Why do we play?

Because moving is how humans have always learned.

We built a place that does both.

A science museum teaches. A playground moves. Here, the learning is built into the play, so every slide, kick and climb is a lesson your whole body remembers.

How to read our signs

Play: start here. For kids.

Connect: go further. For big kids and grown-ups.

Grow: go deep. The full math and science.

PLAY IRON RANGE
PLAY. CONNECT. GROW.

People have always played

Play

Kids in every country on Earth play. Kids played ten thousand years ago too. Playing is how people learn to be people.

Connect

Play has been documented in cultures around the world and in many animals. Among hunter-gatherer peoples, children spend most of the day in free play with kids of all ages, and that play is how they practice the skills of adult life.

Grow

Johan Huizinga's *Homo Ludens* (1938) argues that play is older than culture and is the ground culture grows from. Peter Gray's surveys of hunter-gatherer ethnographies describe self-directed play as the primary means of education. Lev Vygotsky held that in play a child acts "a head taller than himself", working inside the zone of proximal development.

School: History → University: Anthropology → PhD: Anthropology of play

Free play and games with rules

Play

Free play is making it up as you go. A game with rules is when everyone agrees how to play. You need both!

Connect

Free play builds imagination, problem solving and the courage to try new things. Games with rules build turn-taking, fairness and teamwork. Most play slides back and forth between the two, like a game of tag that keeps inventing new rules.

Grow

Roger Caillois (1958) named the two poles *paidia*, spontaneous improvisation, and *ludus*, rule-bound play, and sorted games into contest, chance, pretend and vertigo. Mildred Parten (1932) charted social play from solitary and parallel play to cooperative play. For G. H. Mead, the "game stage" is where a child learns to take the role of the "generalized other", the root of social life.

School: Social studies → University: Sociology → PhD: Sociology of childhood

Big muscles and small muscles

Play

Running, climbing and jumping use your big muscles. Drawing, pegs and buttons use the small muscles in your hands. Your brain grows with both.

Connect

Big-muscle skills are called gross motor skills, and small-muscle skills are fine motor skills. Children build control from the center of the body outward, so strong shoulders and a strong core come before a steady pencil grip.

Grow

$$MT = a + b \log_2(2D / W)$$

Motor control generally develops from head to toe and from the trunk outward, a principle described by Arnold Gesell. Whole-body play loads the vestibular and proprioceptive systems, while fine manipulation recruits corticospinal control of the hand. Fitts's law, above, models the speed and accuracy of every reach: movement time MT grows with distance D and shrinks with target width W.

School: Science → University: Kinesiology → PhD: Motor control

Moving bodies, focused minds

Play

Your body is made to move a lot every day. After you play hard, your brain is ready to learn.

Connect

For nearly all of human history, children walked, carried, climbed and ran for hours every day, and bodies and brains grew up expecting it. Studies find that children pay attention better after active play. Health experts recommend at least 60 minutes of it every day.

Grow

In a small study of 20 children, a single 20-minute walk was followed by more accurate performance on an attention task and higher reading comprehension scores (Hillman and colleagues, 2009). Their randomized FITKids trial (2014) found that a daily after-school activity program improved executive control. In studies of adults, exercise raises brain-derived neurotrophic factor (BDNF), a protein involved in learning and memory. The World Health Organization recommends an average of at least 60 minutes of moderate to vigorous activity a day for ages 5 to 17.

School: Science → University: Psychology → PhD: Cognitive neuroscience of exercise

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Why is free play important to child development?

Play

When you make up your own game, you are in charge of your own learning. Free play grows your body, your brain and your friendships, all at the same time.

Connect

Free play is play that children choose and direct themselves. The child sets the goal, solves the problems and handles the feelings, so one game exercises planning, self-control, movement, language and friendship together.

Grow

Twenty fields of study, each one a path to a PhD, have looked at play. Every box on the board starts with what play does for a child, in bold, and then shows the research behind it. They all point the same way.

Twenty fields agree: free play is good for kids. It builds a strong body, a sharp mind and good friends.

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Exercise physiology

Active play builds stronger bones.

Jumping and landing load growing bones, and the bone it builds at the hip has been measured years later (Gunter and colleagues, 2008). Hard, breathless play strengthens the heart and the lungs.

Kinesiology

Kids who move well are more likely to stay active.

Running, jumping, throwing and balancing are learned skills. Children skilled at throwing, catching and kicking were more likely to be active as teenagers (Barnett and colleagues, 2009).

Neuroscience

Play shapes the growing brain.

In laboratory studies, rough-and-tumble play changes how neurons grow in the prefrontal cortex, the region that manages attention and self-control (Bell, Pellis and Kolb, 2010).

Biology

Play gets kids ready for surprises.

Play takes energy, yet puppies, kittens, foals and the young of many other animals do it too. Scientists think it is practice for the unexpected (Spinka, Newberry and Bekoff, 2001).

Pediatrics

Doctors prescribe play.

The American Academy of Pediatrics' 2018 report, The Power of Play, advises doctors to prescribe play: it builds skills and buffers children against stress.

Clinical psychology

Play builds confidence and courage.

In free play children make decisions, solve problems and manage fear on their own. Peter Gray (2011) ties the decline of free play to rising anxiety and depression in children.

Community health

Adventurous play is linked to better health.

Active, adventurous play is linked to more physical activity and better social health (Brussoni and colleagues, 2015).

Occupational therapy

Swinging, spinning and climbing train balance.

Occupational therapists describe play as the main occupation of childhood. In A. Jean Ayres's theory, swinging, spinning and climbing feed the senses of balance and body position that support attention and coordination.

Education

Kids who get recess behave better in class.

Recess works. In a study of more than 10,000 third-graders, classes with daily recess were rated as better behaved (Barros and colleagues, 2009).

Linguistics

Pretend play and language grow together.

Pretend play is full of storytelling, bargaining and new words. Children's pretend play and their language skills grow together (Lillard and colleagues, 2013).

Cognitive science

Kids at play think like scientists.

Children play like scientists. Given a toy that works in a puzzling way, preschoolers keep exploring until they find the cause (Schulz and Bonawitz, 2007).

Developmental psychology

Make-believe is practice in self-control.

In make-believe, children practice holding a rule in mind and controlling their impulses. Vygotsky called play a leading activity of the preschool years.

Law and human rights

Every child has a right to play.

Play is a right. Nearly every country in the world has agreed in writing that children have a right to rest, leisure and play.

Economics

Skills learned early pay off for life.

Skills learned early make later skills easier to learn. James Heckman's research finds that investing in early childhood, especially for children who start with less, returns more than investing later.

Anthropology

Play is how kids have always learned.

In hunter-gatherer bands, children play freely in mixed-age groups for most of the day, and that play is how they learn the skills of their culture (Gray, 2009).

Sociology

Play is where kids learn to belong.

In play, children build their own little communities, borrowing from the adult world and making it their own (Corsaro, 1992).

Mathematics education

Kids do math while they play.

Math shows up in free play all by itself. When researchers watched young children at free play, the children were doing something mathematical, such as counting, comparing sizes and making patterns, 43 percent of the time (Seo and Ginsburg, 2004).

Engineering

Build it, test it, fix it: that is engineering.

Play is prototyping: build it, test it, watch it fall, fix it. That loop of trying and improving is the engineering design process.

Computer science

Curiosity works so well that computers copy it.

Computer programs face a child's choice: use what works, or explore something new. Programs built to be curious, a kind of play, learn better when rewards are rare (Pathak and colleagues, 2017).

Philosophy

Play is part of being human.

Johan Huizinga argued that culture itself begins in play. Friedrich Schiller wrote that a person is fully human only when at play.

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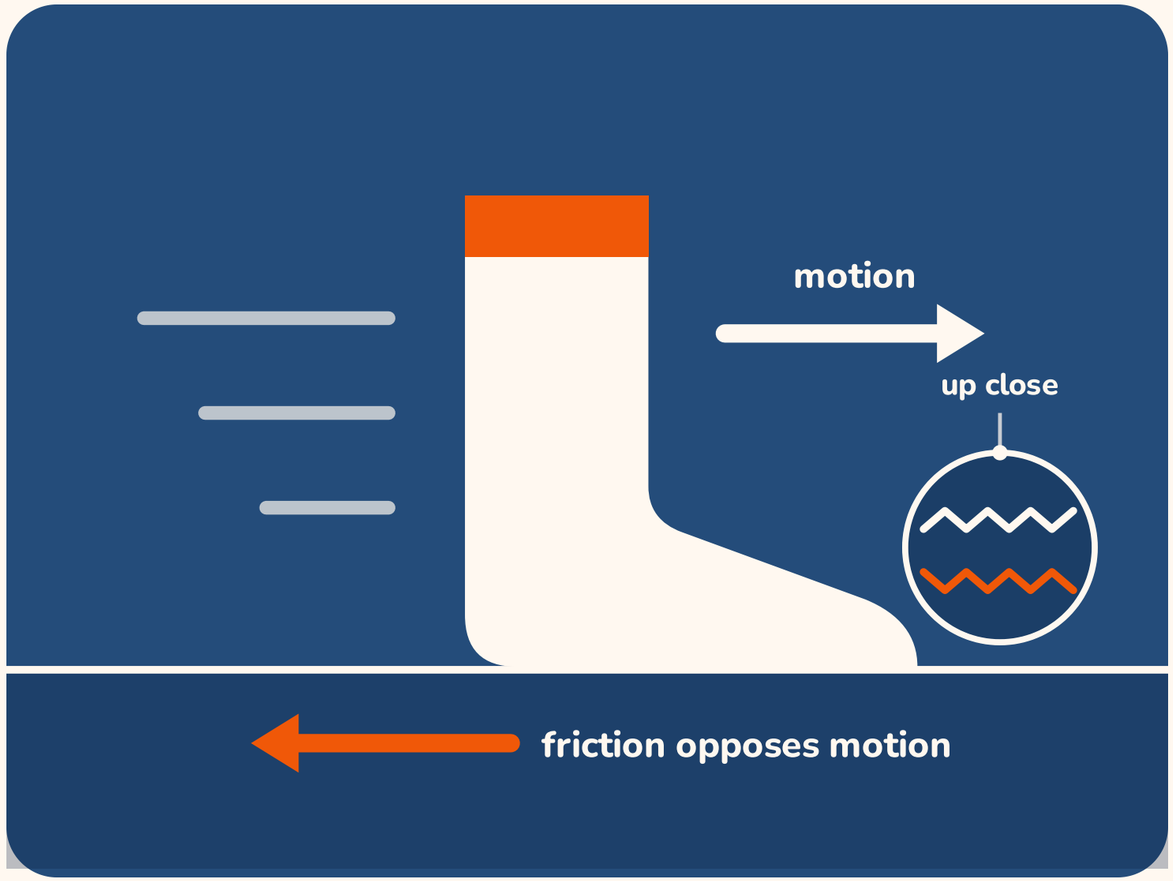
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Science

Sock Skating Rink

Why do socks slide?



Try it

Take a small slide in your socks. Then press your hand flat on the floor and push it along.

References

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Play

When two things rub together, they grip each other. That grip is called friction. Socks on a slick floor make very little friction, so you glide.

Connect

Friction always pushes against the direction you slide, and it turns your motion into a little heat. Its strength depends on the two surfaces and on how hard they press together. The size of the patch that touches barely matters.

Grow

$$F_f = \mu_k N \quad a = -\mu_k g \quad d = v_0^2 / (2\mu_k g)$$

Amontons-Coulomb kinetic friction: the force is proportional to the normal load N and independent of contact area. On level ground your mass cancels, so the stopping distance d depends only on your launch speed v_0 and the coefficient μ_k. Halving μ_k doubles your glide.

School: Science → University: Physics → PhD: Tribology, the science of friction and wear

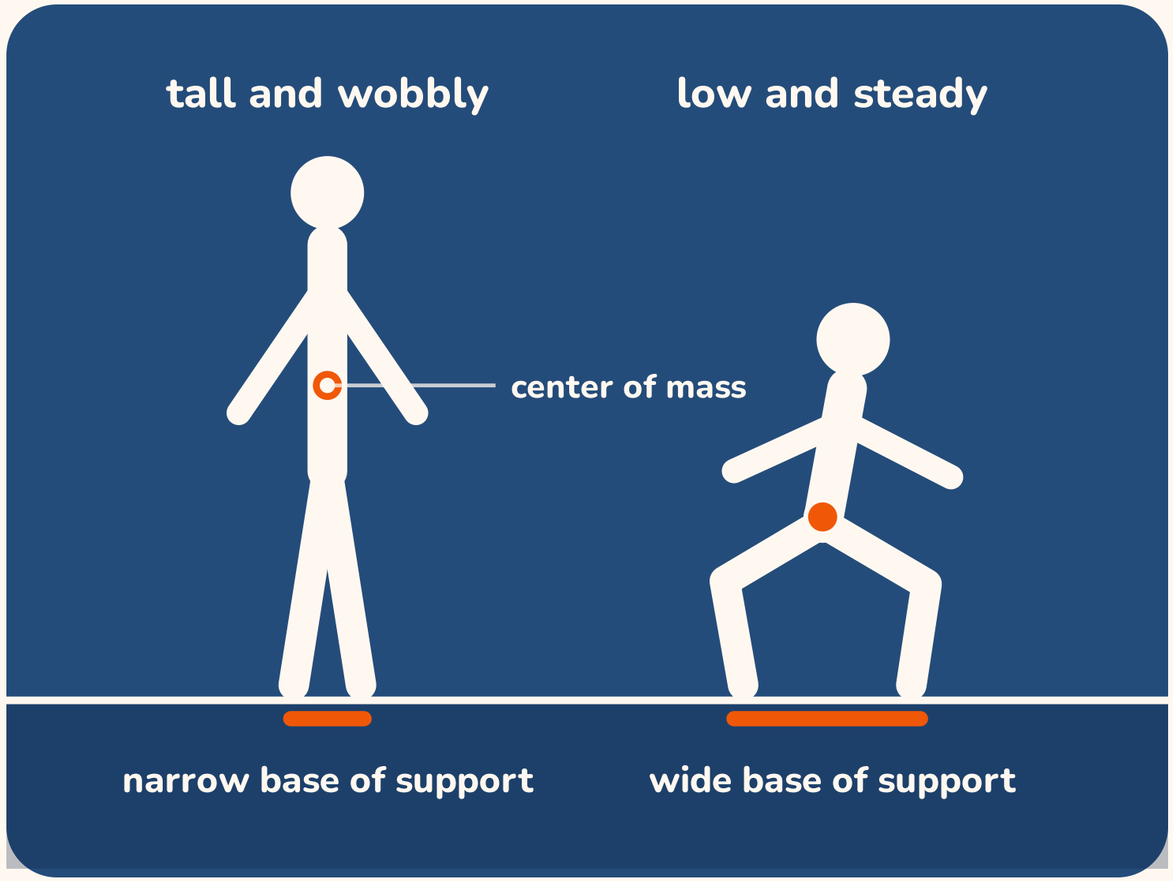
Talk about it: what would change if you wore rubber boots out here?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Sock Skating Rink

Why bend your knees?



Try it

Stand tall and wobble side to side. Now bend your knees low and wobble again.

References

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Play

Your body has a balance point just below your belly button. Bend your knees and it moves closer to the floor, so you get much steadier. That point is your center of gravity.

Connect

You stay up as long as your balance point is above the space between your feet. A wide stance and a low body give you more room to lean before you tip, which is why skaters and goalies crouch.

Grow

$$\theta_c = \arctan(b / h) \quad \tau = mgh \sin\theta$$

Static stability requires the vertical projection of the center of mass to fall inside the base of support. With half-width b and center-of-mass height h, tipping begins past the critical angle θ_c. Lowering h raises θ_c and shrinks the toppling torque τ about the edge of your foot.

School: Science → University: Physics or Kinesiology → PhD: Biomechanics

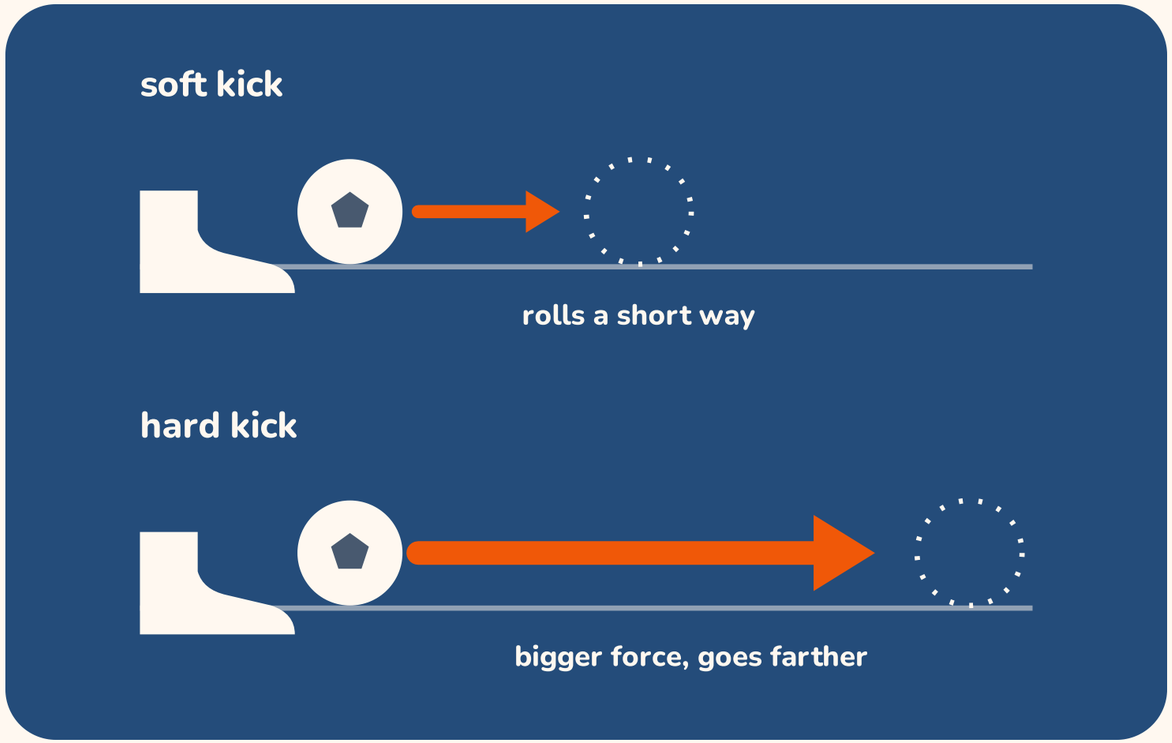
Talk about it: which is steadier, feet together or feet apart?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Kick Room

What makes the ball go?



Try it

Tap a ball softly with your foot. Then give it a big kick. Watch how far each one goes.

References

Shinkai, H., Nunome, H., Isokawa, M., & Ikegami, Y. (2009). Ball impact dynamics of instep soccer kicking. *Medicine & Science in Sports & Exercise, 41*(4), 889-897. https://doi.org/10.1249/MSS.0b013e31818e8044

Halliday, D., Resnick, R., & Walker, J. (2014). *Fundamentals of physics* (10th ed.). Wiley.

Play

A kick is a push. Scientists call a push or a pull a force. A bigger force makes the ball speed up more, so it goes farther.

Connect

The ball's speed depends on how hard you push and on how long your foot stays on the ball. Following through keeps your foot on the ball a split second longer, and that is why coaches teach it. Then the turf and the air slow the ball back down.

Grow

$$\mathbf{F} = \mathrm{d}\mathbf{p}/\mathrm{d}t \quad \mathbf{J} = \int \mathbf{F}\,\mathrm{d}t = m\Delta\mathbf{v} \quad F_{\mathrm{D}} = \tfrac{1}{2}\rho C_{\mathrm{D}} A v^2$$

Newton's second law in momentum form. The impulse **J** delivered during roughly 10 milliseconds of foot contact sets the launch velocity. In flight the ball loses momentum to aerodynamic drag F_{D}, which grows with the square of its speed v, the air density $\boldsymbol{\rho}$ and the ball's cross-section A.

School: Science → University: Physics → PhD: Sports physics and impact mechanics

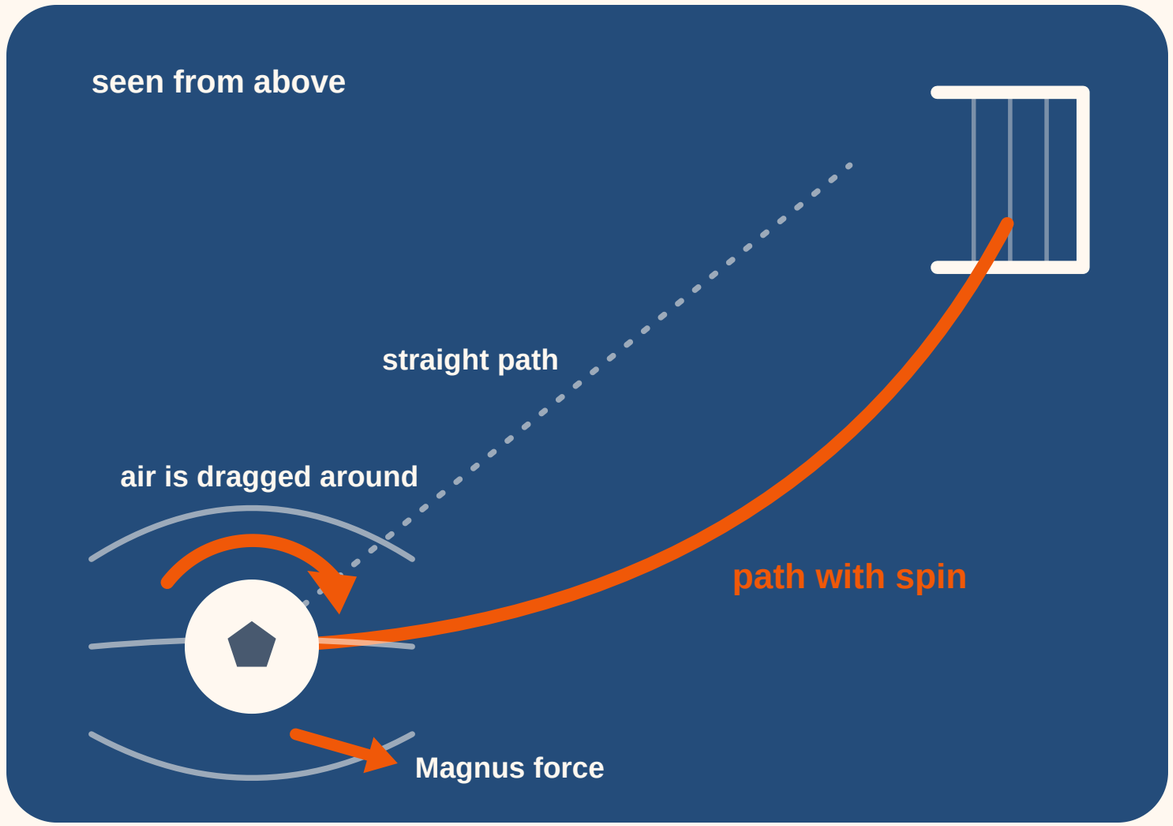
Talk about it: what slows the ball down after you kick it?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Kick Room

Can you bend a kick?



Try it

Kick the ball a little off center so it spins. Watch its path closely.

References

Mehta, R. D. (1985). Aerodynamics of sports balls. *Annual Review of Fluid Mechanics, 17*, 151-189. https://doi.org/10.1146/annurev.fl.17.010185.001055

Goff, J. E., & Carré, M. J. (2009). Trajectory analysis of a soccer ball. *American Journal of Physics, 77*(11), 1020-1027. https://doi.org/10.1119/1.3197187

Play

A ball kicked off center starts to spin. A spinning ball pulls air around with it, and the air pushes the ball sideways. That push bends its path.

Connect

The spinning surface drags the air and throws it off to one side. The ball is pushed the opposite way, the same way a rocket is pushed by its exhaust. More spin and more speed make a bigger curve, and soccer players use it to bend the ball around defenders.

Grow

$$F_M = \tfrac{1}{2}\rho A C_L v^2 \qquad C_L = f(S) \qquad S = r\omega / v$$

The Magnus force acts along ω × v. The lift coefficient C_L rises with the spin parameter *S*, the ratio of the ball's surface speed *rω* to its flight speed *v*. Asymmetric boundary-layer separation deflects the wake to one side, and the reaction on the ball is the sideways force.

School: Science → University: Aerospace engineering → PhD: Fluid dynamics

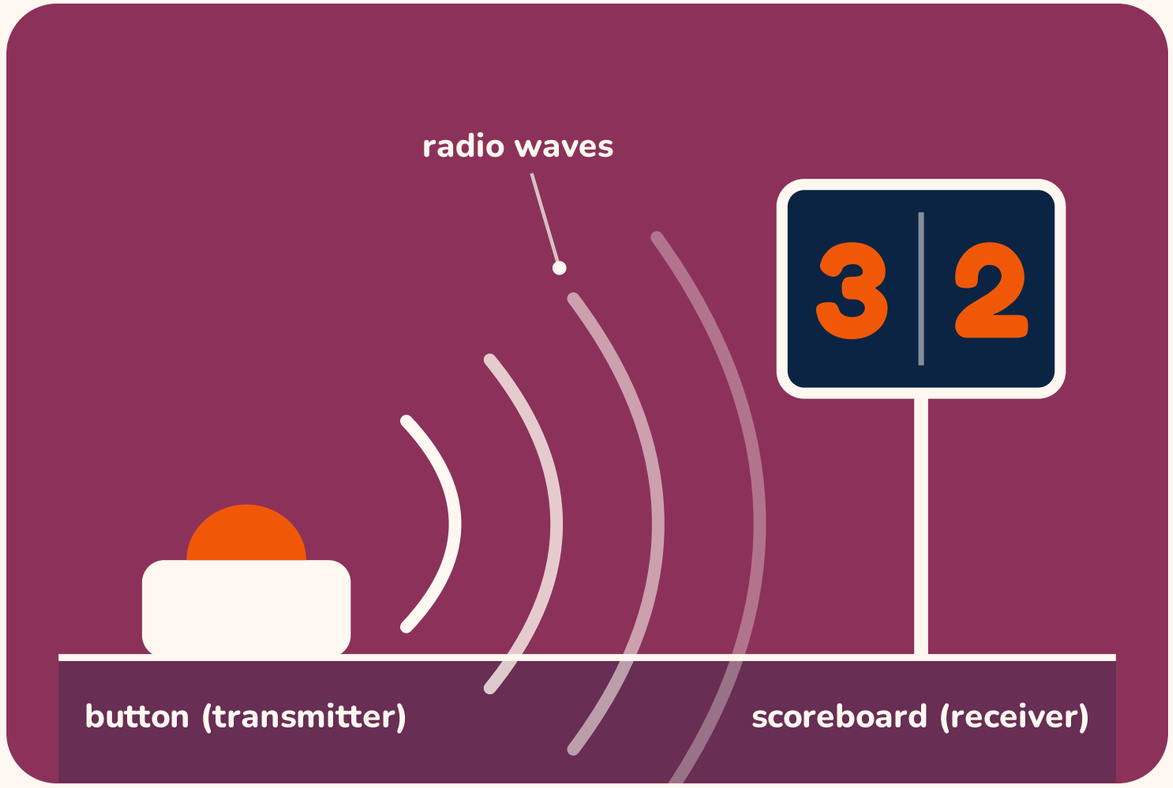
Talk about it: which way does the ball curve when you kick its left side?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Technology

Kick Room Scoreboard

How does the button reach the scoreboard?



Try it

Press the button and watch the scoreboard. Walk farther away and press it again.

References

Friis, H. T. (1946). A note on a simple transmission formula. *Proceedings of the IRE, 34*(5), 254-256. https://doi.org/10.1109/JRPROC.1946.234568

Play

The button sends an invisible signal through the air called a radio wave. The scoreboard hears it and adds a point.

Connect

Radio waves are the same kind of wave as light, with a much longer wavelength than your eyes can see. The button turns your press into a short coded burst of waves, and the scoreboard decodes it. Wi-Fi, phones and car keys send messages the same way.

Grow

$$c = \lambda f \quad P_r = P_t G_t G_r (\lambda / 4\pi d)^2$$

Electromagnetic waves obey $\nabla^2 \mathbf{E} = \mu_0 \varepsilon_0 \, \partial^2 \mathbf{E} / \partial t^2$ and travel at $c = 3.0 \times 10^8$ m/s, so a 2.4 GHz signal has a wavelength of about 12.5 cm. The Friis equation gives the received power P_r: it falls with the square of the distance d, and that sets the button's range.

School: Technology → University: Electrical engineering → PhD: Radio-frequency engineering

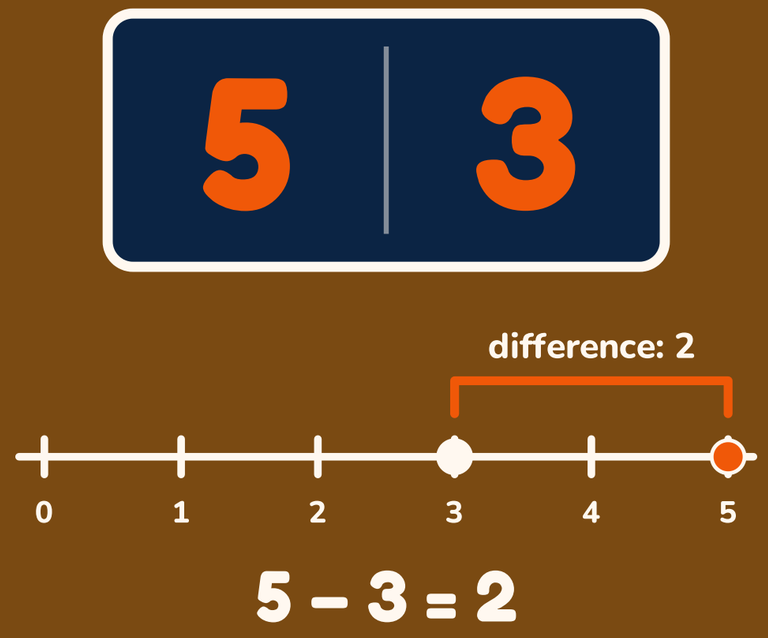
Talk about it: what else at your house works without a wire?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Math

Kick Room Scoreboard

Who is ahead, and by how much?



Try it

Read both scores out loud. Take the smaller number away from the bigger one.

References

Skellam, J. G. (1946). The frequency distribution of the difference between two Poisson variates belonging to different populations. *Journal of the Royal Statistical Society, 109*(3), 296. https://doi.org/10.2307/2981372

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Play

Every goal adds one. Take the smaller score away from the bigger one and you get the difference. That is how far ahead the leader is.

Connect

The difference can be written as a signed number: +2 for the team ahead and −2 for the team behind. A difference of 0 means a tie. Adding the two scores tells you how many goals were scored in the whole game.

Grow

$$P(D = k) = \mathrm{e}^{-(\lambda_1+\lambda_2)}\,(\lambda_1/\lambda_2)^{k/2}\,I_{\mathrm{k}}(2\sqrt{(\lambda_1\lambda_2)})$$

Model each team's goals as an independent Poisson process with rates $\boldsymbol{\lambda_1}$ and $\boldsymbol{\lambda_2}$. The goal difference D then follows the Skellam distribution, where I_k is the modified Bessel function of the first kind. Sports analysts use it to estimate the chance of a win, a loss or a tie.

School: Math → University: Statistics → PhD: Stochastic processes

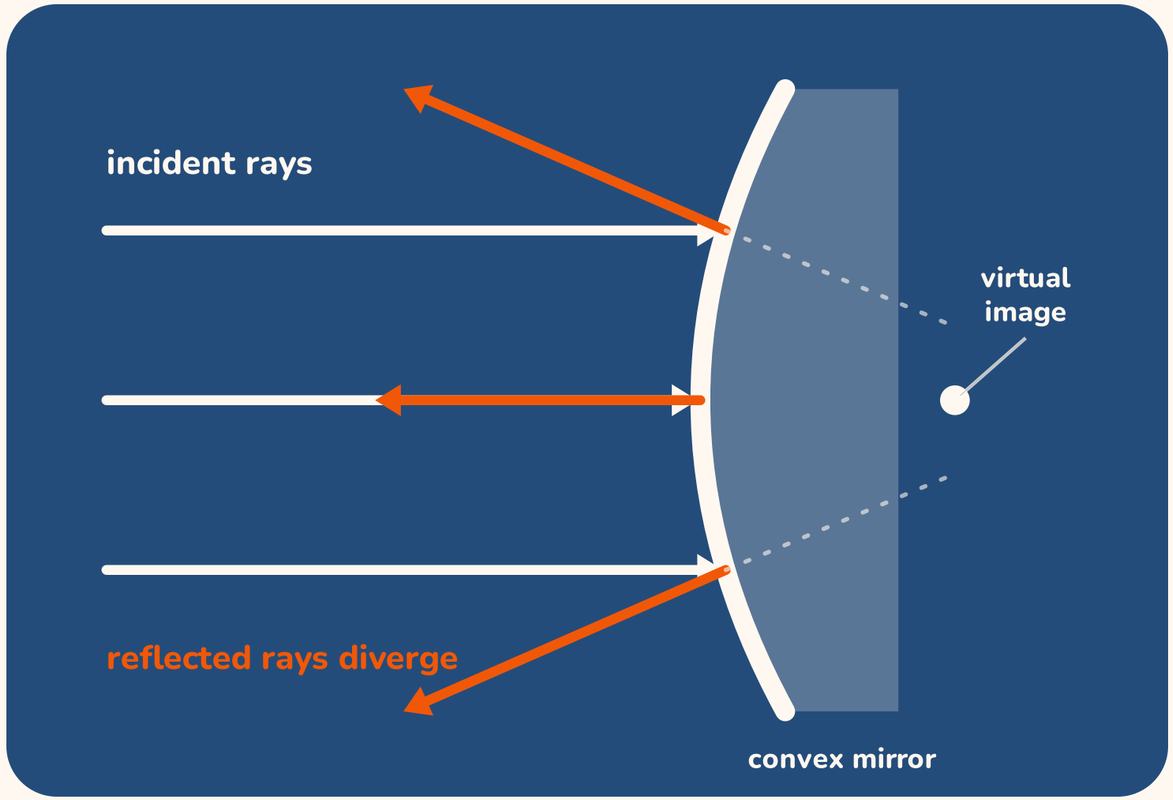
Talk about it: the score is 4 to 1. How many goals ties the game?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Curved Mirrors

Why do you look so small?



Try it

Stand close to the mirror, then walk backward. Count how many friends you can see in it.

References

Hecht, E. (2017). *Optics* (5th ed.). Pearson.

Play

This mirror bulges out like the back of a spoon. A bulging mirror is called convex. It shows a very wide view and makes everything look small.

Connect

Light bounces off a mirror at the same angle it arrives. On a curved surface each spot faces a slightly different way, so the reflected rays fan out. Your brain traces them back to a small picture that seems to sit behind the mirror. Stores use these mirrors to see around corners.

Grow

$$1/d_o + 1/d_i = 1/f \quad f = -R/2 \quad m = -d_i / d_o$$

For a convex mirror the focal length f is negative, so the image distance d_i is negative for every real object: the image is virtual, upright and reduced, with a magnification m between 0 and 1. The field of view widens as the radius of curvature R shrinks.

School: Science → University: Physics → PhD: Optics

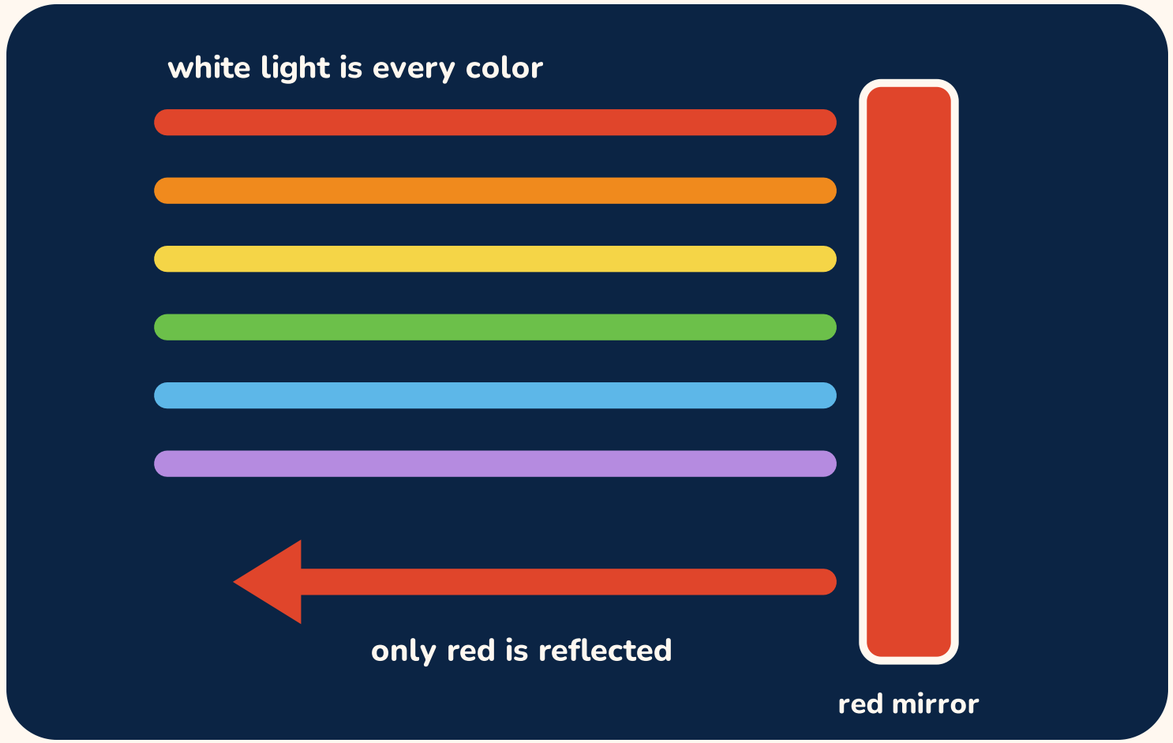
Talk about it: where have you seen a mirror like this before?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Colored Mirrors

Where did the colors go?



Try it

Look at your shirt in each colored mirror. Find the mirror that changes its color the most.

References

Commission Internationale de l'Éclairage. (2018). *Colorimetry* (4th ed., CIE 015:2018). https://doi.org/10.25039/TR.015.2018

Smith, T., & Guild, J. (1931). The C.I.E. colorimetric standards and their use. *Transactions of the Optical Society, 33*(3), 73-134. https://doi.org/10.1088/1475-4878/33/3/301

Play

White light is every color mixed together. A colored mirror soaks up most colors and bounces one back. To reflect means to bounce light back.

Connect

Each color of light has its own wavelength. The tint in the mirror absorbs some wavelengths and lets the others pass to the shiny layer and back out. The light crosses the tint twice, once going in and once coming out, so the color comes back extra strong.

Grow

$$I(\lambda) = I_0(\lambda)\, R(\lambda)\, \mathrm{e}^{-2\alpha(\lambda) d} \qquad X = \int I(\lambda)\, \bar{x}(\lambda)\, \mathrm{d}\lambda$$

Beer-Lambert absorption over a double pass through a tinted layer of thickness d and absorption coefficient $\boldsymbol{\alpha(\lambda)}$, times the reflectance $R(\boldsymbol{\lambda})$ of the backing. The color you perceive follows from integrating the reflected spectrum against the CIE color-matching functions $\bar{x}$, $\bar{y}$ and $\bar{z}$.

School: Science → University: Physics → PhD: Color science and spectroscopy

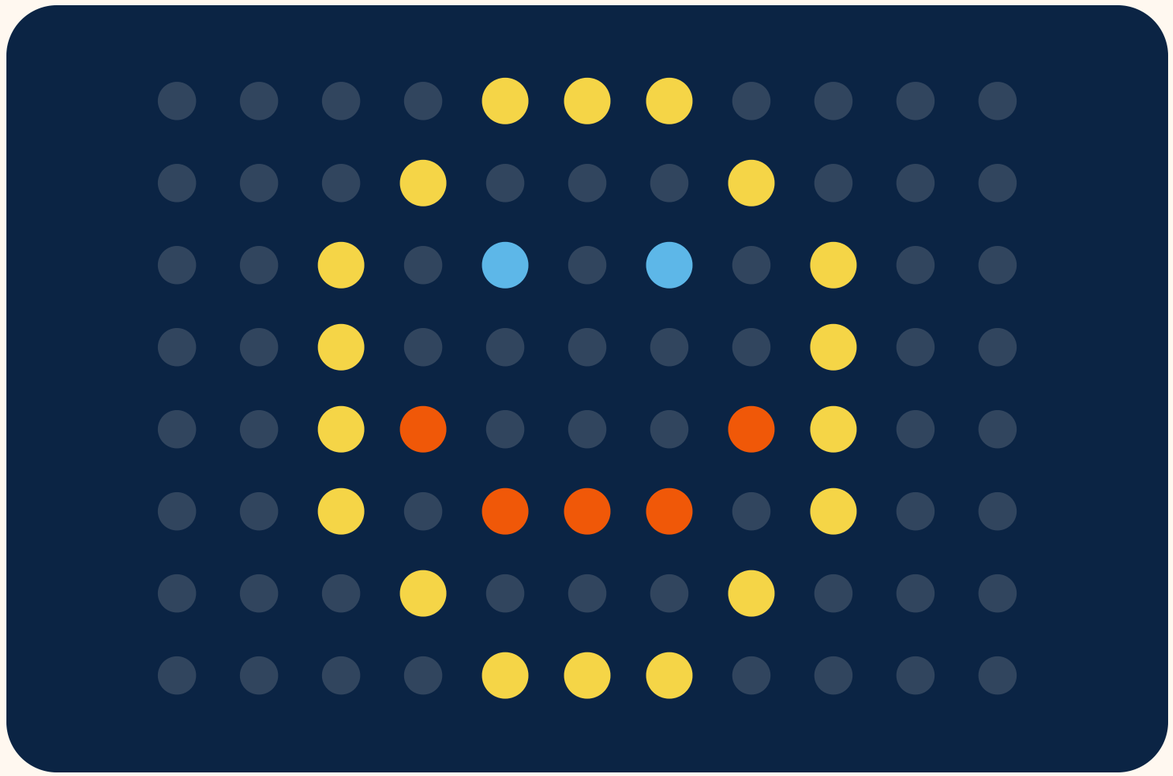
Talk about it: what color does a white shirt turn in each mirror?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Technology

Light Wall

How do dots make a picture?



Try it

Build a shape with the pegs. Then take ten big steps back and look again.

References

Shannon, C. E. (1949). Communication in the presence of noise. *Proceedings of the IRE, 37*(1), 10-21. https://doi.org/10.1109/JRPROC.1949.232969

Play

Up close you see single dots. From far away your eyes blend them into one picture. One dot of light in a picture is called a pixel.

Connect

A screen is a grid of pixels, and each one is set to a color. More pixels in the same space make a sharper picture. A phone screen packs in millions of them, each far too small to pick out with your eye.

Grow

$$\theta = s / D < 1' \approx 2.9 \times 10^{-4}\ \text{rad} \quad f_s > 2f_{\max}$$

The eye resolves about one arcminute, so dots with spacing s merge beyond a viewing distance D of roughly 3,400 s. The Nyquist-Shannon sampling theorem sets how fine a pattern any grid can show: the sampling frequency f_s must exceed twice the highest spatial frequency in the image.

School: Technology → University: Computer science → PhD: Image processing

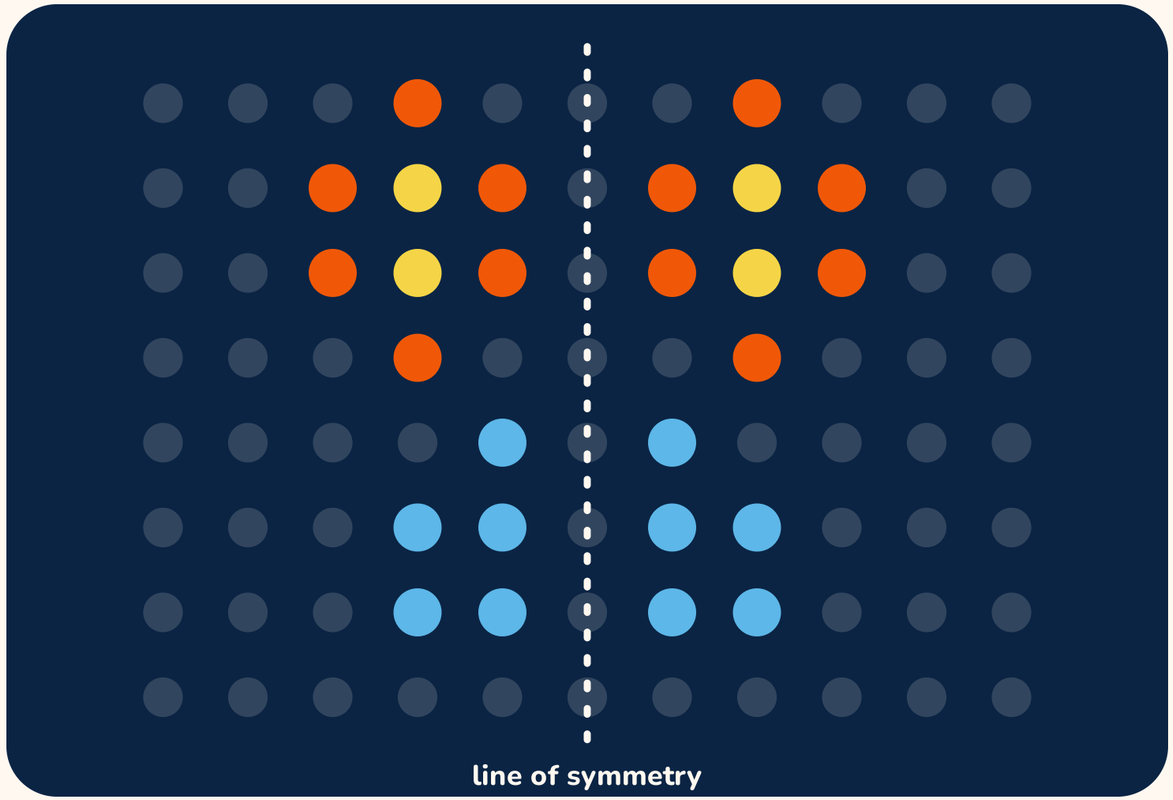
Talk about it: what is the fewest dots you need to draw a smiley face?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Math

Light Wall

Can you make both sides match?



Try it

Pick a middle line. Place a peg on one side, then place its twin on the other side.

References

Dummit, D. S., & Foote, R. M. (2004). *Abstract algebra* (3rd ed.). Wiley.

Play

When both halves match like a mirror picture, the shape has symmetry. Butterflies, snowflakes and your own face all have it.

Connect

The fold line is called the line of symmetry. Some shapes have several: a square has four and a circle has endless lines. A shape can also have turn symmetry, which means it looks the same after a spin. A pinwheel is a good example.

Grow

$$\sigma(x, y) = (-x, y) \quad \sigma^2 = e \quad D_{\mathrm{n}} = \langle r, s \mid r^{\mathrm{n}} = s^2 = e, srs = r^{-1} \rangle$$

A mirror flip across the vertical axis is the linear map σ, and applying it twice returns the identity e. The symmetries of a regular polygon with n sides form the dihedral group D_{n} of order $2n$, generated by a rotation r and a reflection s. Group theory is the mathematics of symmetry.

School: Math → University: Mathematics → PhD: Group theory

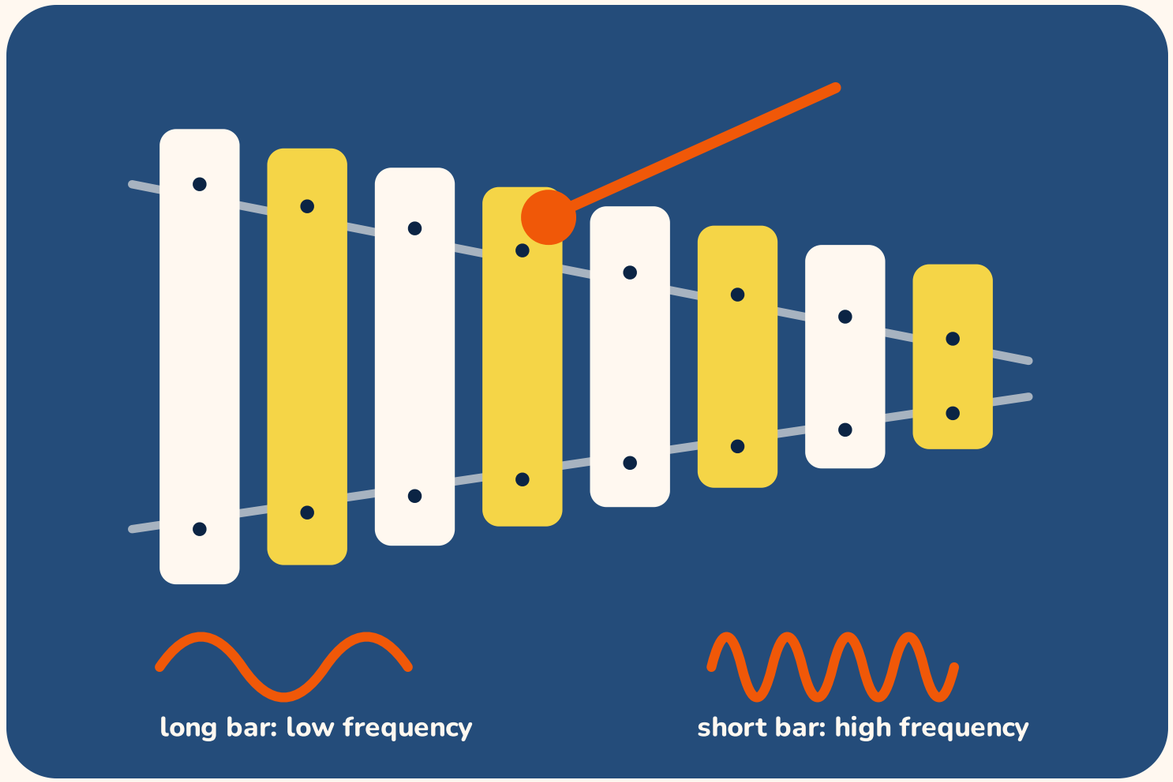
Talk about it: where can you find symmetry on your own body?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Quiet Zone Xylophone

Why does each bar sound different?



Try it

Tap the longest bar, then the shortest bar. Rest a finger lightly on a bar while it rings.

References

Fletcher, N. H., & Rossing, T. D. (1998). *The physics of musical instruments* (2nd ed.). Springer. https://doi.org/10.1007/978-0-387-21603-4

Play

Tapping a bar makes it shake very fast. That shaking is called vibration, and it reaches your ears as sound. Long bars make low notes. Short bars make high notes.

Connect

The number of times a bar shakes each second is its frequency, measured in hertz. Faster shaking means a higher note. Each bar rests on two quiet spots that barely move, so the rest of the bar can ring freely.

Grow

$$f_1 = ((\beta_1 L)^2 / 2\pi L^2)\,\sqrt{(EI / \rho A)} \quad \beta_1 L = 4.730$$

Euler-Bernoulli theory for a bar with free ends: E is Young's modulus, I the second moment of area, ρ the density and A the cross-section. Frequency scales as $1/L^2$, so a bar half as long rings two octaves higher. The supports sit at the nodes, 22.4% of the length in from each end.

School: Science → University: Physics → PhD: Acoustics

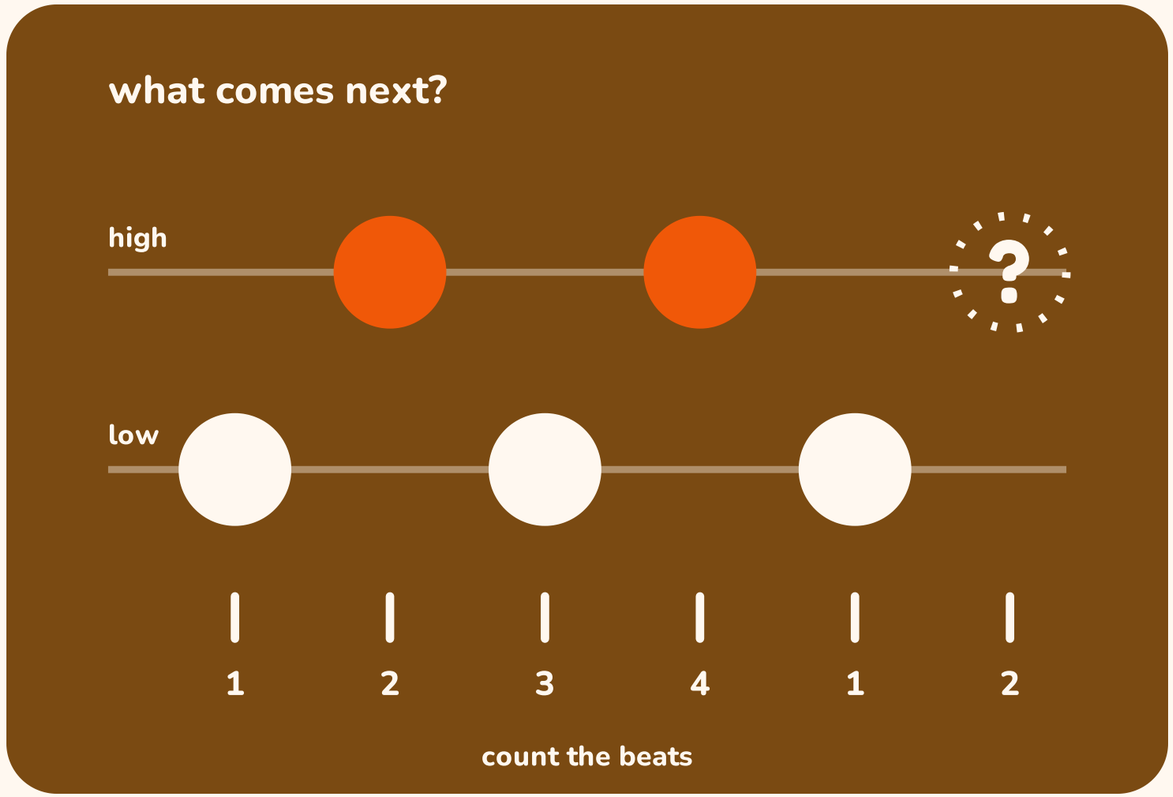
Talk about it: what happens to the sound when you hold the bar still?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Math

Quiet Zone Xylophone

Can you play a pattern?



Try it

Tap two bars: low, high, low, high. Then make up a pattern of three notes and play it four times.

References

Toussaint, G. (2005). The Euclidean algorithm generates traditional musical rhythms. In R. Sarhangi & R. V. Moody (Eds.), *Renaissance Banff: Mathematics, music, art, culture* (pp. 47-56). Bridges Conference. https://archive.bridgesmathart.org/2005/bridges2005-47.html

Play

Music is made of patterns. A beat that repeats is called rhythm. Your brain loves to guess what comes next.

Connect

Notes that sound good together have simple number matches. A note that vibrates exactly twice as fast as another is one octave higher. Musicians count beats in groups, like 1-2-3-4, and that count is the pattern you tap your foot to.

Grow

$$f_n = f_0 \cdot 2^{n/12} \quad \text{octave } 2:1 \quad \text{fifth } 3:2$$

Twelve-tone equal temperament spaces pitches geometrically, so each semitone multiplies frequency by $2^{1/12} \approx 1.0595$. A rhythm of k onsets in n pulses is a subset of the cyclic group $\mathbb{Z}_n$. Spreading the onsets as evenly as possible gives the Euclidean rhythms $E(k, n)$, which appear in traditional music around the world.

School: Music and math → University: Music theory → PhD: Mathematical music theory

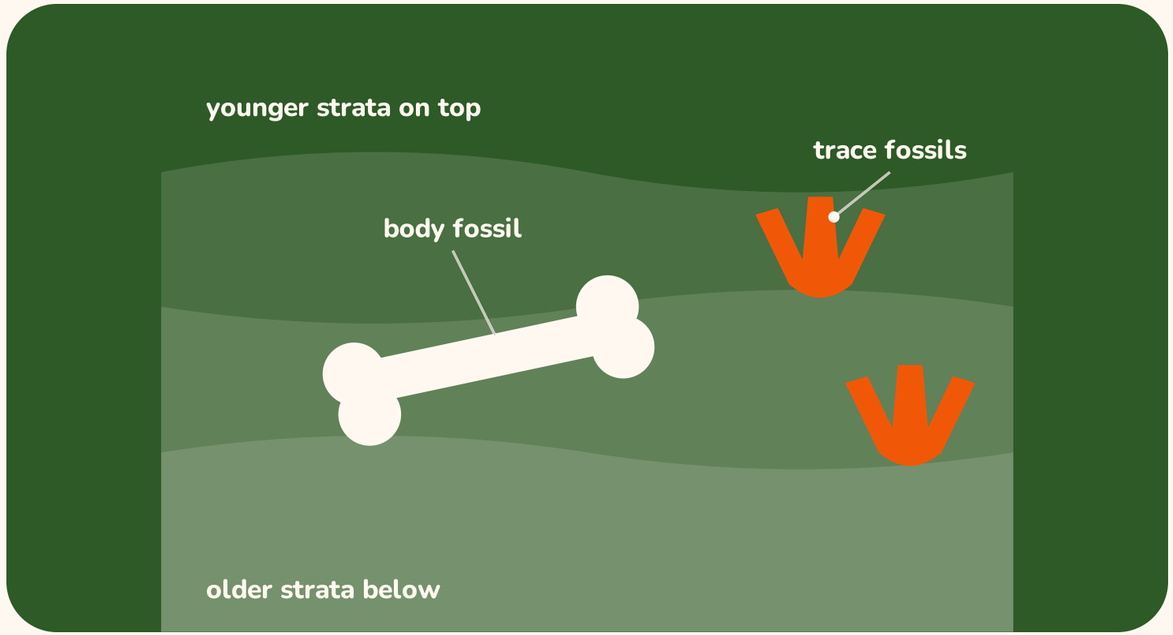
Talk about it: can someone clap your pattern back to you?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Quiet Zone Dinosaur

How do we know about dinosaurs?



Try it

Look closely at the dinosaur. Is it built to run fast, reach high or stay low? What makes you think so?

References

Jaffey, A. H., Flynn, K. F., Glendenin, L. E., Bentley, W. C., & Essling, A. M. (1971). Precision measurement of half-lives and specific activities of ^{235}U and ^{238}U. *Physical Review C, 4*(5), 1889-1906. https://doi.org/10.1103/PhysRevC.4.1889

Renne, P. R., Deino, A. L., Hilgen, F. J., Kuiper, K. F., Mark, D. F., Mitchell, W. S., Morgan, L. E., Mundil, R., & Smit, J. (2013). Time scales of critical events around the Cretaceous-Paleogene boundary. *Science, 339*(6120), 684-687. https://doi.org/10.1126/science.1230492

Play

Dinosaurs lived long before people. We know about them from fossils: bones, teeth and footprints that turned to stone.

Connect

A fossil forms when mud or sand buries a living thing quickly and minerals slowly take its place. Deeper rock layers are usually older, so scientists read the layers like pages in a book. Birds are living dinosaurs, so you have seen one today.

Grow

$$N(t) = N_0\, e^{-\lambda t} \quad t = (1/\lambda)\ln(1 + D/P) \quad t_{1/2} = \ln 2 / \lambda$$

Radiometric dating: a parent isotope P decays to a daughter D at a constant rate λ, so their ratio is a clock. Uranium-238 decays to lead-206 with a half-life of 4.47 billion years. Dated volcanic ash beds place the extinction of the non-avian dinosaurs at about 66 million years ago.

School: Science → University: Geology → PhD: Paleontology

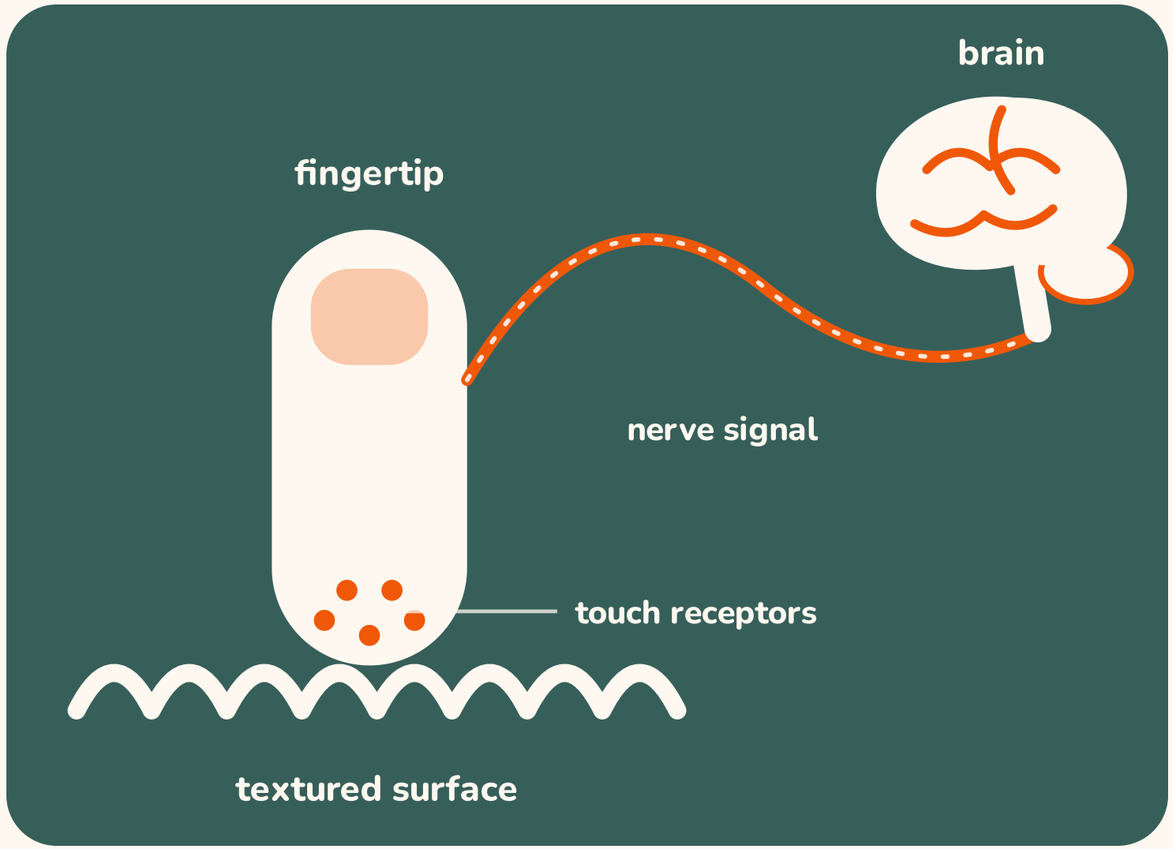
Talk about it: what could a footprint tell you about an animal?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Quiet Zone Touch Pads

How do fingers feel?



Try it

Close your eyes and touch each pad. Describe it: bumpy, smooth, soft or rough?

References

Stevens, S. S. (1957). On the psychophysical law. *Psychological Review, 64*(3), 153-181. https://doi.org/10.1037/h0046162

Abraira, V. E., & Ginty, D. D. (2013). The sensory neurons of touch. *Neuron, 79*(4), 618-639. https://doi.org/10.1016/j.neuron.2013.07.051

Play

Your fingertips are full of tiny sensors. They send a message to your brain when you touch something. How a surface feels is called its texture.

Connect

Your skin has different sensors for pressure, stretch, buzzing and light touch. Fingertips are among the most sensitive spots on your body, which is why you can read tiny bumps with them. The message races along your nerves about as fast as a race car.

Grow

$$\psi = kI^a \quad \Delta I / I = c$$

Four mechanoreceptor types (Merkel, Meissner, Ruffini and Pacinian) encode touch, and fingertip two-point discrimination is about 2 to 4 mm. Perceived intensity ψ follows Stevens' power law in stimulus intensity I, and the just-noticeable difference follows Weber's law. Aβ nerve fibers conduct at 35 to 75 m/s.

School: Science → University: Biology → PhD: Sensory neuroscience

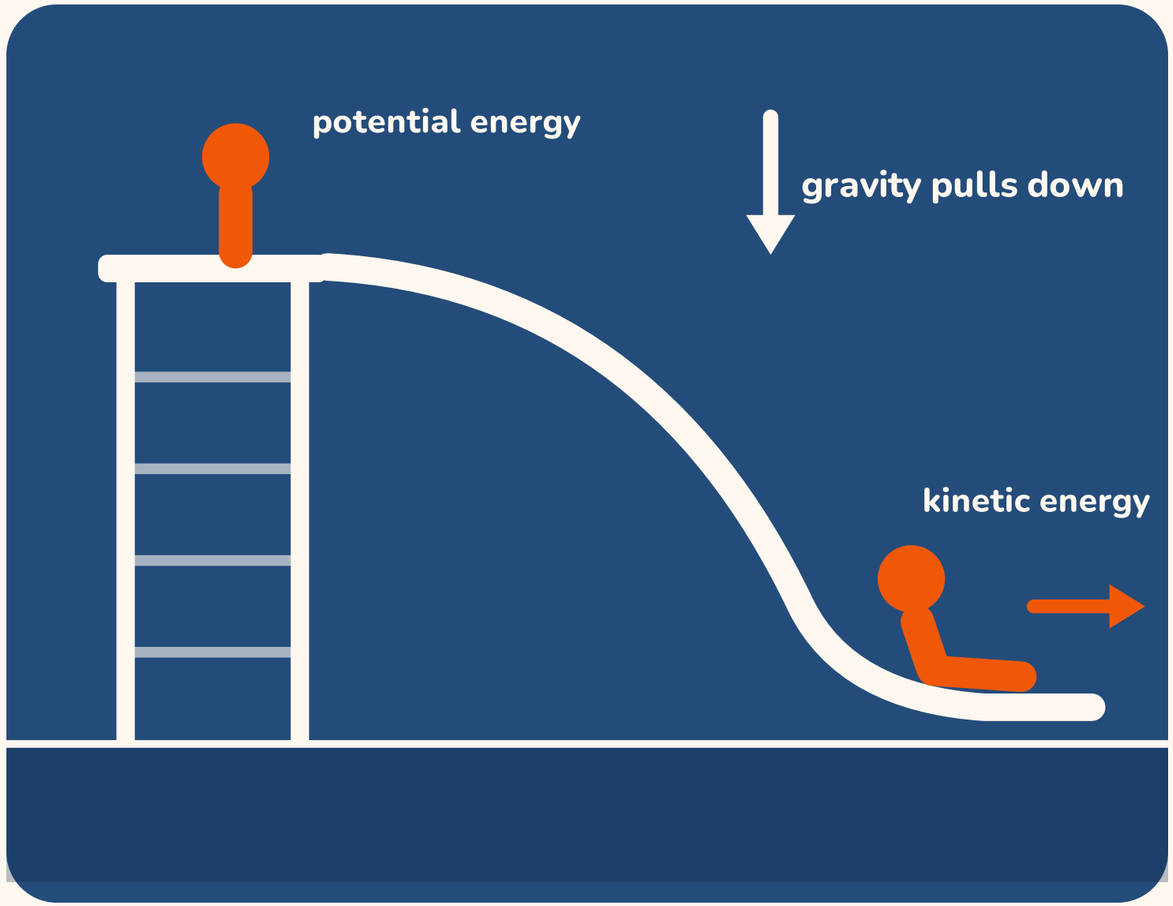
Talk about it: which pad is your favorite, and why?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Play Tower Slides

Why do you speed up?



Try it

Go down a gentle slide, then a steeper one. Feel which one is faster.

References

Halliday, D., Resnick, R., & Walker, J. (2014). *Fundamentals of physics* (10th ed.). Wiley.

Play

Earth pulls everything down. That pull is called gravity. It pulls you down the slide, and a steeper slide lets it pull you faster.

Connect

Climbing up stores energy in your height. Sliding down turns that stored energy into speed. Friction between you and the slide turns some of it into heat, which is why slick pants are faster than grippy ones.

Grow

$$a = g(\sin\theta - \mu\cos\theta) \quad v = \sqrt{(2gh(1 - \mu\cot\theta))}$$

On an incline at angle θ with kinetic friction μ, energy conservation gives $mgh = \frac{1}{2}mv^2 + \mu mg\cos\theta \cdot (h / \sin\theta)$. The mass m cancels, so a big kid and a small kid reach the bottom at the same speed. You slide only when $\tan\theta$ exceeds μ.

School: Science → University: Physics → PhD: Classical dynamics and gravitation

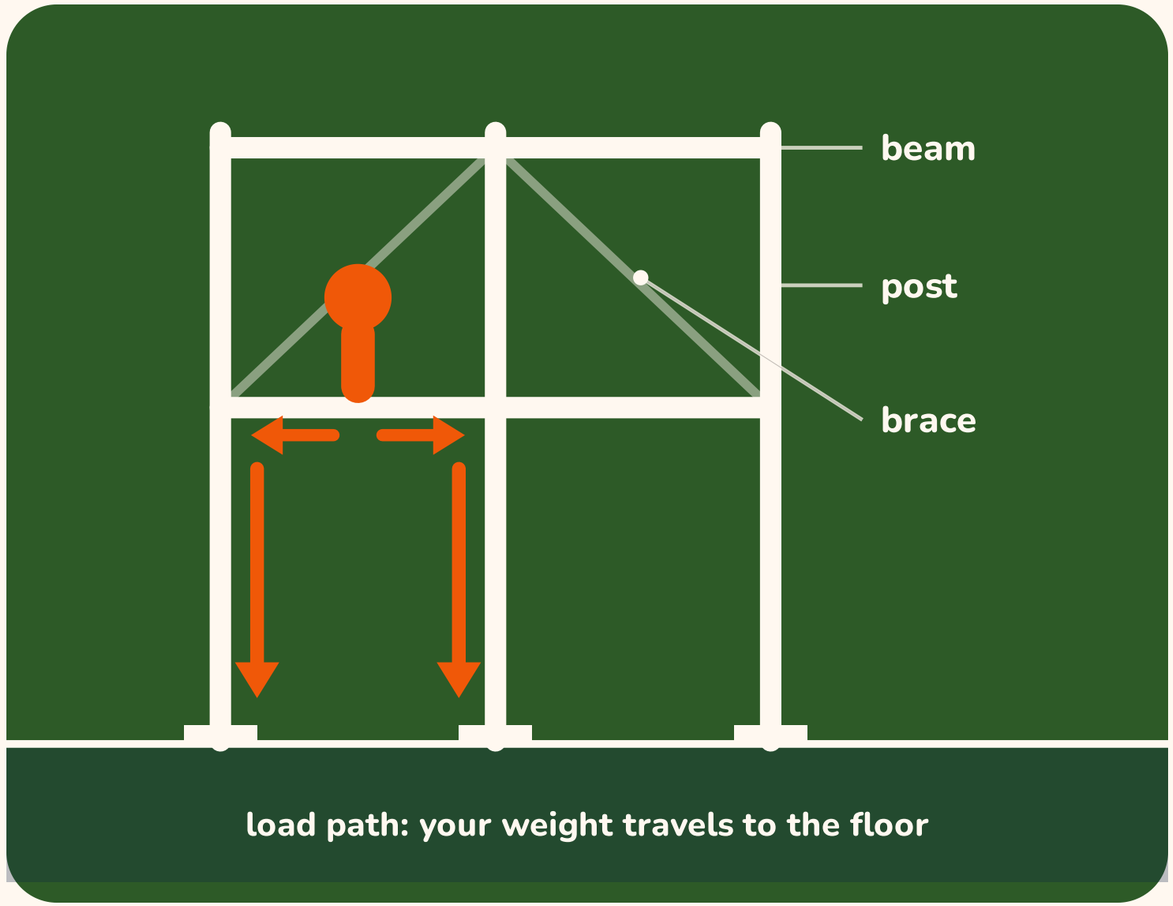
Talk about it: where did the energy to reach the top come from?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Engineering

Play Tower

What holds you up?



Try it

Find a steel post and follow it with your eyes all the way down to the floor.

References

Timoshenko, S. P., & Gere, J. M. (1961). *Theory of elastic stability* (2nd ed.). McGraw-Hill.

Play

This tower is a frame of steel posts and beams. A frame that carries weight is called a structure. Your weight goes down the posts and into the floor.

Connect

Beams carry your weight sideways to the posts, and the posts squeeze it straight down into the floor. Every joint shares the load with its neighbors. With many posts sharing one load, each part works far below its limit.

Grow

$$\Sigma \mathbf{F} = 0 \quad \Sigma \mathbf{M} = 0 \quad \sigma = F/A \quad P_{\mathrm{cr}} = \pi^2 EI \,/\, (KL)^2$$

A structure at rest satisfies static equilibrium at every joint. Posts are checked for axial stress σ and for Euler buckling: the critical load P_{cr} falls with the square of the unbraced length L, so bracing that halves L makes a post four times stronger against buckling.

School: Engineering and math → University: Civil engineering → PhD: Structural engineering

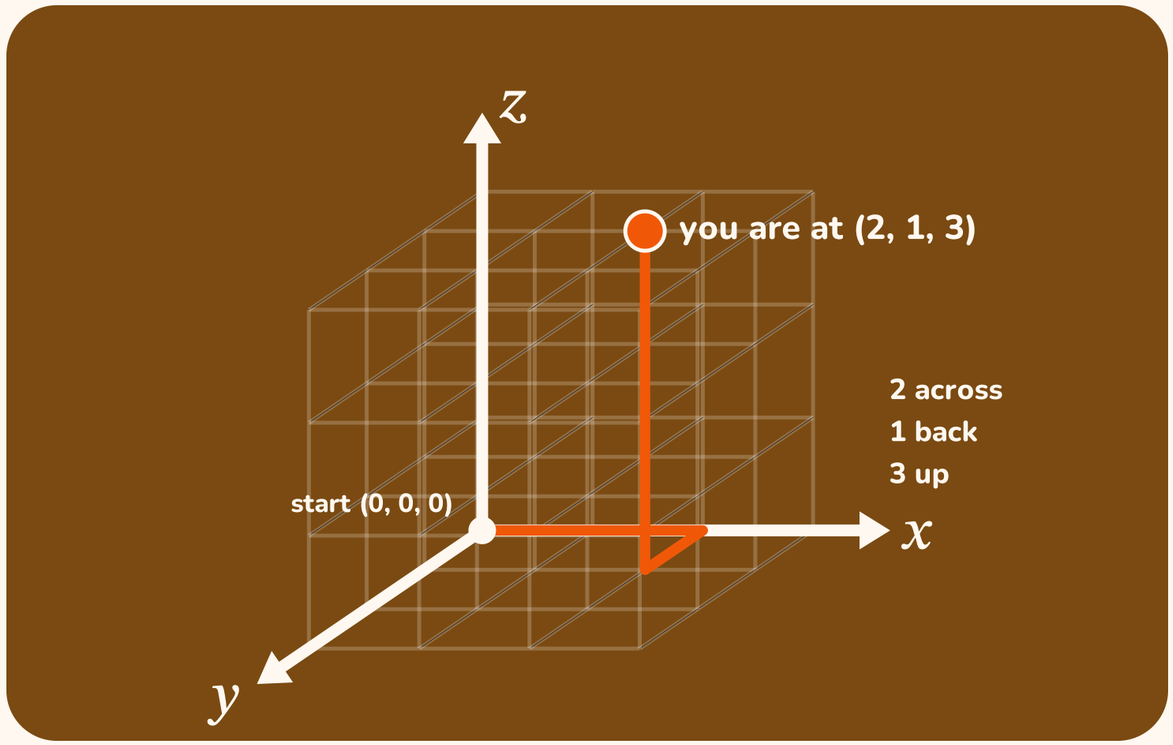
Talk about it: where else have you seen a frame like this one?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Math

Play Tower Grid

Where are you in the grid?



Try it

Pick a corner as your start. Count the cubes across, back and up to where you are. Call out your three numbers.

References

Strang, G. (2016). *Introduction to linear algebra* (5th ed.). Wellesley-Cambridge Press.

Play

This tower is a grid of cubes. Three numbers tell anyone exactly where you are: how far across, how far back and how far up. Those numbers are your coordinates.

Connect

The three directions are the x, y and z axes. A move from one cube to another is a vector, written (x, y, z). Add two moves by adding their numbers: (1, 0, 2) + (1, 1, 1) = (2, 1, 3). The straight-line distance from the start is $\sqrt{(x^2 + y^2 + z^2)}$.

Grow

$$R_z\mathbf{v} = \begin{pmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 2 \\ 1 \\ 3 \end{pmatrix} = \begin{pmatrix} -1 \\ 2 \\ 3 \end{pmatrix}$$

Positions are vectors in $\mathbb{R}^3$ with basis $\mathbf{e}_1$, $\mathbf{e}_2$, $\mathbf{e}_3$. A matrix is a machine that moves every point at once: this one turns the whole tower a quarter turn about the z axis. Doing one move after another is matrix multiplication. The determinant gives the change in volume (here 1), and a vector that a matrix leaves pointing the same way is an eigenvector (here the z axis).

School: Math → University: Mathematics → PhD: Linear algebra and its applications

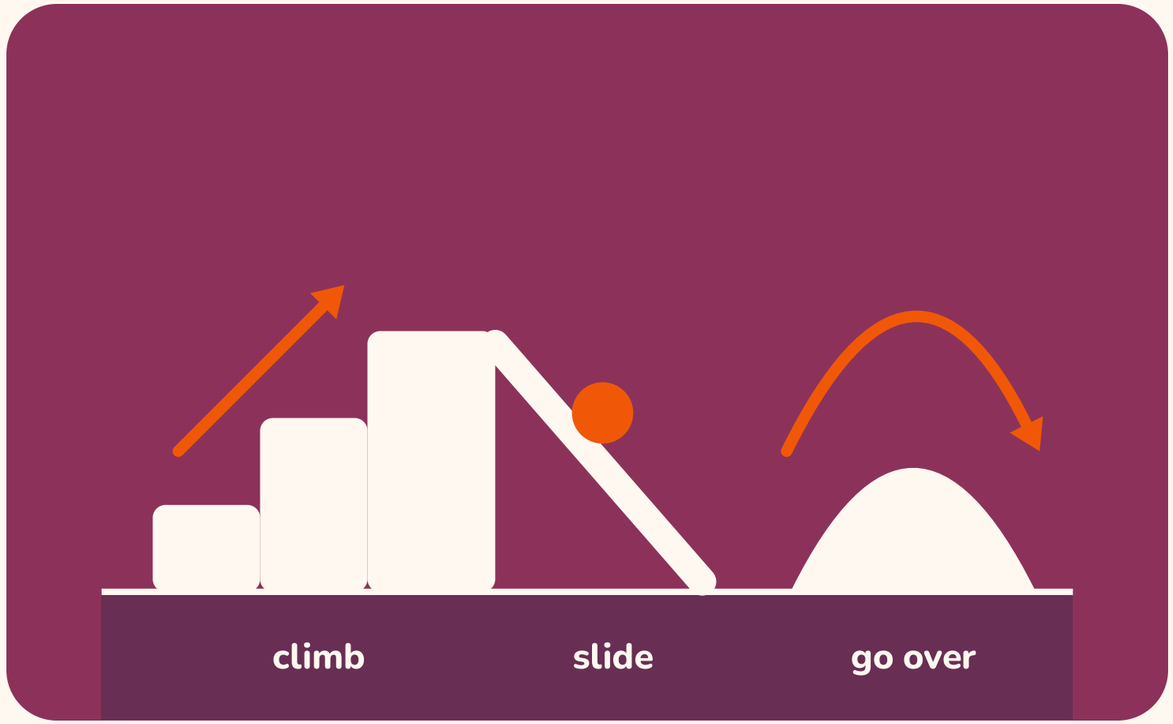
Talk about it: which cube is at (0, 0, 0)? What are the coordinates of the highest cube you can reach?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Toddler and Crawler Cove

What is your little one learning?



Try it together

Say what you see out loud: up, down, in, out, fast, slow. Count the steps together.

References

Piaget, J. (1952). *The origins of intelligence in children* (M. Cook, Trans.). International Universities Press. https://doi.org/10.1037/11494-000

Gopnik, A., Glymour, C., Sobel, D. M., Schulz, L. E., Kushnir, T., & Danks, D. (2004). A theory of causal learning in children: Causal maps and Bayes nets. *Psychological Review, 111*(1), 3-32. https://doi.org/10.1037/0033-295X.111.1.3

Play

Every climb, every slide and every trip over an obstacle is a small experiment. Doing it again and again is how toddlers test what happens. One thing making another thing happen is called cause and effect.

Connect

From birth to about age two, children learn mostly through their senses and their movement. Around their first birthday they start changing one thing on purpose to see what happens, like trying a new way over the same obstacle. Naming what they do builds their vocabulary at the same time.

Grow

$$P(H \mid D) \propto P(D \mid H)\, P(H)$$

Piaget called this the sensorimotor stage, and its tertiary circular reactions (about 12 to 18 months) are deliberate experiments. Developmental scientists model the learning as Bayesian inference: each result D updates the child's belief in a hypothesis H about how the world works.

School: Science → University: Psychology → PhD: Developmental cognitive science

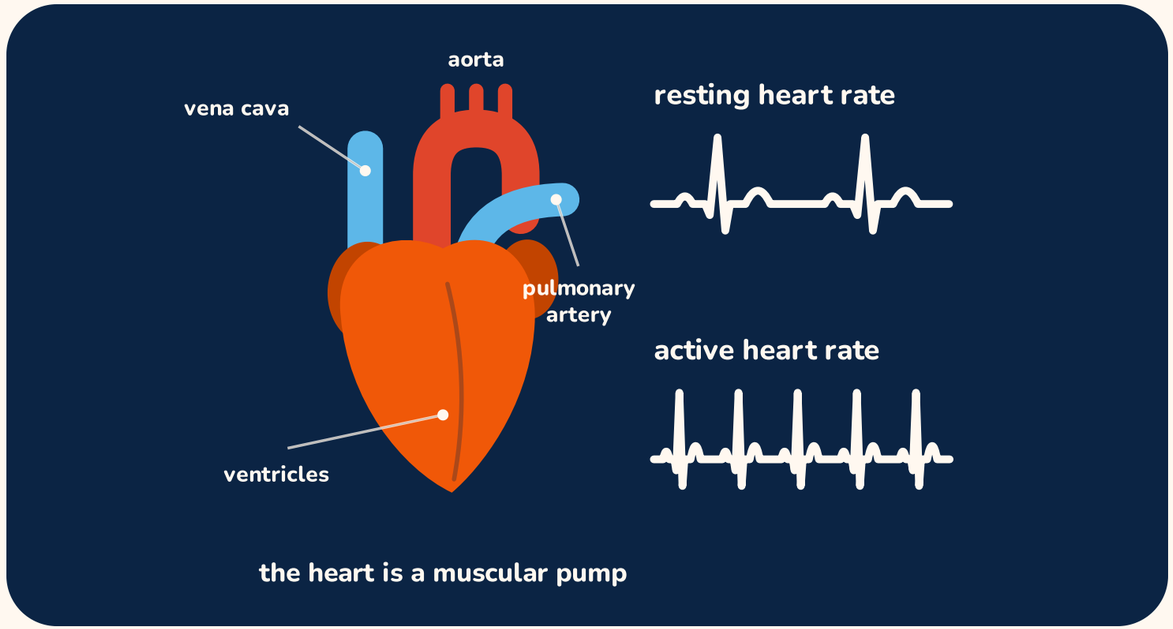
Ask your little one: what happens next?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Your Body

Why is your heart pounding?



Try it

Put two fingers on the side of your neck and count the beats for ten seconds. Play hard for one minute and count again.

References

World Health Organization. (2020). *WHO guidelines on physical activity and sedentary behaviour*. https://www.who.int/publications/i/item/9789240015128

McArdle, W. D., Katch, F. I., & Katch, V. L. (2015). *Exercise physiology: Nutrition, energy, and human performance* (8th ed.). Wolters Kluwer.

MedlinePlus. (n.d.). *Pulse*. U.S. National Library of Medicine. https://medlineplus.gov/ency/article/003399.htm

Play

Your heart is a muscle that pumps blood. When you play hard, your muscles need more oxygen, so your heart beats faster. Each beat you feel is your pulse.

Connect

Blood carries oxygen from your lungs to your muscles. A kid's resting heart beats about 70 to 110 times a minute and can pass 180 during hard play. Regular active play makes the heart stronger, so it moves more blood with every beat.

Grow

$$Q = \mathrm{HR} \times \mathrm{SV} \quad \dot{\mathrm{V}}\mathrm{O}_2 = Q\,(C_\mathrm{a} - C_\mathrm{v})$$

Cardiac output Q is heart rate times stroke volume. The Fick principle ties oxygen uptake $\dot{\mathrm{V}}\mathrm{O}_2$ to Q and the difference in oxygen content between arterial and venous blood. Training raises stroke volume, so the same output takes fewer beats. The World Health Organization recommends an average of at least 60 minutes of moderate to vigorous activity a day for ages 5 to 17.

School: Science → University: Biology or Kinesiology → PhD: Exercise physiology

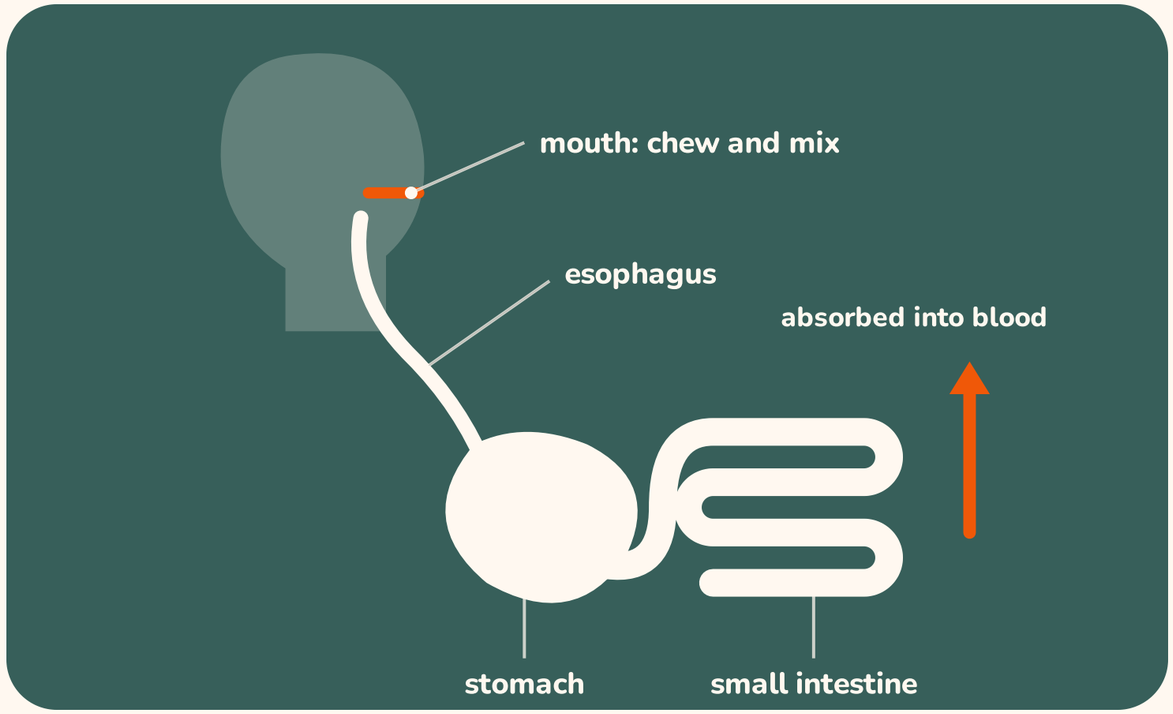
Talk about it: how long does your heart take to slow back down?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Cafeteria

What happens to the food you eat?



Try it

Chew one bite of bread or cracker slowly, twenty times. Notice how the taste changes.

References

Michaelis, L., & Menten, M. L. (1913). Die Kinetik der Invertinwirkung. *Biochemische Zeitschrift, 49*, 333-369.

Helander, H. F., & Fändriks, L. (2014). Surface area of the digestive tract – revisited. *Scandinavian Journal of Gastroenterology, 49*(6), 681-689. https://doi.org/10.3109/00365521.2014.898326

Hall, J. E., & Hall, M. E. (2021). *Guyton and Hall textbook of medical physiology* (14th ed.). Elsevier.

Play

Food is your body's fuel and its building blocks. Your body breaks food into tiny pieces and sends them everywhere in your blood. Breaking food down is called digestion.

Connect

Digestion starts in your mouth: chewing grinds the food, and saliva starts turning starch into sugar, which is why bread tastes sweeter the longer you chew. Your stomach and small intestine finish the job. Carbohydrates and fats give you energy, protein builds and repairs you, and vitamins and minerals keep everything running.

Grow

$$v = V_{\max}[\mathrm{S}] \,/\, (K_{\mathrm{m}} + [\mathrm{S}])$$

Digestive enzymes follow Michaelis-Menten kinetics: the reaction rate v rises with substrate concentration [S] and saturates at $V_{\max}$. Salivary **α**-amylase hydrolyzes the **α**-1,4 glycosidic bonds of starch into maltose and other short sugar chains. Most absorption happens across the folded lining of the small intestine, whose villi and microvilli give it a surface of roughly 30 square metres.

School: Science → University: Biology → PhD: Biochemistry

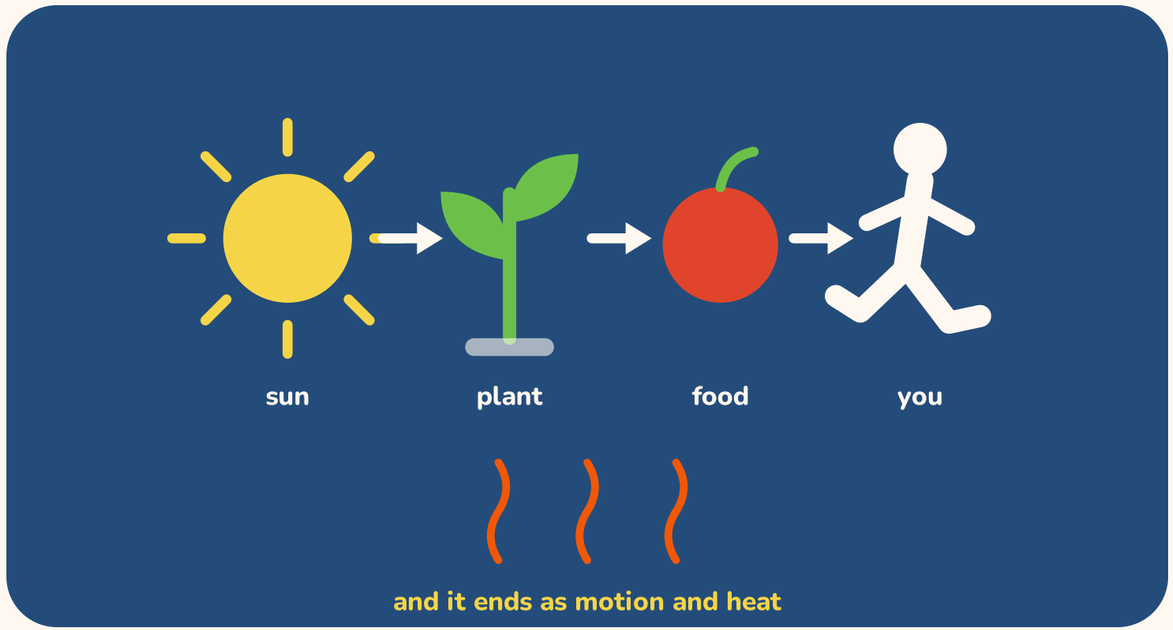
Talk about it: which foods on your plate give you energy, and which ones help you grow?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

Science

Cafeteria

Where does your energy come from?



Try it

Rub your hands together fast for ten seconds. Feel the heat? That warmth started as your lunch.

References

Food and Agriculture Organization of the United Nations. (2003). *Food energy: Methods of analysis and conversion factors* (FAO Food and Nutrition Paper 77). https://www.fao.org/4/y5022e/y5022e00.htm

Berg, J. M., Tymoczko, J. L., Gatto, G. J., Jr., & Stryer, L. (2019). *Biochemistry* (9th ed.). W. H. Freeman.

Gaesser, G. A., & Brooks, G. A. (1975). Muscular efficiency during steady-rate exercise: Effects of speed and work rate. *Journal of Applied Physiology, 38*(6), 1132-1139. https://doi.org/10.1152/jappl.1975.38.6.1132

Play

Plants catch energy from the sun and store it. When you eat, that energy moves into you. The energy in food is measured in calories.

Connect

Energy changes form and is always passed along. Sunlight becomes sugar in a plant, the sugar becomes fuel in your muscles, and your muscles turn it into running, climbing and body heat. That is why you warm up when you play hard, and why you get hungry afterward.

Grow

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O \quad \Delta G^{\circ\prime} \approx -2870\ \text{kJ/mol}$$

One food Calorie is 1 kcal = 4.184 kJ. The Atwater factors give about 4 kcal per gram of carbohydrate or protein and 9 per gram of fat. Cells capture the energy of glucose oxidation as ATP, whose hydrolysis releases about 30.5 kJ/mol. Muscle converts roughly 20 to 25 percent of that chemical energy into mechanical work, and the rest leaves as heat, in keeping with the first law of thermodynamics.

School: Science → University: Chemistry → PhD: Bioenergetics

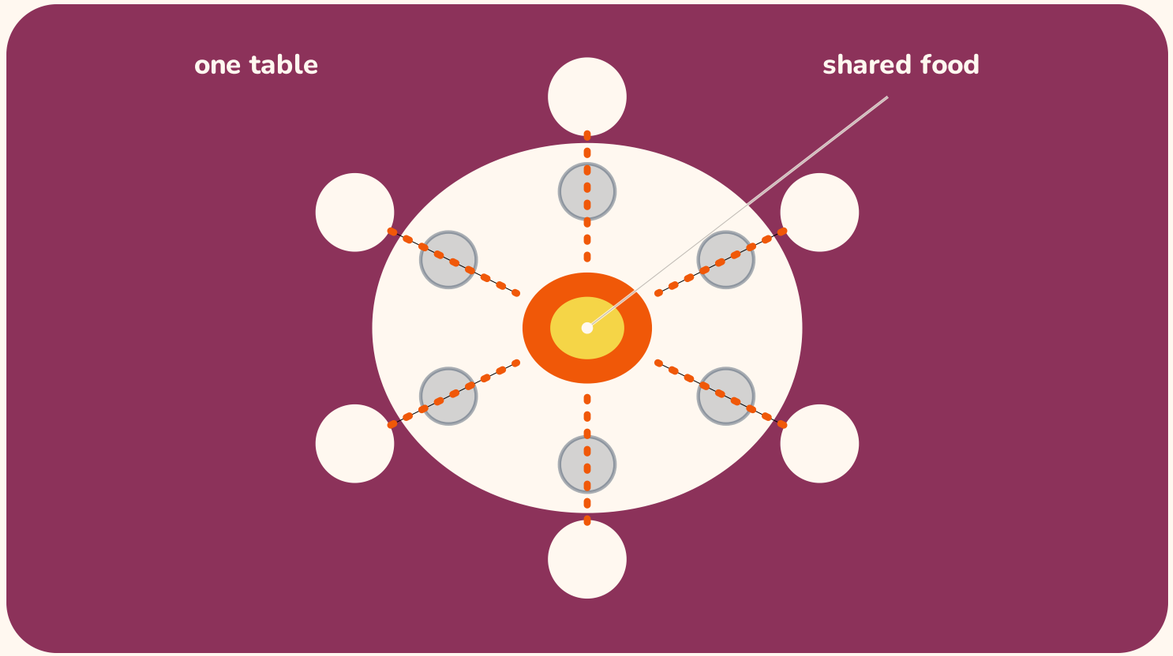
Talk about it: trace your snack back to the sun. How many steps does it take?

PLAY IRON RANGE
PLAY. CONNECT. GROW.

People and culture

Cafeteria

Why do we eat together?



Try it

Ask everyone at your table: what is your favorite meal to share, and who first made it for you?

References

Winterhalder, B. (1986). Diet choice, risk, and food sharing in a stochastic environment. *Journal of Anthropological Archaeology, 5*(4), 369-392. https://doi.org/10.1016/0278-4165(86)90017-6

Wrangham, R. (2009). *Catching fire: How cooking made us human*. Basic Books.

Douglas, M. (1972). Deciphering a meal. *Daedalus, 101*(1), 61-81. https://www.jstor.org/stable/20024058

Dunbar, R. I. M. (2017). Breaking bread: The functions of social eating. *Adaptive Human Behavior and Physiology, 3*(3), 198-211. https://doi.org/10.1007/s40750-017-0061-4

Play

People all over the world eat together. Sharing food is how we take care of each other and become friends. A meal is a time to talk, laugh and listen.

Connect

Every culture has shared meals, from family dinners to feasts and holidays. Long ago, a hunter who shared a big catch today could count on a share of someone else's tomorrow, so sharing kept the whole group fed. Cooking over a fire gave people a place to gather, and stories and traditions grew up around it.

Grow

$$\mathrm{Var}(\bar{x}) = \sigma^2 / n$$

Anthropologists call eating together commensality, from the Latin for sharing a table. When each forager's luck is independent of the others', pooling an uncertain food supply among n foragers cuts the variance of each person's daily share to σ^2/n, a model applied to food sharing among hunter-gatherers. Richard Wrangham argues that cooking made us human, Mary Douglas read the meal as a code of social relations, and Robin Dunbar's 2017 survey found that people who eat with others more often report more friends and greater life satisfaction.

School: Social studies → University: Anthropology → PhD: Anthropology of food

Talk about it: what is a food your family makes for special days?

PLAY IRON RANGE
PLAY. CONNECT. GROW.