent feathers of adult ducks are looser and not as watertight. As a result, water is able to reach the skin, cooling down the body. This is why, after diving, mallards carefully preen their neck feathers, and wet ducklings can even die from hypothermia if they do not warm up quickly under a heat lamp or next to their mother.

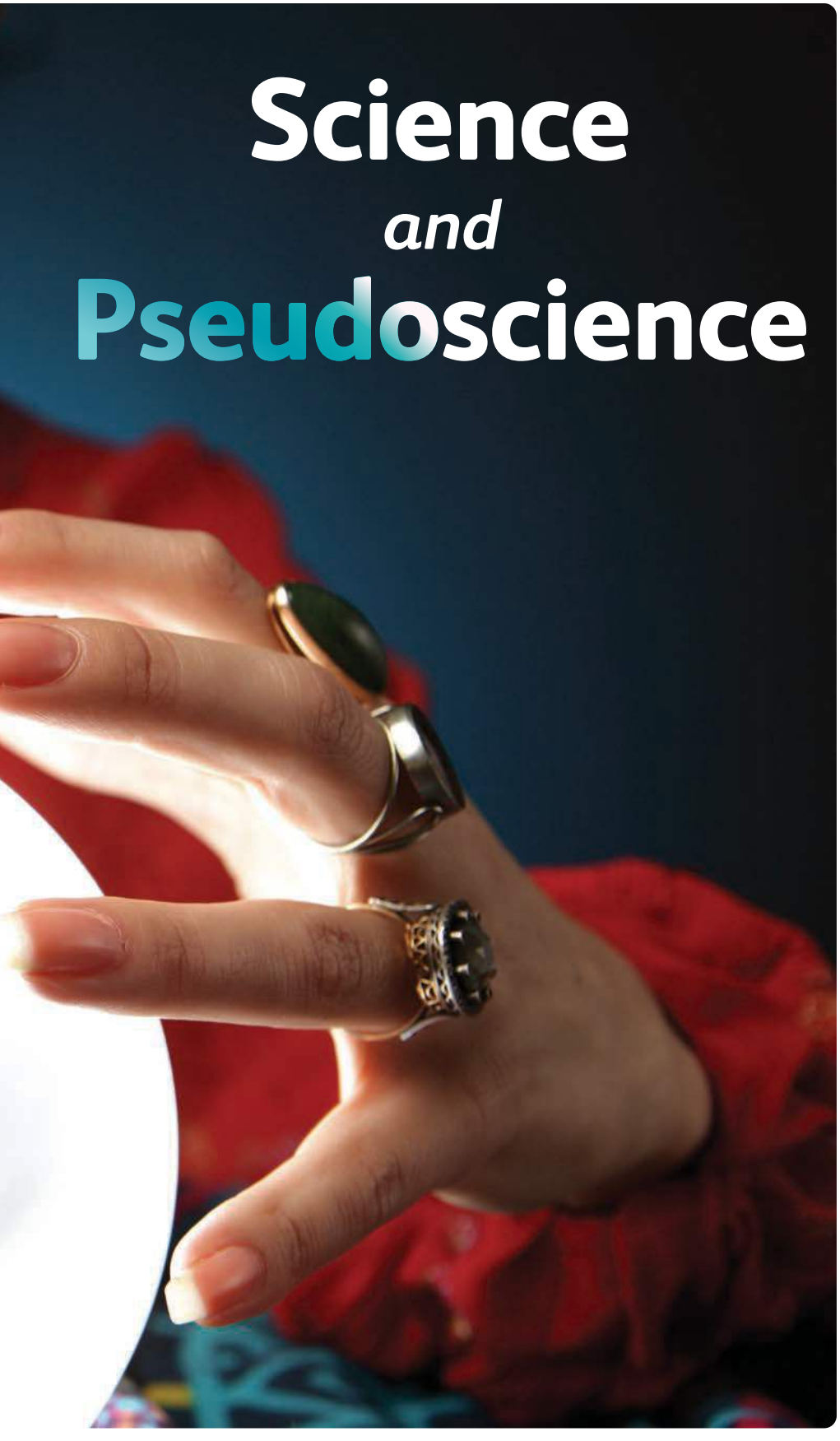
Unlike the water in which the duck swims, raindrops fall on the bird from above, impacting with its body. The force of raindrops thus causes discomfort and potentially harms delicate body parts.

Finally, even if someone really enjoys something, they don't have to do it all the time! Although ducks find their food in and around the water and can usually be found swimming, it doesn't mean they have to spend all their time there.



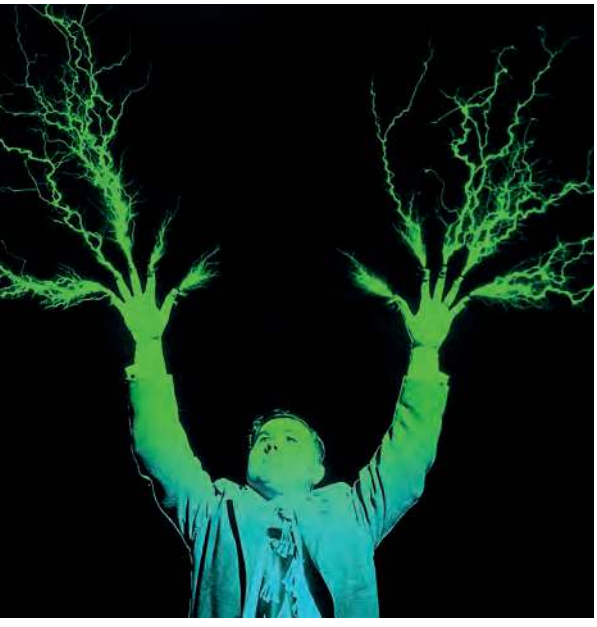


Science *and* Pseudoscience



Science has always been the driving force behind human progress. But, as the old adage goes, for every action, there's a reaction—like the contrast between black and white, truth and lies, or real science and something called pseudoscience. While science pushes us forward, pseudoscience is like a sneaky computer virus that confuses and misguides people, slowing down our progress.

So what exactly is pseudoscience, and why should we care? Today, this question is more relevant than ever as the Internet is overflowing with stuff that looks like science but isn't. Instead of doing proper experiments or making logical arguments, pseudoscience relies on things such as unproven "evidence," so-called "common sense," and the support of people who seem important, all without really thinking deeply about their own ideas. In this article, we're going to break down what pseudoscience is, why it's a problem, and how it can hold us back from discovering real truths and making genuine progress.

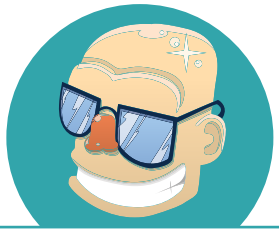












THEY SAY:

"We receive thousands of support letters, and one girl even recovered from advanced cancer."

PSEUDOSCIENCE:

The obvious lack, or complete absence, of reliable and replicable evidence. Instead, individual stories and anecdotal evidence are offered as facts.

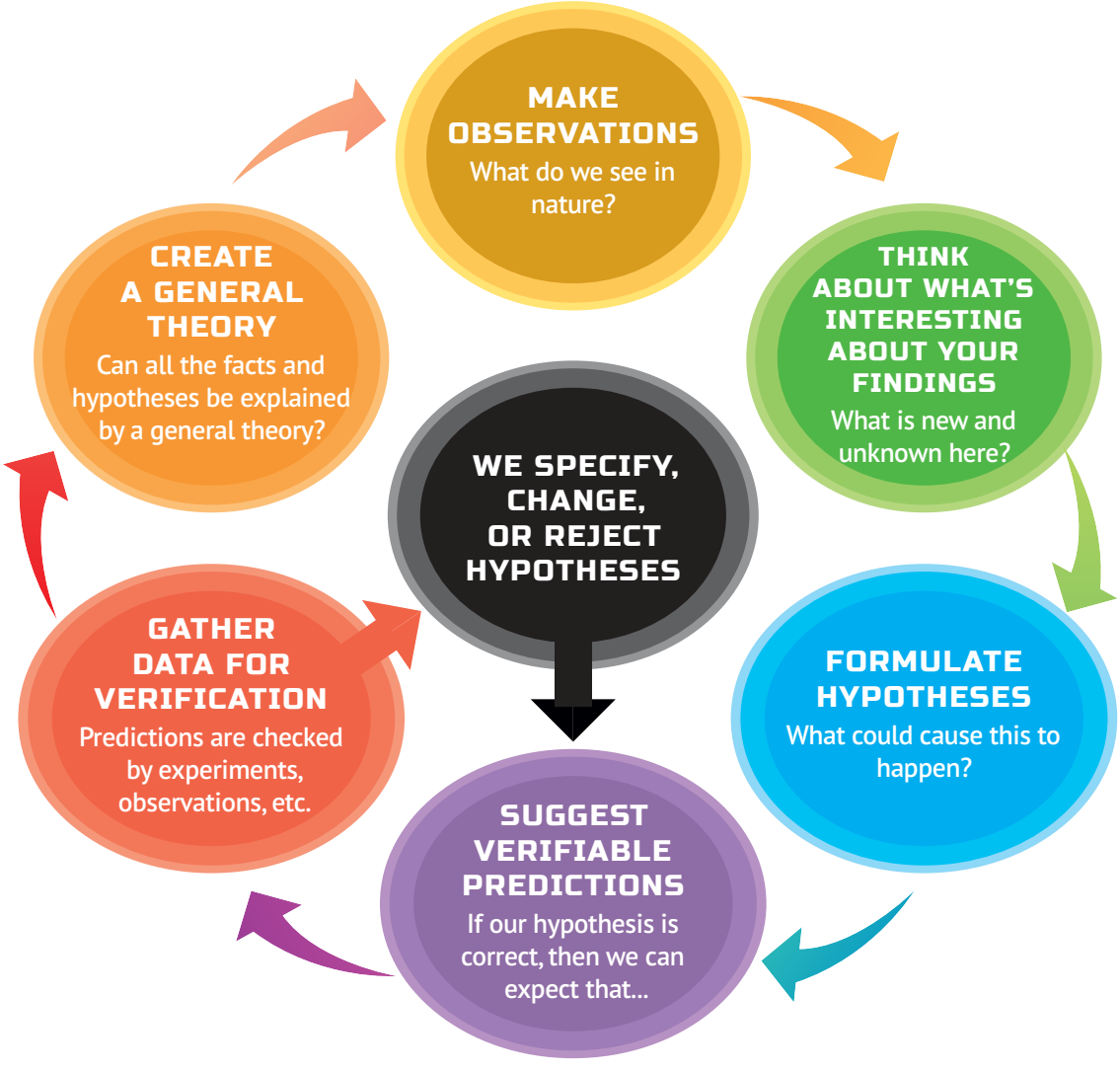
Is Pseudoscience Dangerous?

The scientific method has reshaped life on Earth, revolutionising our modes of transportation, combating diseases, and extending human life expectancy. Yet, this remarkable progress has inadvertently given rise to the troubling proliferation of pseudoscientific ideas. Much like ancient mystics claiming secret knowledge, today's pseudoscientists use sophisticated language to peddle ineffective solutions, posing a threat to genuine scientific achievements. The consequences of pseudoscience are tangible, leading even seasoned professionals astray and diverting scientific progress in damaging directions.

Pseudoscience is especially dangerous when it comes to questions of public health, where pseudoscientific beliefs undermine scientifically sound treatments. The World Health Organization experts and volunteer doctors from Cochrane tirelessly combat these trends, emphasising the risks associated with practices like aura healing or **homeopathy** for treating serious diseases. Aside from their ineffectiveness, these practices come at a high cost—for example, despite homeopathy being widely regarded by scientists as a "placebo therapy at best and quackery at worst," the global homeopathic market reached a staggering $11 billion in 2022 and is expected to reach over US$34.32 billion by 2032, promising solutions that often prove empty.

Staunch opposition to preventative measures, such as vaccines, is another example of pseudoscientific ideas gaining wide public support. It not only hampers scientific progress but also harms society. The anti-vaccination movement spreads

THE SCIENTIFIC METHOD is a continuous process of explaining observations by obtaining data through testing and experimentation.



false information, making people hesitant about vaccines even though there's clear proof they are safe and effective. This not only hinders efforts to control diseases but also puts the health of the community at risk. The resurgence of preventable and once-eradicated diseases, such as the 2022 outbreak causing an 18% increase in global **measles** cases, shows the real harm of ignoring proven scientific solutions. To deal with these problems, it's crucial to spread awareness, clear up false beliefs, and support practices based on solid evidence to improve both science and society.

Scientific Method

So what makes real science different from pseudoscience? It comes down to the tools and methods scientists use. Every field of science has its own unique tools and methods. Historians may rely on material artefacts and written sources, biologists draw insights from chromatography and electrophoresis, astronomers look at the spectra of distant space objects, and chemists set up experiments. But despite these diverse approaches, all scientists share a common foundation—the **scientific method**. It is used everywhere, from biochemical laboratories to sociological surveys.

Think of the scientific method as a way to say, "Prove it!"—like when you're in an argument, and someone challenges you to show that you're right. In science, a theory isn't just an idea; it has to be proven with experiments, and those experiments have to be done repeatedly to ensure the results are consistent. In practice, this process is often a bit more complex. Science uses a kind of circular approach to figure things out. It all starts with observations and experiments to discover new processes and phenomena. Then, based on the knowledge they already have, scientists come up with

educated guesses (called **hypotheses**) to explain these new findings. These hypotheses lead to new predictions that are tested and improved through more observations and experiments. And so, the cycle keeps going—new experiments, new discoveries, and the process starts over. It's like a continuous loop of learning and figuring out the world!

A **hypothesis** is a tentative explanation for observed phenomena, acting as the initial step in the scientific method. Through systematic experimentation and data collection, a hypothesis can evolve into a **scientific theory**—a comprehensive and substantiated explanation of natural occurrences. The strength of a theory lies in its ability to withstand rigorous testing and repeated experimentation.

The word "theory" can be confusing because, in everyday conversations, it means something different. People might say things like, "Evolution is just a theory." So it is important to remember that within the scientific method, a theory represents **a well-substantiated explanation supported by extensive evidence**.

The scientific method evolved over time through contributions from various thinkers, including ancient Greek philosophers like Aristotle and mediaeval Islamic scholars such as Ibn al-Haytham. During the Renaissance, figures such as Francis Bacon, Galileo Galilei, and René Descartes played key roles in shaping its development. Prominent figures of the Scientific Revolution, such as Isaac Newton, further contributed to the evolution of the scientific method. In the 1930s, philosopher Karl Popper introduced an additional criterion for authentic scientific knowledge: **falsifiability**.

According to Popper's criterion of falsifiability, any scientific statement should be potentially disprovable. Popper observed that many views considered scientific did not meet this requirement. For instance, while you can design an experiment to test whether gravity on the Moon pushes objects away from the surface, it's impossible to conduct measurements that could refute Freud's psychoanalysis, as it's challenging to experimentally prove or disprove abstract concepts such as dream analysis or the interpretation of symbols.

Real Miracles

There are other methods involved in the scientific method, including thought experiments (think of Schrodinger's cat), theoretical modelling, and more. However, **empirical knowledge**, the knowledge obtained through observation



THEY SAY:

"The charge of positive bioenergy accumulated in our talismans will make them a reliable protector of your aura."

PSEUDOSCIENCE:

The terminology used here is strange, outdated, or completely made up. This type of language may sound familiar, but it doesn't mean it's reputable or scientific.



and experience, remains the basis of the scientific method. In disciplines such as physics, chemistry, and especially in medicine, experiments adhere to strict requirements to ensure accuracy and reliability, minimising external interference or deceit. Detailed protocols accompany scientific work, outlining all procedures and calculations.

Still, every now and then, the scientific world is shaken by stories like the one involving **Andrew Wakefield**, a British anti-vaccine activist and former physician who claimed a connection between the MMR vaccine and autism. However, the study was later found to have serious methodological flaws, and Wakefield's results were discredited. This example underscores the importance of rigorous scientific protocols to maintain accuracy and reliability in research, preventing the spread of misinformation that can have significant public health implications.



THEY SAY:

"A well-known academic, N, is confident that people who bought our healing stones are two times less likely to suffer from psoriasis."

PSEUDOSCIENCE:

References to authorities in other places and direct suggestions to buy a product show that the authors of the "study" stand to receive direct financial benefits for promoting their ideas.

Unlike science, which continuously refines its theories based on new evidence, pseudoscience selectively considers only information that supports its claims, disregarding empirical evidence and violating fundamental scientific principles.

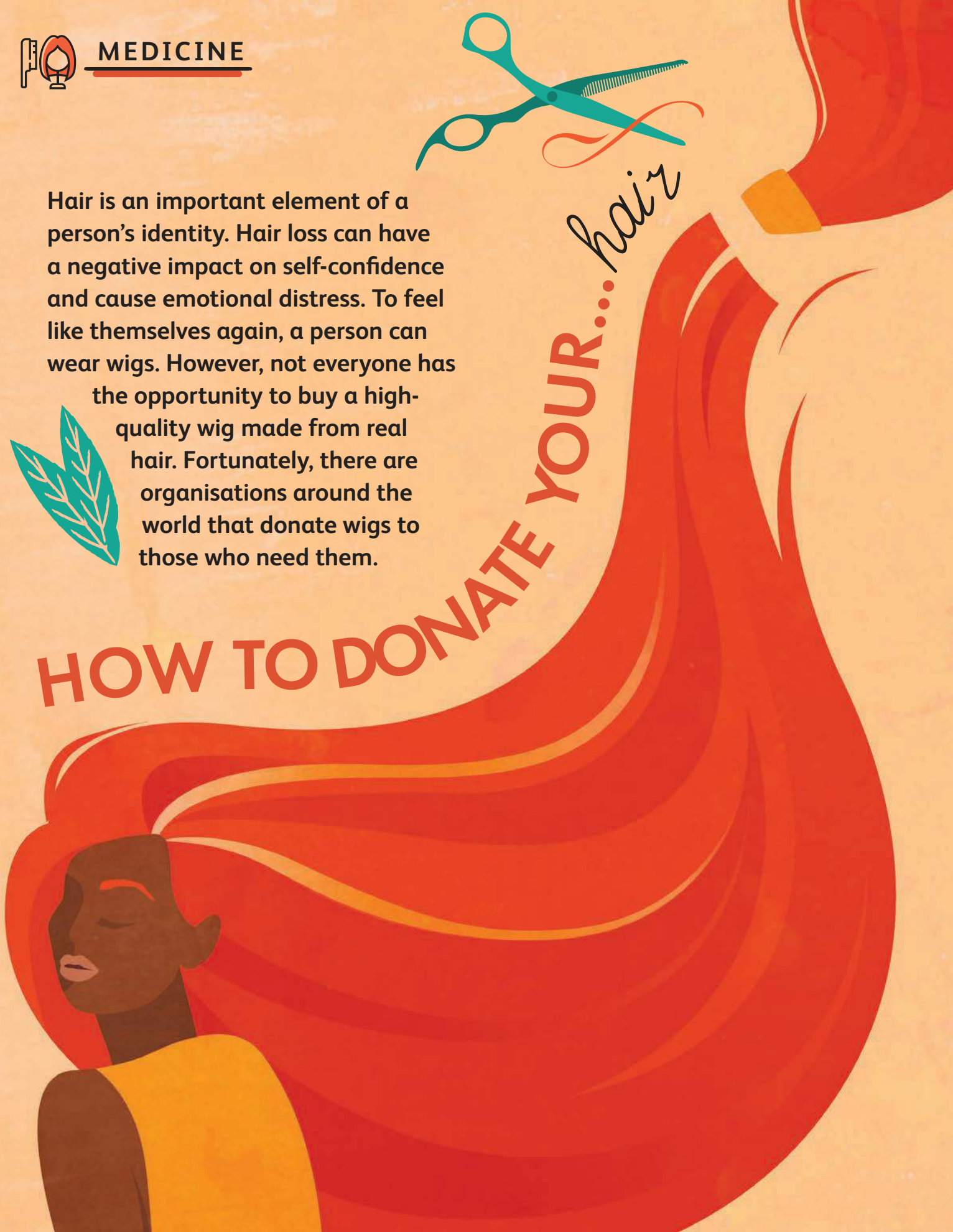
It's important to note that scientists don't conceal valuable knowledge for deceptive purposes. If someone could convincingly demonstrate the influence of a specific star arrangement at birth on fate or propose a method to cure cancer through touch, such a person would undoubtedly make history. Any astronomer or oncologist would likely welcome such groundbreaking discoveries. However, the reality is that these opportunities don't exist.

While we may sometimes lament the notion that science has left no room for miracles in our lives, the reality is quite the opposite. The pre-scientific past witnessed very few miracles. Progress, driven by science, has bestowed upon us the marvels of audio players, the magical ability to communicate with people on the other side of the Earth, and even the potential for resuscitation, the seemingly miraculous prospect of rising from the dead. The key lies in understanding and not taking science on faith. With a little effort, science has the power to unveil the wonders of our world.



HOW TO DONATE YOUR... hair

Hair is an important element of a person's identity. Hair loss can have a negative impact on self-confidence and cause emotional distress. To feel like themselves again, a person can wear wigs. However, not everyone has the opportunity to buy a high-quality wig made from real hair. Fortunately, there are organisations around the world that donate wigs to those who need them.





Most people lose approximately 50 to 100 hairs per day. This is completely normal—new hairs typically replace the old ones. But sometimes the lost hair doesn't regrow. This condition is known as **alopecia**, and it comes in different types.

During chemotherapy, more than 65% of people with cancer experience hair loss—a condition known as **anagen effluvium**. It occurs in response to drugs and radiation therapy, which cause the destruction of hair follicles. While the onset of this type of alopecia can be gradual or sudden, the good news is that it is reversible. Most patients typically start regrowing hair within two months after completing treatment.

In cases of **alopecia areata**, the immune system targets hair follicles, causing hair loss on the head and throughout the body, including in the nose and ears. Eyebrows and eyelashes may also be affected. There are treatments available for this type of alopecia in some instances.

Androgenic alopecia is the leading cause of hair loss in people of all genders. It is typically caused by genes that instruct hair follicles to shrink, halting hair growth. This type of loss can start as early as teen years, but it usually begins later in life. Unfortunately, this type of alopecia is often irreversible, but in some cases treatment can be effective in stopping or slowing down the process of hair loss.

Wigs can help people with alopecia feel more confident and comfortable. But not everyone can afford them—a wig made from human hair costs anywhere from £300 to £5000. Fortunately, various foundations create wigs for people who have lost hair due to illness or accidents, such as fires. These foundations rely on donors who can contribute their hair, provided it meets specific criteria. Donating your hair to these organisations is a meaningful way to support those in need.

Foundations That Accept Hair Donations

Various charities and organisations accept hair donations for wig-making to support people experiencing hair loss. Before donating, check each organisation's website for specific requirements. Some notable charities include:

- **Wigs For Kids** is a US-based organisation that provides wigs to children facing hair loss due to medical conditions. Hair donations can be sent to 24231 Center Ridge Road, Westlake, OH 44145, USA.
- **Hair We Share** is based in Long Island, New York. It provides wigs to people of all ages who are affected by medical hair-loss conditions. Address: 350 Jericho Turnpike, Suite #3, Jericho, NY 11753, USA.
- **Pink Heart Funds** is a charity that provides wigs for children and adults with cancer-related hair loss or severe hair loss. Address: 5095 Beatline Road, Long Beach, MS 39560, USA.
- **Wigs & Wishes** is a non-profit organisation dedicated to providing wigs to people battling cancer, through various salons across the globe. Address: 304 Hurffville Crosskeys Road Sewell, NJ 08080, USA.
- **Little Princess Trust** is a charity organisation in the UK that offers real hair wigs to children and young people up to the age of 24. Address: The Hannah Tarplee Building, 22-25 Berrington Street, Hereford, HR4 0BJ, UK.

After receiving the hair, the foundations send a thank you email to each donor.





Hair Donation Requirements

People of any age, gender, and ethnicity can donate hair. Hair can be straight, curly, or wavy and of any natural colour. Specific requirements may vary among foundations, but general criteria often include:

- Clean and dry hair without any styling products.
- No split ends.
- Dyed hair (natural colours only) may be accepted if it has not been bleached and is in good condition.
- Length: 30 cm (ideally 40 cm or more). Pull curly hair straight for a more accurate measurement, but don't straighten or braid it.
- Recently cut hair (within the last five years) is accepted if it is in good condition.

How to

CUT YOUR HAIR FOR A DONATION

To donate your hair, follow these steps:

1 Grow your hair to at least 30 cm and visit the hairdresser. Make sure your hair is washed and dried thoroughly—this can be done either at home or at the hair salon. Avoid using conditioner or styling products. If conditioner needs to be used, it must be rinsed out.

2 Request your hairdresser to divide your hair into four (or even better, six) equal parts, creating four or six ponytails. Secure each ponytail with an elastic band at the tip and another in the middle. If your hair is thick, you may require additional ponytails. Note that some organisations may require the ponytail to be braided and secured with an elastic band.









How Wigs Are Made

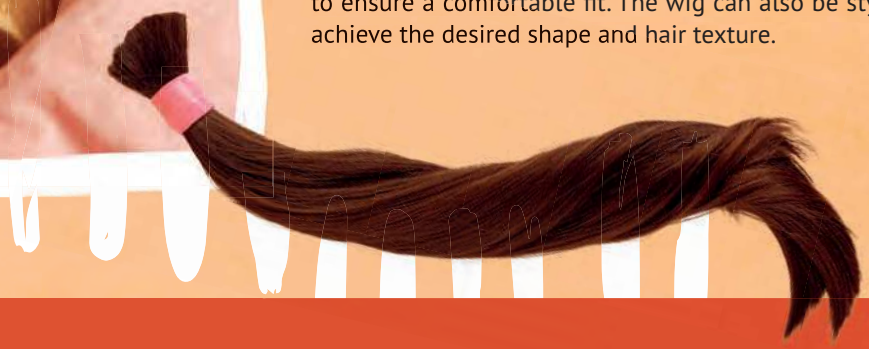
After reaching wig manufacturers, donated hair is sorted based on length and colour. It takes approximately 16 donors to contribute enough hair for one wig.

Selected ponytails are gathered into one, then mixed and combed using a special brush. Next, the hair is placed between two plates to prevent tangling and to ensure a secure arrangement.

The wig maker selects multiple hairs from the bundle and uses a special hook to weave them into a soft, elastic mesh—the base of the wig designed to mimic the scalp. The maker uses a double knot to securely attach the hair to the base.

Crafting one wig requires about two weeks of meticulous work.

A wig is individually selected for each client, considering their head size and preferences for hair colour and length to ensure a comfortable fit. The wig can also be styled to achieve the desired shape and hair texture.



3 Ask your hairdresser to cut the hair above the top bands.

4 Place your hair in a recyclable cardboard or heavyweight paper envelope. Attach the completed hair donation form, which can be downloaded from the website of the organisation to which you decide to donate your hair.

5 Go to the post office and send your parcel. Before visiting the hairdresser, make sure to study the organisation's requirements for hair length and quality, as well as guidelines on how to cut and package it correctly.







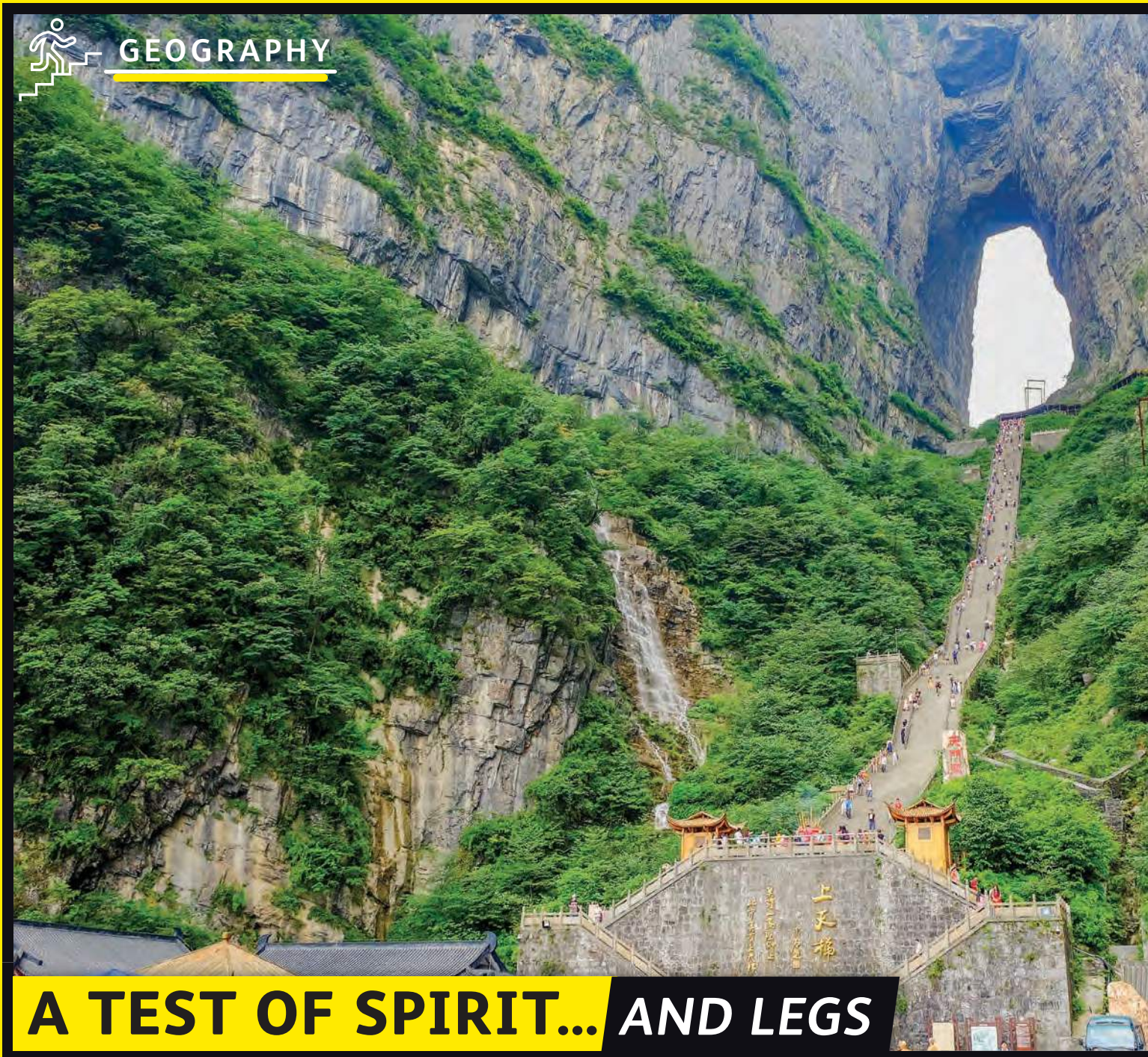


Losing the Forest for the Trees

Over the past 50 years, almost 20% of the Amazon Rainforest, the world's largest tropical forest, has been destroyed. Destruction is accelerating, with 1.4 billion trees lost annually. This is especially catastrophic for the millions of species that call the Amazon their home.

Large areas of the Amazon Rainforest have been destroyed in order to make room for mining, roads, dams, hydropower plants, and urban expansion. However, the forest is primarily being cut down for agricultural purposes, particularly for growing soybeans and raising cattle. The demand for these products is constantly growing, resulting in the continuous clearance of more and more land to facilitate crop production and livestock farming.

The extensive deforestation of any forest raises environmental concerns, but the Amazon Rainforest holds unique significance for our planet. The Amazon stores approximately 123 billion tonnes of carbon above and below ground. The release of this carbon into the atmosphere would intensify climate change, leading to higher temperatures, rising sea levels, and an increase in the frequency of natural disasters.



A TEST OF SPIRIT... *AND LEGS*

We tend to think of stairs as a way to get somewhere. But sometimes the stairs themselves deserve our attention! As it turns out, a flight of stairs can be a work of art, a tourist attraction, and even a spiritual challenge.

Who came up with stairs? The idea didn't come from a single person, or even from people in general. Stairs were "created" by nature! Even our ancient ancestors used trampled **goat trails** and ledges in the rocks. Climbing higher allowed people to get a better view and spot any approaching dangers. Over time, going up and down, people began to "refine" the paths they were using, adding more comfortable steps and primitive handrails.

The first civilisations—the ancient Egyptians, Sumerians, and Greeks—effectively incorporated stairs into their architecture.

Surprisingly, stairs have not changed much since ancient times, except for the emergence of universal **standards**. It turns out that we quickly adapt to a particular height of steps within a staircase—if the height suddenly changes even slightly, a person can stumble and fall. In modern houses, steps are typically made the same size, but in old buildings, you need to walk







Stairway to "Heaven's Gate" *China*

In 263 CE, a **natural arch** appeared in Tianmen Mountain, creating a passage in the rock with a height of more than 130 m. Imagine the amazement of the locals! Of course, the arch has since become a **place of pilgrimage**. No real surprise there—the passage is absolutely stunning. The staircase leading to "Heaven's Gate" consists of **999 steps**: the number 9 in Chinese culture is associated with eternity and prosperity. Before the stairs, there is an altar where believers perform divine services, and the end of the path is at an altitude of 1170 m above sea level. If you're going to climb to "Heaven's Gate," it's best to go slowly and make frequent stops for rest. There's also an escalator nearby, but that wouldn't be as interesting, would it?

very carefully, because no one paid much attention to maintaining consistent steps back then.

Getting up to the ninth floor without a lift can be quite a challenge. Climbing stairs is a **strenuous physical activity** that requires a lot of oxygen and muscle work, leaving us huffing and puffing after climbing just a few floors. But why don't we feel the same way after a simple walk? After all, there seems to be no significant difference between climbing stairs and walking—you simply work your legs in both cases. The thing is, when climbing stairs, we move not only forward but also upward, thus working against gravity. In addition, during stair climbing, we raise our knees higher than when walking or running.

Doctors and fitness trainers recommend using stairs instead of lifts. Just make sure to approach climbing stairs like you would any exercise: warm up a little beforehand, do not overdo it, and practise regularly.

In many cultures, climbing stairs is considered a physical and spiritual challenge. Temples were often built high up in the mountains (*closer to the sky meant closer to the divine*), so **pilgrims** had to climb numerous stone steps. Of course, after a while, turning back seemed like not such a bad idea, so only those of strong will and belief could reach the sacred place.

You might recall a famous poem by A.A.Milne that goes like this: "Halfway down the stairs is a stair where I sit. There isn't any other stair quite like it." This month, we'll look at stairs around the world that aren't quite like the others.



Photo by Xavier von Erlach on Unsplash

MOUNT NIESEN FUNICULAR STAIRCASE *SWITZERLAND*



Paradoxically, the **longest staircase in the world** is not found in the world's tallest building. The Burj Khalifa skyscraper has only 2909 steps—almost four times fewer than Mount Niesen's staircase, which boasts an impressive 11,674 steps! The mountain is also known for having an almost perfect triangular shape, which casts an impressively even shadow. The mountain even earned the nickname "the Swiss Pyramid" for this unusual feature. Tourists get to the top of Mt Niesen by funicular railway, but next to it lies a "modest" service staircase, more than **three kilometres long**. It is normally closed to the public, but every June, it hosts a race for several hundred participants. The winners conquer the climb in about an hour.

Bramante Staircase *The Vatican*

Two in one! In 1505, the Tuscan architect **Donato Bramante**, commissioned by **Pope Julius II**, built an amazing spiral staircase resembling a DNA helix: instead of traditional steps, it has two separate staircases that **don't intersect**. One staircase is for ascending and the other is for descending, which allows people to go up or down without crossing paths. In fact, staircase isn't quite the right word—there are no steps here, just one continuous ramp. This innovative layout allowed people not only to walk but also to ride carriages and transport goods on mules. It's important to mention that if you have been to the Vatican, you walked **along a completely different staircase**, which was built in 1932. The original, hidden from prying eyes, requires a permit to visit.

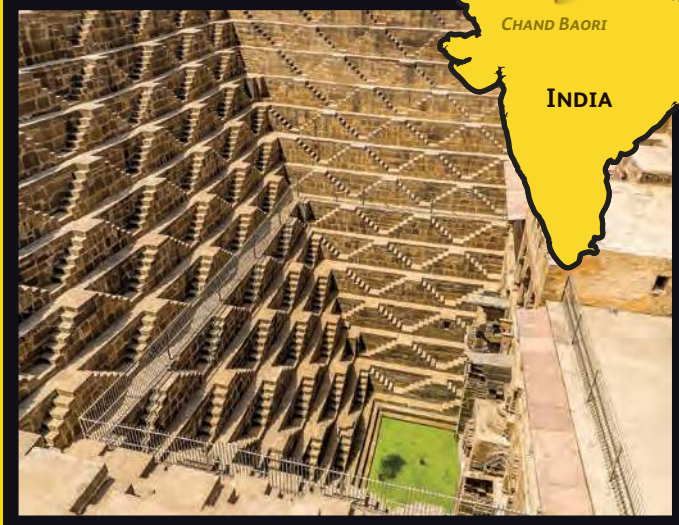


V Original Bramante Staircase (1505)

V Modern version of the staircase (1932)









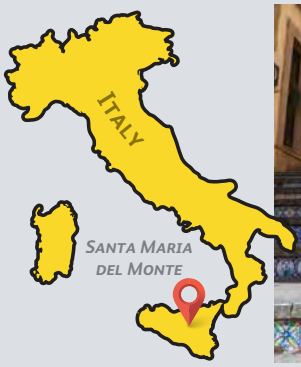


Chand Baori *India*

To be more precise, this is not a staircase but a **stepwell**—an artificial pit for collecting rainfall and groundwater, commonly found in India and Pakistan. Chand Baori was built more than a thousand years ago, in the 8th–9th century CE. It has a unique feature: all the steps (*and there are three and a half thousand of them!*) are arranged in **perfect symmetry**, forming a complex pattern. According to a local legend, the well was built overnight—the work of a genie, no less. They also say that it's impossible to go down and up the same path in Chand Baori. Indeed, it is pretty easy to lose your way in this vertical maze.

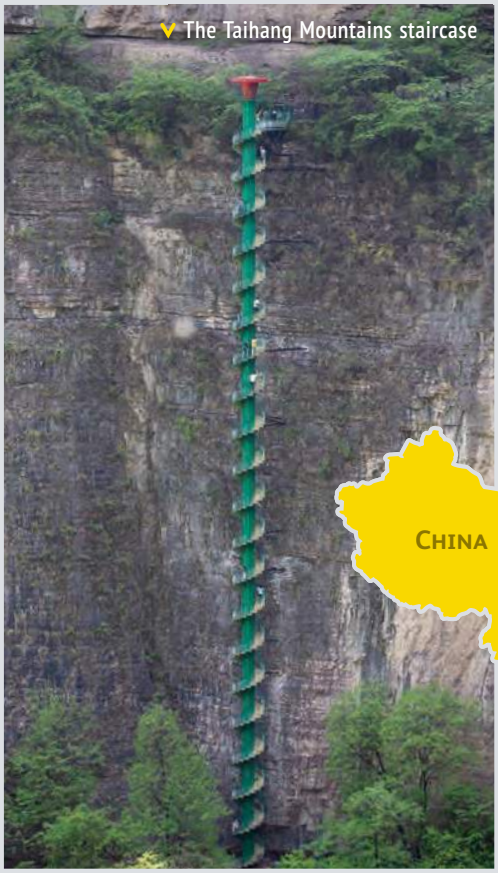
Staircase of Santa Maria del Monte *Italy*

Only 142 steps, but what steps! The Italian city of Caltagirone on the island of Sicily is famous for its ceramics, so it's only natural that the stairs are **decorated with handmade ceramic tiles**, and each step has its own unique pattern. The staircase was originally built at the beginning of the 17th century to connect the upper and lower parts of the city. Twice a year, Santa Maria del Monte becomes the centre of everyone's attention. In May, Caltagirone celebrates a flower festival, and hundreds of pots of flowers are placed on the steps to form a single large pattern. Another holiday is in July on the day of St James, the patron saint of the city. The stairs are lined with thousands of oil lamps, together forming a grandiose pattern several tens of metres in size.







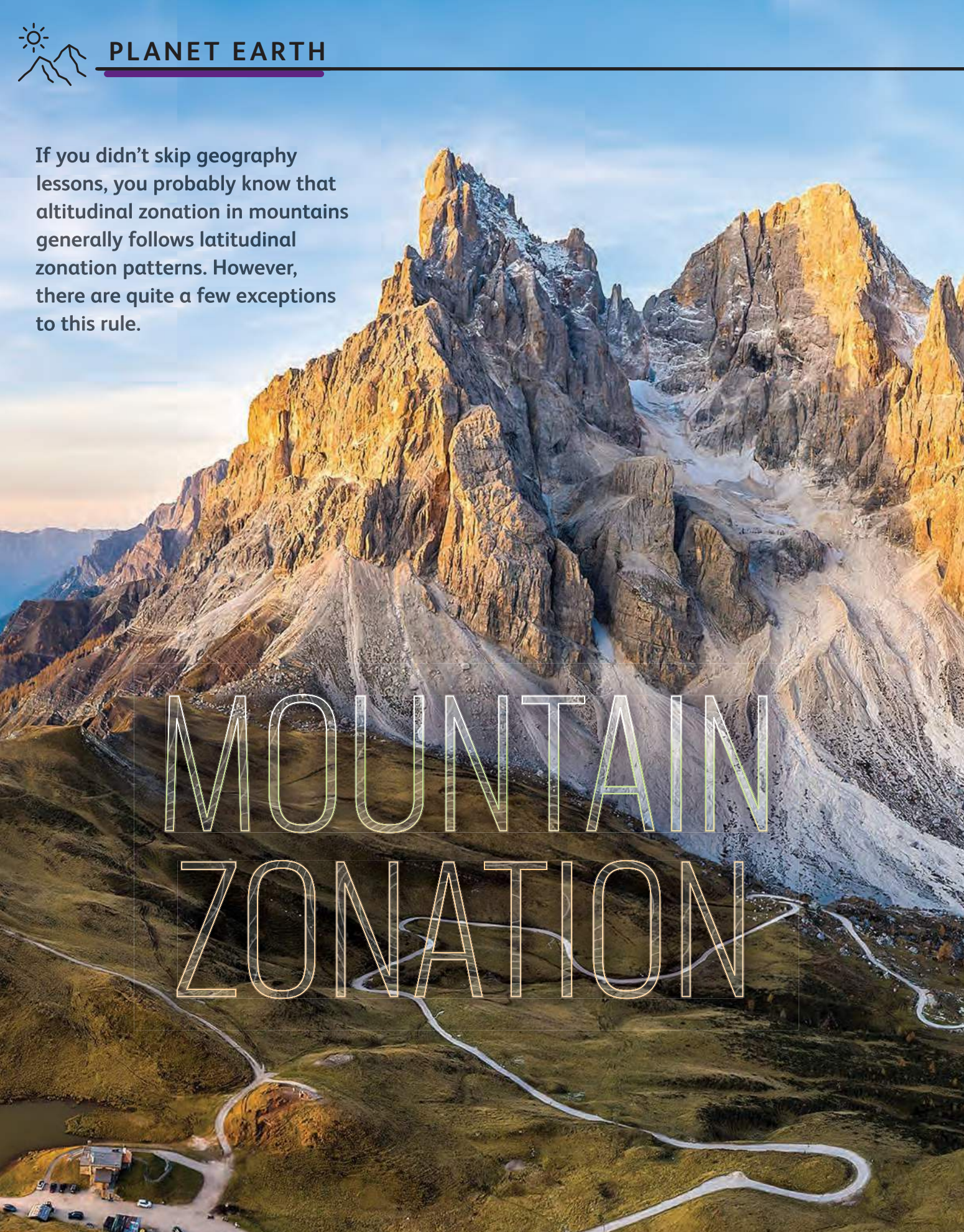


Staircase in the Taihang Mountains *China*



China boasts another grand staircase on the edge of a 400 km mountain range. A huge spiral staircase with a **height of 91 m** is embedded into the face of a mountain, inviting tourists to marvel at the local beauty. This is only two metres shorter than the **Statue of Liberty**! Anyone who wants to climb these stairs must sign an official form confirming that they have no health problems. People over 60 years old are not allowed to climb the staircase. The authorities' concern is justified: there are no rest areas on the stairs so it's advisable to make the journey in one go to avoid causing delays for other visitors. The climb is not for the faint of heart: the stairs creak, and strong winds blow through them.

If you didn't skip geography lessons, you probably know that altitudinal zonation in mountains generally follows latitudinal zonation patterns. However, there are quite a few exceptions to this rule.



MOUNTAIN ZONATION



Above the Treetops

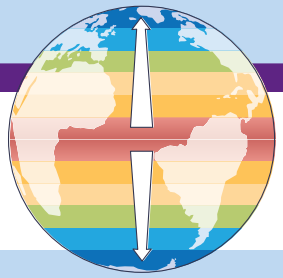
Let's look first at the Alps—one of the most studied mountain ranges in the world. The term "Alps" has become synonymous with the general concept of mountains: for example, mountain climbing is sometimes referred to as **alpinism**. There are "Alps" in Australia, New Zealand, and even on the Moon.

At first glance, when climbing a mountain, natural zones change the same way they do when moving north from the equator: Mediterranean vegetation is replaced by deciduous forests, then by coniferous ones, and then … Stop! This is where the parallels end. As you go north, the taiga is replaced by tundra, but as altitude increases in the Alps, the taiga is replaced by subalpine and alpine meadows (another mountain term originating from the Alps), which have no equivalents on the plains of the tundra.

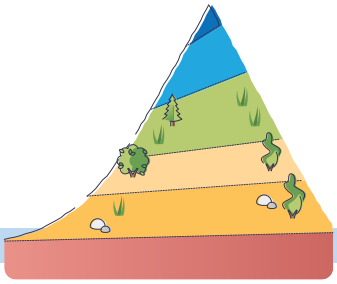
This isn't surprising—after all, natural conditions at high altitudes differ significantly from those of the polar regions. Mountains get more rainfall, tend to have smaller differences between summer and winter temperatures, and don't experience polar day or polar night.

Subalpine and alpine meadows are found in most mountain systems on Earth, but they are not the only type of ecosystem to exist between forests and year-round snow or glaciers.

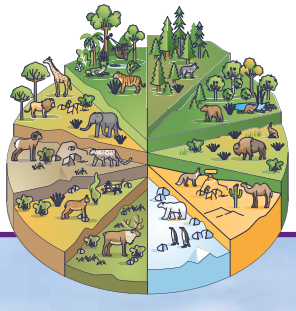
Latitudinal zonation refers to changes in natural geographic features with movement from the poles to the equator.



Altitudinal zonation refers to changes in natural conditions, zones, and landscapes in mountains as altitude increases from sea level to peak.



Biocenosis is a distinct collection of animals, plants, fungi, and microorganisms that inhabit a specific area of land or body of water. These organisms are interconnected and interact with each other as well as with their environment.





Mountain scenery with lush green meadows in the Berchtesgaden Alps, Germany



In tropical regions, **high-altitude ecological biocenoses** are made up of various ecological communities that share a number of similarities. Due to their location near the equator, they experience virtually no seasonal temperature fluctuations. Instead, they are characterised by strong daily fluctuations: during the day the temperature can rise to over 30°C, and at night it can drop below zero! We can say that in these ecosystems, the seasons change daily: **every day is summer**, and **every night is winter**.

Such unusual climatic conditions give rise to a special type of vegetation. In these areas, grasses predominate, but other herbs, cushion and rosette plants, large and small shrubs, and low-growing trees also play important roles.

Probably the most unusual life form of plants characteristic of these high-altitude ecosystems is the giant groundsel. This plant has a thick branchless trunk that can reach up to ten metres high, at the top of which sprouts a dense bunch of fleshy leaves. Most species of giant groundsels don't shed dead leaves. Instead, these leaves protect the plant from the night cold.



^ Páramo in the Columbian Andes

< Yareta is a cushion plant native to the Andes

v "Forest" of giant groundsels





Chajnantor Plateau in the Chilean Andes

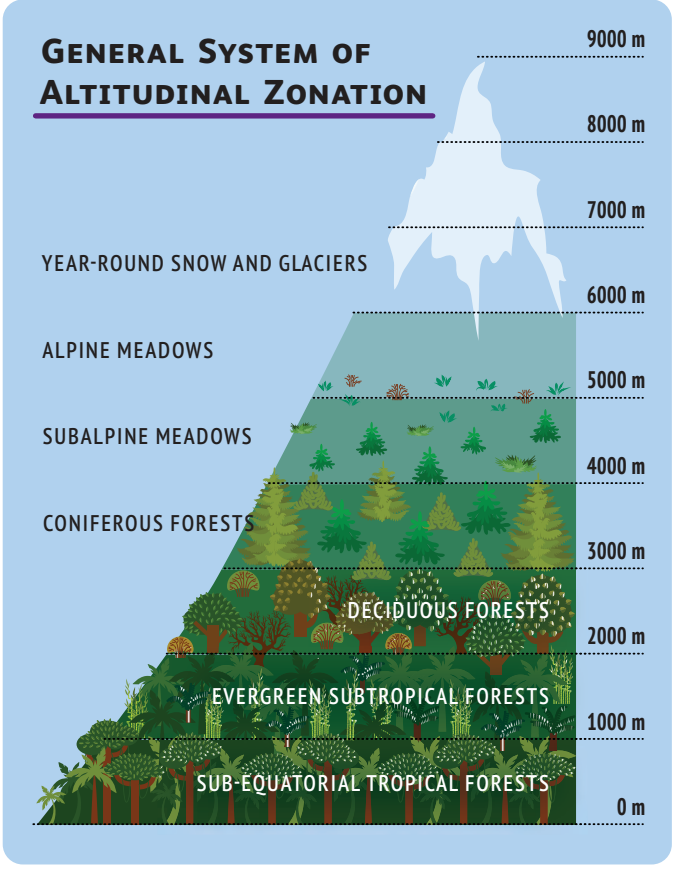
Rain Matters

Vegetation patterns at lower mountain altitudes don't always follow latitudinal patterns, either. This usually happens due to **differences in humidity**. For example, on the western slopes of the Andes in northern Chile, despite the altitude (over 6000 m), there's virtually no altitudinal zonation. Due to a complete absence of precipitation, a lifeless desert stretches from sea level to the highest peaks, and there are not even any glaciers. At the same time, the opposite slope of the Andes experiences a lot more precipitation, which makes altitudinal zonation much more apparent. Additionally, due to sufficient moisture across all altitudes in this region, there is no tropical desert zone, characteristic of latitudinal zoning. Instead, forests cover the slopes entirely, transitioning from tropical to subtropical and then to temperate as altitude increases.



Cloud forest in the Philippines

In general, when climbing mountains—at least to a certain height—temperature tends to decrease, while precipitation typically increases. This happens because as the air gets colder, it holds less water vapour. Therefore, as rising air masses cool, their water vapour condenses, forming clouds from which rain and snow fall—this phenomenon is called **orographic precipitation**.





Puna ecosystem

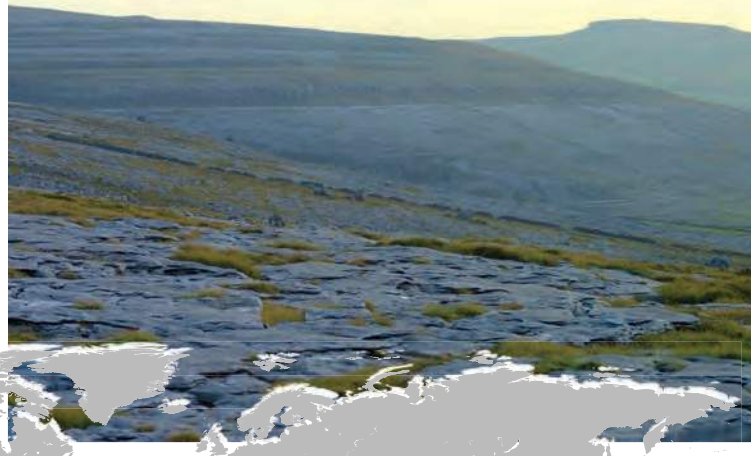
In some mountain systems, this effect creates zones where humidity remains constant at almost 100%, resulting in persistent fog. These conditions can give way to a unique type of ecosystem known as **cloud forests**. These ecosystems are characterised by an abundance of mosses, which sometimes form a continuous green carpet that covers the ground.

This moisture phenomenon also affects the type of vegetation that develops beyond the upper forest boundary. If there is insufficient precipitation in this higher altitudinal zone, then instead of subalpine and alpine meadows, ecosystems requiring less moisture are formed—**mountain grasslands**.

This type of ecosystem is found in many mountain systems around the world and has unique names in different languages. For example, in Bolivia and northern Argentina, it is called *puna*, and in Mexico it is called *zacatonal*.



In Ireland, limestone rock formations create a dry, steppe-like landscape amidst the generally humid climate.



^ Rocky Mountains in Idaho, US: the north-facing slopes are occupied by forest and the south-facing slopes by steppe.

Speckled Slopes

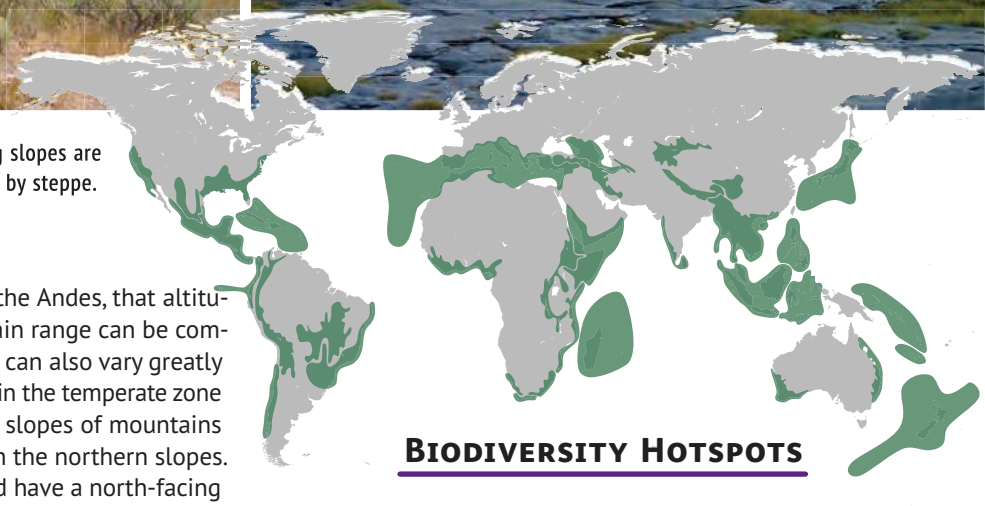
We've already seen, as in the example of the Andes, that altitudinal zones on opposite sides of a mountain range can be completely different. But mountain vegetation can also vary greatly even on neighbouring slopes. For example, in the temperate zone of the northern hemisphere, the southern slopes of mountains receive much more sunlight and heat than the northern slopes. Because of this, the same river valley could have a north-facing slope covered entirely in taiga, while its south-facing slope at the same altitude will be characterised by grassland.

Rock formations that make up the ridges of mountains also affect vegetation. For example, water goes through limestone easily, so it doesn't stay on the surface for long. Because of this, areas composed of limestone develop more drought-resistant vegetation compared to areas where water-resistant rocks predominate.

In the mountains, various factors influence the formation of biocenoses. Therefore, it makes sense that in mountainous areas, ecosystem diversity is much higher than it is on a similar-sized flat area.

It is also not surprising that almost all **biodiversity hotspots** on land are located in mountainous areas. This makes studying mountain ecosystems fascinating, but it also means they are more delicate. This is because each community of ecosystems in the mountains covers a smaller area compared to a similarly sized one on flat land, making it more vulnerable to different kinds of disruptions.

Unique ecosystems often occupy only one river valley or even just a small section of it. For example, there is a tropical dry broadleaf forest ecosystem in Colombia covering around 2000 km^2 (about the size of West Sussex) in the valley of the small Patía River. This ecosystem can't be found anywhere else in the world! Sadly, many of the natural ecosystems in this region have already been destroyed by humans. Nature conservation in the mountains, therefore, requires special attention.



Biodiversity Hotspots

v Moorlands in the Pennine Hills



Sometimes human activities can shape altitudinal zones in mountains. Take the Pennine Hills in England as an example—above 300 m, you won't find many trees. However, the moorlands that you see dominating the landscape weren't formed by natural processes; they emerged due to continuous grazing by domesticated sheep. Without this grazing, most of these areas would likely be covered by broadleaf forests.

WHEN INSECTS WERE GIANTS



Insects are one of the most successful groups of land animals. Today, for every species of mammal there are more than 160,000 species of insects. Most of them can easily fit on an adult person's fingertip, but millions of years ago, when coal was still a lush forest and our ancestors were just beginning to explore the land, giant insects reigned on Earth. Why did they disappear, and could they one day make a comeback?

Arthropod Giants of the Carboniferous Period

Monsters of a Bygone Era

Insects first appeared on Earth during the **Early Ordovician period**, about 479 million years ago, reaching their biggest sizes around 300 million years ago during the late Carboniferous and early Permian periods. Around the same time, giant insects began to roam the Earth. Best known among these giants is ***Meganeura***, a huge relative of dragonflies. The wingspan of the largest modern representative of this order, the blue-winged helicopter (*Megaloprepus caerulatus*), is "merely" 19 cm, while *Meganeura*'s wingspan reached 75 cm—the size of a pigeon! However, the body mass of this "super dragonfly" was much less than that of a bird, at only 100–150 g. Still, together with its closest relatives, *Meganeura* holds the title of the largest flying invertebrate of all time.

But *Meganeura* was not alone: the Carboniferous period was full of hefty arthropods roaming the land—from the 70-centimetre-long scorpions to gargantuan centipedes that reached 2.6 m in length and weighed 50 kg. In later eras, the number of species of giant insects noticeably decreased, but they could still be found on Earth for at least 250 million years. For example, about 48 million years ago, you could encounter giant ants the size of hummingbirds in Europe and North America.



Meganeuropsis

A relative of the ancient *Meganeura* dragonfly from the Permian period, it lived about 285 million years ago in what is now the United States. Its wingspan was about 70 cm.



Mazothairos

A member of the extinct order Palaeodictyoptera, *Meganeura*'s favourite prey. Despite its impressive wingspan (55 cm), *Mazothairos* was a peaceful vegetarian, using its spiny proboscis to extract plant juices. This species lived about 309 million years ago in the modern-day US.

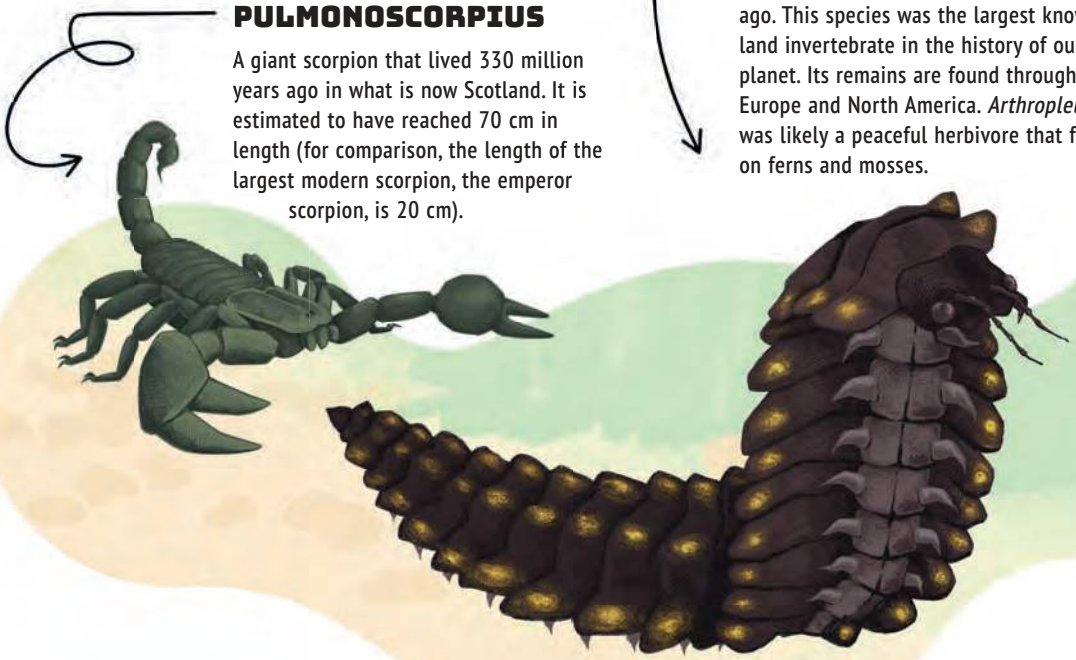
Arthropleura

A relative of modern centipedes, *Arthropleura* reached up to 2.6 m long. It lived in the Carboniferous and Permian periods from 314 to 290 million years ago. This species was the largest known land invertebrate in the history of our planet. Its remains are found throughout Europe and North America. *Arthropleura* was likely a peaceful herbivore that fed on ferns and mosses.



Pulmonoscorpius

A giant scorpion that lived 330 million years ago in what is now Scotland. It is estimated to have reached 70 cm in length (for comparison, the length of the largest modern scorpion, the emperor scorpion, is 20 cm).



* *All insects are arthropods, but not all arthropods are insects. Arthropods are animals with an external chitinous skeleton, articulated legs, and a segmented body. Apart from insects, they include crustaceans, arachnids, horseshoe crabs, and millipedes.*

So how did ancient insects become so large? The answer is simple: **oxygen**. All animals need this gas to breathe, and insects are no exception. Today, oxygen makes up 21% of our atmosphere, but during the Carboniferous period, its proportion was **more than one and a half times** greater. In that distant era, the climate was humid and warm, and thick **swampy forests** covered much of the land. Mosses, ferns, horsetails, and primitive relatives of modern pines all grew uncontrollably, filling the air with oxygen.

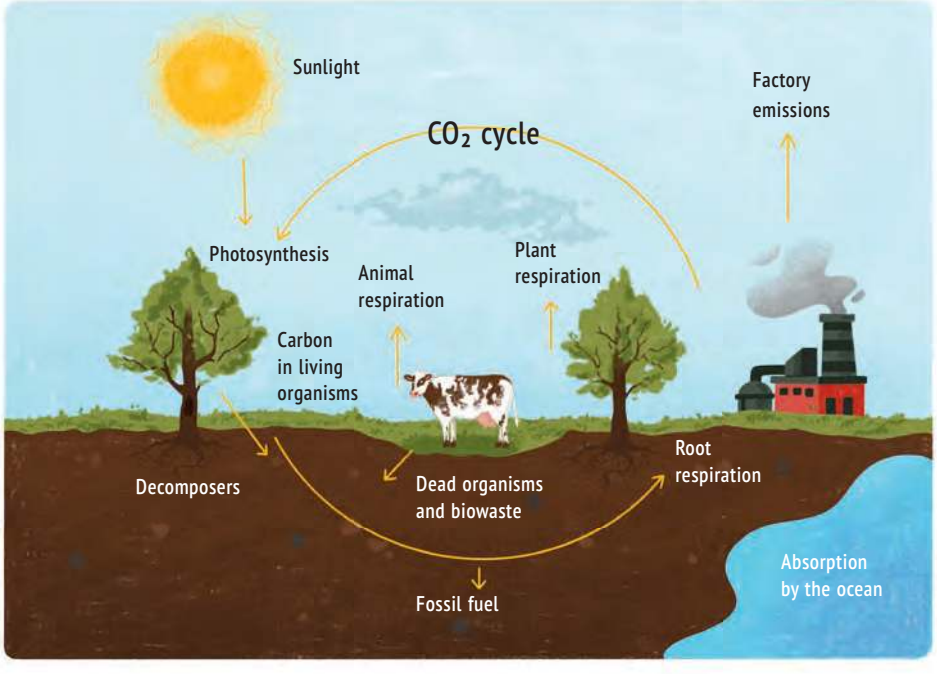
But wait, you might say, today's Earth has a lot of trees, too! The tropical jungles of the Amazon and Southeast Asia, the endless boreal forests of Siberia and Canada—aren't they enough to saturate the atmosphere with oxygen? There are indeed many forests on the planet today, which cover about a third of the total land area, but our world is very different from that of the Carboniferous period. Nowadays, when a tree falls to the ground due to old age or disease, scavengers—**decomposers**—immediately begin to "recycle" it. The primary actors in this process are bacteria that break down wood. As they work, they actively absorb oxygen and release carbon dioxide.

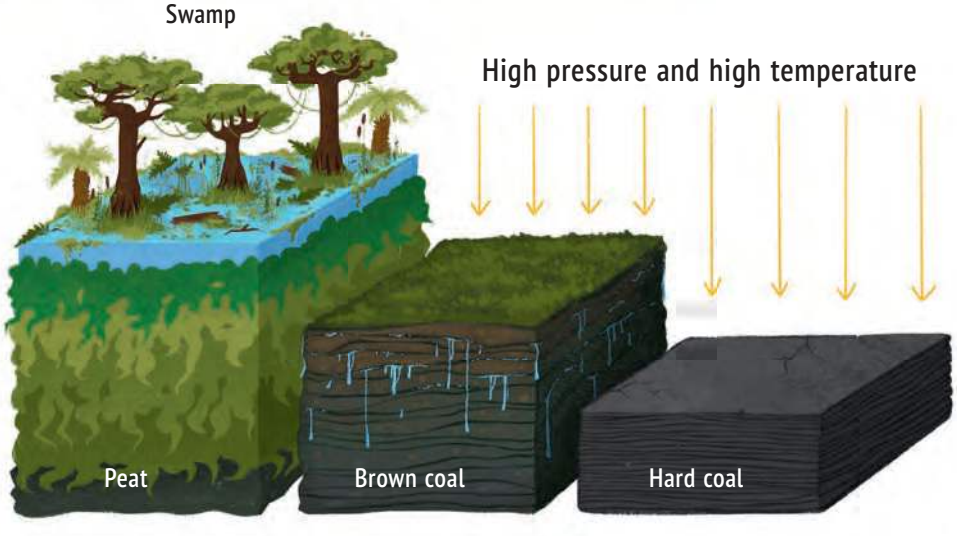
Three hundred million years ago, however, such bacteria did not yet exist on our planet, so there was no one to release carbon dioxide back into the atmosphere. Through photosynthesis, trees absorbed carbon dioxide, converting it into nutritious glucose with the help of sunlight. However, instead of decomposing after death, these ancient trees accumulated, gradually compressing and forming massive deposits of **coal**. Thus, the "trapped" carbon dioxide was removed from the atmosphere for millions of years. Meanwhile, living trees continued to "breathe in" carbon dioxide and saturate the atmosphere with oxygen, until its concentration reached an impressive 35%!

It's no surprise then that forest fires of the Carboniferous period were the largest in the history of Earth. Even a single lightning strike in an oxygen-rich atmosphere could be enough to set a huge area of forest on fire.

THE CARBON CYCLE

Unlike the modern world, the Carboniferous period had no large herbivores, and decomposer organisms had not yet had time to get a proper "taste" of wood. As a result, masses of dying wood accumulated in the bowels of the planet in the form of coal.

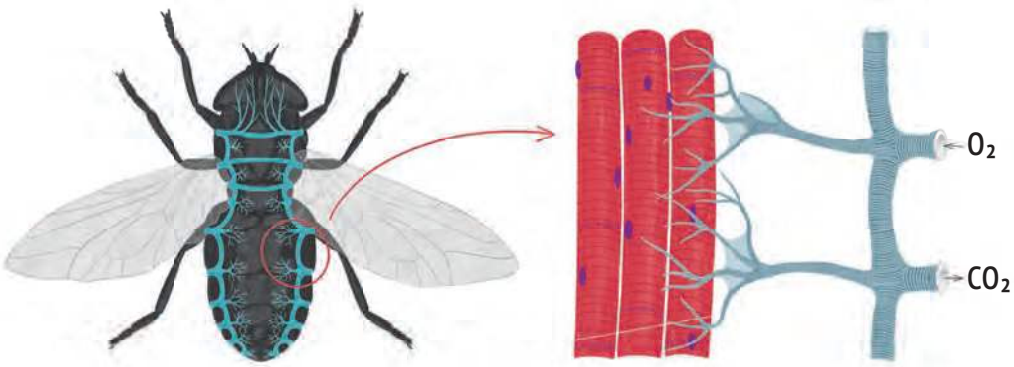




COAL FORMATION

During the Carboniferous period, plants absorbed carbon dioxide through photosynthesis, and their deceased remains accumulated at the bottom of swamps. As new layers pressed on each other, peat transformed into brown coal, gradually evolving into hard coal. Three-quarters of the composition of this coal is carbon derived from carbon dioxide.

RESPIRATORY SYSTEM OF INSECTS



Insects breathe completely differently from humans. An insect doesn't have lungs, and air freely enters the body through special openings, called the spiracles, on each segment of the body. These spiracles, in turn, lead to a branched system of tubes called tracheae. The end parts of the trachea are covered with extremely thin outgrowths, tracheoles, through which oxygen passively seeps into the internal organs and carbon dioxide is expelled. In flying insects, the trachea can form air sacs.

"That'll Do!"

To understand the relationship between the concentration of oxygen in the atmosphere and the size of insects, you need to look at the structure of the **insect respiratory system**. Insects have a relatively inefficient gas exchange system. Their haemolymph is the sole tissue fluid in their bodies responsible for carrying nutrients, providing immune protection, and for removing metabolic products. However, haemolymph does not contain respiratory pigments like our haemoglobin and cannot transport oxygen. Moreover, due to their small surface area, the tracheoles' ability to absorb oxygen is much lower than that of the alveolar lungs found in mammals and birds. Flying insects face particular challenges as their actively working flight muscles burn oxygen very vigorously. In many flying insects the trachea form special swellings called **air sacs**, which not only increase the volume of air circulating in the trachea but also act as primitive lungs, pumping air through the entire system of tubes like a blacksmith's bellows.

Such an imperfect respiratory system means that the amount of oxygen entering an insect's body will largely depend on the oxygen content in the atmosphere. In simple terms, the more oxygen in the air, the more that will penetrate through the tracheal tubes into the body, allowing more cells to receive it. Indeed, scientists have conducted experiments with various insects, subjecting them to conditions of oxygen scarcity or excess. For some species, such as the superworm beetle, a direct correlation between body size and the oxygen content in the environment has been demonstrated.



During the Carboniferous period, the first **real forests** appeared on Earth and spread over vast territories. They arose thanks to **lignin**. This substance made the walls of plant cells stronger and the stems thicker and taller. Before the emergence of lignin, the height of the oldest land plants did not exceed a few centimetres! In modern conifers (which include one of the tallest trees on the planet, the giant sequoia), the lignin content reaches 50%!

There are alternative explanations for the gigantism of Carboniferous insects. For example, one hypothesis states that insects grew gigantic because there was no one around to eat them. In the Carboniferous period, relatives of today's dragonflies were the only animals on Earth that had mastered active flight, so they had to remain vigilant only on land or near water, as predatory fish, amphibians, and other non-flying predators were found there. In the air, these insects enjoyed complete freedom.

It's also possible that insects such as *Meganeura* and its relatives became giants to successfully rival their prey—other insects with impressive wingspans. "Arms races" like this are not uncommon in the animal world: for example, bats and moths are constantly improving their echolocation detection systems and defences.

However, the oxygen hypothesis is considered the most reliable.



Early pterosaurs, such as this *Eudimorphodon*, appeared by the end of the Triassic period and quickly dominated the skies as predators, while dragonflies, relatives of the already extinct *Meganeura*, had to become their prey.

The Fate of the Goliaths

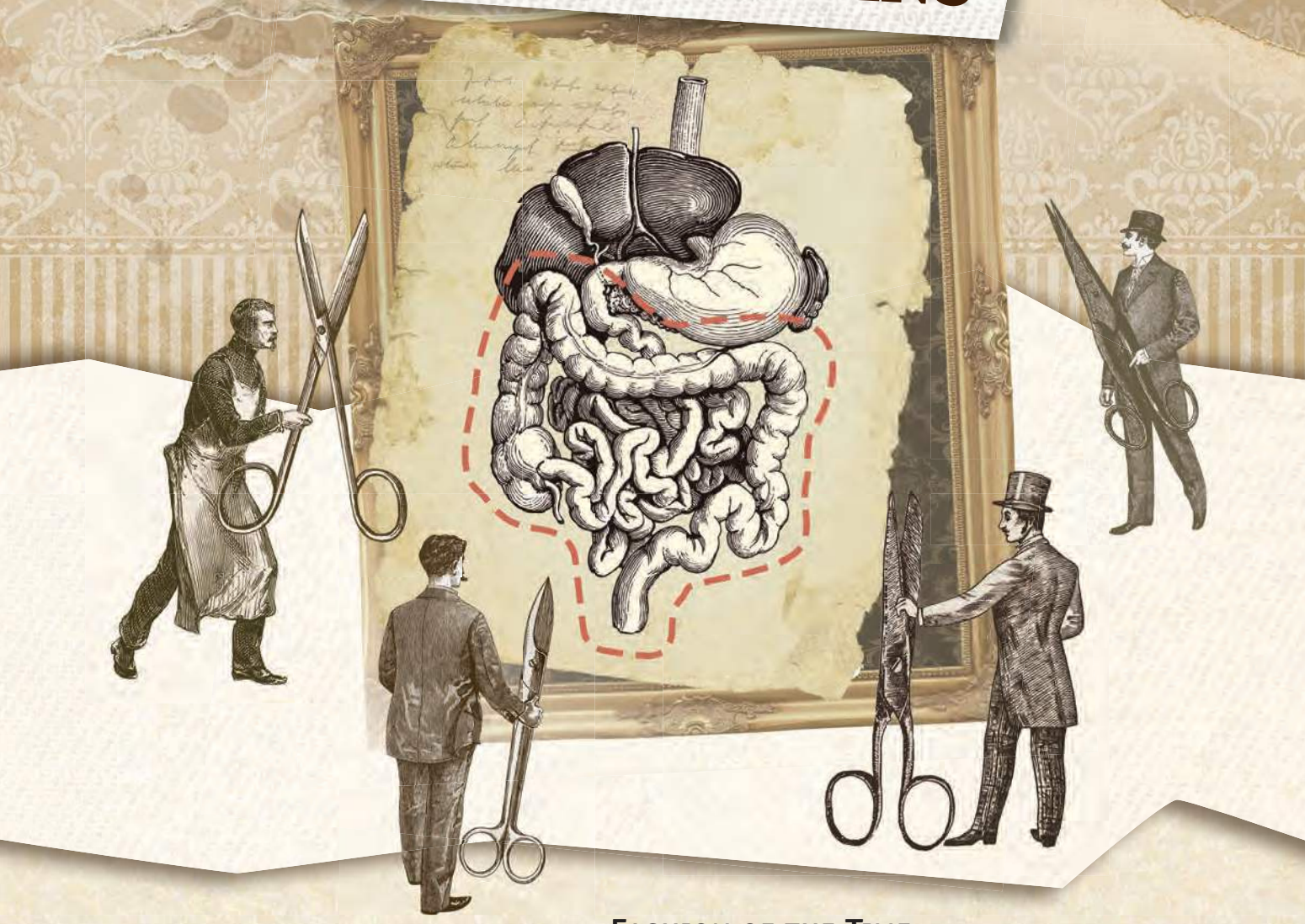
So what happened to the giant insects after the end of the Carboniferous period? Some time after the **Permian period** began and decomposer bacteria appeared, insects remained pretty large by today's standards: the Permian *Meganeuropsis* had a wingspan that rivalled that of *Meganeura*. But then, oxygen levels in the atmosphere drastically dropped: in just 20 million years, they had decreased from almost 30% to 16%, spelling a death sentence for giant insects. There are different hypotheses as to the exact cause of this disaster, but most scientists believe that volcanic eruptions in today's Siberia played a leading role: up to 5 million cubic kilometres of lava spurted from beneath the ground over half a million years, covering a territory double that of modern France.

Naturally, the drop in oxygen levels led to a sharp reduction in the size of arthropods and the extinction of many ancient groups of insects. The atmosphere took millions of years to recover, and during this time, insects lost their title as the only flyers on Earth. Reptiles mastered real flight about 230 million years ago, when the first **pterosaurs** took to the air. These agile and dexterous hunters quickly occupied the position that once belonged to *Meganeura*. Another 100 million years or so later, **birds** and then **bats** began to master flight. Many species of these animals feed on insects even today.

As a result, while giant *Meganeura* reigned in the air in the sleepy forests of the Carboniferous period, they completely and utterly lost the competition in the sky in the subsequent era. When pursued by a hungry insectivorous reptile or bird, it makes more sense to be small and agile to dodge the deadly claws and teeth. So it's not surprising that most insects that came after are of a much more familiar size—no more than a few centimetres in length.

However, giant bugs may still emerge, say, in the event of a global cataclysm. If there are no more land vertebrates, no higher plants, nor even bacteria that decompose wood left on Earth, evolution might be able to start "from scratch." Endless forests will again spread across the marshy lowlands, and, like 300 million years ago, animals will start exploring the land anew, and giant insects may well appear among them . . .

Antiquated science AGAINST "SPARE" ORGANS



Would we be happier without our bowels? How about without a stomach? Today these questions sound absurd, but a little over a century ago this topic was seriously discussed by European scientific and medical luminaries. What sparked these ideas?

Fashion of the Time

Sir William Arbuthnot Lane (1856–1943) was a true legend of British surgery: his colleagues were jealous of how quickly and skillfully he carried out his operations. He even operated on members of the royal family and was granted the title of Baronet! However, some of his views could today be called eccentric, if not dangerous.

Lane believed that most human diseases shared a common source: bipedalism. According to him, walking upright caused an uneven distribution of weight across the human body, causing bones and joints to deform, and organs to shift and malfunction.



The most affected organ, according to Lane, was **the bowel**. To Sir William, it resembled a bend in a sewer pipe, where waste accumulated, releasing toxins. He was certain: these biological poisons were to blame for ill health!

To "straighten out" the intestines, Lane invented a special brace, and to cleanse the body he recommended regular use of a potent paraffin-based **laxative**. This reached a point where, at a gala dinner in Lane's honour, guests were even offered small bottles of laxatives!

The doctor's experiments led to digestive problems among the members of his household. In fairness, Lane himself took laxatives three times a day an hour before meals and boasted of his improved health.

If the brace and laxatives did not help, the doctor insisted on removing entire sections of the intestine. Lane invented a unique diagnosis that he called "chronic intestinal stasis"—sluggish or stagnant movement of the intestines. Diseases such as cancer, epilepsy, rheumatoid arthritis, anorexia nervosa, and even alopecia were declared to be a consequence of stasis. Lane believed that his operations were especially beneficial for women with mental health disorders.

Resection (partial removal) of the bowel became a fashionable procedure in the UK and US in the 1900s. If you complained to Dr Lane or one of his students at that time about persistent fatigue, their first recommendation would be to go on the operating table. Many patients took pride in having parts of their digestive organs removed. Obviously, the popularity of such operations is a typical case of the placebo effect, or in other words, the result of a patient's self-suggestion. Even when Lane's supporters were told about the severe complications that followed such operations, they responded with something like this: *"Well, what do you want? Man has been poisoning himself with useless organs for years! The doctor is doing what he can!"*







Cut Away the Excess

Lane was not alone in his crusade against the bowel: he had an influential ally, the Russian biologist **Ilya Ilyich Mechnikov** (1845–1916). Mechnikov's main contribution to humanity was his discovery of cellular immunity. For his study of the protective functions of organisms, he received the Nobel Prize in 1908.

For Mechnikov, cellular immunity embodied the struggle of life against death, or more precisely, the body's struggle against everything superfluous and foreign. He considered some organs of the human gastrointestinal tract to be superfluous and even obsolete. While our bodies indeed possess **vestigial structures**—parts that have lost their significance through evolution, such as wisdom teeth, the tailbone, and ear muscles—Mechnikov took a rather radical approach to this concept.







Mechnikov was the first scientist in history to figure out how cellular immunity works. Mechnikov called open cells phagocytes (from the Greek φαγεῖν—"devour" and κύτος—"cell"). Accordingly, the process of immune cells capturing and breaking down foreign bodies is called phagocytosis.

The scientist observed that the large intestine is found exclusively in four-legged mammals. Mechnikov suggested that the main function of this organ is to hold excrement while its owner pursues prey or escapes from enemies. The faster you run, the higher your chances of survival, meaning that an unplanned trip to the bathroom may indeed be your last. Thus, the large intestine, according to Mechnikov, is simply a repository for waste. For example, flying birds can defecate even when chased by a predator, eliminating the need for such storage.

On the streets of modern cities we're not likely to meet hungry lions or angry pumas, and our "hunting," as a rule, takes place in shops and cafes. Consequently, Mechnikov argued, the large intestine is a vestigial organ, and a dangerous one at that. Premature ageing of the body, malignant intestinal tumours, fatal infections—according to the great immunologist, all of these were the result of putrid poisons accumulating in the body.

Most mammals require a complex digestive system because they cannot process their own food (think of the cow with its four stomachs!).



In 1903 the famous Russian writer Leo Tolstoy wrote in his diary: "I read Mechnikov's article again on the same topic: that if you cut out the rectum, then people will no longer think about the meaning of life and will be as stupid as Mechnikov himself."

But everything that happens in the intestines for an animal happens in the kitchen for a person. Isn't turning meat and vegetables into soup and grains into porridge part of *digestion*? Mechnikov thereby reached his final verdict: it's sufficient to leave a person with only the **pancreas and small intestine**! The biologist predicted that in the future such surgical "editing" of the human body would be planned and routine, like the removal of wisdom teeth or inflamed tonsils.

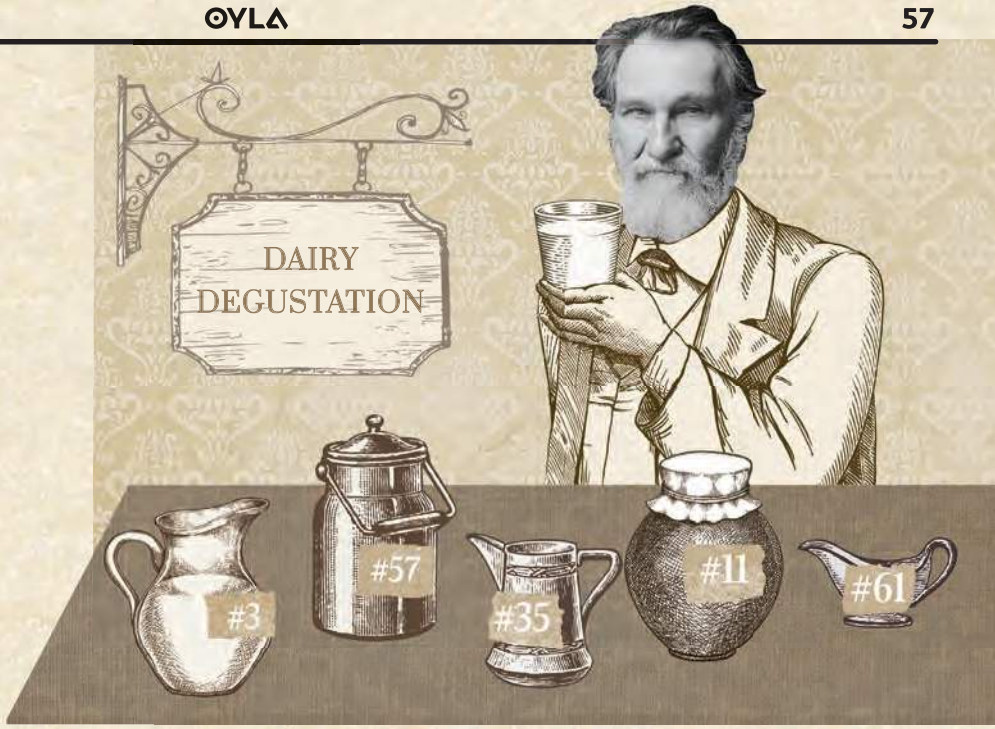
Lane and Mechnikov corresponded and were personally acquainted. Support from an authoritative scientist, of course, inspired the London doctor, who with even greater enthusiasm set about shortening other people's intestines.



A Royal Mistake

After World War I, treatment of "chronic stasis" went out of fashion: the terrible war spurred the development of surgery, and the functions and structure of the digestive organs were more thoroughly investigated. Today we know that removing the large intestine, or any other part of the gastrointestinal tract, is a difficult and dangerous operation. Performing it without serious indications, as a way to "cleanse" the body, **is strictly forbidden**. Even the appendix, which generations of doctors considered a useless part of our body, is not considered completely superfluous nowadays.





The history of scientific breakthroughs is inseparable from the history of its defeats and mistakes. The cost of such mistakes can be high: Lane's experiments killed some of his patients. Ilya Mechnikov's prediction, that surgeons of the future would remove "extra" digestive organs on a first-come, first-served basis, also did not come true. However, **dairy products** rose to popularity thanks to Mechnikov, and their benefits are undoubted.

Fermented milk has a longer shelf life, since lactic acid prevents decay. Mechnikov reasoned: if lactic acid can break down spoilage microorganisms in yogurt, then why can't it work in our intestines? The scientist meticulously selected fermented milk products suitable for "spring cleaning" our digestive system. Kefir did not meet his standards due to the presence of ethanol, commonly known as alcohol. However, he found **curdled milk and yogurt** quite suitable for his noble cause.

Lane continued to fight for the health of humanity after the war. In 1925 he founded the New Health Society. Lane proposed a fairly reasonable idea: caring for the human body should not begin in the doctor's office or in the hospital room. He began to advocate for a **healthy lifestyle**—good nutrition, and exposure to the sun, and fresh air. Unfortunately, here too Lane and his fans went to extremes. Lane and his supporters sympathised with eugenics and social Darwinism, the doctrine of artificial or natural selection of the "fittest" and "healthiest" people.

According to followers of these ideas, by displacing the weak, sick and the marginalised, they would form an ideal human population. The history of World War II showed where such goals can lead. However, many of Lane's tips on hygiene and nutrition can still be useful to us today!



It would be wrong to consider Lane a charlatan or a medical eccentric! He was responsible for innovative methods for treating severe fractures and repairing cleft palates. However, Sir William's main contribution to medicine is undoubtedly the invention of long-handled surgical instruments, which prevent accidental contact with an open wound. This made operations much safer—some of the instruments created by Lane are still used by surgeons today.

TECHNOLOGY

Imagine wearing a suit with hundreds of small air-filled balloons stitched into the fabric.

If you were to stumble or crash into a wall wearing this suit, there would be no pain—the air sealed inside the balloons would protect you from feeling any impact.

SEA-LED AIR

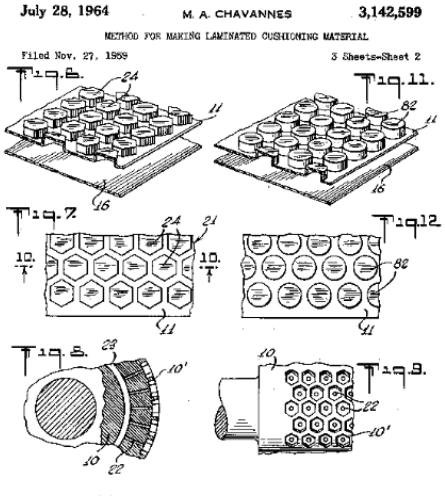
The same principle is behind Bubble Wrap, a popular packaging material.

After unwrapping, the film transforms into an equally popular anti-stress toy. But that's not all!

Wallpaper 2.0

In 1957, American engineer **Alfred Fielding** and his friend, Swiss chemist **Marc Chavannes**, collaborated on the creation of a textured wallpaper. This wasn't your typical wallpaper; it aimed to be both easy to clean and to capture the era's spirit—marked by a keen interest in experimentation, new technologies, and materials.

Initially, the inventors attempted to create plastic wallpaper on a paper base. This kind of wallpaper could be taken down and re-applied elsewhere. Sounds pretty convenient, doesn't it? However, this idea didn't catch on in the market. So, as part of their quest to find the ideal texture, Fielding and Chavannes tried sticking two shower curtains together using a heat-sealing machine. Unfortunately, their plans were foiled by trapped air between the curtains, which created bumps. While it was unique, no one was interested in buying this wallpaper either—who would want bubbles on their walls?


July 28, 1964 M. A. CHAVANNES 3,142,599
METHOD FOR MAKING LAMINATED CUSHIONING MATERIAL
Filed Nov. 27, 1959 3 Sheets-Sheet 2

^ The 1964 patent for Bubble Wrap





Marc Chavannes

Alfred Fielding

Still, the inventors saw potential in this novel material. The layer of trapped air boasted several useful properties: it prevented heat from seeping out, felt soft and pleasant to the touch, offered protection from external influences, and was easy to manufacture. In 1960, Fielding and Chavannes founded a company they named Sealed Air, actively seeking clients for their miraculous film. They came up with over 400 applications for their "bubble film"! For example, they pitched it to farmers for greenhouse insulation. Unfortunately, even though the film was tested in greenhouses, Sealed Air couldn't secure a long-term contract in that sector. Undeterred, Fielding and Chavannes decided to aim high and approached IBM—a leading company (even at that time!) in the production of computers and software.

"Computer Blanket"

In 1959, a game-changing development hit the market: the IBM 1401, a transistor computer that revolutionised the industry. Despite not being especially powerful even for its own time, it was remarkably compact for the 1960s—the size of a small closet! Companies across different industries purchased or rented it for financial calculations.

Delivery of the valuable and delicate equipment required reliable packaging. Computers were placed in cardboard boxes filled with crumpled newspapers. However, this method had drawbacks: printing ink stained the product and packers' hands, and the crumpled paper provided poor cushioning. Other options, such as polystyrene foam and foam rubber, had been invented but weren't as widespread at that time. That's when Fielding and Chavannes came to IBM with their innovative proposal to wrap computers in the "elastic air."



The idea proved highly successful. The air bubble film, dubbed "Bubble Wrap" by its creators, quickly became a hit. Not content to stop there, the inventors went on to create new variations of their product. In recent years, Bubble Wrap has seen numerous options emerge:



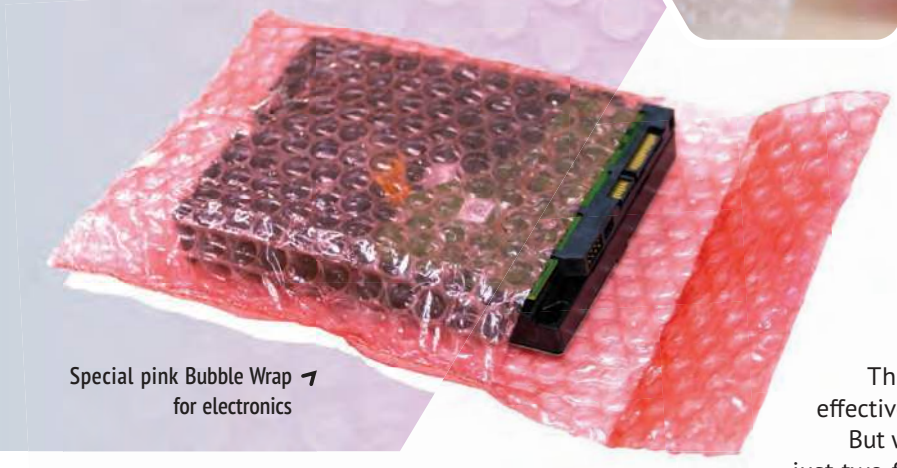


The IBM 1400 series computers; 1401 is in the middle.

film with both large and small bubbles and metallised coatings, combinations with cardboard, and transparent and coloured varieties. The colour isn't just for aesthetics—for instance, pink film boasts an antistatic effect, making it ideal for packaging electronic devices or microcircuits, while blue film comes equipped with light stabilisers, additives that provide protection against ultraviolet radiation and other harmful effects.

There is even a film that initially has no bubbles, which makes it easier to transport. The air is then trapped inside it using a special pump.

And then there is . . . paper Bubble Wrap! It's similar to regular Bubble Wrap but crafted from recycled paper. However, the original Bubble Wrap doesn't lag behind in sustainability: it's reusable, 100% recyclable, and incorporates recycled materials.



Special pink Bubble Wrap for electronics



Paper Bubble Wrap

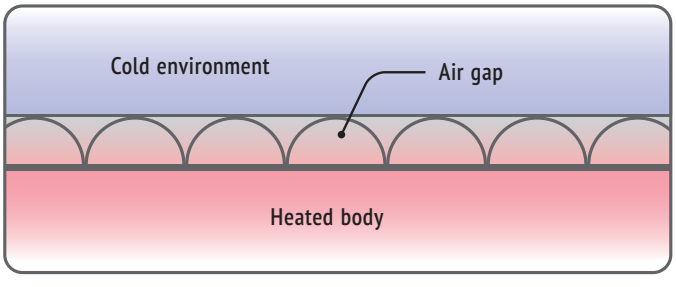
The Physics of Bubbles

Why do bubbles on the film protect fragile equipment from damage during transportation? It's just air, right? The secret lies in **Boyle's law**, which states that decreasing the volume of a contained gas will increase its pressure. Each bubble is completely isolated from the others, and the air doesn't escape unless its shell is damaged. So, when external pressure is applied, the gas compresses and reacts by pushing back, attempting to return to its original state.

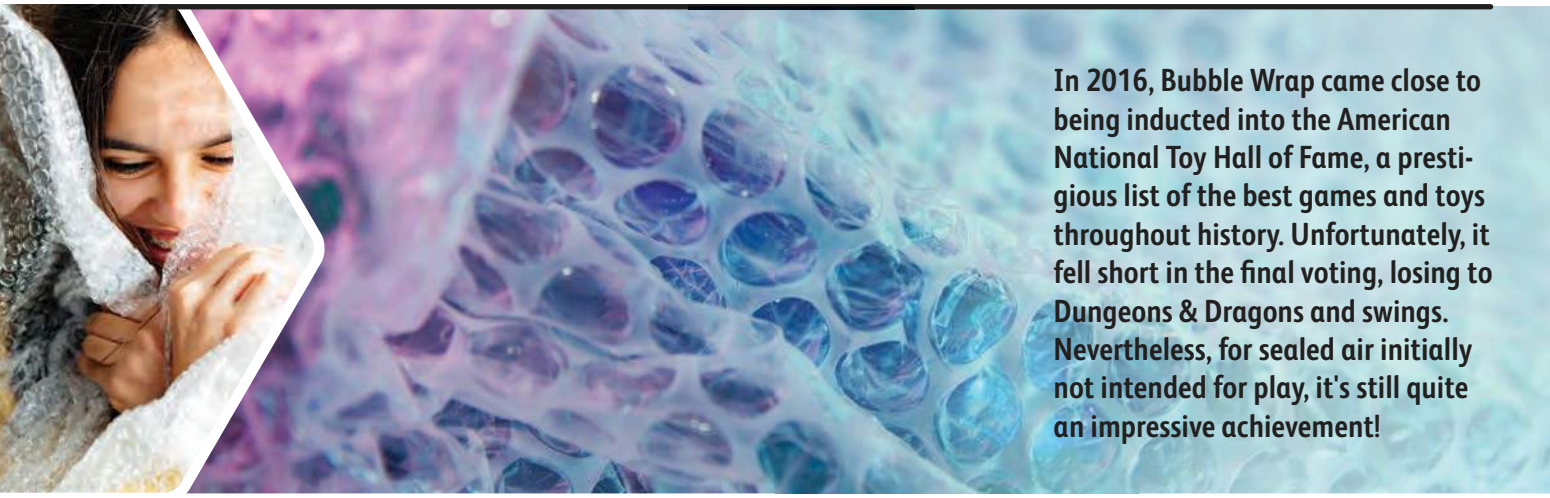


This pressure is what absorbs external influences, effectively dampening shocks and vibrations.

But wait, everyone knows that bubbles burst easily with just two fingers! That's true, but it happens when force is applied to one individual bubble. However, if you decide to hit the film or even jump on it, the entire sheet remains unharmed. Why? Pressure is **evenly distributed** across the surface, so the larger it is, the less pressure on each individual point. This principle is similar to why we don't sink through the snow on our skis.



How does Bubble Wrap retain heat? It creates an air barrier between different environments. Gas is a **poor heat conductor** because thermal energy is transferred through particle interaction. In solid substances, particles are connected in an ordered structure, allowing for quick energy transfer—adjacent particles push each other, increasing the substance's total energy. Gases lack such a rigid connection; energy transfer only occurs during infrequent collisions. This explains why wearing multiple layers of clothing helps in winter—the air layer retains heat. It's no surprise that Fielding and Chavannes proposed using Bubble Wrap in greenhouses! By the way, many modern farmers adopt this method.



In 2016, Bubble Wrap came close to being inducted into the American National Toy Hall of Fame, a prestigious list of the best games and toys throughout history. Unfortunately, it fell short in the final voting, losing to Dungeons & Dragons and swings. Nevertheless, for sealed air initially not intended for play, it's still quite an impressive achievement!

Bubbles of Relaxation

Howard Fielding, Alfred's son, remembers playing with Bubble Wrap samples as a child: *"I remember looking at the stuff and my instinct was to squeeze it. They were really fun to pop. The bubbles were a lot bigger then, so they made a loud noise."* Howard discovered another use for the wrap that hadn't crossed his father's mind—to systematically destroy it!

Many people enjoy popping these bubbles, finding the process both calming and entertaining. Psychologist **Kathleen M. Dillon** conducted a scientific study on this topic in the 1990s, and the results were published in the journal *Psychological Reports*.

Dillon believes the pleasure of popping bubbles may be linked to our instincts. According to her, these mechanical movements help us relieve muscle tension and serve as a distraction—essential for resisting stress. Engaging in crafts or other repetitive activities provides the brain with an opportunity to work "in background mode," quietly processing information or solving problems without a sense of urgency. Items like a rosary or anything small that people carry in their pocket to fiddle with have a comparable effect. Moreover, our brain particularly enjoys completing tasks, and with Bubble Wrap in our hands, it couldn't be simpler: click, click, click—done, done, done!

The only downside is that the wrap quickly becomes unusable. It is better to opt for special fidget toys such as Pop It and Simple Dimple. They are very similar to Bubble Wrap, but instead of popping, the bubbles flip to the other side, offering reusable fun!

Multifaceted Film

The utility of Bubble Wrap doesn't stop there. In 2014, a team of Harvard chemists suggested using its bubbles as . . . test tubes for medical, chemical, environmental, and other samples, and even for medical tests. You might wonder, why do all this work when there is regular laboratory glassware readily available? The idea proves beneficial in field conditions or regions with limited resources, where using expensive equipment, and sometimes even electricity (such as for operating an autoclave to sterilise test tubes), is unfeasible. Moreover, the bubbles inside are already sterile.

You can use protective film not only for wrapping equipment and valuable cargo but also, for instance, for cushioning the handle of a shovel to prevent calluses. The thermal insulation properties of Bubble Wrap extend beyond greenhouses; try wrapping it around items that require prolonged cold storage. And layering multiple sheets of Bubble Wrap can even create an excellent handmade mattress, providing a soft and warm sleeping surface for unexpected guests!







Pop It

BLACK MIRROR

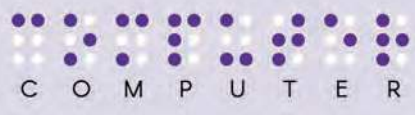


WHAT IS IT LIKE TO PLAY WITH THE MONITOR TURNED OFF?

Today, most of us are glued to computer and smartphone screens for hours on end. Imagine the struggle for those with visual impairments—they can't dive into a video game or casually scroll through the news feed, right? Nonsense! To beat even the most seasoned gamer, a blind or visually impaired person doesn't even need a monitor or a mouse.

The Voice behind the Screen

Wait, but how can you navigate a computer without seeing the screen? Documents, folders, buttons, shortcuts, articles on the Internet—all of these involve text that can be spoken. This is where **screen reader software** comes into play—the computer itself vocalises the content displayed on the monitor. Of course, it doesn't read everything (that would be overwhelming), but rather only what the user has highlighted. For instance, if you hover over the "My Documents" shortcut, that's the name the program will read aloud.

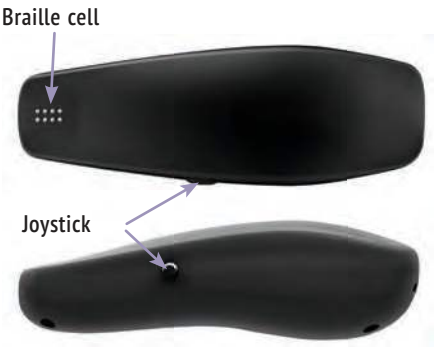


The word "computer" written in Braille—the actual font is raised and dotted, providing a convex surface for blind and visually impaired individuals to feel with their fingers.

So do you really have to aimlessly move the mouse until you stumble upon the desired file? People with visual impairments don't really need a mouse, because any command can be executed using the keyboard and "**hotkeys**." You might be familiar with some of them: *Ctrl* + *C* for "copy," *Ctrl* + *V* for "paste," etc. Navigating between shortcuts on the desktop and taskbar can be easily done using the Tab button and arrow keys. Opening anything is as simple as hitting Enter, and to close, you can use Alt + F4. There is a wide variety of these shortcuts, and people with visual impairments happily make the most of them.



The Dot smart watch with a Braille display. With its assistance, users can read messages, receive notifications, and access other information.



BraiBook is a device that converts digital text into Braille one character at a time.

There are special keyboards **with Braille markings**—a writing system of raised dots. However, using a regular keyboard isn't a problem for a blind person; even sighted people rarely look at the keys when they type! The same screen reader helps control the typing process by reading out the typed words and symbols, allowing the user to verify that everything is written correctly.



This is what a refreshable Braille display looks like. The dots rise and fall to form text, with every eight dots representing one symbol. This device can connect to both a personal computer and a smartphone or tablet.

The voices reproduced by the screen reader are likely familiar to you; they speak in a similar manner to Siri, Google Assistant, and other voice assistants. However, the reading speed is often increased several times for user convenience—**up to 700 words per minute**! It might be challenging for an unprepared person to follow text at such a rapid pace, but for the trained ear of a blind person, it's a piece of cake.

So it turns out that the monitor doesn't even need to be turned on (since all the computing work happens in the processor and the display is just an output device). Of course, this doesn't mean that blind people don't buy monitors at all, as they may still be needed for someone who will configure and repair the entire system if necessary. However, there's no point in overpaying for a fancy monitor or video card.

Controlling your smartphone without looking at the screen is even easier. Even a sighted person can probably find shortcuts to their favourite applications with their eyes closed! Gadgets also have screen readers that will tell you exactly what your finger is pointing at. You can write a message by voice typing or by connecting a keyboard, and the program will read the other person's replies.



< Shikun Sun's DrawBraille phone is the first smartphone designed for the blind. It allows users to make calls, send messages, and use applications. The phone consists of two parts: a Braille keyboard and a touch screen.

Haben Girma is a disability rights lawyer, author, and speaker. The first Deafblind person to graduate from Harvard Law School, she became Lenovo's first Accessibility and Inclusion Advisor.



Image credit: California State University, Sacramento

^ Photo description: "Haben Girma speaking at the Green and Gold Speaker series at Sacramento State. Girma is wearing a coral-coloured dress and standing behind the podium. Behind her are a potted tree and grey chairs arranged in a line." Do you think describing colours is pointless? Keep in mind that such descriptions are used not only by those who are blind from birth but also by individuals who have become blind later in life or those who have low vision but can still distinguish colours.



^ There are mobile applications designed to help blind people identify currency and banknote denominations.

A World Beyond

But we don't just read texts when we're online. We look through our friends' latest photos, watch videos, scroll through memes and comics, and play video games. How much of this world is accessible to blind and visually impaired people? It depends on us.

There are organisations developing additional **audio tracks** that narrate everything happening in a film or video. This is called **audio description**. For example, if there is a long action scene in a movie, the announcer will describe verbatim who hit whom or what exploded. Such comments can even be inserted in the middle of a dialogue—here the ability of blind and visually impaired individuals to process rapid speech becomes particularly useful. However, audio description is usually done by volunteers, although it could become standard practice when creating videos.

More and more media companies are incorporating **text descriptions** into their visual content. For example, when posting a picture, the creators provide literal descriptions of what is depicted in it. Just imagine the possibilities that can open up for people with limited vision if this simple detail becomes a standard practice for every Instagram post! Why not consider adding brief descriptions to your photos on social networks?



^ Here's what *The Last of Us II* looks like in low vision mode. The characters are highlighted in contrasting colours to give the player an idea of how many people are in the frame and how they interact. The game offers more than 60 accessibility settings, including text-to-speech, guards against falling off ledges, haptic dialogue feedback, and more.

You might not be aware, but many of your favourite video games have additional settings for people with visual impairments. Buttons in the menu, names of items in the inventory, the protagonist's health status, and any in-game notes can be audibly conveyed through the built-in screen reader. Some shooters incorporate an aim assist mode, and puzzles often come with a skip option (a feature every gamer wishes to use at times!).

The player can easily navigate in space using a form of echolocation. Pressing a button sends out waves from the player character, and if there's an interactable object nearby, it emits a signal. High-quality headphones enable precise determination of the required direction to go in. Similarly, the sound will alert you to the direction from which an enemy is approaching.

Unfortunately, not all games support these functions as their creation requires additional resources. And some people don't even need them: for example, many blind and visually impaired people play fighting games at the level of professional gamers. The battles take place in two-dimensional space, so there is no danger of getting lost or running into a wall—the character automatically turns in the right direction, and all you have to do is press the required combinations of moves. However, this doesn't mean that anyone can close their eyes and become a master of the game! As always, a blind or visually impaired gamer must listen carefully to discern the attacks of their opponent and block them in time.



Audio games

< There are games specifically designed to be experienced solely through audio. For instance, *The NightJar* and *A Blind Legend* have no visuals at all—you are meant to explore the game world through headphones.

Race

Racing game *Forza Motorsport* (2023) has a steering guide option that will pan engine noise and tyre sounds to the left or right based on the direction you have to turn. When the player is dangerously close to going off track they will get a beeping sound. >





Fighting games

< The fighting games *Street Fighter* and *Mortal Kombat* have excellent sound design. Different types of attacks have clear audio signals indicating whether the strike hit the target or was blocked.

The majority—that is, sighted and able-bodied people—have the power to transform the media industry and make it inclusive. Are you willing to invest a couple of minutes to make a post accessible on a social network, pay a little extra for a game whose developers prioritised accessible settings, or support a blind streamer on Twitch?

Blinders for the Mind: CONFIRMATION BIAS



Imagine you and a friend have opposing opinions about a famous politician. You come across an article describing the politician's biography and positions. You send the article to your friend, convinced that it will change their mind. But for some reason, they reply that the article supports their views instead! How did it happen that both of you only saw things backing up your original position?

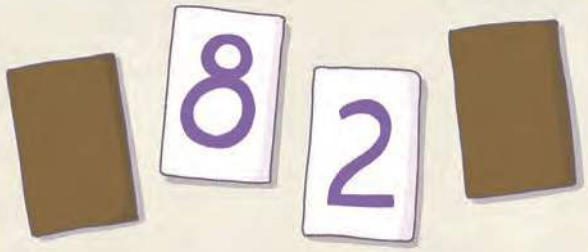
I Think, Therefore I'm Wrong

In the past, psychologists used to think that all people's reasoning was guided by the same principles. In other words, if people studied the same information, they would all reach similar conclusions. But if that were really the case, you and your friend should have agreed after reading the same article about the politician. But in reality, that's not what happened. So what went wrong? English psychologist **Peter Cathcart Wason** argued that people often make illogical conclusions and act irrationally. For example, when reading an article, they select **only those arguments that support their opinion** and ignore anything that goes against it. Why? Because we tend to unconsciously want to prove ourselves right. To investigate this phenomenon, the psychologist developed a logic puzzle in 1966. It became known as the Wason selection task and looked like this:

You are shown a set of four cards placed on a table, each of which has a number on one side and a colour (red or brown) on the other. The cards are arranged in the following order: 3, 8, red and brown. Which card(s) must you turn over in order to test that if a card shows an even number on one face, then its opposite face is red?

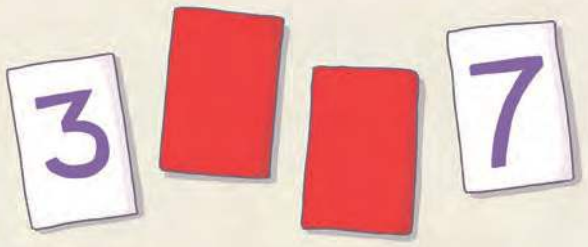


Most of Wason's subjects came up with the following hypothesis: there must be a card with an even eight, and there must be a card with a red back. To test this, let's turn over the card with the number three and one with the red back to see what's on the other side. If the card with the number three has a brown back, and the red-back has an even number, then we can confirm the statement holds true.



How would you go about solving this problem? Let's think it through. If we turn over the card with the number 3 and discover a red back, it does not necessarily disprove the statement that an even card has a red back (maybe the odd ones can be red too!). The same holds true if we turn over the red-backed card and find an odd number. After all, we can't determine the colour of the card with the even eight—what if it's red?

Correct answer: you need to flip over the cards with the number 8 and with the brown back. If there is an even number on the back of the brown card, it contradicts the statement—although the card has an even number, its back is not red. The card with the number 8 can be checked the same way: if the back of the even-numbered card is not red, the statement is disproven. As we've observed, the remaining cards won't provide a conclusive test. **Contradictions are key to testing the hypothesis**.



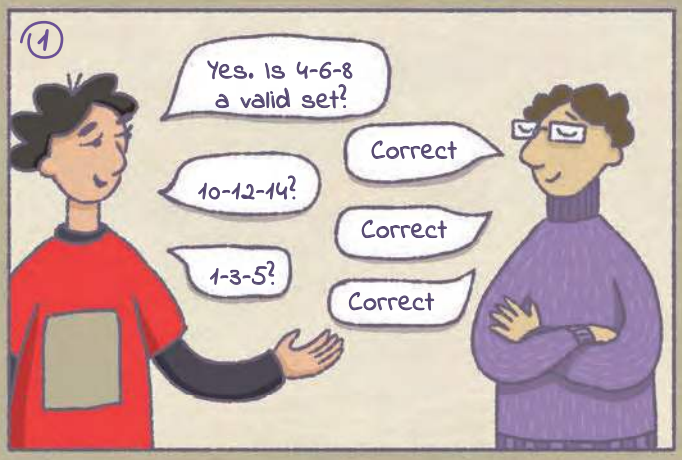
But Wason's subjects did not seek to disprove their hypothesis—on the contrary, they selected cards to confirm it!

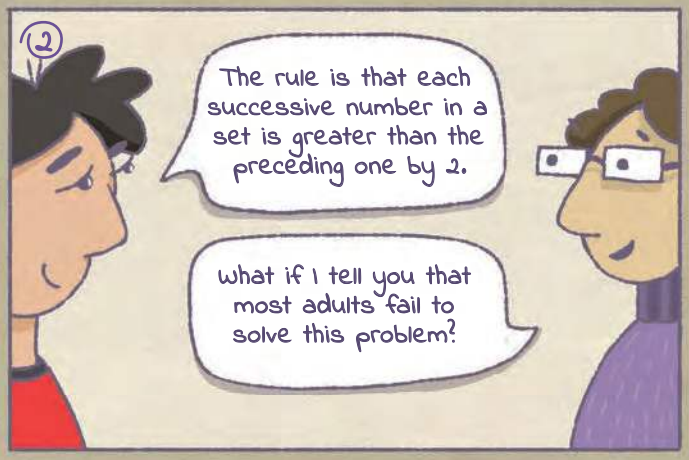
> **This tendency to favour information that is consistent with one's original point of view, beliefs, or hypotheses is called confirmation bias.**

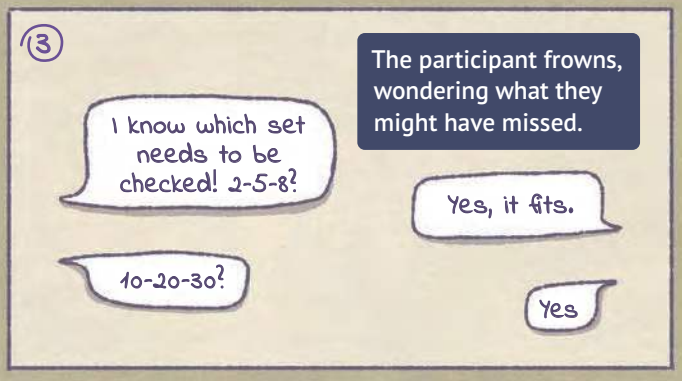
While Wason coined the term, other scientists have also identified a similar bias.

Before the card selection task, Wason presented participants with the "**2–4–6 task.**" Think of this experiment like a performance with two roles: the host, who conducts the experiment, and the participant, actively involved in the process.



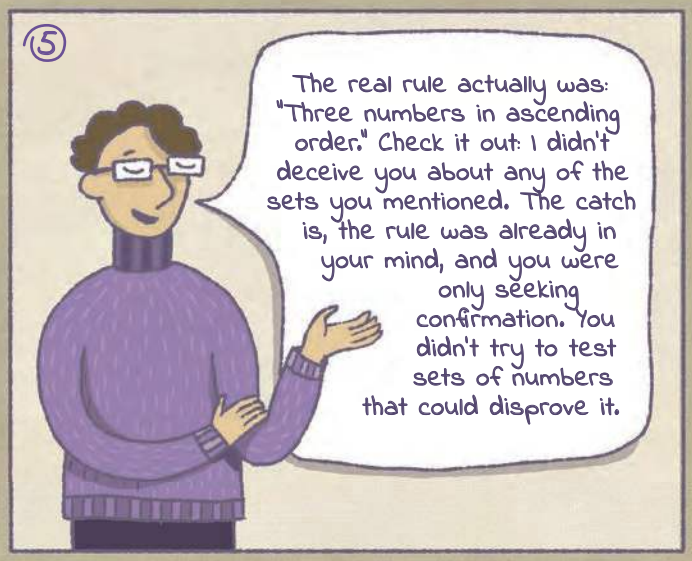






The participant frowns, wondering what they might have missed.





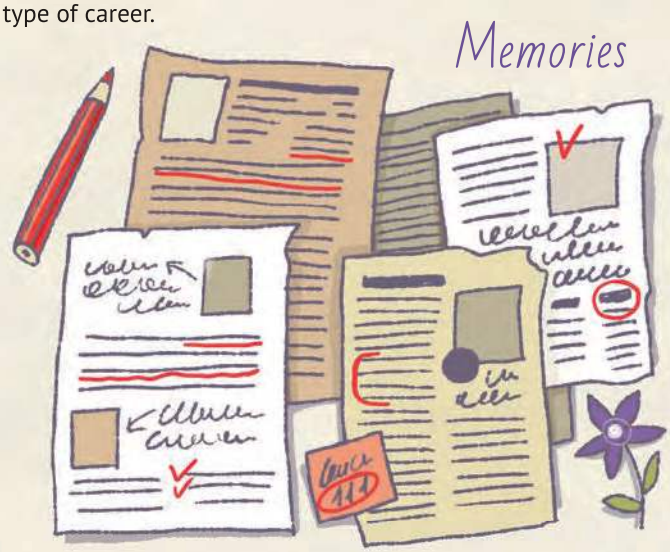
Do you believe your friends will be able to figure out the solution to this problem right away?

Inner Yes-Man

We tend to look for information that aligns with our beliefs, and technology helps with this. In social networks and search engines, **algorithms** show us content based on our searches and likes. Over time, our Instagram feed, for example, becomes filled with people who share our views. This creates a "filter bubble" where we might not see information that challenges our preferences. However, the world is more intricate and diverse than what our filter bubble might show!

Confirmation bias affects not only what information we seek but also how we interpret it. In 2018, Duke University sociologists conducted an experiment dividing volunteers by political views: Democrats and Republicans. Participants subscribed to a Twitter account—a bot retweeting posts from various political accounts every hour. Democrats followed a Republican bot, and Republicans a Democratic bot. After a month, participants discussed their political views again. Surprisingly, **exposure to opposing accounts didn't change their views**; instead, it intensified them. Information about the opposition was interpreted in such a way as to reinforce their own beliefs.

Surprisingly, even memories can be biased! In the late 1970s, Mark Snyder and Nancy Cantor conducted a study. Participants were given a narrative about an imaginary woman named Jane. Notably, Jane was described as **displaying both extroverted and introverted behaviours**. Later, the subjects were divided into two groups, and one group was told that Jane was considering a job as a real estate agent, while the other group was told she was thinking about becoming a research librarian. Interestingly, the group that was initially asked about the real estate job perceived Jane as suitable for it, focusing on her extroverted behaviours in their memories as evidence. When later asked about the librarian job, they opposed the idea, claiming she was too outgoing for such work. Conversely, the second group, initially asked about the librarian job, supported the idea, recalling instances of Jane's introverted behaviour as justification. When later asked about the real estate job, they strongly objected, arguing that Jane was too reserved for that type of career.





In 1978, psychologists Margaret W. Matlin and David J. Stang introduced the Pollyanna principle, named after the novel by the American writer Eleanor H. Porter, in which the main character always found good in any situation. According to the Pollyanna principle, the brain processes positive information more effectively than negative information. Therefore, we tend to remember the past in a more favourable light than it really was—in other words, we are **"positively biased."** This effect can encourage a person, for example, to get back together with an ex-partner, as they focus on pleasant moments rather than fights and misunderstandings that led to the breakup. However, this principle does not universally apply. People suffering from depression or anxiety tend to exhibit **negativity bias**: their brains may be better at remembering bad events while dismissing good ones. That is why you should not advise someone with depression to "just enjoy life": sometimes only a professional can help them feel differently.



The Benefit of Bias

So why do people try so hard to confirm their initial assumptions? Psychologist James Friedrich believes that a person's primary motivation is to **avoid the "costliest" mistakes rather than seek the truth**. In 1993, Friedrich observed that employers often ask the same questions when interviewing a potential employee, focusing on reasons why the candidate left their previous job, expectations from the current company, and their goals. Their emphasis is on making sure they weed out unsuitable candidates. This desire may stem from our evolutionary past when it was important to avoid irreversible mistakes that could sabotage survival. In earlier times, selecting a reliable hunter was more crucial than choosing simply the best one.

Friedrich's colleague, Raymond S. Nickerson, proposed that testing multiple hypotheses simultaneously might be challenging for people. Instead, **most people tend to focus on one idea** at a time. For instance, they might concentrate on the hypothesis that comes to mind most easily and appears more obvious. In 2006, Nickerson replicated Wason's card selection task, yielding similar results. Interestingly, when the task only required evaluating the correctness of a statement without specifying the need to turn over cards, many participants skipped this step or turned over only one card. These actions limited the information available for drawing conclusions, as participants did not actively seek contradictions and, rather than testing, aimed to confirm their initial hypotheses.

Sometimes prejudices are so strong that . . . they shape reality! A **self-fulfilling prophecy** is a socio-psychological phenomenon where a certain assumption or expectation comes true because a person strongly believes in it. Driven by this belief, a person unconsciously acts so that the "prophecy" actually becomes a reality by creating the necessary conditions. Sociologist Robert K. Merton came up with an example of this prophecy involving a hypothetical bank. Initially, the bank's financial affairs are pretty good: it has a reserve of funds from depositors, most of which is invested elsewhere. But one day, for an unknown reason, a large group of depositors visit the bank at the same time. Investors, seeing the crowd, become anxious. An unfounded rumour spreads that the bank is in financial trouble and will soon go bankrupt. Consequently, the number of people wanting to withdraw money increases sharply, causing panic. As everyone rushes to withdraw their deposits, the bank, unable to issue all deposits at once, is indeed declared insolvent and bankrupt.

Biased Brain

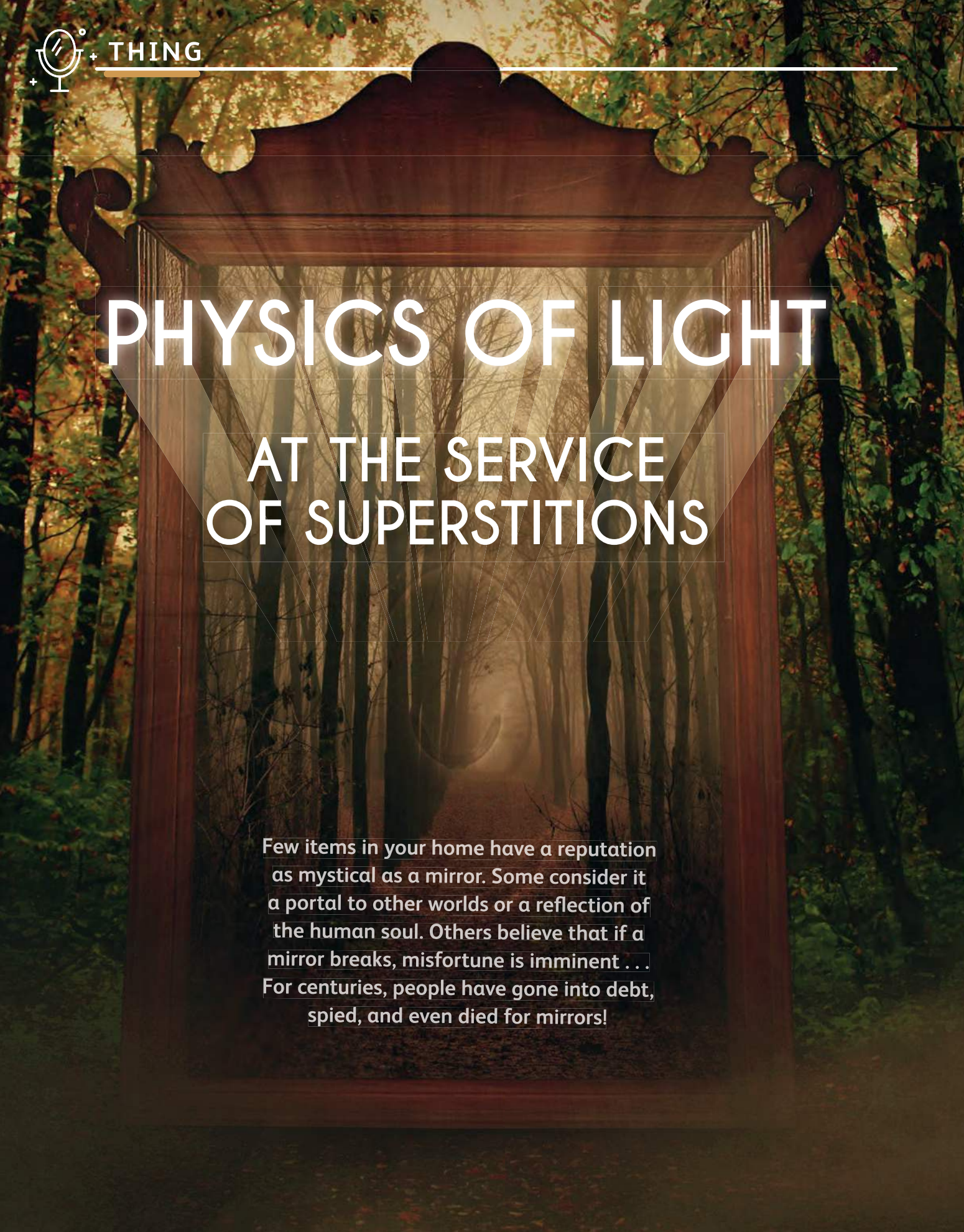
In 2019, scientists from the University of London set out to investigate the **reactions that occur in the brain** when we are biased. They conducted a study with 42 participants and paired them up. Each participant in a pair was asked to evaluate housing prices: for example, they were shown a picture of a house and asked whether it was worth less than or more than a million dollars. Each participant could wager within £1, with winnings or deductions based on correct or incorrect estimates. If the participant estimated the value of the house correctly, they were awarded the amount they won. If the statement turned out to be incorrect, the bet amount was deducted. At the end of the experiment, each participant was given the amount they had earned.

Post-experiment, participants were placed in MRI machines with a transparent screen between them. Each viewed houses with their own and their partner's bids, deciding whether to consider or disregard their partner's opinion while adjusting their bet. It turned out that when participants saw their and their partner's assessments align, they were **more likely to alter their bet** than when opinions differed. That is, participants favoured a different opinion if it supported their own views. Scientists noticed that when opinions aligned, a specific area in the prefrontal cortex associated with decision-making showed increased activation, particularly when the partner's bid was lower. This indicated heightened processing of decision-influencing information after a decision was made.

At the same time, scientists noted that the activity in this area was variable and heavily reliant on our actions. This suggests that **the more we succumb to confirmation bias, the more entangled we become in its influence**. Well-trodden neural pathways emerge, enabling the brain to swiftly react in the simplest and most familiar manner—prioritising attention to information that aligns with an already established opinion, rather than considering information that contradicts it.

The good news is that we can **reduce the impact of confirmation bias** when we actively engage in the practice of scrutinising our conclusions by deliberately studying opposing opinions. This is very important, because confirmation bias is not just about a harmless argument with a friend about how good or bad a popular politician is. Confirmation bias prevents us from making sound judgements about our health, community initiatives, or controversial legislation under consideration. It may also prevent scientists from independently evaluating their work as they unwittingly try to confirm their initial hypotheses. Likewise, driven by confirmation bias, law enforcement specialists might narrow their focus to whomever they consider guilty, without considering alternative possibilities. Is the desire to be right really worth it?





PHYSICS OF LIGHT

AT THE SERVICE OF SUPERSTITIONS

Few items in your home have a reputation as mystical as a mirror. Some consider it a portal to other worlds or a reflection of the human soul. Others believe that if a mirror breaks, misfortune is imminent . . . For centuries, people have gone into debt, spied, and even died for mirrors!



Ancient Egyptian bronze mirror, 1540–1296 BCE

Source: clevelandart.org



In China, bronze mirrors were manufactured from around 2000 BCE (back side shown)

Roman fresco of a woman holding a mirror, Italy, 1st century CE



Almighty Force

For most of us, the mirror is intimately associated with morning hygiene: we look at our reflection while cleaning our teeth, washing our face, and brushing our hair. But the most ancient mirrors date back to as early as 6000 years BCE, which means that humans began to use mirrors long before soap and toothbrushes appeared!

The first mirrors were made from polished pieces of **obsidian**, a black volcanic glass formed from cooling lava. This material has surprisingly high optical quality. Look at yourself in the switched off screen of your smartphone—this is what your reflection would look like in an ancient obsidian mirror.

But obsidian is a rare material, so in ancient Egypt, China, and Greece mirrors were made from polished **bronze**. Remember the story of the Gorgon Medusa, who saw her reflection in the polished shield of Perseus? That's direct proof that the ancient Greeks were adept at making primitive mirrors. According to the Roman philosopher **Seneca**, by the 1st century CE mirrors were already so large that you could see yourself in full size. Ancient Roman fashionistas even carried bronze mirrors in small protective boxes, just like how many of us carry mirrors now!

However, the purpose of mirrors was not always limited to self-admiration and makeup application. In many cultures across the world, this item carried **mystical and religious significance**. In ancient Egypt, round mirrors were a symbol of the sun god Ra and the mother goddess Hathor. These mirrors were often used in funeral rituals: the Egyptians probably believed that the soul of the deceased remained in the mirror. In mediaeval Japan, mirrors were used to ward off evil spirits and communicate with the divine. In Europe, people believed that mirrors could predict the future and protect against evil (recall how vampires were thought to not have mirror reflections!), while a broken mirror was seen as an omen of misfortune.

Obsidian



A Kingdom for a Reflection

At the beginning of the 1st millennium CE, humans mastered the art of glassblowing, creating glass mirrors coated with a thin layer of metal. Initially, these mirrors had concave or convex surfaces, which distorted the image. Perfectly flat mirrors first emerged in 16th-century Venice: artisans would inflate a glass cylinder, cut it lengthwise, and flatten it on a hot plate. Next, the glass was covered with **amalgam**—an alloy of tin and mercury.



Unfortunately, mirror makers inevitably got sick from the poisonous mercury vapour, suffering a slow and painful demise. On average, an artisan lived no more than 10 years from the moment they began working in mirror production.

Yet, poisoning was not the most dangerous part of this work. Venice, holding a monopoly on the mirror market, closely guarded the recipe for achieving the perfect reflection. Artisans and their families, faced with the threat of a **death penalty**, were forced to live on a separate island and were strictly forbidden to leave. If a guild member needed to be away, his family remained hostage.

People across Europe had to purchase Venetian mirrors at exorbitant prices. Look at the records of a certain Countess de Fiesque as an example. She proudly recounts a great bargain—she bought a mirror by selling a plot of arable land! It's no surprise then that neighbouring countries kept sending **spies** to Venice, and at long last, by 1672, the French managed to unlock the secrets of mirror making.

And so the Sun King **Louis XIV** was finally able to surround himself with the radiance of his own reflections as the Hall of Mirrors, comprising 357 mirrors, appeared in the Palace of Versailles. Every mirror in the hall was crafted in France. Gradually, the industry advanced to the point where mirrors ceased to be a luxury item and became available to everyone.



In 1835, chemist **Justus von Liebig** proposed avoiding the use of mercury and, instead, suggested spraying **silver nitrate** on glass. Modern mirror-making technology is not very different from that invented by von Liebig 200 years ago; the only difference is that now we use aluminium because silver darkens over time.



The Hall of Mirrors in the Grand Palace of Versailles

A Piece of Physics

So how does a mirror work? There is neither a parallel world nor your double on the other side—all you see is just reflected light. The principle is the same as with any other object.

Remember that white light is a mixture of coloured light waves? A yellow object, such as a T-shirt, absorbs all rays except yellow ones, which are then reflected to us. White objects reflect all colours of the spectrum, while black ones absorb most of them. If you imagine light falling as a beam of parallel rays that hits a rough surface, the rays will be chaotically reflected in different directions. But if the surface is perfectly smooth, light is reflected in the form of similar parallel rays. That's why we see ourselves in a mirror, window glass, a switched-off TV screen, or in calm water: the light is first reflected from our face (which is by no means flat), and then bounces back from a smooth surface.

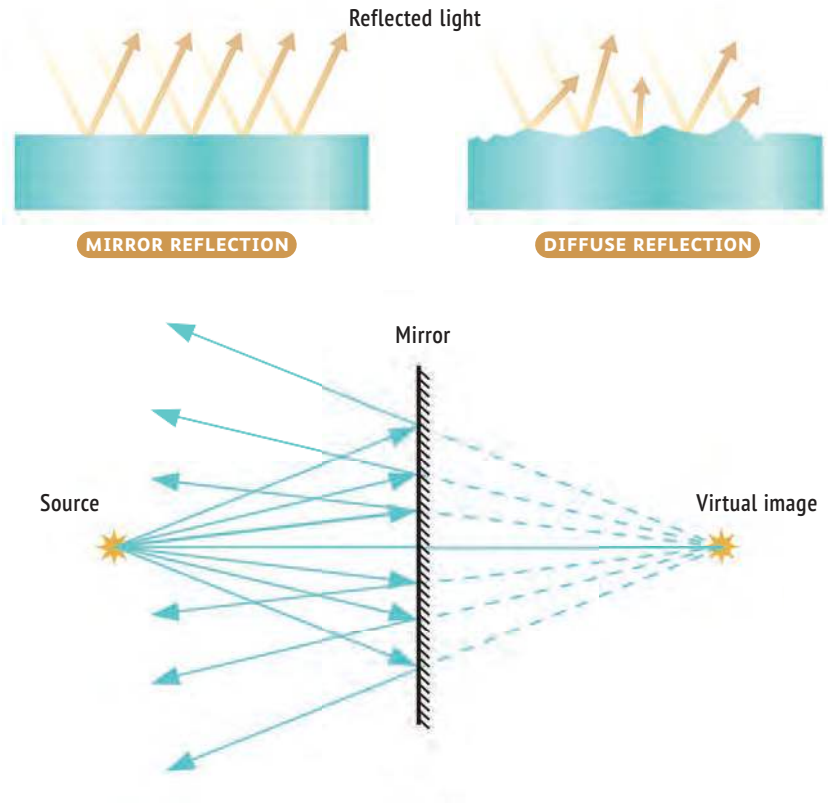
But why does our home mirror provide a higher-quality reflection than a polished table or TV screen? Here, the properties of the material come into play. Ordinary transparent glass splits the incoming light into two parts: one part is reflected, while the remainder passes through (otherwise it would be pointless to have glass windows in houses). In contrast, a mirror with silver or aluminium coating prevents light from passing through, making the reflection clearer.

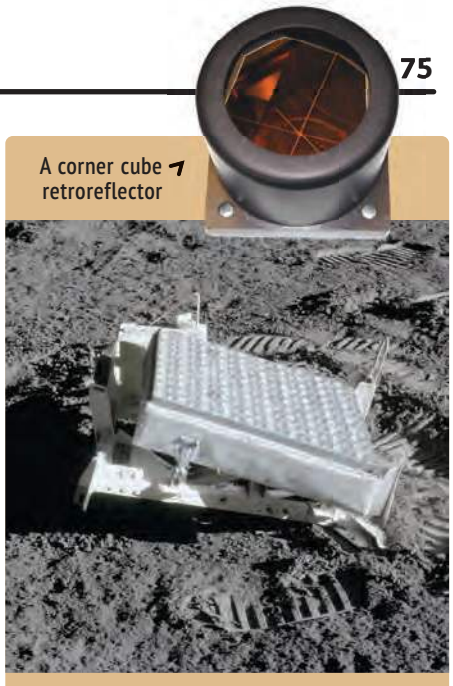
Since the surface of an ordinary mirror is flat, we see an undistorted image of people and objects reflected in it. This is easy to prove. Let's draw rays of light from a pointed source falling on a mirror and reflecting off it. As these rays hit the mirror, they are reflected according to a law that states that "the angle of incidence is equal to the angle of refraction."

There is, of course, nothing behind the mirror, but if we extend the straight lines of our reflected rays into the space behind it, they will all converge at one point again—and this occurs for each point, all of which combined create a virtual image, such as your face.

Non-flat surfaces, however, can "glitch." For example, the funhouse mirrors in amusement parks are concave or convex, making us appear taller or bigger than we really are.

HOW A MIRROR WORKS





A corner cube retroreflector

On July 21, 1969, Apollo astronauts installed a corner reflector (^) on the Moon: it was a system of three mirrors that reflected rays exactly in the same direction from which they came. Thanks to this design, we can direct a laser beam from Earth and receive its reflection from a mirror on the lunar surface. From the time it takes for a laser pulse to travel from Earth and back, we can calculate the distance to the Moon with remarkable precision, down to a few centimetres.

It's hard to see a mirror as some magical artefact when you know how it works, right?
Of all the possible superstitions and signs associated with a mirror, perhaps only one is undoubtedly true: if you break it, your parents won't be very happy.

DECEIVING THE FUNHOUSE MIRROR



Looking in a distorting mirror is a lot of fun: it can give you a giant head or funny long legs. Even if you've never been to a funhouse (*this is what they call rooms with lots of distorting mirrors in amusement parks*), you've more than likely seen your face distorted in any curved reflective surface, such as a spoon.

Why does this happen? An ordinary flat mirror reflects all light falling on it in the same way, while a curved one **changes angles**, directing the rays in different directions. When these altered rays reach our retinas, our eyes process them as a normal image, making it seem as if we are looking at an elongated or inverted copy of ourselves.

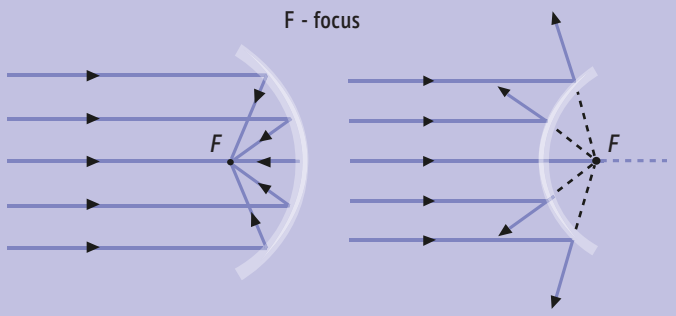
The point at which the rays converge is called the **focus**. The image in the focus is closest to the real thing: you can see it for yourself using a regular spoon. The inner side of a spoon acts as a **concave mirror**, gathering the rays before itself and turning them over. This causes higher rays to appear lower, and vice versa. So if you look at yourself in the spoon, you'll see you have been turned upside down. But if you move your finger really close to the surface of the spoon, closer than the focus, the reflection of the finger will not be inverted.

It gets a bit more complex with the outside of the spoon. The focus of a **convex mirror** appears to be inside it, which means that we would have to be at a **distance of less than zero** from the spoon to obtain a real image. Since this is obviously impossible, the image in a convex mirror is always distorted, narrowing the picture and making it smaller. Spoons usually have an irregular shape, so if you want to see this optical effect more clearly, try using the side of a cylinder, such as an aluminium can.

The convex mirror is the one we will try to deceive. For this experiment we will need:

1. **Aluminium drink can**;
2. **Mirror film** for car tinting or something similar *(if you want to get creative, you can observe the effect directly on the smooth side of the can, but using film will enhance the results)*;
3. **Felt-tip pen**.

We have established that light rays falling on a convex mirror are focused "inside" the mirror, making any image smaller and narrower. What's the conclusion? Begin with a stretched picture when using the mirror!

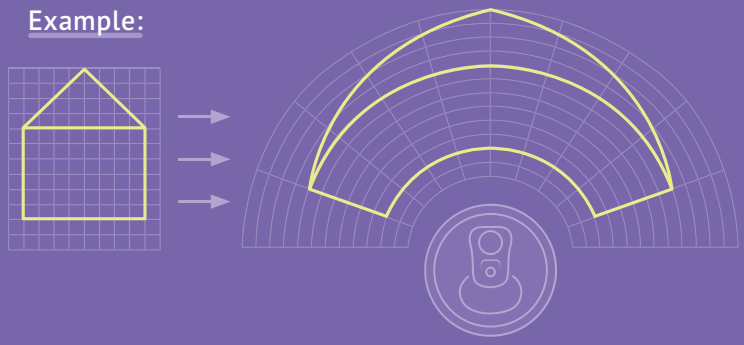


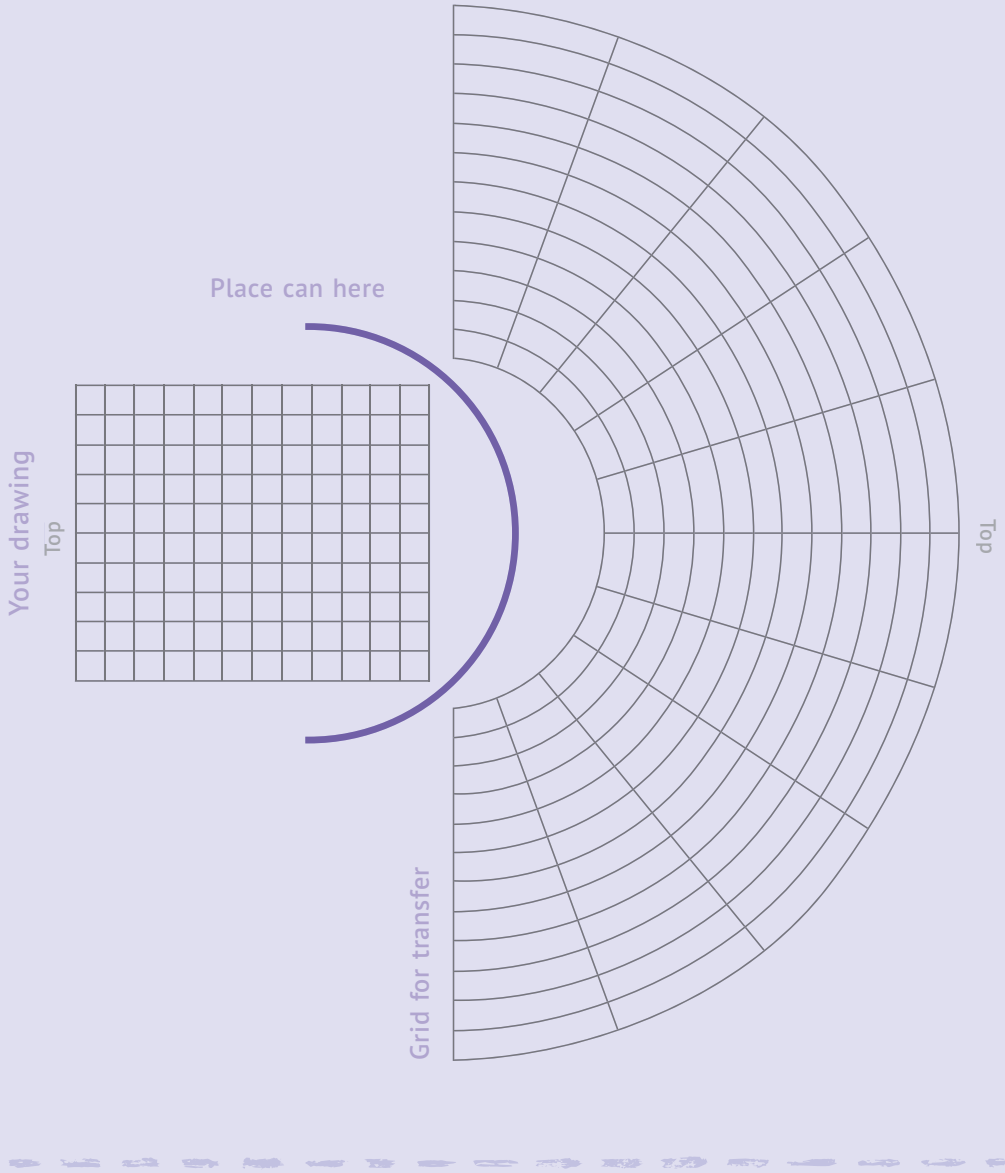
Concave—"gathering" mirror

Convex—"scattering" mirror

This is easily done using our template. First, draw the "correct" image on a regular grid *(use the cells to make it easier)*, and then carefully transfer it to the curved grid. Now, place the can wrapped in reflective film in the designated spot *(purple line)*. Behold the magic of optics! The reflection of the stretched image looks exactly like what you had in mind.

Example:





Excuses Granted by STARS



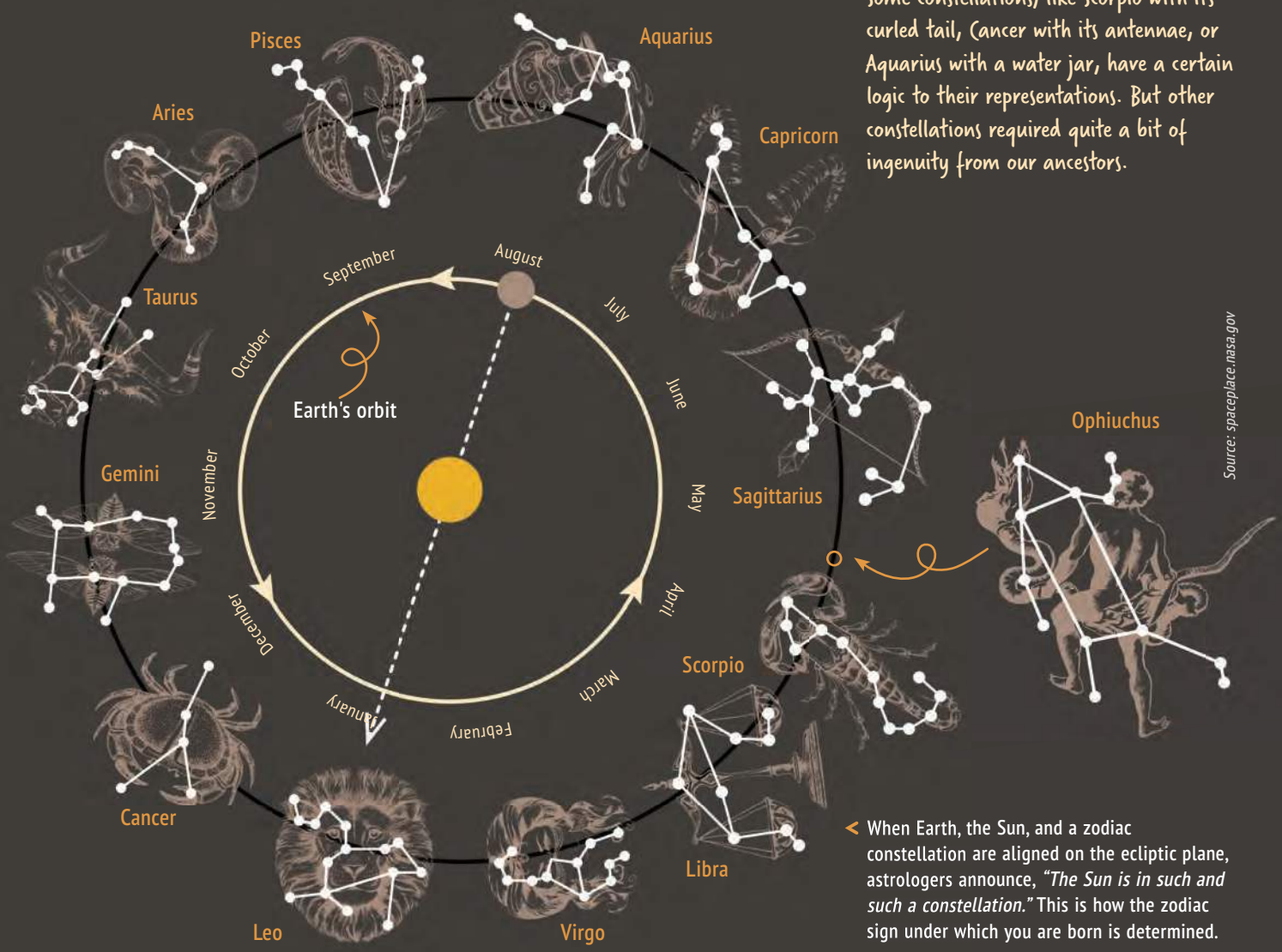
Not every word that ends in "-logy" is a science! For example, astrology is nothing more than a set of superstitions that some people inexplicably consult when making important decisions. What are astrological horoscopes based on, and should you trust them with your life?

Know Your Enemy

Space is full of stars. All of them are located at different distances from our planet but far enough away to appear equally small. When gazing at the sky, our ancestors saw merely a black expanse patterned with tiny bright dots, but their imagination allowed them to combine these dots into simple images. This is how **constellations** emerged. Each civilisation saw something different in the night sky, so the names and number of constellations differ across ancient cultures. In our time, astronomers have agreed on a single official system of 88 constellations.

WHAT DO ZODIAC CONSTELLATIONS LOOK LIKE?

Some constellations, like Scorpio with its curled tail, Cancer with its antennae, or Aquarius with a water jar, have a certain logic to their representations. But other constellations required quite a bit of ingenuity from our ancestors.



When Earth, the Sun, and a zodiac constellation are aligned on the ecliptic plane, astrologers announce, *"The Sun is in such and such a constellation."* This is how the zodiac sign under which you are born is determined.

Thirteen of these constellations lie on the **ecliptic plane** – the imaginary plane containing the Earth's orbit around the Sun. However, ancient people did not know this, so for them, the ecliptic plane was the line along which the Sun changed its position relative to the stars throughout the year. These constellations are called the **zodiac**, from the Greek *zōidiakós kýklos*, meaning "circle of little animals." (Despite the name, not all zodiac signs are represented by animals; for example, Libra is symbolised by scales.)

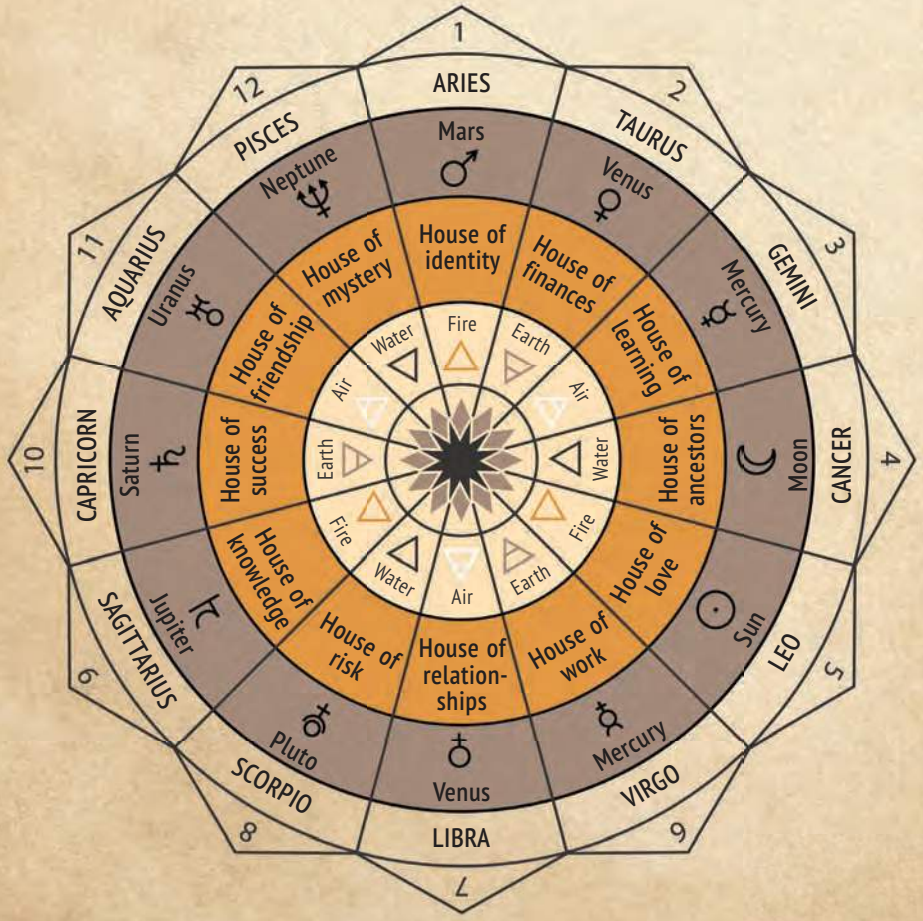
Wait, why 13 and not 12? Not widely known, there is a 13th constellation called **Ophiuchus**. Three thousand years ago, when the Babylonians, the originators of the zodiac, first created the circle of constellations, they opted not to consider the 13th sign. This decision was made for the sake of symmetry, as by that time, Babylon had already adopted a 12-month calendar. So the ancient astronomers chose to omit Ophiuchus and divided the entire ecliptic into 12 equal parts, like a huge pizza. Each segment corresponded to approximately one month and was named after one of the zodiac constellations. In reality, the constellations vary in size and shape, and the Sun **passes through them at different rates**. For example, it aligns with Virgo for 45 days, while it passes through Scorpio in about a week. The Babylonians chose to overlook this fact as well.

All Is Flux

It's important to remember that the zodiac calendar was created 3,000 years ago. Over the years, Earth's rotational axis has shifted due to the influence of the gravity of the Moon and the Sun—a process known as **precession**. No need for concern: this does not pose any danger to us! Precession occurs regularly and takes about 25,800 years, and it is a perfectly normal process. The only change it brings can be seen in the sky: the position of the stars changes slightly over the years for an observer on Earth. For example, starting from approximately 3100 CE, Gamma Cephei will replace Polaris as the Earth's northern pole star.

The same process affects the zodiac constellations: over the years, they **have shifted by about a month**, no longer aligning with the original calendar. In 2016, NASA published new birth dates for all zodiac signs, causing great concern among astrology enthusiasts. If you once identified as an Aquarius, it's likely that you are now considered a Capricorn, and so forth. Also contributing to this shift was the fact that NASA did not omit Ophiuchus and refrained from dividing the year into equal intervals; they presented the zodiac as it actually is. Neighbouring zodiac sign dates may overlap because constellations don't shift magically at midnight. So the updated zodiac calendar now looks like this: ↓

- ♑ CAPRICORN: January 20—February 16
- ♒ AQUARIUS: February 16—March 11
- ♓ PISCES: March 11—April 18
- ♈ ARIES: April 18—May 13
- ♉ TAURUS: May 13—June 21
- ♊ GEMINI: June 21—July 20
- ♋ CANCER: July 20—August 10
- ♌ LEO: August 10—September 16
- ♍ VIRGO: September 16—October 30
- ♎ LIBRA: October 30—November 23
- ♏ SCORPIO: November 23—November 29
- ⛎ OPHIUCHUS: November 29—December 17
- ♐ SAGITTARIUS: December 17—January 20



So it's clear where the dates come from and what it means to be "born under the sign of Sagittarius." But how are horoscopes and forecasts created? This is where pseudoscience and various superstitions come into play. Astrologers draw special tools called **birth charts**, which help calculate the positions and angles of other planets relative to the ecliptic. The ecliptic is divided into different sectors called **houses**, each supposedly responsible for different areas of human life. For instance, if Neptune, the symbol of dreams and mysteries, was in the second house when you were born, an astrologer might suggest that you'd strive for easy money and could incur debts. However, don't be disheartened. There are at least 15 systems for dividing the ecliptic into houses! If you're unsatisfied with one astrologer's prediction, you can always seek another opinion—or even take fate into your own hands.

↓ Astrological map of houses. Don't try to figure it out: there is no strict logic here, just someone's wild imagination.

Human Weaknesses

The first horoscope section in a newspaper appeared in the British *Sunday Express* on the 21st of August, 1930, and it was intended personally for the newborn Princess Margaret. Following its publication, public interest in astrological forecasts increased, prompting the newspaper to commission several more articles from the astrologer. One of these articles prophesied a potential danger to British aviation in October. Coincidentally, on October 5 of that year, a plane crash did occur. As a result, a regular **astrology column** was established in the newspaper. According to a survey conducted in 2018, 29% of American adults still believe in astrology and horoscopes.

Perhaps there is some grain of truth in these predictions? After all, some horoscopes do seem to come true, and there are people whose character largely coincides with the description of their zodiac sign. That's the trick! It turns out that people tend to readily trust vague descriptions of their character, especially if they believe the text was written personally for them. In 1948, psychologist **Bertram Forer** conducted an experiment: he told students that he had written a psychological character assessment for each of them and asked them to rate the accuracy of the analysis on a five-point scale. The results averaged above four! Interestingly, the text was the same for all students.

If that doesn't convince you, science has even stronger arguments. For instance, in 1958, English scientists began monitoring more than 2000 newborn children. All children were born in London within minutes of each other, and according to astrology, they should have had similar destinies and characters. For decades, scientists compared these "astrological twins," including their intelligence, talents, aggressiveness, sociability, marital status, career success, and tendency to get into accidents. The study concluded in 2003 and did not reveal any relationship between the horoscope and the fate of the participants in the experiment.

Another problem is that belief in horoscopes is not as harmless as one might think. People often spend significant amounts on astrologers, rely on them for business decisions, and may even make life-altering choices, such as ending relationships, based solely on zodiac sign compatibility.

And this is not the worst that astrology can lead to! In 1999, over 60,000 workers fled the port city of Alang in India because a horoscope predicted its destruction. Fortunately, no disaster occurred, but the production downtime cost almost $60 million. In 1987, an astrologer predicted to **U Ne Win**, the then-ruler of Burma (present-day Myanmar), that his life would be prosperous if he was surrounded by the number 9. So what did Ne Win do? He banned 50 and 100 kyat bills (the local currency) throughout the country and issued new ones, 45 and 90 kyat. These sudden changes and the spending of the state budget caused chaos, riots, and a devastating economic crisis. Ne Win himself was forced to resign a year later.

This is the text Forer distributed to the students in his experiment. Would you agree that it describes you?

You have a great need for other people to like and admire you. You have a tendency to be critical of yourself. You have a great deal of unused capacity which you have not turned to your advantage. While you have some personality weaknesses, you are generally able to compensate for them. Disciplined and self-controlled outside, you tend to be worrisome and insecure inside. At times you have serious doubts as to whether you have made the right decision or done the right thing. You prefer a certain amount of change and variety and become dissatisfied when hemmed in by restrictions and limitations. You pride yourself as an independent thinker and do not accept others' statements without satisfactory proof. You have found it unwise to be too frank in revealing yourself to others. At times you are extroverted, affable, sociable, while at other times you are introverted, wary, reserved. Some of your aspirations tend to be pretty unrealistic. Security is one of your major goals in life.

Why do people still believe in horoscopes? Perhaps the reason lies in the pleasant feeling of freedom from personal responsibility that horoscopes grant. After all, who can blame you for having a difficult personality if you are a Scorpio? That's just how the stars aligned.

ANTI-AWARDS:

WHY DO WE LAUGH AT ABSURDITY?



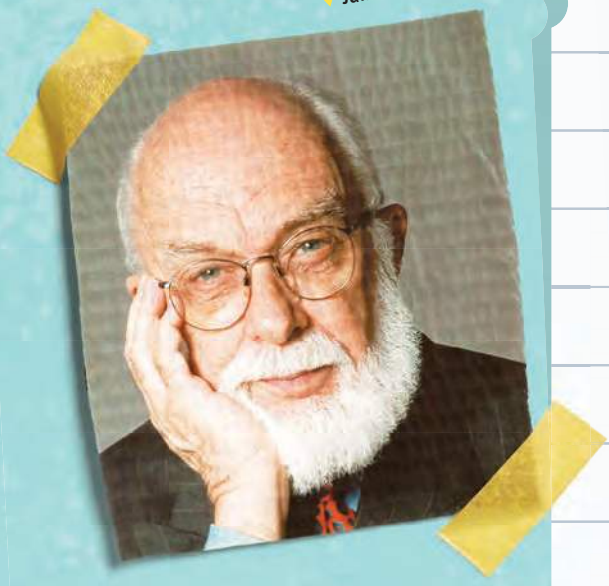


Mocking awards, also called anti-awards, seem like an unnecessary and even cruel phenomenon: why give a prize to someone who has done something senseless or unscientific? So that everyone knows, of course! Ignorance is worthy of reproach—though not of a malicious kind. Anti-awards are necessary to motivate people to move on, not to compromise . . . plus, they are also very funny.

Pigasus Award

One of the earliest humorous scientific anti-awards was introduced by illusionist and sceptic **James Randi** back in 1979. It was originally called the **Uri Trophy**, after the notorious hoaxer **Uri Geller**, who claimed that he could bend spoons with just a glance. Through this award, Randi exposed remarkable charlatans masquerading as telepaths, psychics, and other pseudoscientists. Each year, he personally selected candidates and announced the winners on April Fools' Day. The symbol of the award was a bent spoon, to pay homage to the very same Uri Geller.

James Randi



Randi had frequent clashes with Geller, dedicating many years to exposing the spoon trick and other stunts of the self-proclaimed psychic. In the 1990s, Geller repeatedly sued the Committee for Skeptical Inquiry, of which Randi was a member, but to no avail. In 1997, Randi apparently decided to leave Geller alone and renamed the prize the **Pigasus Award** (from the combination of "pig" and "Pegasus"). Its symbol, a winged pig, is a reference to the expression "when pigs fly," signifying a highly unlikely event.

James Randi said, "*The awards are of course announced via telepathy, the winners are allowed to predict their winning, and the Flying Pig trophies are sent via psychokinesis. We send; if they don't receive, that's probably due to their lack of paranormal talent.*"

Pigasus Award



THE PIGASUS AWARD HAD FIVE CATEGORIES:



The scientist who said or did something silly related to the supernatural, paranormal or occult. For example, the 2006 laureate was the biochemist **Rupert Sheldrake**, who earnestly studied "telephone telepathy"—the ability to predict who is calling you before looking at the number.
Another notable recipient was psychiatrist **Colin A. Ross**, who claimed in 2008 that he could shoot electromagnetic radiation from his eyes.



The funding organisation that supported the most useless study of a supernatural, paranormal or occult claim during the year. The 2004 winner was the US Air Force Research Laboratory, which donated $25,000 to study the possibilities of transporting people "across space dimensions or parallel universes."



The media outlet that reported as fact the most outrageous supernatural, paranormal or occult claim. You have probably come across similar programs yourself more than once. Randi mocked a variety of TV channels for segments about encounters with UFOs, dietary supplement ads, and much more.



The "psychic" performer who fooled the greatest number of people with the least talent. The 1980 laureate, psychic **Dorothy Allison**, was helping the police find a serial killer and offered 42 (!) possible names for the perpetrator, none of which advanced the investigation.



Most persistent refusal to face reality. In 2008, the award went to **Kevin Trudeau**, who was fined $37 million for promoting his books about curing diseases with coral calcium, snake oil, and other quackery.
In 2013, Trudeau was sentenced to 10 years in federal prison.

How can you not subject such people to public ridicule?! However, the Pigasus stopped announcing winners after the year 2013. James Randi passed away in 2020.

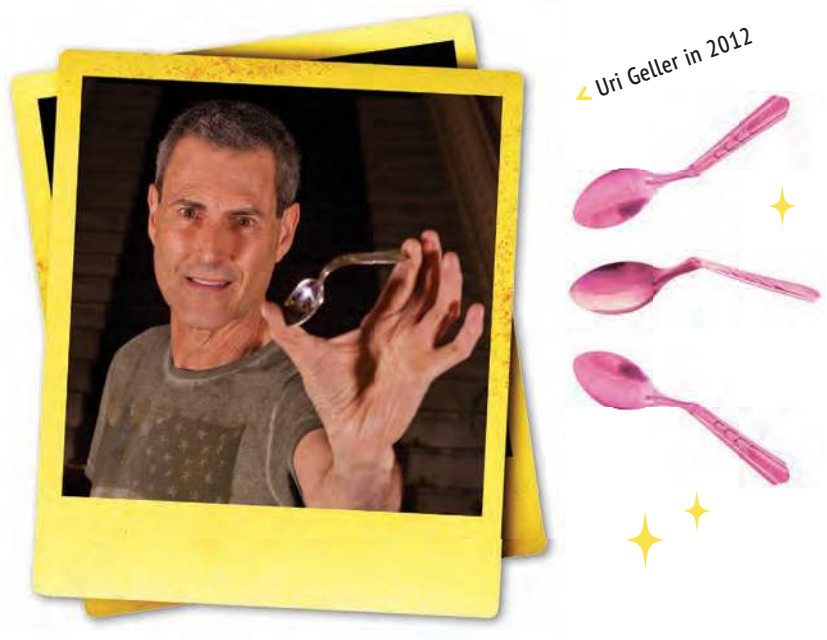
But His Idea Lives On!

Pigasus laureates come from all over the world, but most of them were based in the US, where James Randi encountered them. But what do you do about the frauds and charlatans living outside America?



"The Golden Blockhead"

For these people, there are alternative, local awards. For example, German-speaking countries have an anti-award called **Das Goldene Brett vorm Kopf** ("The Golden Blockhead"). The Society for the Scientific Investigation of Pseudosciences awards it for "the most astonishing pseudoscientific nuisance of the year." The laureates even receive an actual prize—a golden figurine depicting a man butting his head against a wooden block (this is the literal translation of the idiom *Brett vorm Kopf*). In 2018, the winner was **Christoph Fasching**, who drew an "energetic protective wall" around a Vienna hospital (commissioned by the administration!).



Uri Geller in 2012

Australians decided not to overthink it and named their **Bent Spoon Award** in honour of the same Uri Geller. This is how the organisation Australian Skeptics describes the award, "*The award trophy is a piece of gopher wood, probably from Noah's Ark, and topped with a spoon rumoured to have been used at the Last Supper. The spoon is said to have been bent by an energy unknown to science and plated with gold using an Atlantean process.*"

Have there been any individuals in Australia deserving of such a prestigious award? Of course! In 1994, the then Federal Attorney-General for Australia, **Michael Lavarch**, received the coveted prize for allowing staff in his department to get medical certificates from naturopaths, homoeopaths, and faith healers.

In 1998, Southern Cross University was awarded the prize for offering a degree course in naturopathy while also conducting research into whether there really was a scientific basis for naturopathy. Incidentally, these studies faced significant criticism from the scientific community, but the university continues to offer a naturopathy course to this day.

Since 2016, the Russian scientific and educational Internet portal Antropogenez.ru and the Evolution Foundation have been presenting an anti-prize for the **Honorary**

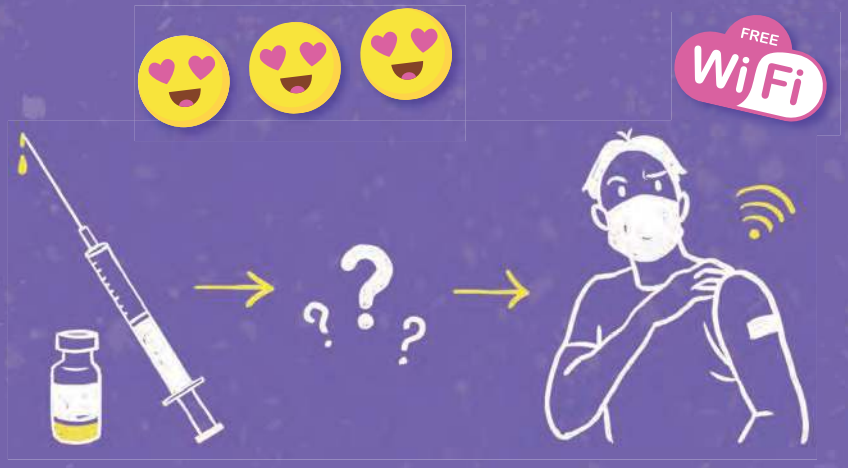


Naturopathy is a form of alternative medicine that relies on natural remedies (such as herbs, leeches, honey, and sunlight) and dietary supplements while rejecting synthetic drugs. One of the main principles of naturopathy is that the body has an innate ability to cure itself. Modern science does not support naturopathic techniques, which are considered potentially risky to the health of patients.



Academician of VRAL (VRAL is a play on the Russian word "to lie" and represents a fictional Liar Academy of Pseudosciences). Candidates are determined through online voting, and the award takes the form of a figurine of a "sad reptilian" (a fictional race often featured in tabloids and conspiracy theories). Notable winners included a leader of the anti-vaccine movement, the creator of a film about flat Earth, and a film director who made a conspiracy YouTube video about "micro-chipping the population using coronavirus vaccinations."

Do you know why we need anti-awards? Because if we don't mock pseudoscience now, there might come a day when there's nothing left to laugh at.



"Sad reptilian" >



Do not confuse mocking awards with the **Ig Nobel Prize**! This award is given to real scientists whose research may seem ridiculous and inconsequential but is rooted in original ideas, sometimes leading to unexpectedly valuable outcomes. What is the probability of slipping on a banana peel? How quickly do headphones get tangled in your pocket? How much soup can you eat without feeling stuffed? The Ig Nobel Prize laureates answer these and other questions with extreme meticulousness and adherence to scientific standards—and big kudos to them for that.

Science is not the only field that has anti-prizes. For instance, in the world of cinema, there is the Golden Raspberry film award, recognising the worst film, actor, and more as a playful contrast to the Oscars. The Bookseller magazine awards the Diagram prize for the weirdest book title, and one can receive a Turnip Prize for truly terrible and low-effort modern art.



ME YOU NO UNDERSTAND:
Scientific Dictionary

If you love science, sooner or later you will come to its defence in a conversation or debate. However, when fighting ignorance, don't forget: many disputes arise from simple misunderstandings or even from misinterpretation of just one word. In this article, we've gathered a list of the most commonly misused scientific terms to prevent any future miscommunication.

All Theory Is Grey, My Friend...

"It's just a theory!" is one of the most common arguments used by opponents of the theory of evolution. Many think this argument can't be beaten, but we know better than that: the words "theory" and "hypothesis" are not to be confused.

So where does the confusion come from? It's just that over the centuries, the word "theory" has acquired an additional, colloquial meaning of "idea," "opinion," or "assumption." Have you ever come across fan theories? That's the kind of meaning that some mistakenly attribute to scientific theories. By all accounts, these should be called "hypotheses," and there would be no confusion.

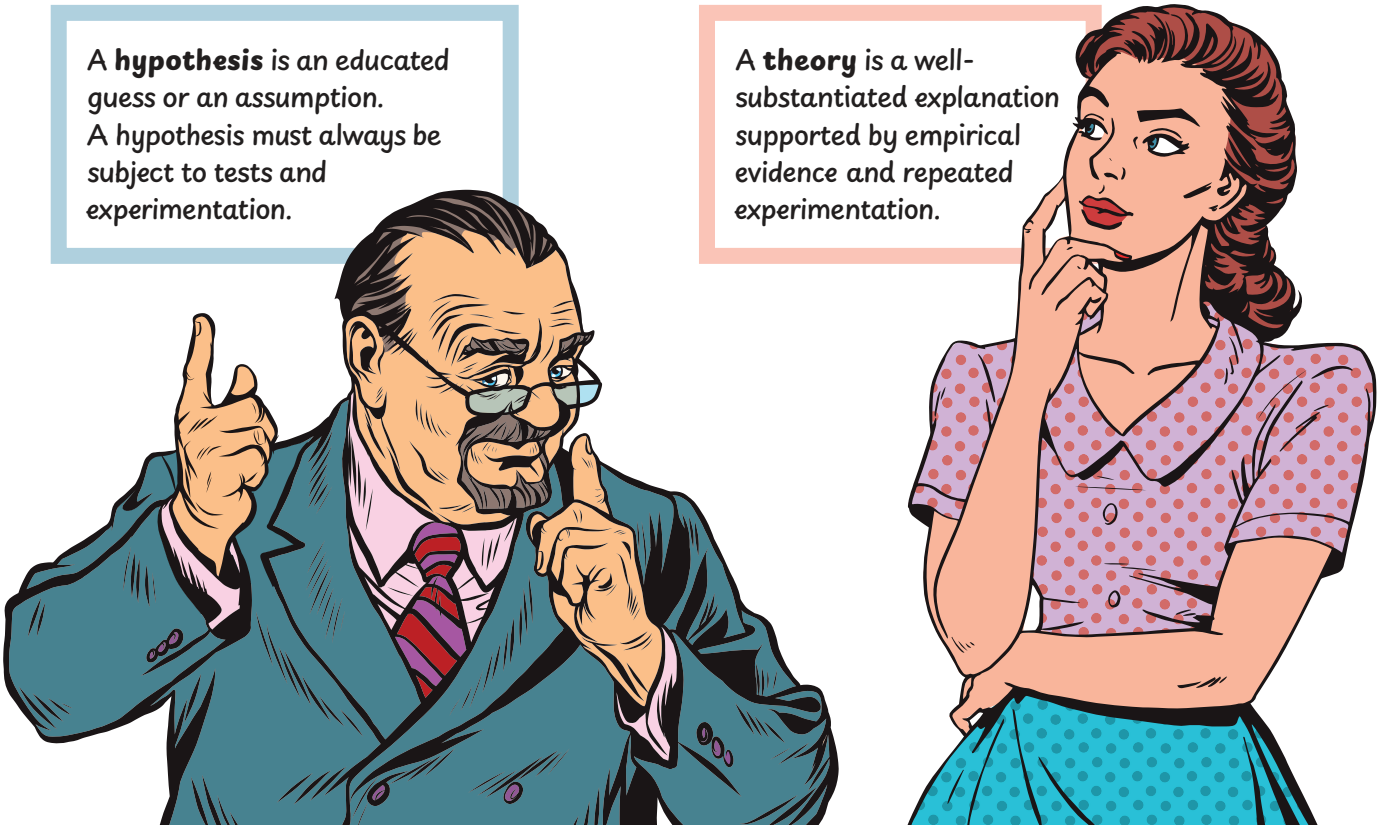
However, if it's a scientific theory we are talking about, then it's a completely different matter.

No theory appears out of nowhere; it is born from many independent scientific observations, findings, analyses, experiments, and modelling. All this is done for the scientific community to be sure of the validity of the conclusions made. Before developing any theory, you need a **hypothesis**, which must be meticulously investigated.

There can be additions, changes, and expansions to a theory. For example, the theory of evolution, one of the most reliable knowledge systems created by humans, underwent significant expansion when biologists discovered genes and DNA. A scientific theory can also be rejected as new arguments emerge, which was exactly what happened to the theory of geocentrism when **Nicolaus Copernicus** proved that the Earth revolves around the Sun and not the other way around. And it wasn't "just a theory" that the Polish astronomer refuted. Geocentrism did not appear out of thin air: ancient Greek scientist **Ptolemy** developed this model based on his observations, and his calculations helped quite accurately predict the movement of celestial bodies for many centuries.

A **hypothesis** is an educated guess or an assumption. A hypothesis must always be subject to tests and experimentation.

A **theory** is a well-substantiated explanation supported by empirical evidence and repeated experimentation.





Evidence in everyday life *is often seen as irrefutable and solid proof that guarantees truth.*

Go Prove It

Another problem follows from the fact that big scientific theories, supported by observations and calculations, may still turn out to be incorrect. We are used to thinking of evidence as irrefutable facts that can't be doubted. For example, our judicial system is based on the fact that evidence of the defendant's guilt should lead to their punishment. Sounds logical, right?

With science, however, things are a bit different. Scientists of the past boldly claimed that their evidence was ironclad, accepting it as indisputable dogma. So, for them, it was "obvious" that rocks could not fall from the sky, or that fly larvae spontaneously generated in meat.

That's why a modern scientist must understand that claiming to have fully studied anything is not tenable. This doesn't mean science is cheating and looking for excuses in case of a possible mistake. Instead, it means there is no limit to perfection and no boundaries to knowledge.

The most important thing is to avoid the extremes described above. Just because the word "evidence" bears a little less significance for a scientist than for a layperson, scientific theories with a lot of evidence don't automatically become "just theories."



Evidence in science *is just an argument in favour of a theory. It does not guarantee absolute truth.*



A sceptic in colloquial terms is a person who harbours a distrustful and often negative attitude towards everything, rejecting new ideas.

Scientific scepticism is a position in which any hypothesis should be verified through testing and experiments, and those statements that cannot be confirmed should be questioned.

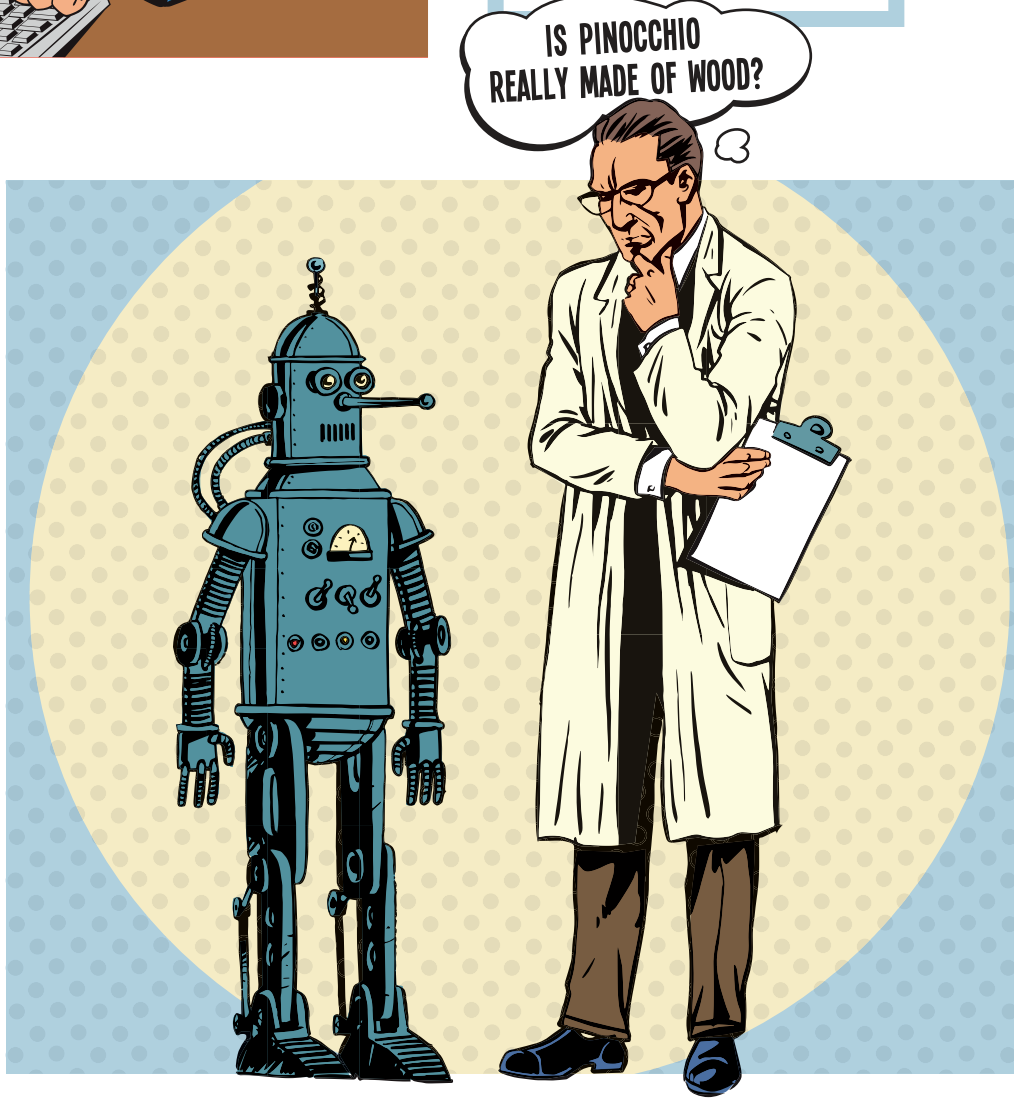
In Defence of the Sceptics

The word "sceptic" has acquired a negative connotation both in the media and in our everyday lives. Outside science, sceptics are often seen as people who have a negative and biased attitude towards any scientific data, frequently without offering any reasonable arguments. In contrast, any scientist will take the term "sceptic" as a compliment.

In science, a sceptic is a person who adopts doubt as the main principle of reasoning, gathering facts while taking theories and hypotheses with discretion. True sceptics evaluate scientific evidence impartially and are always open to new arguments for or against a given theory.

If you want to think in a scientific way, take your cue from . . . little kids. These are the real sceptics! Is the kettle hot? Can you cut yourself with a knife? Is it easy to smear everything in sight with play-doh? Let's check!

In our rapidly changing world, it is especially important to approach any data with a dose of healthy scepticism. With access to huge amounts of information that can be contradictory and confusing, the ability to understand it and find that one kernel of truth will certainly come in handy.



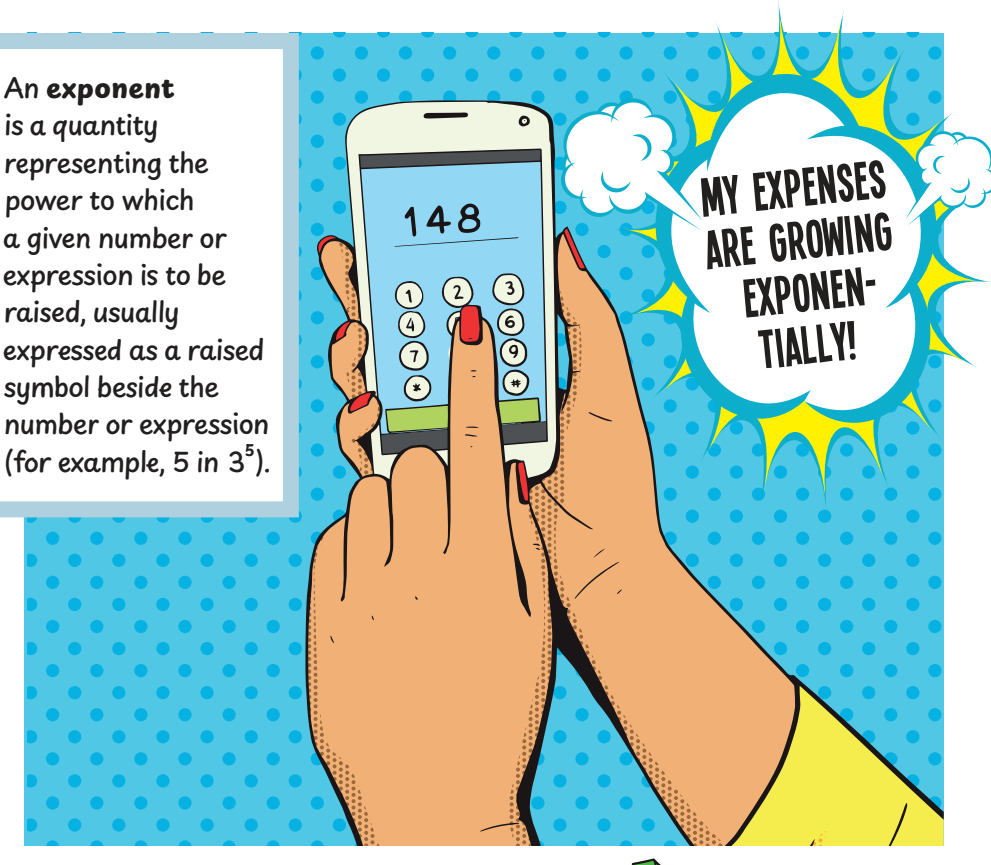
Exponentially Complicated

The multifaceted scientific words mentioned above are just the tip of the iceberg. Mathematicians are sounding the alarm: people are misusing concepts they should have learned in middle school! Here, we are talking about the term "exponential."

"The traffic is growing exponentially," "I have exponentially more work to do," "The popularity of the song is rising exponentially"—if after these phrases you are not yet rolling your eyes and clenching your fists, then we have bad news for you. In the context of mathematics, "exponential growth" refers to a trend where a quantity increases at a rate proportional to its current value rather than a single comparison.

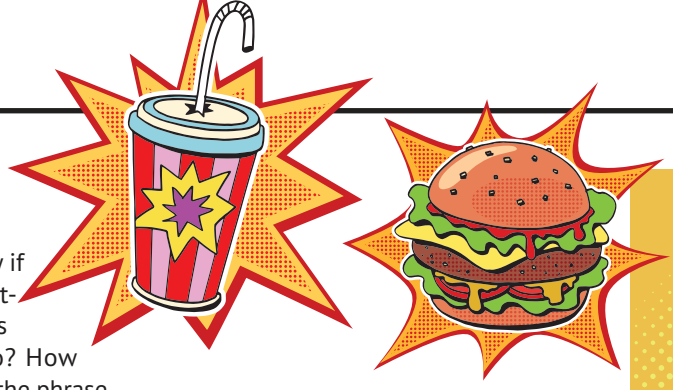
While it's not uncommon for colloquial speech to adopt technical terms and alter their original meanings, the misuse of the word "exponential" can have real-life negative consequences. As Dr **Manil Suri** explains in an article for *The New York Times*, imprecise formulations can be costly and even dangerous when reporting on medical or mathematical findings. However, language is not carved in stone; it is alive and constantly changing—if you repeat the same mistake often, it becomes the norm. And in this case, lexicographers gave in to the masses: using "exponentially" to mean "lots" is now seen as perfectly valid. Whether such changes are for the better is a philosophical question.

An **exponent** is a quantity representing the power to which a given number or expression is to be raised, usually expressed as a raised symbol beside the number or expression (for example, 5 in 3^5).





Exponential refers to a mathematical concept where a quantity grows or decreases at a rate proportional to its current value. In exponential growth, the quantity increases rapidly as it is repeatedly multiplied by itself, while in exponential decay, the quantity decreases rapidly in a similar manner.



Nothing but Chemistry

What's wrong with our society if the name of one of the greatest and most useful sciences has basically become taboo? How many people have recoiled at the phrase, "Don't eat that; it's all chemicals"?

Of course, people who use these phrases aren't criticising the science itself or the objects of its study but are referring to substances created or recreated synthetically. Nevertheless, the essence remains unchanged. In the pursuit of simplification and profit, marketing campaigns have thoroughly muddled everyone's understanding. First of all, it has become the norm to believe that everything natural is beneficial, and everything artificial is harmful. Let's find out what these words really mean.

Certainly, many natural wild berries may have health benefits, and human-made dishwashing liquid isn't safe to eat. We have made these examples intentionally absurd so that you see that naturalness has nothing to do with usefulness!

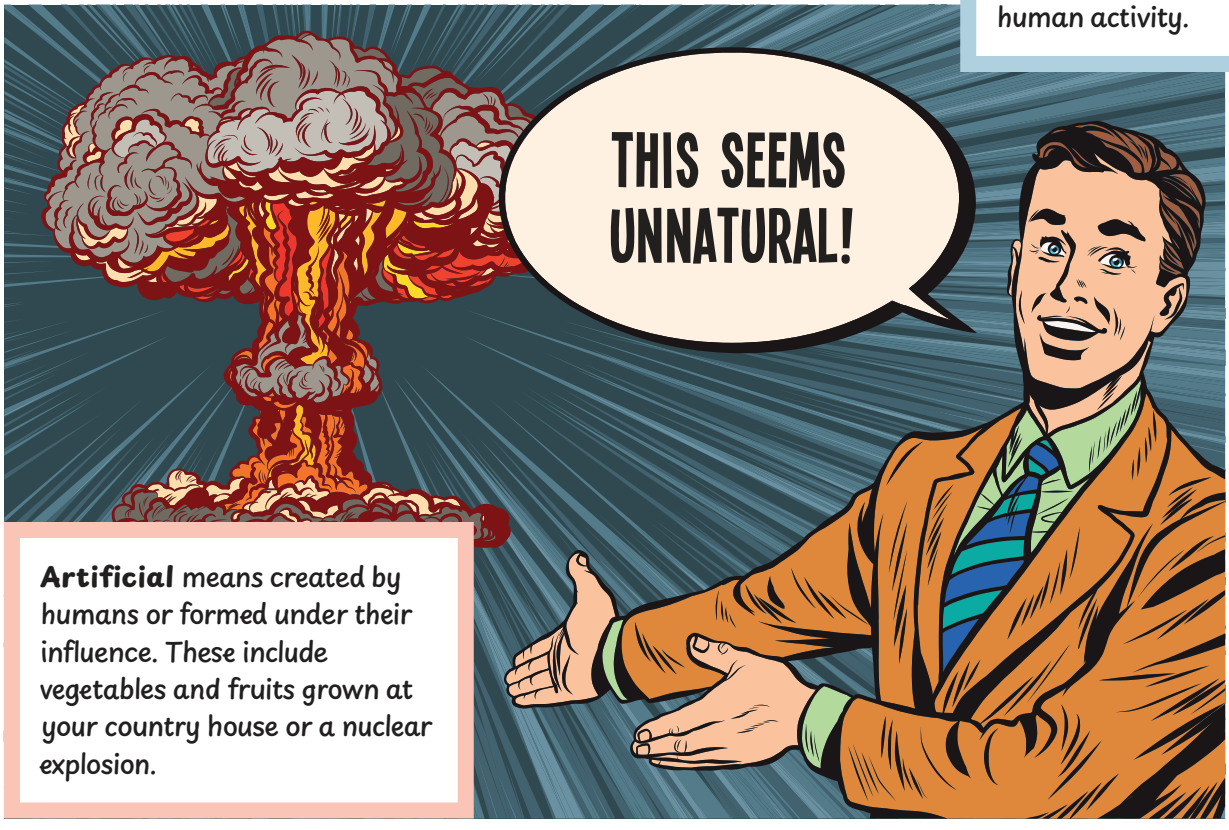
It's the same with the word "organic." Ads use it as a fill-in for "natural," "chemical-free," and "healthy." In reality, any food and many household items are organic because they're made of carbon and its compounds.

What about "chemicals"? Are synthetic substances really that bad? In reality, medicines and supplements made of artificially created compounds save countless lives.

In fact, our entire world, including ourselves, is nothing but chemistry. This has been the case long before humans emerged and will persist for millions of years to come. We exist thanks to chemistry, and our lives have become even better with the advent of synthetic chemistry. It might be worth keeping this in mind.



Natural means formed in nature without human participation or influence. Do you know what occurs naturally? Mercury, uranium, fly agarics, flies . . . Although flies are controversial. After all, urban flies depend on human activity.

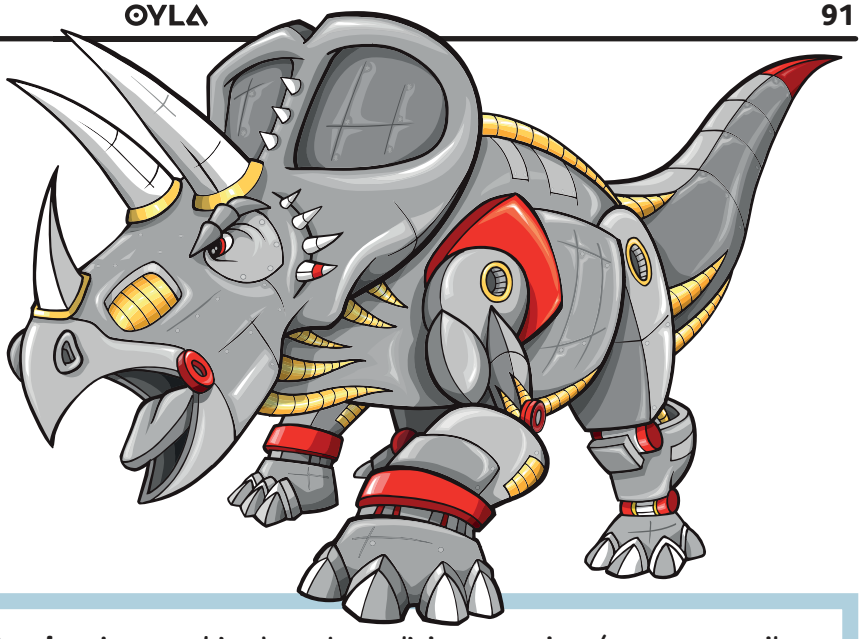


Artificial means created by humans or formed under their influence. These include vegetables and fruits grown at your country house or a nuclear explosion.

T-800 Is Not a Cyborg

Advertising indeed has a way of muddling words in our minds, but so does Hollywood. The popularity of science fiction is pushing screenwriters to create more and more robots, cyborgs, androids, droids, bots, mechs, and so on and so forth. They may simply have no time to think about whether the names of their creations sound scientific, but either way, it creates a less-than-scholarly confusion in our minds.

So, from a scientific standpoint, what is our good old Terminator? Although it says in Arnold Schwarzenegger's voice that it's a cybernetic organism, believe it not, it's most definitely an android. A cyborg is something you could see in the fourth part of the franchise as the main character.

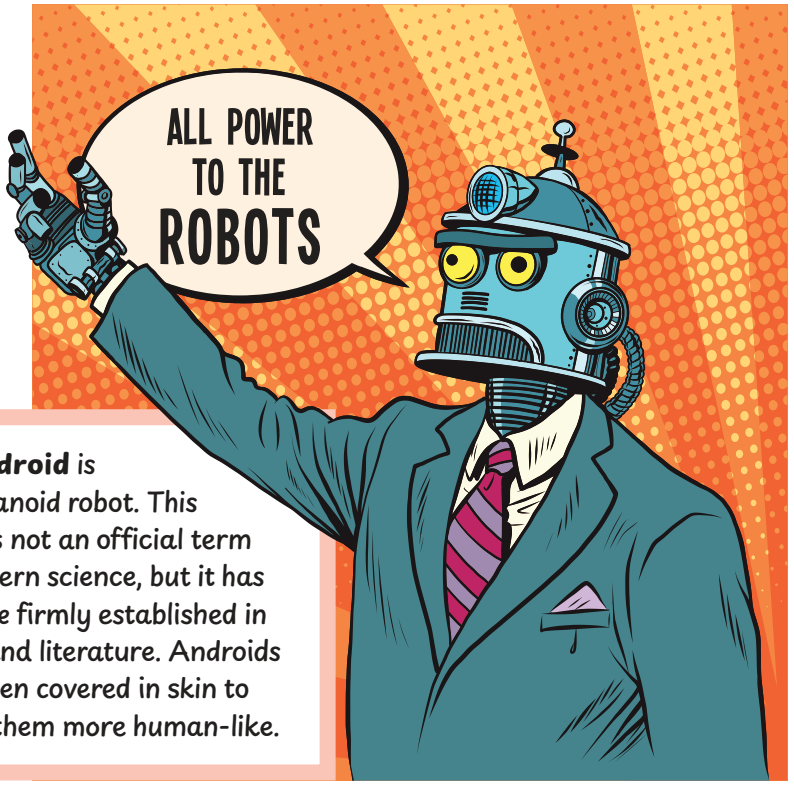


A **robot** is a machine based on a living organism (not necessarily human). This means that it has sensors (analogous to sensory organs) and the ability to perform certain operations independently.



A **cyborg** is a living organism with additional mechanical or electronic components. The word is formed from "**cyb**ernetic **org**anism."

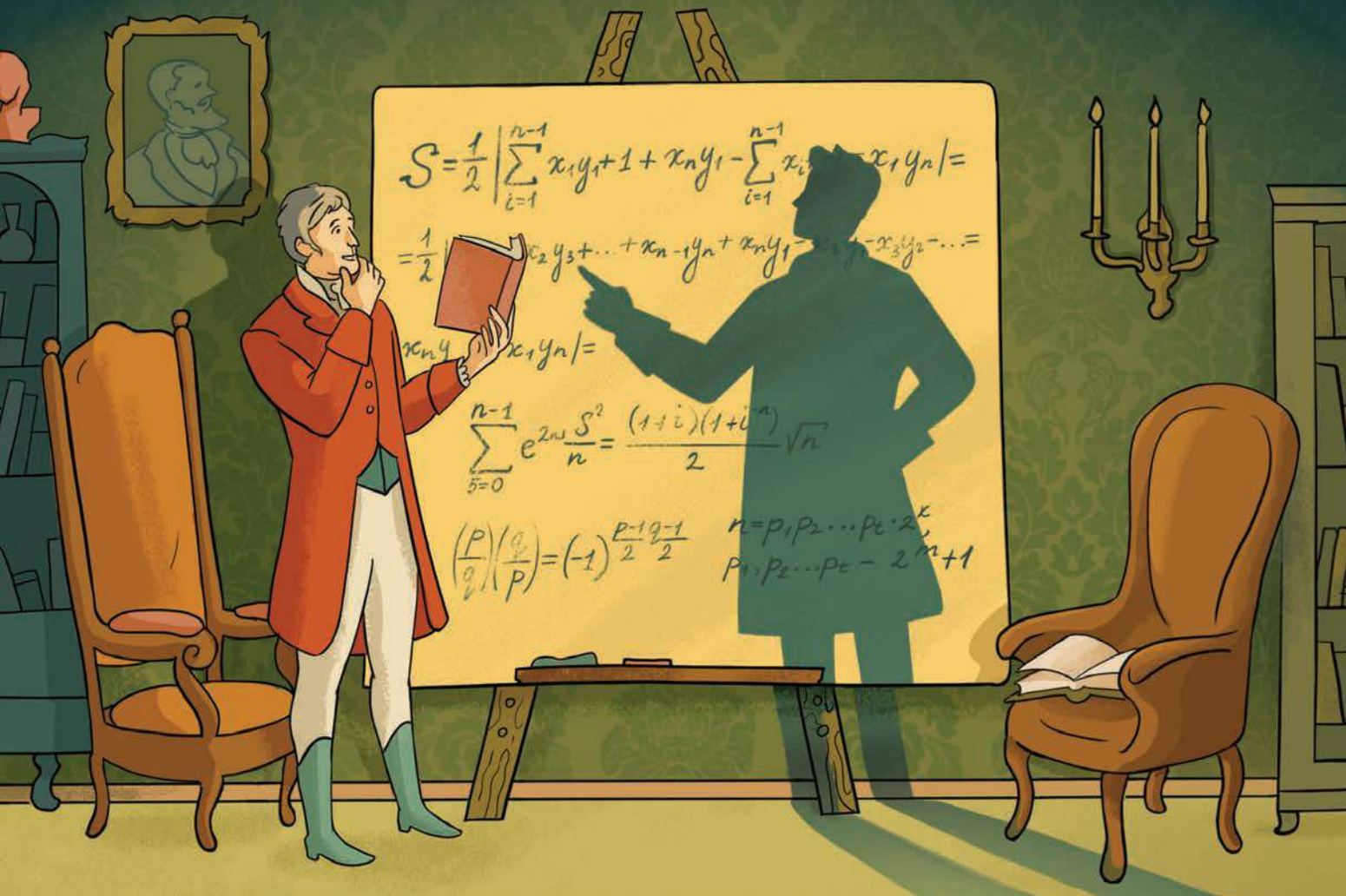
Now you are armed for battle in the name of science. You can now safely defend it, but remember: too much irritation and aggression in a dispute will do neither you nor science any credit. Stay open to other people's opinions and support your own with arguments.



An **android** is a humanoid robot. This word is not an official term in modern science, but it has become firmly established in films and literature. Androids are often covered in skin to make them more human-like.

Sophie Germain:

In the Shadow of Men's Names



On November 27, 1806, the mathematician Carl Friedrich Gauss was visited by an officer from Napoleon's army, which had annexed the city not long before. Gauss answered the door with trepidation. But, confusingly, it seemed like the officer had come to inquire about the scientist's health and make sure he was all right. Gauss was even more surprised to find out that he had a certain "Miss Sophie Germain" from Paris to thank for the officer's concern. Gauss had never heard of such a person! But the mathematician was wrong. He actually knew Miss Germain extremely well—but under a different name.

Not a Woman's Job

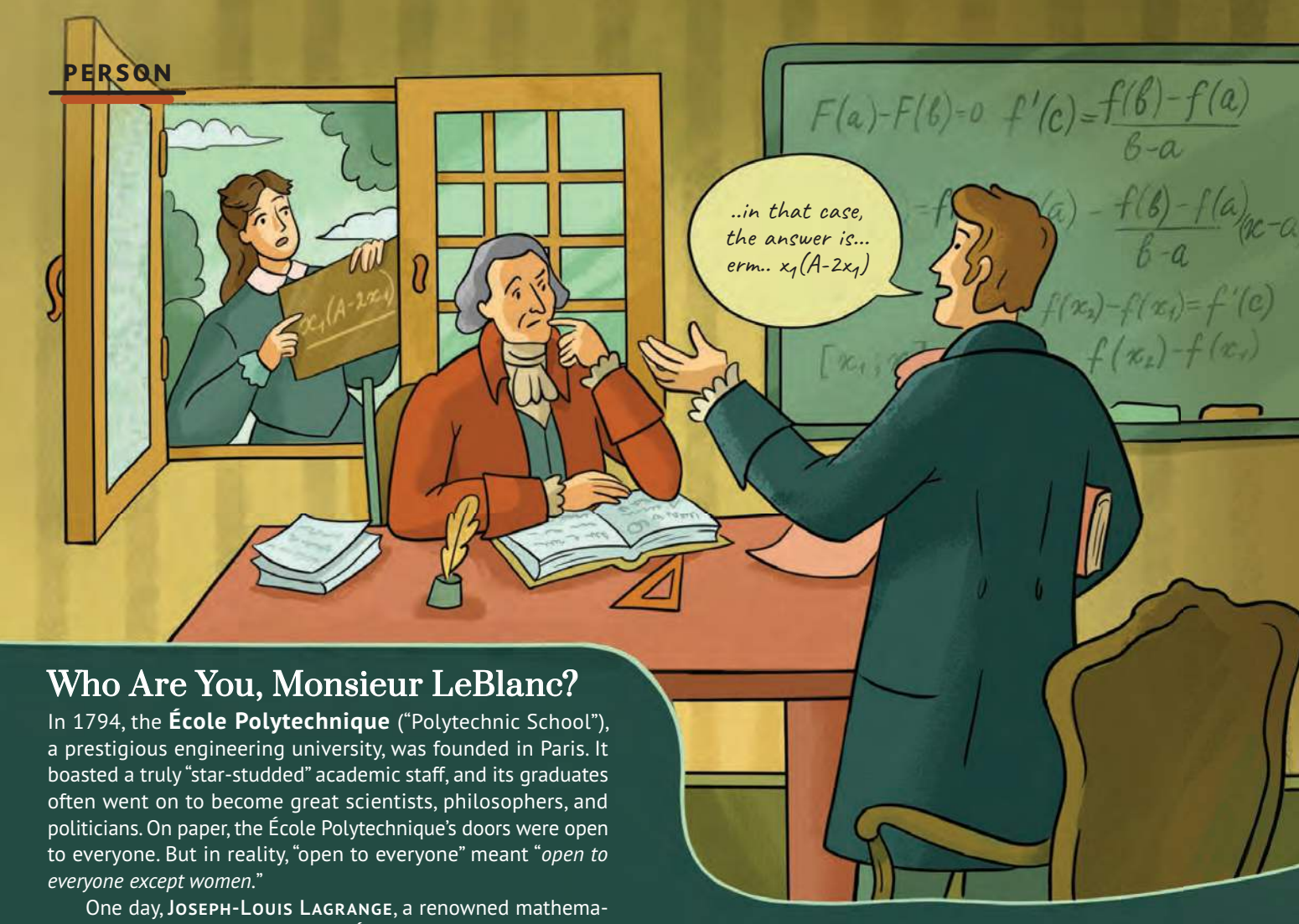
Sophie Germain was born in Paris in 1776, the middle daughter of the respected bourgeois merchant **Ambroise-François Germain**, who was elected deputy to the National Assembly in 1789 and later the director of the Bank of France. Monsieur Germain was already 50 when Sophie was born.

As a child, Sophie spent all her free time in her parents' library. Most girls her age preferred novels and prayer books, but Sophie enthusiastically studied **Jean Étienne Montucla**'s *Histoire des mathématiques* ("A history of mathematics")—a book that changed her life. She was especially struck by the story of **Archimedes**. According to legend, when Archimedes' hometown was captured by enemy troops, he was so deeply absorbed in a mathematical problem that he allegedly told a soldier who interrupted his work, "Don't disturb my circles." The soldier promptly killed him.

Sophie couldn't help but notice that the history of mathematics was actually the history of *mathematicians*. But practically none of the mathematicians that she read about were women! Scientists seemed to be afraid of women. They laughed at women, or just plain ignored them. Even when a scientist seemed to admire a woman, it was rare that he admired her as an equal. Back then, women were unable to receive higher education. Therefore, any woman who wanted to learn about science had to study it independently and often quite sporadically.

Even Monsieur Germain, a distinguished member of the National Assembly, was indifferent to such "nonsense" as women's rights. All the greater was his amazement when he learned that his daughter wanted to become a mathematician! Sophie's parents tried to stymie her interest by taking away her books and forbidding her to use candles or the fireplace so that she wouldn't be able to work. Sophie had to suffer through the cold and the damp, but it was already too late to put out the fire that had been lit inside her. She boldly took on the most advanced and difficult scientific books—the works of **Isaac Newton** and **Leonard Euler**! Her parents finally gave in: first her mother, followed by her father. Sophie lived on her father's money her entire life.





Who Are You, Monsieur LeBlanc?

In 1794, the **École Polytechnique** ("Polytechnic School"), a prestigious engineering university, was founded in Paris. It boasted a truly "star-studded" academic staff, and its graduates often went on to become great scientists, philosophers, and politicians. On paper, the École Polytechnique's doors were open to everyone. But in reality, "open to everyone" meant "*open to everyone except women*."

One day, **Joseph-Louis Lagrange**, a renowned mathematician and professor of analysis at École Polytechnique, noticed something strange. One of his students, a young man with rather mediocre abilities by the name of **Antoine-Auguste LeBlanc**, suddenly began to demonstrate brilliant mathematical talent. He started doing his homework exceptionally well and began to correspond with Lagrange, discussing Lagrange's lectures and giving his own thoughtful comments on the material. How could such a sudden change in the student's behaviour be explained? Well, as it turns out, the letters were penned not by LeBlanc but by . . . Sophie Germain! The real Antoine-August LeBlanc had given up his studies and left the city.

Lagrange became young Sophie's first mentor. He tried to help her organise her vast, but scattered, knowledge. He mentioned her to **Jérôme Lalande**, the director of the Paris Observatory, who sent her his popular science book *Astronomie des dames* ("Astronomy for ladies"). At that time, Germain was already reading something much more serious: **Pierre-Simone Laplace**'s *The System of the World*, and she was offended by Lalande's condescending gift. Her relationship with the leading astronomer was tarnished forever.

Still another scientist, **Adrien-Marie Legendre**, corresponded with Sophie for many years. His book *Essai sur la théorie des nombres* ("Essay on number theory"), published in 1798, became one of the most important books in her life and heavily influenced her later research.

An Impenetrable Theorem

For several centuries straight, mathematical minds had been boggled by **Pierre Fermat**'s last theorem. In 1637, the self-taught mathematician thought up a simple and elegant formula:

$$x^n + y^n \neq z^n, \text{ if } n \geq 3.$$

Try substituting any number for ***n***, and you will find that the equation is true. That means that the formula is correct, right? But mathematicians won't accept an argument like that. Mathematical proof is the proof of the general principle underlying a given pattern. It should be supported by strict logical principles, taking into account all possible situations. And nobody could find such a proof for Fermat's theorem! Even Leonard Euler himself, one of the greatest mathematicians of all time, could only prove the theorem for ***n = 3*** and ***n = 4***.

While studying Euler's works, Sophie Germain learned that the logic behind the theorem's proof could change based on whether or not one of the numbers used for ***x***, ***y***, or ***z*** was divisible by ***n***. That's why mathematicians sometimes talk about *Case 1* and *Case 2* of Fermat's last theorem. Sophie proposed a special class of prime numbers, which are now called **Sophie Germain primes**.

Let's recall: what is a prime number? A prime number is a number that can only be divided by one or by itself; for example: **2**, **3**, **5**, **7**, **11**, **13**, and so on. Now think of any prime number—we'll call it p. If $2p + 1$ is also a prime number, then p is a Sophie Germain prime. As an example, out of the first six prime numbers (listed above), **2**, **3**, **5**, and **11** are also Sophie Germain primes, and **7** and **13** are not.

While studying the properties of her special prime numbers, Germain discovered that Case 1 of Fermat's theorem always holds true for them. She formulated her conclusions as a new theorem. As it turns out, Germain's work in some sense had surpassed that of Euler himself: without defining n, she undertook one of the first attempts at generalising the theorem's proof for an entire class of prime numbers, thereby taking a significant step forward towards the riddle's final solution. Germain never published her theorem, but she explained it in a letter to Legendre.

As a result, Legendre (thanks to Sophie Germain) and the German mathematician **Peter Gustav Lejeune Dirichlet** were able to prove Fermat's theorem for $n = 5$. By using Legendre's theorem, which was based on Germain's theorem, it was possible to prove Fermat's theorem for any exponent $p < 197$. Lagrange acknowledged Germain in the reissue of his treatise on number theory.





In 1801, Carl Friedrich Gauss published a treatise titled *Disquisitiones Arithmeticae* ("Studies in arithmetic"). This book promptly earned him the distinction of the greatest working mathematician in Europe. Germain, one of the first to read his book, wrote an entire series of important additions to Gauss' work. In 1804, she decided to send her additions to Gauss, signing the letter with the name of an old acquaintance: Antoine-Auguste LeBlanc. Gauss was thrilled to encounter such a talented correspondent and said that arithmetic had found a new friend in LeBlanc.

As we already know, Germain had to disclose her true name to Gauss due to the war. She was determined not to let Gauss meet the unfortunate fate of Archimedes. She did everything she could (likely with the help of her father's connections) so that Gauss wouldn't suffer. Years later, Germain would show the same concern for Évariste Galois—a gifted young mathematician and passionate republican who frequently found himself in trouble. Unfortunately, Germain's fears for her younger colleague were founded. At 23 years old, Galois was killed in a duel.

PERSON



A Test of Strength

In 1809, the French Academy of Sciences offered a prize for a mathematical theory of the vibrations of an elastic surface and its correlation with experimental data. Lagrange said that this would require the creation of a brand new branch of mathematical analysis!

Only two brave souls stepped up to the challenge: a young professor named **Siméon Denis Poisson** and Sophie Germain. Poisson was assisted by his mentor, Laplace, and Germain had the support of Legendre. Germain proposed the first version of her calculations in autumn 1811, but the jury rejected it, citing a lack of basis for her equations. Nevertheless, Germain didn't give up; what's more, she refused any further help from Legendre. Soon she became the only contender for the prize: in March 1812, Poisson was elected as a member of the Academy, meaning that he was now on the jury. The next year, Sophie tried for victory again—and again was unsuccessful! The jury praised Germain for the theoretical depth of her calculations but found errors in her work.

And suddenly, Poisson sprang into the picture once more. In this publication, without acknowledging Germain, he attempted to integrate her proposed equation (as refined by Lagrange) with the molecular theory of elasticity developed by his mentor, Laplace. This was an apparent display of Poisson's wounded pride: he evidently did not want to concede to Germain, even though the formal competition had been concluded. He continued to contend, albeit from the security of his new position.

On January 8, 1816, Sophie Germain made history as **the first woman to be awarded a prize** by the French Academy of Sciences. However, this victory carried a bitter aftertaste. Sophie was weary from the prolonged competition, and there were lingering errors in her calculations that troubled her. The dispute with Poisson persisted, with him frequently referencing his 1814 publication and implying that he was the true winner.

Winning the prize should have been grounds for Sophie to attend meetings of the Academy of Sciences, but there was a rule forbidding unmarried women to enter the temple of science. Only in 1823 did she receive an official letter from **Jean-Baptiste Joseph Fourier**, Secretary of the Academy, stating that a chair in the meeting room would be reserved for her from then on.

In 1829, Sophie was diagnosed with breast cancer. On June 27, 1831, she passed away. Her death certificate designated her as a "rentiere–annuitant" (someone who receives income from rent or annuity), failing to mention her work as a mathematician. Even her contributions to the Academy couldn't overcome society's bias against female scientists. This would take many more years . . .





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