exclusive online issue | no.25

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best of Ask the Experts

BEST OF ASK THE EXPERTS

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From why the sky is blue to how Internet search engines work, we're serving up answers to your burning science and technology questions. Over the years, we have invited readers to submit their queries to us. We've then found scientists with the appropriate expertise to offer explanations. This compilation brings together the most fascinating of these exchanges to date.

In this issue, you'll find the answers to more than 80 fascinating questions about every day--and not so every-day--occurrences. Learn how caffeine is removed from coffee, what causes hiccups, why bees buzz and why life expectancy is longer for women than it is for men. Find out how long a person can survive without food, how the abbreviations of the periodic table were determined--or even what would happen if you fell through a hypothetical hole in the earth.

These Q&As are sure to make you the shining star at any cocktail party. And who knows, maybe after reading them, you'll be inspired to send in your own questions. If so, just drop us a line at experts@sciam.com. —*The Editors*

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ASK THE EXPERTS

What is antimatter?

—R. Bingham, Lakewood, Colo.

R. Michael Barnett of Lawrence Berkeley National Laboratory and Helen R. Quinn of the Stanford Linear Accelerator Center offer this answer, parts of which are paraphrased from their book, *The Charm of Strange Quarks:*

In 1930 Paul Dirac formulated a quantum theory for the motion of electrons in electric and magnetic fields, the first theory that correctly included Einstein's theory of special relativity in this context. This theory led to a surprising prediction—the equations that described the electron also described, and in fact required, the existence of another type of particle with exactly the same mass as the electron but with a positive instead of a negative electric charge. This particle, which is called a positron, is the antiparticle of the electron, and it was the first example of antimatter.

Its discovery in experiments soon confirmed the remarkable prediction of antimatter in Dirac's theory. A cloud chamber picture taken by Carl D. Anderson in 1931 showed a particle entering a lead plate from below and passing through it. The direction of the curvature of the path, caused by a magnetic field, indicated that the particle was a positively charged one but with the same mass and other characteristics as an electron.

Dirac's prediction applies not only to the electron but to all the fundamental constituents of matter (particles). Each type of particle must have a corresponding antiparticle type. The mass of any antiparticle is identical to that of the particle. All the rest of its properties are also closely related but with the signs of all charges reversed. For example, a proton has a positive electric charge, but an antiproton has a negative electric charge.

There is no intrinsic difference between particles and antiparticles; they appear on essentially the same footing in all particle theories. But there certainly is a dramatic difference in the numbers of these objects we find in the world around us. All the world is made of matter, but any antimatter we produce in the laboratory soon disappears because it meets up with and is annihilated by matter particles.

Modern theories of particle physics and of the evolution of the universe suggest, or even require, that antimatter and matter were once equally common during the universe's earliest stages. Scientists are now attempting to explain why antimatter is so uncommon today.

Why does your stomach growl when you are hungry?

—A. Gillespie, Lancaster, Calif.

Mark A. W. Andrews, associate professor of physiology and associate director of the Independent Study program at the Lake Erie College of Osteopathic Medicine, provides this explanation:

The physiological origin of this "growling" involves muscular activity in the stomach and small intestines. Although such growling is commonly associated with hunger—when the stomach and intestines are empty of contents that would otherwise muffle the noise—such sounds can occur at any time.

SARA CHEN

In general, the gastrointestinal tract is a hollow tube that runs from mouth to anus with walls primarily composed of layers of smooth muscle. This muscle is nearly always active to some extent. When these walls squeeze to mix and propel food, gas and fluids, rumbling noises may be heard. Such squeezing, called peristalsis, involves a ring of contraction moving toward the anus, a few inches at a time.

A rhythmic fluctuation of electrical potential in the smooth muscle cells, known as the basic electrical rhythm (BER), generates the waves of peristalsis. BER is the result of the inherent activity of the enteric nervous system found in the walls of the gut. The autonomic nervous system and hormonal factors also modulate this rhythm.

After the stomach and small intestines have been empty for about two hours, there is a reflex generation of waves of electrical activity (migrating myoelectric complexes, or MMCs) in the enteric nervous system. These trigger hunger contractions, which can be heard as they clear out any stomach contents and keep them from accumulating at any one site. SA

ASK THE EXPERTS

Why do my eyes tear when I peel an onion?

—Patrick Rose, Oakland, Calif.

Thomas Scott, dean of the college of sciences at San Diego State University, provides this explanation:

In this case, tears are the price we pay for flavor and nutritional benefits. The rowdy onion joins the aristocratic shallot, gentle leek, herbaceous chive, sharp scallion and assertive garlic among the 500 species of the genus *Allium*. *Allium cepa* is an ancient vegetable, known to Alexander the Great and eaten by the Israelites during their Egyptian bondage. Indeed, his charges chastened Moses for leading them away from the onions and other flavorful foods that they had come to relish while in captivity. And with good reason: onion is a rich source of nutrients (such as vitamins B, C and G), protein, starch and other essential compounds. The chemicals in onions are effective agents against fungal and bacterial growth; they protect against stomach, colon and skin cancers; they have anti-inflammatory, antiallergenic, antiasthmatic and antidiabetic properties; they treat causes of cardiovascular disorders, including hypertension, hyperglycemia and hyperlipidemia; and they inhibit platelet aggregation.

The tears come from the volatile oils that help to give *Allium* vegetables their distinctive flavors and that contain a class of organic molecules known as amino acid sulfoxides. Slicing an onion's tissue releases enzymes called allinases, which convert these molecules to sulfenic acids. These acids, in turn, rearrange to form syn-propanethial-S-oxide, which triggers the tears. They also condense to form thiosulfinates, the cause of the pungent odor associated with chopping onions—and often mistakenly blamed for the weepy eye. The formation of syn-propanethial-S-oxide peaks about 30 seconds after mechanical damage to the onion and completes its cycle of chemical evolution over about five minutes.

The effects on the eye are all too familiar: a burning sensation and tears. The eye's protective front surface, the cornea, is densely populated with sensory fibers of the ciliary nerve, a branch of the massive trigeminal nerve that brings touch, temperature, and pain sensations from the face and the front of the head to the brain. The cornea also has a smaller number of autonomic motor fibers that activate the lachrymal (tear) glands. Free nerve endings detect syn-propanethial-S-oxide on the cornea and drive activity in the ciliary nerve—which the central nervous system registers as a burning sensation. This nerve activity reflexively activates the autonomic fibers, which then carry a signal back to the eye to order the lachrymal glands to wash the irritant away.

There are several solutions to the problem of onion tears. You can heat onions before chopping to denature the enzymes. You might also try to limit contact with the vapors: chop onions on a breezy porch, under a steady stream of water or mechanically in a closed container. Some say that wearing contact lenses helps. But do not forgo the sensory pleasure and healthful effects of *Allium cepa*.

SRAA CHEN

What is the origin of zero?

—Rolf Ebeling, New York City

Robert Kaplan, author of *The Nothing That Is: A Natural History of Zero*, offers this answer:

The first evidence we have of zero is from the Sumerian culture in Mesopotamia, some 5,000 years ago. The Sumerians inserted a slanted double wedge between cuneiform symbols for numbers to indicate the absence of a number in a specific place (as we would write 102, the "0" indicating no digit in the tens column).

The symbol changed over time as positional, or place-sensitive, notation, for which zero was crucial, made its way to the Babylonian empire and from there to India, most likely via the Greeks (in whose own culture zero made a late and only occasional appearance; the Romans had no trace of it at all). Arab merchants brought the zero they encountered in India to the West. After many adventures and much opposition, the symbol we use took hold and the concept flourished. Zero acquired much more than a positional meaning and has played a crucial role in our mathematizing of the world. SA

Do people lose their senses of smell and taste as they age?

—N. Sly, Windsor, Australia

Charles J. Wysocki, a neuroscientist at the Monell Chemical Senses Center in Philadelphia who studies variation among individuals in the perception of odors and the response of the human nose to chemical irritation, offers this answer:

It's true that as people age they often complain about a decrease in—or even the loss of—their ability to taste a superb meal or appreciate a fine beverage. When people eat, however, they tend to confuse or combine information from the tongue and mouth (the sense of taste, which uses three nerves to send information to the brain) with what is happening in the nose (the sense of smell, which utilizes a different nerve input).

It's easy to demonstrate this confusion. Grab a handful of jellybeans of different flavors with one hand and close your eyes. With your other hand, pinch your nose closed. Now pop one of the jellybeans into your mouth and chew, without letting go of your nose. Can you tell what flavor went into your mouth? Probably not, but you most likely experienced the sweetness of the jellybean. Now let go of your nose. Voilà—the flavor makes its appearance.

This phenomenon occurs because smell provides most of the information about the flavor. Chemicals from the jellybean, called odorants, are inhaled through the mouth and exhaled through the nose, where they interact with special receptor cells that transmit information about smell. (It's the reverse process that one experiences downwind from a pig farm or chocolate factory.) These odorants then interact with the receptor cells and initiate a series of events that are interpreted by the brain as a smell.

Estimates for the number of odorant molecules vary, but there are probably tens of thousands of them. Taste, in contrast, is limited to sweet, sour, bitter, salty and umami (the taste of monosodium glutamate, or MSG).

The sense of smell diminishes with advancing age—much more so than the sensitivity to taste. This decrease may result from an accumulated loss of sensory cells in the nose. The loss may be perhaps as much as two thirds of the original population of 10 million. Although the elderly are in general less sensitive than young people to the overall perception of the food they eat, there are exceptions: some 90-year-olds may be more sensitive to smells than some 20-year-olds.

SARA CHEN

What happens when an aircraft breaks the sound barrier?

—M. Kerr, Marlow, England

Tobias Rossmann, a research engineer with Advanced Projects Research, Inc., and a visiting researcher at the California Institute of Technology, provides this explanation:

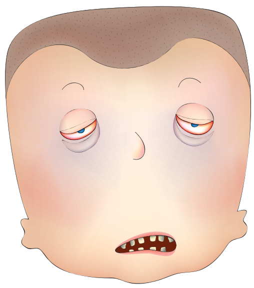
A discussion of what happens when an object breaks the sound barrier must begin with the physical description of sound as a wave with a finite propagation speed. Anyone who has been far enough away from an event to see it first and then hear it is familiar with the relatively slow propagation of sound waves. At sea level and a temperature of 22 degrees Celsius, sound waves travel at 345 meters per second (770 mph). As the local temperature decreases, the sound speed also drops, so that for a plane flying at 35,000 feet—where the ambient temperature is, say, –54 degrees C—the local speed of sound is 295 meters per second (660 mph).

Because the propagation speed of sound waves is finite, sources of sound that are moving can begin to catch up with the sound waves they emit. As the speed of the object increases to the sonic velocity, sound waves begin to pile up in front of the object. If the object has sufficient acceleration, it can burst through this barrier of unsteady sound waves and jump ahead of the radiated sound, thus breaking the sound barrier.

An object traveling at supersonic speeds generates steady pressure waves that are attached to the front of the object (a bow shock). An observer hears no sound as an object approaches. After the object has passed, these generated waves (Mach waves) radiate toward the ground, and the pressure difference across them causes an audible effect, known as a sonic boom. SA

How long can humans stay awake?

J. Christian Gillin is at the San Diego Veterans Affairs Medical Center and is professor of psychiatry at the University of California at San Diego, where he conducts research on sleep, chronobiology and mood disorders. Gillin supplies the following response:



SARA CHEN

The quick answer is 264 hours, or 11 days. In 1965 Randy Gardner, a 17-year-old high school student, set this apparent world record as a science-fair project. Several other research subjects have remained awake for eight to 10 days in carefully monitored experiments. None experienced serious medical or psychiatric problems, but all showed progressive and significant deficits in concentration, motivation, perception and other higher mental processes. Nevertheless, all returned to relative normalcy after one or two nights of sleep. Other, anecdotal reports describe soldiers staying awake for four days in battle and unmedicated patients with mania going without sleep for three to four days.

The more complete answer revolves around the definition of the word "awake." Prolonged sleep deprivation in normal subjects induces numerous brief episodes of light sleep (lasting a few seconds), often described as "microsleep," alternating with drowsy wakefulness, as well as loss of cognitive and motor functions. Many people know about the dangerous drowsy driver on the highway and sleep-deprived British pilots during World War II who crashed their planes, having fallen asleep while flying home from the war zone. Gardner was "awake" but basically cognitively dysfunctional at the end of his ordeal. Excluding accidents, however, I am unaware of any deaths in humans from sleeplessness.

In certain rare medical disorders, the question of how long people can remain awake receives surprising answers—and raises more questions. Morvan's syndrome, for example, is characterized by muscle twitching, pain, excessive sweating, weight loss, periodic hallucinations and sleeplessness. Michel Jouvet and his colleagues in Lyons, France, studied a 27-year-old man with this condition and found that he had virtually no sleep over a period of several months. During that time, the man did not feel sleepy or tired and did not show any disorders of mood, memory or anxiety. Nevertheless, nearly every night between approximately nine and 11 he experienced 20 to 60 minutes of auditory, visual, olfactory and somesthetic (sense of touch) hallucinations, as well as pain and vasoconstriction in his fingers and toes.

The ultimate answer to this question remains unclear. Indeed, the U.S. Department of Defense has offered research funding for the goal of sustaining a fully awake, fully functional "24/7" soldier, sailor or airman. Will bioengineering eventually produce soldiers and citizens with a variant of Morvan's syndrome, who need no sleep but stay effective and happy? I hope not. A good night's sleep is one of life's blessings. As Coleridge wrote in *The Rime of the Ancient Mariner,* "Oh sleep! it is a gentle thing, / Beloved from pole to pole!"

When *Tyrannosaurus rex* fell, how did it get up, given its tiny arms?

—B. Lawrence, Montreal

Paleontologist Gregory M. Erickson of Florida State University provides this explanation:

I think we can look to birds (avian dinosaurs) for the answer, because they can stand up without the aid of arms. It's simply a matter of getting the legs below the center of gravity—where the front and back halves of the body will balance. Furthermore, tyrannosaurs would have had the aid of their tails. From skeletal evidence and tracks from tyrannosaur cousins known as albertosaurs, in which the tails did not drag, it is clear that tyrannosaur tails acted as counterbalances. The tail would have helped a 10,000-pound *T. rex* keep its center of gravity near its hips as its legs moved into position. Clearly, tyrannosaurs got up at least once during their lives (at birth), and there is no reason to believe that they could not do so throughout life—pathetic arms or not.

ASK THE EXPERTS

How can an artificial sweetener contain no calories?

—A. Rivard, Argyle, Minn.

Arno F. Spatola is professor of chemistry and director of the Institute for Molecular Diversity and Drug Design at the University of Louisville. His current research focuses on peptides, including artificial sweeteners. He offers this answer:

Sweetness is a taste sensation that requires interaction with receptors on the tongue. Many sugar substitutes, such as saccharin and acesulfame K, also known as Sunette, do not provide any calories. This means that they are not metabolized as part of the normal biochemical process that yields energy in the form of adenosine triphosphate, or ATP. In some cases, small quantities of additives such as lactose are present to improve the flow characteristics or to give bulk to a product. But the amounts are so small that they do not represent a significant source of energy.

The low-calorie approach of the sugar substitute aspartame, also called NutraSweet, is more interesting. This synthetic compound is a dipeptide, composed of the two amino acids phenylalanine and aspartic acid. As with most proteins, which are chains of amino acids, it can be metabolized and used as an energy source. In general, we obtain energy in the amount of four calories (more correctly termed kilocalories) per gram of protein. This is the same value as the number of calories acquired from sugars or starches. (In contrast, each gram of fat consumed provides more than twice that amount, or about nine calories a gram.)

So if aspartame has the same number of calories per gram as common table sugar (sucrose), how is it a low-calorie sweetener? The answer is that aspartame is 160 times as sweet as sugar. That is, a single teaspoon of aspartame (four calories) will yield the same sweetening effect as 160 teaspoons of sugar (640 calories). If 3,500 extra calories is equivalent to a gain of one pound in weight, it is easy to see why so many people turn to artificially sweetened beverages in an effort to maintain some control over their amount of body fat.

But does that actually lead to weight loss? Perhaps not. Either by a physical effect, or perhaps a psychological one, many of us seem to make up the loss of sugar calories by eating or drinking other foods. For this reason, artificially sweetened diet drinks alone are hardly likely to have much of an effect on the problem of obesity in the U.S.

What is a blue moon?

—B. Purvis, Carlisle, Pa.

George F. Spagna, Jr., chair of the physics department at Randolph-Macon College, supplies an explanation:

The definition has varied over the years. A blue moon once meant something virtually impossible, as in the expression "When pigs fly!" This was apparently the usage as early as the 16th century. Then, in 1883, the explosion of Krakatau in Indonesia released enough dust to turn sunsets green worldwide and the moon blue. Forest fires, severe drought and volcanic eruptions can still do this. So a blue moon became synonymous with something rare—hence the phrase "once in a blue moon."

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The more recent connection of a blue moon with the calendar apparently comes from the 1937 *Maine Farmer's Almanac*. The almanac relies on the tropical year, which runs from winter solstice to winter solstice. In it, the seasons are not identical in length, because the earth's orbit is elliptical. Further, the synodic, or lunar, month is about 29.5 days, which doesn't fit evenly into a 365.24-day tropical year or into seasons roughly three months in length.

Most tropical years have 12 full moons, but occasionally there are 13, so one of the seasons will have four. The almanac called that fourth full moon in a season a blue moon. (The full moons closest to the equinoxes and solstices already have traditional names.) J. Hugh Pruett, writing in 1946 in *Sky and Telescope,* misinterpreted the almanac to mean the second full moon in a given month. That version was repeated in a 1980 broadcast of National Public Radio's *Star Date,* and the definition stuck. So when someone today talks about a blue moon, he or she is referring to the second full moon in a month. SA

What exactly is déjà vu?

—Ayako Tsuchida, Ube, Japan

James M. Lampinen, assistant professor of psychology at the University of Arkansas, supplies this answer:

Most people experience déjà vu—the feeling that an entire event has happened before, despite the knowledge that it is unique. We don't yet have a definitive answer about what produces déjà vu, but several theories have been advanced.

One early theory, proposed by Sigmund Freud, is that déjà vu takes place when a person is spontaneously reminded of an unconscious fantasy. In 1990 Herman Sno, a psychiatrist at Hospital de Heel in Zaandam, the Netherlands, suggested that memories are stored in a format similar to holograms. Unlike a photograph, each section of a hologram contains all the information needed to reproduce the entire picture. But the smaller the fragment, the fuzzier the resultant image. According to Sno, déjà vu occurs when some small detail in one's current situation closely matches a memory fragment, conjuring up a blurry image of that former experience.

Déjà vu can also be explained in terms of what psychologists call global matching models. A situation may seem familiar either because it is similar to a single event stored in memory or because it is moderately similar to a large number of stored events. For instance, imagine you are shown pictures of various people in my family. Afterward, you happen to bump into me and think, "Hey, that guy looks familiar." Although nobody in my family looks just like me, they all look somewhat like me, and according to global matching models the similarity tends to summate.

Progress toward understanding déjà vu has also been made in cognitive psychology and the neurosciences. Researchers have distinguished between two types of memories. Some are based on conscious recollection; for example, most of us can consciously recall our first kiss. Other memories, such as those stimulated when we meet someone we seem to recognize but can't quite place, are based on familiarity. Researchers believe that conscious recollection is mediated by the prefrontal cortex and the hippocampus at the front of the brain, whereas the part housed behind it, which includes the parahippocampal gyrus and its cortical connections, mediates feelings of familiarity. Josef Spatt of the NKH Rosenhügel in Vienna, Austria, has argued that déjà vu experiences occur when the parahippocampal gyrus and associated areas become temporarily activated in the presence of normal functioning in the prefrontal cortex and hippocampus, producing a strong feeling of familiarity but without the experience of conscious recollection.

As you can tell, this is an area still ripe for research.

How can graphite and diamond be so different if they are both composed of pure carbon?

—M. Hurley, North Attleboro, Mass.

Miriam Rossi, professor of chemistry at Vassar College, provides an explanation:

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The distinct arrangement of atoms in diamond and carbon makes all the difference to their properties. In a diamond, the carbon atoms are organized tetrahedrally. Each carbon atom is attached to four others, forming a rigid three-dimensional network. This accounts for diamond's extraordinary strength, durability and other properties. Diamond, the hardest material known, can scratch all other materials. It conducts more than copper does, but it's also an electrical insulator. The gemstone disperses light into a rainbow of colors, giving rise to the "fire" of diamonds.

In comparison, the carbon atoms in graphite are arranged in layers. The atoms have two types of interactions with one another. First, each is bonded to three others and arranged at the corner of a network of hexagons. These planar arrangements extend in two dimensions to form a horizontal, hexagonal "chicken-wire" array. Second, these arrays are held together weakly in layers. Graphite is soft and slippery and can be used as a lubricant or in pencils because its layers cleave readily. The planar structure allows electrons to move easily within the planes, permitting graphite to conduct electricity and heat as well as to absorb light so that it appears black in color. SA

How is caffeine removed to produce decaffeinated coffee?

—Rick Woolley, Everett, Wash.

Fergus M. Clydesdale, head of the food science department at the University of Massachusetts at Amherst, provides this answer:

There are currently three main processes, all of which begin with moistening the green or roasted beans to make the caffeine soluble. Decaffeination is typically carried out at 70 to 100 degrees Celsius.

In the first method, called water processing, the moistened coffee beans are soaked in a mixture of water and green-coffee extract that has previously been caffeine-reduced. Osmosis draws the caffeine from the highly caffeine-concentrated beans into the less caffeine-concentrated solution. Afterward, the decaffeinated beans are rinsed and dried. The extracted caffeine-rich solution is passed through a bed of charcoal that has been pretreated with a carbohydrate. The carbohydrate blocks sites in the charcoal that would otherwise absorb sugars and additional compounds that contribute to the coffee's flavor but permits the absorption of caffeine. The caffeine-reduced solution, which still contains compounds that augment the taste and aroma, can then be infused into the beans. The water process is natural, in that it does not employ any harmful chemicals, but it is not very specific for caffeine, extracting some noncaffeine solids and reducing flavor. It eliminates 94 to 96 percent of the caffeine.

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An alternative method extracts caffeine with a chemical solvent. The liquid solvent is circulated through a bed of moist, green coffee beans, removing the caffeine. The solvent is recaptured in an evaporator, and the beans are washed with water. Finally, the beans are steamed to remove chemical residues. Solvents, such as methylene chloride, are more specific for caffeine than charcoal is, extracting 96 to 97 percent of the caffeine and leaving behind nearly all the noncaffeine solids.

In the third approach, carbon dioxide is circulated through the beans in drums operating at roughly 250 to 300 times atmospheric pressure. At these pressures, carbon dioxide takes on unique supercritical properties, having a density similar to that of a liquid but with the diffusivity of a gas, allowing it to penetrate the beans and dissolve the caffeine. These attributes also significantly lower the pumping costs for carbon dioxide. The caffeine-rich carbon dioxide exiting the extraction vessel is channeled through charcoal or water to absorb the caffeine and is then returned to the extraction vessel. Carbon dioxide is popular because it has a relatively low pressure critical point, it is nontoxic, and it is naturally abundant. Supercritical carbon dioxide decaffeination is more expensive, but it extracts 96 to 98 percent of the caffeine.

Why is spider silk so strong?

—D. Gray, Corinna, Maine

Biologist William K. Purves of Harvey Mudd College offers an explanation:

Dragline silk, the silk that forms the radial spokes of a spider's web, is composed of two proteins, making it strong and tough—yet elastic. Each protein contains three regions with distinct properties. The first forms an amorphous (noncrystalline) matrix that is stretchable, giving the silk elasticity. When an insect strikes the web, the matrix stretches, absorbing the kinetic energy of the insect's impact. Embedded in the amorphous parts of both proteins are two kinds of crystalline regions that toughen the silk. Both regions are tightly pleated and resist stretching, and one of them is rigid. It is thought that the pleats of the less rigid crystalline regions anchor the rigid crystals to the matrix.

A spider's dragline is only about one tenth the diameter of a human hair, but it is several times stronger than steel, on a weight-for-weight basis. The recent movie *Spider-Man* drastically underestimates the strength of silk—real dragline silk would not need to be nearly as thick as the strands deployed by our web-swinging hero. SA

Why do we yawn when we are tired? And why does it seem to be contagious?

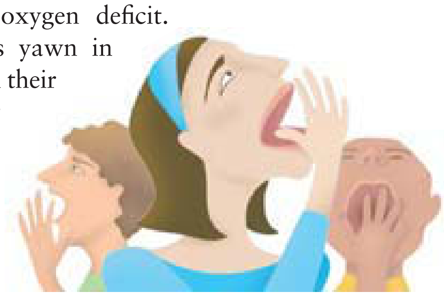
—A. Wong, Berkeley, Calif.

Mark A. W. Andrews, associate professor of physiology and director of the independent study program at the Lake Erie College of Osteopathic Medicine, provides an explanation:

Yawning appears to be not only a sign of tiredness but also a much more general sign of changing conditions within the body. Studies have shown that we yawn when we are fatigued, as well as when we are awakening and during other times when our state of alertness is changing.

Yawning is characterized by a single deep inhalation (with the mouth open) and stretching of the muscles of the jaw and trunk. It occurs in many animals and involves interactions between the unconscious brain and the body.

For years it was thought that yawns served to bring in more air when low oxygen levels were sensed in the lungs by nearby tissue. We now know, however, that the lungs do not necessarily detect an oxygen deficit. Moreover, fetuses yawn in utero, even though their lungs are not yet ventilated. In addition, different regions of the brain control yawning and breathing. Low oxygen levels in the paraventricular nucleus (PVN) of the hypothalamus of the brain can induce yawning. Another hypothesis is that we yawn because we are tired or bored. But this, too, is probably not the case—the PVN also plays a role in penile erection, an event not typically associated with boredom.



It does appear that the PVN of the hypothalamus is, among other things, the "yawning center" of the brain. It contains a number of chemical messengers that can induce yawns, including dopamine, glycine, oxytocin and adrenocorticotropic hormone (ACTH). ACTH, for one, surges at night and prior to awakening and elicits yawning and stretching in humans. Yawning also seems to require production of nitric oxide by specific neurons in the PVN. Once stimulated, the cells of the PVN activate cells of the brain stem and/or hippocampus, causing yawning. Yawning likewise appears to have a feedback component: if you stifle or prevent a yawn, the process is somewhat unsatisfying.

You are correct that yawns are contagious. Seeing, hearing or thinking about yawning can trigger the event, but there is little understanding of why. Many theories have been presented over the years. Some evidence suggests that yawning is a means of communicating changing environmental or internal body conditions to others, possibly as a way to synchronize behavior. If this is the case, yawning in humans is most likely a vestigial mechanism that has lost its significance.

SARA CHEN

Why do stars twinkle?

John A. Graham, an astronomer at the Carnegie Institution in Washington, D.C., offers an answer:

Have you ever noticed how a coin at the bottom of a swimming pool seems to wobble? This occurs because the water in the pool bends the path of light reflected from the coin. Similarly, stars twinkle because their light has to pass through several miles of Earth's atmosphere before it reaches the eye of an observer. It is as if we are looking at the universe from the bottom of a swimming pool.

Our atmosphere is turbulent, with streams and eddies forming, churning and dispersing all the time. These disturbances act like lenses and prisms that shift a star's light from side to side by minute amounts several times a second. For large objects such as the moon, these deviations average out. (Through a telescope with high magnification, however, the objects appear to shimmer.) Stars, in contrast, are so far away that they effectively act as point sources, and the light we see flickers in intensity as the incoming beams bend rapidly from side to side. Planets such as Mars, Venus and Jupiter, which appear to us as bright stars, are much closer to Earth and look like measurable disks through a telescope. Again, the twinkling from adjacent areas of the disk averages out, and we see little variation in the total light emanating from the planet. SA

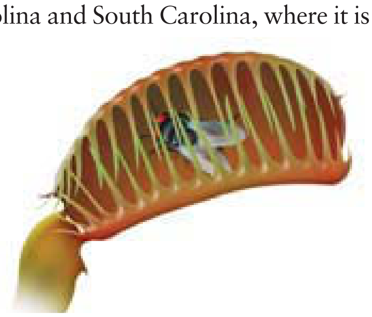
Q How does the Venus flytrap digest flies?

—F. Alikham, Daly City, Calif.

Lissa M. Leege, a plant ecologist and assistant professor of biology at Georgia Southern University, explains:

Before we talk about how the Venus flytrap (*Dionaea muscipula*) digests its prey, it is important to know why it does so. It can make its own food through photosynthesis, so the insect-eating plant does not use prey for the traditional animal objectives of harvesting energy and carbon. Rather it mines its food primarily for essential nutrients (nitrogen and phosphorus in particular) that are in short supply in its boggy, acidic habitat.

The Venus flytrap occurs in a restricted range of sandy shrub bogs in coastal North Carolina and South Carolina, where it is an endangered species. Frequent fires there clear out competing plants and volatilize nitrogen in the soil. Hence, Venus flytraps' unique adaptation enables them to access nitrogen when other plants can't get it from the soil.



How does this plant manage to attract, kill, digest and absorb its prey? First it lures its victim with sweet-smelling nectar, secreted on its steel-trap-shaped leaves. Unsuspecting insects land in search of a reward, trip the bristly trigger hairs and are imprisoned behind the interlocking teeth of the leaf edges. There are three to six trigger hairs on the surface of each leaf. If the same hair is touched twice or if two hairs are touched within a 20-second interval, the cells on the outer surface of the leaf fill with watery fluid to expand rapidly, and the trap shuts. If insect secretions, such as uric acid, stimulate the trap, it will clamp down further and form an airtight seal. Once the trap closes, digestive glands that line the interior edge of the leaf secrete enzymes that dissolve the soft parts, kill bacteria and fungi, and break down the insect into the necessary nutrients. These are then absorbed into the leaf. Five to 12 days after capture, the trap reopens to release the leftover exoskeleton. (If tripped by a curious spectator or a falling twig, the trap will reopen within a day or so.)

After three to five meals, the trap will no longer capture prey but will spend another two to three months simply photosynthesizing before it drops off the plant, only to be replaced by a new one. Plant owners should beware of overstimulating a Venus flytrap: after approximately 10 unsuccessful trap closures, the leaf will cease to respond to touch and will serve only as a photosynthetic organ.

Q How do rewritable CDs work?

—R. Raiszadeh, Kerman, Iran

Gordon Rudd, president of Clover Systems in Laguna Hills, Calif., offers this answer:

All CDs—and DVDs—work by virtue of marks on the disc that appear darker than the background. These are detected by shining a laser on them and measuring the reflected light.

In the case of molded CDs or DVDs, such as those bought in music or video stores, these marks are physical "pits" imprinted into the surface of the disc. In CD-Recordable (CD-R) discs, a computer's writing laser creates permanent marks in a layer of dye polymer in the disc.

CD-Rewritable (CD-RW) discs are produced in a similar fashion, except that the change to the recording surface is reversible. The key is a layer of phase-change material, an alloy composed of silver, indium, antimony and tellurium. Unlike most solids, this alloy can exist in either of two solid states: crystalline (with atoms closely packed in a rigid and organized array) or amorphous (with atoms in random positions). The amorphous state reflects less light than the crystalline one does.

When heated with a laser to about 700 degrees Celsius, the alloy switches from the original crystalline phase to the amorphous state, which then appears as a dark spot when the disc is played back. These spots can be erased using the same laser (at a lower power) to heat the material to a temperature of 200 degrees C or so; this process returns the alloy to its crystalline state. Most CD-RW makers suggest that one disc can be overwritten up to 1,000 times and will last about 30 years. SA

SARA CHEN

ASK THE EXPERTS

How do Internet search engines work?

—A. Dharia, Houston

Javed Mostafa, Victor H. Yngve Associate Professor of Information Research Science and director of the Laboratory of Applied Informatics, Indiana University, offers this answer:

Publicly available Web services—such as Google, InfoSeek, Northernlight and AltaVista—employ various techniques to speed up and refine their searches. The three most common methods are known as preprocessing the data, "smart" representation and prioritizing the results.

One way to save search time is to match the Web user's query against an index file of preprocessed data stored in one location, instead of sorting through millions of Web sites. To update the preprocessed data, software called a crawler is sent periodically by the database to collect Web pages. A different program parses the retrieved pages to extract search words. These words are stored, along with the links to the corresponding pages, in the index file. New user queries are then matched against this index file.

MATT COLLINS

Smart representation refers to selecting an index structure that minimizes search time. Data are far more efficiently organized in a "tree" than in a sequential list. In an index tree, the search starts at the "top," or root node. For search terms that start with letters that are earlier in the alphabet than the node word, the search proceeds down a "left" branch; for later letters, "right." At each subsequent node there are further branches to try, until the search term is either found or established as not being on the tree.

The URLs, or links, produced as a result of such searches are usually numerous. But because of ambiguities of language (consider "window blind" versus "blind ambition"), the resulting links would generally not be equally relevant. To glean the most pertinent records, the search algorithm applies ranking strategies. A common method, known as term-frequency-inverse document-frequency, determines relative weights for words to signify their importance in individual documents; the weights are based on the distribution of the words and the frequency with which they occur. Words that occur very often (such as "or," "to" and "with") and that appear in many documents have substantially less weight than do words that appear in relatively few documents and are semantically more relevant.

Link analysis is another weighting strategy. This technique considers the nature of each page—namely, if it is an "authority" (a number of other pages point to it) or a "hub" (it points to a number of other pages). The highly successful Google search engine uses this method to polish searches.

What is quicksand?

—S. Yamasaki, Brussels, Belgium

Darrel G. F. Long, a sedimentologist in the department of earth sciences, Laurentian University in Sudbury, Ontario, explains:

Quicksand is a mixture of sand and water or of sand and air; it looks solid but becomes unstable when it is disturbed by any additional stress. Grains frequently are elongated rather than spherical, so loose packing can produce a configuration in which the spaces between the granules, or voids, filled with air or water make up 30 to 70 percent of the total volume. This arrangement is similar to a house of cards, in which the space between the cards is significantly greater than the space occupied by the cards. In quicksand, the sand collapses, or becomes "quick," when force from loading, vibration or the upward migration of water overcomes the friction holding the particles in place. In normal sand, in contrast, tight packing forms a rigid mass, with voids making up only about 25 to 30 percent of the volume.

Most quicksand occurs in settings where there are natural springs, such as at the base of alluvial fans (cone-shaped bodies of sand and gravel formed by rivers flowing from mountains), along riverbanks or on beaches at low tide. Quicksand does appear in deserts, on the loosely packed, downwind sides of dunes, but this is rare. And the amount of sinking is limited to a few centimeters, because once the air in the voids is expelled, the grains nestle too close together to allow further compaction. SA

Why do some people get more cavities than others do?

Joel H. Berg, professor and chair of pediatric dentistry at the University of Washington School of Dentistry and president of the American Academy of Pediatric Dentistry Foundation, offers this answer:

Dental caries, the culprit behind the creation of cavities, is the most prevalent infectious disease in humans, affecting 97 percent of people at some point in their lifetime. Many factors are involved in the progression of tooth decay.

Caries is acid demineralization of the teeth caused by plaques of biofilms, complex communities of microorganisms that can coat surfaces in the mouth and reduce local pH levels. When tooth enamel is subjected to a pH lower than 5.5, it begins to demineralize, or break down; above this so-called critical pH, remineralization can occur. The success of this repair process depends on the presence of minerals in saliva, available fluoride ions and salivary flow rate. When the demineralization side wins this tug of war over time without compensatory remineralization, caries can progress to a visible cavity.

All bacterial biofilms are not alike, however. Although *Mutans streptococci* and other species have been implicated as primary culprits in causing caries, some people who are infected with these bacteria don't get cavities. So it is not simply the quantity of plaque biofilm present that leads to cavities.

Diet is another factor. Caries-causing organisms prefer sugars—specifically sucrose, or common table sugar—as the chief energy source. The metabolism of these sugars into lactic acid is what causes cavities. Controlling the number of sugar exposures—by limiting the consumption of sweets—aids in the remineralization side of the equation.

Salivary flow and composition also affect cavity production. In short, the more saliva there is in the mouth, the better it is at natural debridement—that is, scrubbing—of caries-causing organisms and the acids they generate off the teeth. Tooth morphology, or shape, makes a difference as well. Deep grooves on tooth surfaces (molars in particular) trap biofilms, making their removal by brushing and flossing more difficult.

Obviously, oral hygiene is key to keeping caries under control. Brushing and flossing must be performed religiously, preferably at least daily, to be effective.

MATT COLLINS

Why are snowflakes symmetrical?

—V. Andersen, Santa Clara, Calif.

Miriam Rossi, associate professor of structural chemistry at Vassar College, explains:

Snowflakes reflect the internal order of water molecules as they arrange themselves in their solid forms—snow and ice. As water molecules begin to freeze, they form weak hydrogen bonds with one another. The growth of snowflakes (or any substance changing from a liquid to a solid) is known as crystallization. The molecules align themselves in their lowest-energy state, which maximizes the attractive forces among them and minimizes the repulsive ones. In the water ice found on the earth, each molecule is linked by hydrogen bonds to four other molecules, creating a lattice structure.

As a result, the water molecules move into prearranged spaces. The most basic shape is a hexagonal prism, with hexagons on top and bottom and six rectangular-shape sides. This ordering process is much like tiling a floor: once the pattern is chosen and the first tiles are placed, then all the other tiles must go in predetermined spaces to maintain the pattern. Water molecules settle themselves in low-energy locations that fit the spaces and maintain symmetry; in this way, the arms of the snowflake are made.

There are many types of snowflakes. The differentiation occurs because each snowflake forms in the atmosphere, which is complex and variable. A snow crystal may begin developing in one way and then change in response to alterations in temperature or humidity. The basic hexagonal symmetry is preserved, but the ice crystal branches off in new directions. SA

What is the difference between artificial and natural flavors?

—J. Yerger, State College, Pa.

Gary Reineccius, professor of food science and nutrition at the University of Minnesota, explains:

Natural and artificial flavors are defined in the U.S. Code of Federal Regulations. A natural flavor is "the essential oil, oleoresin, essence or extractive, protein hydrolysate, distillate, or any product of roasting, heating or enzymolysis, which contains the flavoring constituents derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, seafood, poultry, eggs, dairy products, or fermentation products thereof, whose significant function in food is flavoring rather than nutritional." An artificial flavor is one that does not meet these criteria.

MATT COLLINS

Practically speaking, however, the difference between these two types of flavorings is minimal. Both are made in a laboratory by a "flavorist," who blends the appropriate chemicals together in the right proportions, using "natural" chemicals to make natural flavorings and "synthetic" ones to make artificial flavorings. But the formulation used to create an artificial flavor must be exactly the same as that used for a natural one in order to produce the desired flavor. The distinction in terminology comes only from the source of the chemicals.

Is there truly *any* substantive difference, then, between natural and artificial flavorings? Yes—artificial flavorings are simpler in composition and potentially safer, because only safety-tested components are utilized, whereas natural flavorings can contain toxins inherent to their sources. Another difference is cost. The search for "natural" sources of chemicals often requires that a manufacturer go to great lengths. Natural coconut flavorings, for example, depend on a chemical found in the bark of a Malaysian tree. Extracting this chemical involves the removal of the bark, a costly process that also kills the tree. So although this natural chemical is identical to the version made in an organic chemist's laboratory, it is much more expensive. Consumers may pay a lot for natural flavorings, but they are neither necessarily better in quality nor safer than their less pricey artificial counterparts.

How long can the average person survive without water?

Randall K. Packer, professor of biology at George Washington University, offers this answer:

It is impossible to give a definitive answer to this seemingly simple question because many variable factors determine a person's survival time. Under the most extreme conditions—a child left in a closed hot car, say—death can come rather quickly. An adult in comfortable surroundings, in contrast, can survive for a week or more with no water intake.

To stay healthy, humans must maintain water balance. We get water from food and drink and lose it mainly as sweat and urine, with a small amount also present in feces. Another route of water loss usually goes unnoticed—we lose water each time we exhale. Sweating is the only physiological mechanism humans have to keep from overheating: evaporation of sweat cools blood in vessels in the skin, which helps to cool the entire body. If that lost water is not replaced, the total volume of body fluid can fall quickly and, most dangerously, blood volume can drop. If this happens, two potentially life-threatening problems arise: body temperature can soar even higher, while blood pressure decreases because of the low blood volume. Most people cannot survive long under such conditions. Because of their greater skin-surface-to-volume ratio, children are especially susceptible to rapid overheating and dehydration.

A person can stay hydrated by drinking various kinds of fluids, with one exception. Alcoholic beverages cause dehydration because ethanol increases urine volume such that more fluid is lost in urine than is gained from the beverage. SA

ASK THE EXPERTS

Why do computers crash?

—R. L. Feigenbaum, Croton-on-Hudson, N.Y.

Clay Shields, assistant professor of computer science at Georgetown University, explains:

The short answer is: for many reasons. Computers crash because of errors in the operating system (OS) software or the machine's hardware. Software glitches are probably more common, but those in hardware can be devastating.

The OS does more than allow the user to operate the computer. It provides an interface between applications and the hardware and directs the sharing of system resources among different programs. Any of these tasks can go awry. Perhaps the most common problem occurs when, because of a programming flaw, the OS tries to access an incorrect memory address. In some versions of Microsoft Windows, users might see a general protection fault (GPF) error message; the solution is to restart the program or reboot the computer. Other programming mistakes can drive the OS into an infinite loop, in which it executes the same instructions over and over. The computer appears to lock up and must be reset. Another way things can go amiss: when a programming bug allows information to be written into a memory buffer that is too small to accept it. The information "overflows" out of the buffer and overwrites data in memory, corrupting the OS.

Application programs can also cause difficulties. Newer operating systems (such as Windows NT and Macintosh OS X) have built-in safeguards, but application bugs can affect older ones. Software drivers, which are added to the OS to run devices such as printers, may stir up trouble. That's why most modern operating systems have a special boot mode that lets users load drivers one at a time, so they can determine which is to blame.

Hardware components must also function correctly for a computer to work. As these components age, their performance degrades. Because the resulting defects are often transient, they are hard to diagnose. For example, a computer's power supply normally converts alternating current to direct current. If it starts to fail and generates a noisy signal, the computer can crash.

The random-access memory (RAM) can err intermittently, particularly if it gets overheated, and that can corrupt the values the RAM stores at unpredictable times and cause crashes. Excessive heat can crash the central processing unit (CPU). Fans, which blow cooling air into the computer's case, may fail, making components susceptible to overheating. And they push dirt and dust inside, which can lead to intermittent short circuits; compressed air or a vacuum cleaner easily gets rid of such dirt. Still other hardware problems, including a failed video or network card, are trickier to identify, requiring software tests or the sequential replacement of components.

Errors on a computer's hard drive are the most intractable. Hard disks store information in units called sectors. If sectors go bad, the data stored on them go, too. If these sectors hold system information, the computer can seize up. Bad sectors also can result from an earlier crash. The system information becomes corrupted, making the computer unstable; ultimately the OS must be reinstalled. Last and worst, a computer can fail completely and permanently if the machine gets jarred and the head that reads information makes contact with the disk surface.

What causes thunder?

—Tom Blighes, San Antonio, Tex.

Richard C. Brill, professor at Honolulu Community College, offers this answer:

Thunder is caused by lightning, which is essentially a stream of electrons flowing between or within clouds or between a cloud and the ground. The air surrounding the electron stream becomes so hot—up to 50,000 degrees Fahrenheit—that it forms a resonating tube of partial vacuum surrounding the lightning's path. The nearby air rapidly expands and contracts, making the column vibrate like a tubular drumhead and producing a tremendous *crack*. As the vibrations gradually die out, the sound echoes and reverberates, generating the rumbling we call thunder. We can hear the booms from great distances, 10 or more miles from the lightning that caused them. SA

NINA FINKEL

Why do hangovers occur?

—P. Bouchard, Orange, Calif.

Sant P. Singh, a professor and chief of endocrinology, diabetes and metabolism at Chicago Medical School, offers this answer:

Several factors appear to be involved in getting a hangover—the unpleasant consequence visited on 75 percent of those who drink alcohol to intoxication. The effects include headache, nausea, vomiting, thirst, dryness of the mouth, tremors, dizziness, fatigue and muscle cramps. Often there is an accompanying slump in cognitive and visual-spatial skills.

MATT COLLINS

A hangover has been suggested to be an early stage of alcohol withdrawal. Mild shakiness and sweats can occur; some people may even hallucinate. Acetaldehyde, a toxic breakdown product of alcohol metabolism, plays a role in producing symptoms. Chemicals known as congeners that are formed during alcohol processing and maturation also increase the likelihood and severity of a hangover; as a rule of thumb, the darker the liquor, the more congeners it contains. The toxins in congeners are distributed throughout the body as the liver breaks down the alcohol. Last, hangovers cause changes in the blood levels of various hormones, which are responsible for some symptoms. For example, alcohol inhibits antidiuretic hormone, which leads to excessive urination and dehydration. Blood aldosterone and renin levels also increase with a hangover—but unlike antidiuretic hormone, they do not correlate well with symptomatic severity, so their role is less clear.

Individuals are more prone to develop a hangover if they drink alcohol rapidly, mix different types of drinks, and do not dilute the absorption of liquor by eating food or drinking nonalcoholic beverages. Sugar and fluids can help overcome the ensuing hypoglycemia and dehydration, and antacids can reduce nausea. To reduce headache, anti-inflammatory drugs should be used cautiously: aspirin may irritate the stomach, and the toxic effects of acetaminophen on the liver can be amplified by alcohol. Other drugs have been used to treat hangovers, but most have questionable value.

Why does shaking a can of coffee cause the larger grains to move to the surface?

—H. Kanchwala, Pune, India

Heinrich M. Jaeger, a professor of physics at the University of Chicago, explains:

The phenomenon by which larger coffee grains move up and smaller ones travel down when shaking a can is called granular-size separation. It is often referred to as the Brazil nut effect, because the same thing will happen when you jiggle a can of mixed nuts. This occurs for two main reasons.

First, during a shaking cycle—as the material lifts off the bottom of the can and then collides with the base again—larger particles briefly separate from smaller ones, leaving gaps underneath. The tinier bits then slip into the gaps. When the shaking cycle finishes, the large particles cannot return to their original positions, and therefore the bigger particles slowly "ratchet" upward.

The second action at work is called a convective mechanism. When a can shakes, the coffee rubs against the sides. Friction causes a net downward motion of the grains along the walls, which is balanced by a net upward flow in the center—setting up a convection roll pattern. The downward flow is confined to a narrow region only a few (small) particle diameters in width. Once the large java grains reach the top, they move toward the side walls. If they are too large, they cannot fit into the region of downward flow and, after a few shakes, they aggregate near the top. Typically this mechanism dominates unless friction with the side walls is carefully minimized. SA

Why does reading in a moving car cause motion sickness?

Timothy C. Hain, professor of neurology, otolaryngology and physical therapy/human movement science at Northwestern University Medical School, and Charles M. Oman, director of the Man Vehicle Laboratory at the M.I.T. Center for Space Research and leader of the neurovestibular research program at the NASA National Space Biomedical Research Institute in Houston, explain:

Motion sickness—whether caused by traveling in a car or a boat or being in outer space—is the unpleasant consequence of disagreement between the brain's expectations in a given situation and the information it receives from the senses.

To retain balance, the brain synthesizes data from many sources, including sight, touch and the inner ear. The last is particularly important because it detects angular and linear motion. Most of the time, all the inputs agree. When they do not jibe with what the brain expects in that situation, however, motion sickness—with its spatial disorientation, nausea or vomiting—can occur.

Imagine that you are reading in a car's backseat. Your eyes, fixed on the book with the peripheral vision seeing the interior of the car, tell the brain that you are still. But as the car changes speed or turns, the sensors in your inner ear contradict that information. This is why motion sickness is common in this case. It helps to look out the window. (The driver suffers least, because he not only has compatible sensory information but is also controlling the car—so he is prepared for variations in motion.)

Likewise, you can combat seasickness by staying on deck, where you can see the horizon. Once your balance system learns to handle the boat's motion—when you get your "sea legs"—susceptibility to illness fades. Of course, when you go ashore, your body may still anticipate the boat's movement for a few hours or even days, which can make you feel unwell again.

Spaceflight also causes motion sickness, suffered by 70 percent of rookie astronauts. In "weightless," or microgravity, conditions the inner ear cannot determine "down." Some crew members have said they felt as if they were upside down continuously, no matter what their actual orientation.

MATT COLLINS

How long do stars usually live?

—A. Tate, Willard, Mo.

John Graham, an astronomer in the department of terrestrial magnetism at the Carnegie Institution of Washington, answers:

Stars' lifetimes vary from a few million years to billions of years. It depends on how fast a star uses up its nuclear fuel. Almost all stars shine as a result of the nuclear fusion of hydrogen into helium. This process takes place within their hot, dense cores, where temperatures may reach 20 million degrees Celsius. The star's rate of energy generation depends on both temperature and the gravitational compression from its outer layers. More massive stars burn their fuel much faster and shine more brightly than less massive ones. Some large stars will exhaust their available hydrogen within a few million years. On the other hand, the least massive ones that we know are so parsimonious that they can continue to burn longer than the current age of the universe itself—about 15 billion years.

Our sun has been around for nearly five billion years and has enough fuel for another five billion. Almost all the stars we can see in the night sky are intrinsically more massive and brighter than our sun. (Most longer-lasting stars that are fainter than the sun are too dim to view without a telescope.) At the end of a star's life, when the supply of available hydrogen is nearly exhausted, it swells and brightens. Stars that are visible to the naked eye are often in this stage. They are, on average, a few hundred million years old. A supergiant star, such as the 10-million-year-old Betelgeuse in Orion, in contrast, will meet its demise much more quickly. It has been spending its fuel so extravagantly that it is expected to collapse within a million years before probably exploding as a supernova. SA

Would you fall all the way through a hypothetical hole in the earth?

—T. Fowler, Snohomish, Wash.

Mark Shegelski, professor of physics at the University of Northern British Columbia, offers this answer:

Theoretically, yes. For this conjectural trip, let us ignore friction, the rotation of the earth and other complications. Just picture a hole or tunnel that enters the earth at one point, goes straight through the center and comes back to the surface at the opposite side of the planet. If we treat the mass distribution in the earth as uniform (for simplicity's sake), a person could fall into the tunnel and then return to the surface on the other side in a manner much like the motion of a pendulum. Assume that the person's journey began with an initial speed of zero kilometers an hour (he simply dropped into the hole). His speed would increase and reach a maximum at the center of the earth, then decrease until he reached the surface—at which point the speed would again fall to zero. The gravitational force exerted on the traveler would be proportional to his distance from the center of the earth: it is at a maximum at the surface and zero at the center. The total trip time would be about 42 minutes. If there were no friction, no energy would be lost, so our traveler could oscillate through the tunnel repeatedly.

MATT COLLINS

This jaunt could not occur in the real world for a number of reasons. Among them: the implausibility of building a tunnel 12,756 kilometers long, displacing all the material in the tunnel's proposed path, and surviving the journey through a passageway that runs through the earth's molten outer core and inner core—where the temperature is about 6,000 degrees Celsius.

Interestingly, if the tube did not pass through the center of the planet, the travel time would still be about 42 minutes. That is because although the burrow would be shorter, the gravitational force along its path would also diminish compared with that of one that goes through the center of the planet. So the person would travel more slowly. Because the distance and gravity decrease by the same factor, the travel time ends up being the same.

How do manufacturers calculate calories for packaged foods?

—S. Connery, Friday Harbor, Wash.

Jim Painter, associate professor and chair of family and consumer science at Eastern Illinois University, explains:

To answer this question, it helps to first define "calorie," a unit used to measure energy content. The calorie you see on a food wrapper is actually a kilocalorie, or 1,000 calories. A Kcalorie is the amount of energy needed to raise the temperature of one kilogram of water by 1 degree Celsius.

Initially, to determine Kcalories, a given food was placed in a sealed container surrounded by water, an apparatus known as a bomb calorimeter. The food was completely burned, and the resulting rise in water temperature was measured. This method, though not frequently used any longer, formed the basis for how Kcalories are counted today.

The Nutrition Labeling and Education Act of 1990 requires that the Kcalories of packaged foods be totaled from the food's energy-containing components: protein, carbohydrate, fat and alcohol. (Because carbohydrates contain some indigestible fiber, the grams of fiber are subtracted as part of the Kcalorie calculation.)

All food labels use the Atwater system, which establishes the average values of four Kcalories per gram for protein, four for carbohydrate, nine for fat and seven for alcohol. Thus, the label on an energy bar that contains 10 grams of protein, 20 of carbohydrate and nine of fat would read 201 Kcalories. Additional information on this subject, and the Kcalorie counts for more than 6,000 foods, is available on the Nutrient Data Laboratory Web site (www.nal.usda.gov/fnic/foodcomp/). SA

ASK THE EXPERTS

I was vaccinated against smallpox 40 years ago. Am I still protected?

—M. Herrick, Las Vegas

Gigi Kwik of the Center for Civilian Biodefense Strategies at Johns Hopkins University explains:

Edward Jenner, the English physician who first developed the smallpox vaccine in 1796, believed that vaccination caused a fundamental change in a person's constitution and would lead to lifelong immunity to smallpox. Unfortunately, it is now clear that this immunity wanes over time. A vaccination received 40 years ago most likely does not protect you against smallpox infection today, although it may help prevent a fatal outcome.

It is difficult to determine exactly how long the smallpox vaccine provides defense against the virus. Limited research continues with virus samples at the Centers for Disease Control and Prevention in the U.S. and at a Russian government laboratory in Koltsovo, but smallpox infections no longer occur naturally. Thus, modern scientific techniques cannot be brought fully to bear on this question.

Some researchers believe—but have never proved—that smallpox immunity rests on the presence of neutralizing antibodies in the blood, whose levels decline five to 10 years after an inoculation. With smallpox absent now in the wild, it is not possible to study the relation between antibody levels and susceptibility. Scientists do know, however, that having had a vaccination within five years of exposure offers good protection against smallpox; the effectiveness beyond 10 years is not so clear. Moreover, a 1968 CDC study of smallpox cases "imported" by ailing travelers into countries where the disease was not endemic found that mortality was 52 percent among the unvaccinated residents, 11 percent among those who had been vaccinated more than 20 years earlier and 1.4 percent for those vaccinated within 10 years.

If you think you have been exposed to the virus, you should definitely be revaccinated. Vaccination after exposure to an infected person, even as long as four days later, can prevent the disease. But be aware that the vaccine, which is actually a live virus similar to smallpox, is not as innocuous as a flu shot. Historically, about one in 1,000 smallpox vaccine recipients has experienced severe side effects, including rashes or heart problems, and about one in a million has died from the vaccine. People who are revaccinated are, in general, much less likely to suffer from side effects than those vaccinated for the first time. Risk may be higher for those who have eczema, for pregnant women and for those whose immune systems are impaired.

Why is the South Pole colder than the North Pole?

—E. Jenson, Camarillo, Calif.

Robert Bindschadler, senior fellow and glaciologist at the NASA Goddard Space Flight Center, offers this answer:

The high altitude of the South Pole and the land under it help to make the region the coldest on the planet. The lowest temperature ever recorded there by the permanently manned station was –80.6 degrees Celsius, whereas the most frigid temperature at the North Pole has been measured by satellites to a low of only –48.9 degrees C.

Of course, both polar regions of the earth are cold, primarily because they receive far less solar radiation than the tropics and midlatitudes do. Moreover, most of the sunlight that does shine on the two regions is reflected by the bright white surface.

At the South Pole, the surface of the ice sheet is more than two kilometers above sea level, where the air is much thinner and colder. Antarctica is, on average, by far the highest continent on the earth. In comparison, the North Pole rests in the middle of the Arctic Ocean, where the surface of floating ice rides just a foot or so above the surrounding sea. Unlike the landmass underneath the South Pole, the Arctic Ocean also acts as an effective heat reservoir, warming the cold atmosphere above it in the winter and drawing heat from the atmosphere in the summer. SA

MATT COLLINS

ASK THE EXPERTS

What causes insomnia?

—H. York, Builth Wells, Wales

Henry Olders, an assistant professor of psychiatry at McGill University who conducts sleep research, provides this answer:

People can lose sleep for a variety of reasons, including medications, alcohol, caffeine, stress and pain. When the underlying cause is removed, these bouts usually get better on their own. For some people, however, sleep problems turn into insomnia, the chronic inability to either fall asleep or stay sleeping. Research suggests that attitudes about sleep, and the resulting slumber patterns and behaviors, make certain individuals vulnerable to insomnia.

Many insomniacs feel they lack sufficient sleep, but evidence is mounting that they are getting at least as much as they require and possibly more. Insomniacs tend to go to bed early, stay there late and sleep during the day—all of which contribute to the problem.

Why would anyone spend more time asleep than he or she needs? Charles M. Morin of Laval University in Quebec found that insomniacs hold stronger beliefs than normal sleepers do about the detrimental effects of insomnia to physical and mental health and that they perceive their sleep as less controllable and predictable. Individuals with insomnia are more likely to be concerned about not sleeping and to think about problems, events of the day and noises in the environment before falling asleep. Simply put, if you are convinced that you need eight hours of sleep a night, you will arrange your bedtime and rising time so that you spend eight hours in bed. If you require only six hours of sleep, however, you will spend two hours tossing and turning.

How much sleep do you need? And how can you tell if you are getting the right amount? Although eight hours a night is a figure repeated so often that it has almost become an article of faith, the reality is that sleep need is highly individual. Large-scale epidemiological studies have demonstrated that sleeping seven hours a night is associated with the lowest mortality risk (for factors including heart disease, cancer and accidental death) compared with longer or shorter periods of shut-eye. In addition, it is probable that as we age, we need less sleep.

To help treat insomnia, practice "sleep hygiene." This includes adjusting the levels of noise, light and temperature so that you are comfortable; not reading or watching television in bed; avoiding excess food, alcohol, nicotine, caffeine and other stimulants before you turn in; completing exercise at least three hours before lights out; and then determining your optimum bedtime. The longer you are awake, the more slow-wave (delta) sleep you will have; slow-wave sleep is what leads to feeling rested and refreshed. Limiting the time you spend in bed may also help. Together these nonpharmacological approaches are more effective and longer-lasting than medications for insomnia.

Why is the sky blue?

—M. Nasrallah, Amman, Jordan

Anthony D. Del Genio of the NASA Goddard Institute for Space Studies and adjunct professor of earth and environmental sciences at Columbia University explains:

We can thank the scattering effect, which disperses nearly 10 times as much blue light in the atmosphere as light of longer wavelengths (such as red). Sunlight is a mixture of all colors. As sunlight passes through the atmosphere, it acts as a mixture of electromagnetic waves that causes the oscillation of charged particles (electrons and protons) in air molecules. This oscillation produces electromagnetic radiation at the same frequencies as the incoming sunlight, but the radiation is scattered in every direction.

The blue component of visible light has shorter wavelengths and higher frequencies than red. Thus, blue light makes charged particles oscillate faster than red light does. The result is that the scattered blue light is almost 10 times as prevalent as red light. Violet light is scattered even more than blue, but less violet light enters the atmosphere, and our eyes are more sensitive to blue.

A planet with no atmosphere cannot have a bright sky, because there is no scattering effect. Photographs taken by astronauts on the moon show a midnight-black sky. SA

MATT COLLINS

ASK THE EXPERTS

What makes Kansas, Texas and Oklahoma so prone to tornadoes?

—T. Irwin, Kissimmee, Fla.

Harold Brooks, head of the Mesoscale Applications Group at the National Oceanic and Atmospheric Administration's National Severe Storms Laboratory in Norman, Okla., explains:

The central part of the U.S. gets many tornadoes, particularly strong and violent ones, because of the unique geography of North America. The combination of the Gulf of Mexico to the south and the Rocky Mountains to the west provides ideal conditions for tornadoes to develop more often than any other place on earth. The central U.S. experienced a record-breaking week from May 4 through May 10 this year, when close to 300 tornadoes occurred in 19 states, causing 42 deaths, according to NOAA's National Weather Service.

Storms that produce tornadoes start with warm, moist air near the ground. Dry air is aloft (between altitudes of about three to 10 kilometers). Some mechanism, such as a boundary between the two air masses, acts to lift the warm, moist air upward. The boundary can be a front, dryline or outflow from another storm—essentially any kind of difference in the physical properties of two air masses. "Kinks" in the boundary are locations where rotation could occur. An updraft (air going up) traveling over the kink will "stretch" and intensify the rotation, just like an ice skater pulling in her arms.

Strong tornadoes are also most likely to happen when the horizontal winds in the environment increase in speed and change direction with rising altitude. In the most common directional change of this kind, winds at the surface blow from the equator, and winds a few kilometers above the ground blow from the west. When this wind pattern occurs in the central part of the U.S., the surface winds flow from the direction of the Gulf of Mexico, bringing in warm, moist air. The winds aloft, in contrast, come from over the Rocky Mountains and are relatively dry. As a result, when the winds over the central part of the U.S are optimal for making thunderstorms, they often combine the right distribution of atmospheric temperature and moisture to produce tornadoes as well.

MATT COLLINS

Are humans the only primates that cry?

—C. Henderson, Winter Park, Colo.

Kim A. Bard, a researcher in comparative developmental psychology at the University of Portsmouth in England, offers this perspective:

The answer to this question depends on how you define "crying." If it is defined as tears coming from the eyes, then the answer is yes: tears appear to be unique to humans among the primates. If you define crying as a vocalization that occurs under conditions of distress, or what humans might describe as sadness, then you can find it in almost all primates.

Others argue that all mammals have feelings, because emotions are the product of deep-brain functioning with a long evolutionary history. Some researchers reserve such emotional terms for humans alone and will not use such words for other primates. Some scientists take a conservative stance and say that it is too difficult to tell whether or not nonhuman primates have feelings. Rather than broadly describing particular primate vocalizations as crying, scientists prefer specific names for certain conditions. For example, a young primate that is not in contact with its mother produces a separation call. Researchers also describe what the vocalization sounds like, as with the "smooth early high" coos of Japanese macaques. Or scientists note what the animal is trying to communicate, such as when infants try to satisfy their basic needs for food, social contact or relief from pain. SA

ASK THE EXPERTS

What is game theory and what are some of its applications?

—B. Royce, New York City

Saul I. Gass, professor emeritus at the University of Maryland's Robert H. Smith School of Business, explains:

Game theory is a formal way of analyzing competitive or cooperative interactions among people who are making decisions—whether on a game board or in society at large. Starting simply, we can draw some generalizations about common games such as tic-tac-toe or chess. These games are said to have perfect information because all the rules, possible choices and past history of play are known to all participants. That means players can win such games by using a pure strategy, which is an overall plan that specifies moves to be taken in all eventualities that can arise in play. Games without perfect information, such as stone-paper-scissors or poker, offer no pure strategy that ensures a win. If a player employs one strategy too often, his or her opponent will catch on. This is where the modern mathematical theory of games comes into play. It offers insights regarding optimal mixes of strategies and the frequency with which one can expect to win.

Stone-paper-scissors is called a two-person zero-sum game, because any money one player wins, the other loses. Mathematician John von Neumann proved that all two-person zero-sum games have optimal strategies for both players. Such a game is said to be fair if both players can expect to win nothing over a long run of plays, as is the case in stone-paper-scissors, although not all zero-sum games are fair.

The power of game theory goes far beyond the analysis of these relatively uncomplicated games. In many-person competitive situations, some players can form coalitions against other players, games may have an infinite number of strategies, and there are nonzero-sum games, to name a few possibilities. Mathematical analysis of such games yields an equilibrium solution (a set of mixed strategies), one solution for each player, such that no one has a reason to deviate from that game plan (assuming all the players stick to their equilibrium approaches). As mathematician John Nash proved, any many-person, noncooperative, finite-strategy game has at least one equilibrium solution.

The greater significance of game theory is that such contests are metaphors for other interactions and can be used to analyze real-world situations, including missile defense, labor management negotiations and consumer price wars. It is important to note, however, that for many circumstances game theory does not really solve the problem at hand. Instead it helps to illuminate the task by offering a different way of interpreting the competitive interactions and possible results.

Why do we get goose bumps?

—D. Polevoy, Kitchener, Ontario

George A. Bubenik, a physiologist and professor of zoology at the University of Guelph in Ontario, offers this answer:

Getting goose bumps is a physiological phenomenon inherited from our mammalian ancestors that was useful to them but not much help to us. So named because they resemble the skin of poultry after the feathers have been plucked, goose bumps result from the contractions of miniature muscles attached to the hairs on our body. Each contracting muscle creates a shallow depression on the skin surface, which causes the area surrounding the hair to protrude and the hair to stand up. In animals with a thick coat the raised hairs expand the layer of air that serves as insulation. Humans lack a thick coat, but goose bumps persist, perhaps because contraction of the muscles around body hair constricts blood flow to the skin, reducing heat loss.

Hair will also stand up on many animals when they feel threatened, presumably to increase their apparent size and thus frighten potential attackers. Both this reaction and the hair-raising response to cold stem from the stimulation of the autonomic nervous system. Humans get goose bumps not only when they are cold but also in situations that elicit strong emotional responses—even when they hear favorite songs from long ago or watch a horror movie. SA

MATT COLLINS

ASK THE EXPERTS

How does spending prolonged time in microgravity affect astronauts?

—A. Kokacy, Newton, Tex.

Jeffrey Sutton, director of the National Space Biomedical Research Institute, and Nitza Cintrón, chief of NASA's Space Medicine and Health Care Systems Office, explain:

Space affects the body in many ways. A partial list of the consequences of long stays in microgravity (where the pull of Earth's gravity is virtually unnoticeable to humans) includes bone loss at a rate of 1 to 1.5 percent a month, producing changes similar to osteoporosis; an increased risk of kidney stones and bone fractures, both associated with bone demineralization; and loss of muscle mass, strength and endurance, especially in the lower extremities. Other changes are diminished cardiac function and the possible occurrence of heart rhythm disturbances, redistribution of body fluids away from the extremities and toward the head, and alterations in the neurovestibular system that often lead to disorientation and decreased neuromuscular coordination on return from prolonged missions. Disruptions of circadian rhythms because the 24-hour day-night cycle is absent result in sleep loss and stress, and the body experiences reduced blood volume, immunodeficiency and transient postflight decreases in levels of red blood cells, despite adequate nutritional intake.

MATT COLLINS

Space also presents health risks in the form of radiation, normally blocked by Earth's atmosphere. The space environment contains galactic cosmic rays, heavy ions such as iron, trapped electrons and protons, and neutrons. Such radiation can induce cataracts and cancer and adversely affect physiological processes.

To counter these dangers, mission planners have developed a variety of strategies. During prolonged missions, exercise is employed to minimize large-muscle atrophy. Certain tasks, such as extravehicular activities (spacewalks), are not performed routinely until bodily fluid redistribution stabilizes and astronauts have had an opportunity to acclimatize to space for several days. Medications have proved effective in treating motion sickness and orthostatic hypotension (low blood pressure when standing), and some drugs are potentially useful in reducing bone loss. Different lighting intensities and wavelengths are also being studied and implemented as a way to maintain astronauts' normal circadian cycle. To protect against space radiation, special shielding is installed on spacecraft.

How do geckos' feet unstick from a surface?

—S. Beres, Trumbull, Conn.

Kellar Autumn of Lewis & Clark College studies gecko adhesion and provides the following discussion:

The adhesive on the gecko's toes is quite different from a conventional tape. Instead of tacky polymers, geckos have arrays of millions of microscopic hairs—setae—on the bottom of their feet. Each seta ends in a smaller array of nanostructures, called spatulae, permitting intimate contact with surfaces.

Last year research colleagues and I discovered that setae adhere by weak intermolecular van der Waals forces—a function of the geometry of these nanostructures rather than their surface chemistry. This finding suggested that splitting any surface into small protrusions can make the surface sticky. With Ronald S. Fearing and Robert J. Full, both at the University of California at Berkeley, I have used this principle to make the first synthetic versions of the gecko adhesive.

Control of attachment and detachment in geckos is also a function of geometry, not chemistry. All 6.5 million setae on a gecko attached at once could lift 133 kilograms. This impressive gripping power raises the question of how geckos detach their feet in just 15 milliseconds. We learned that simply increasing the angle of the seta to 30 degrees causes detachment. Setae detach easily because the setal shafts act as levers to peel the spatulae away from the wall. The gecko's unusual toe-peeling behavior may also aid in reducing detachment forces by removing only a small number of setae at a time. SA

ASK THE EXPERTS

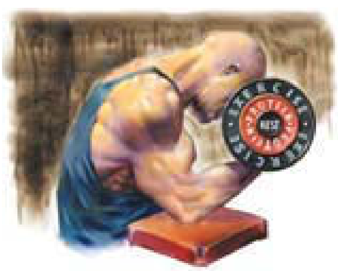
How does exercise make your muscles stronger?

—B. Thrall, St. Louis

Mark A. W. Andrews, professor of physiology and director of the independent study program at the Lake Erie College of Osteopathic Medicine, explains:

The exact mechanism by which exercise augments strength remains unclear, but its basic principles are understood. Two processes appear to be involved: hypertrophy, or the enlargement of cells, and neural adaptations that enhance nerve-muscle interaction.

Muscle cells subjected to regular bouts of exercise, followed by periods of rest that include a sufficient intake of dietary protein, undergo hypertrophy. (This should not be confused with short-term swelling resulting from water uptake into cells.) Improved muscle protein synthesis and incorporation of these proteins into cells cause the muscle-building effect. When a muscle cell is activated by its nerve cell, the interaction of the proteins responsible for muscle contraction—actin and myosin—generates force via changes in protein structure called power strokes. The total force generated depends on the sum of all the power strokes occurring simultaneously within all the cells of a muscle. Because more potential power strokes accompany an increased presence of actin and myosin, the muscle can exhibit greater strength of contraction. In addition, hypertrophy is aided by certain hormones and has a strong genetic component.



MATT COLLINS

The neural basis of muscle strength enhancement primarily involves the ability to recruit more muscle cells—and thus more power strokes—simultaneously. This process, called synchronous activation, is in contrast to the firing pattern seen in untrained muscle, where the cells take turns firing in a more asynchronous manner. Training also decreases inhibitory neural feedback, a natural protective response of the central nervous system to feedback arising from the muscle. Such inhibition keeps the muscle from overworking and possibly ripping itself apart as it creates a level of force to which it is not accustomed. This neural adaptation generates significant strength gains with minimal hypertrophy and is responsible for much of the strength gains seen in women and adolescents who exercise. It also utilizes nerve and muscle cells already present and accounts for most of the strength growth recorded in the initial stages of all strength training; hypertrophy is a much slower process, depending as it does on the creation of new muscle proteins. Thus, overall, the stress of repeated bouts of exercise yields neural as well as muscular changes to add to muscle strength.

What causes a mirage?

Edwin Meyer, professor of physics at Baldwin-Wallace College, provides this answer:

Mirages are caused by photons (particles of light) taking the path of minimum time as they travel through air of differing temperatures and densities.

Ideal conditions for a mirage are a hot, sunny day, when the air is still over a flat surface baked by the sun. The air closest to the surface is hottest, and thus the air density gradually increases with height. Incoming photons take a curved path from the sky to the viewer's eye. The standard freshman physics explanation for this phenomenon is that cooler air has a higher index of refraction than warmer air does. Accordingly, photons travel through hot, less dense air faster than they do through cool air. The quantum electrodynamics rationale is that photons always take the path of minimum time when traveling from one point to another. To get from one point to another in a minimum time, photons take shortcuts, even though the length of the path is curved and it covers a longer distance than the direct route.

Why does your brain see the mirage of water? The mirage occurs because past experience has taught you that when you look at a surface ahead and see the sky, you are *usually* looking at a reflection off of water. So when the conditions are right for a mirage, the brain assumes that water must also be present. SA

ASK THE EXPERTS

Why are blood transfusions not rejected, as can happen with organs?

—K. Dahlke, Troy, Mich.

Robertson D. Davenport, associate professor of pathology and medical director of the Blood Bank and Transfusion Service at the University of Michigan at Ann Arbor, explains:

Blood transfusions from strangers are less likely to be rejected than organ transplants, for three key reasons. First, transfusions are given intravascularly, or into the circulatory system. Immune responses to antigens (foreign substances) received intravascularly tend to be less pronounced than responses from other routes. Second, transplanted organs contain immune cells that can stimulate the recipient's defenses, whereas most such cells in the blood are filtered out before transfusion. Third, the body replaces transfused red blood cells within three months, reducing the chances that they will be recognized as "alien," whereas transplants may remain in place for many years.

SARA CHEN

Rejection of blood is relatively rare. The risk of an acute hemolytic reaction is about one in 80,000 units transfused. To understand this occurrence, it helps to review some basic immunology. The two main types of immune responses are humoral and cellular. Humoral responses produce antibodies specific to a foreign antigen. These antibodies may attach to the antigen, forming immune complexes; the liver and spleen destroy the complexes. The complexes can also activate the complement pathway. Complement activation can punch holes in the membranes of bacteria or cells coated with antibodies. Immune responses elicited by blood transfusions are usually humoral. Organ transplants, in contrast, usually evoke cellular immune responses, which lead to the creation of cell-killing agents called cytotoxic lymphocytes.

The key antigens in blood transfusions are in the ABO system. Blood types can be A (having A but not B antigens on red cells), B (having B but not A), AB (both A and B), or O (neither). Virtually everyone over the age of six months has antibodies to the antigens they don't produce. A patient who receives blood with the wrong antigens can have a serious reaction, including breakdown of red cells and a strong inflammatory response that could lead to kidney failure or even death.

More common is a delayed hemolytic reaction, occurring in one in 5,000 units transfused. The antigens involved are usually not in the ABO system but in one of the other 25 known blood group systems, such as Rh (Rhesus). The antibodies produced tend not to activate complement, so the transfused cells are not usually broken down. Instead the spleen removes the cells, and a milder inflammatory response may occur days to weeks after the transfusion; sometimes this reaction can lead to renal failure.

How can deleted computer files be retrieved at a later date?

Clay Shields, professor of computer science at Georgetown University, offers this answer:

"Deleted" files can be restored because they aren't really gone—at least not right away. This is because it is faster and more efficient for computers to overwrite data only when necessary, when no other space is available to write new data.

A computer stores information in chunks called sectors. A file may be written across several sectors and might be scattered around the disk. The operating system keeps an index of which sectors belong to which files and a directory that maps the file names to the index entries.

When a user deletes a file, its directory entry is either removed or labeled as deleted. A deleted file can thus be salvaged if the index information and sectors have not yet been reused.

Such recovery is easy in operating systems that simply mark directory entries as deleted. A program scans the directory for deleted entries and presents a menu of files to recover. In other types of systems, recovery is more complicated. The directory entries may be lost, making it harder to find the file. The recovery program must look through all the index information and piece together files from various sectors. Because sectors may have been reused, only parts of the file may be accessible. SA

Q How do dimples on golf balls affect their flight?

—T. Grinham, Manchester, England

Tom Veilleux, a senior scientist, and Vince Simonds, director of aerodynamic research at the Top-Flite Golf Company, explain:

Dimples reduce drag and improve lift, so golf balls fly farther. A smooth golf ball hit by a professional would travel only about half as far as one with dimples.

Engineers and scientists in the golf industry study the impact between a golf club and a ball to determine the so-called launch conditions. The impact, which typically lasts just 1⁄2,000 of a second, establishes the ball's velocity, launch angle and spin rate. Gravity and aerodynamics then take over the ball's trajectory (no matter how much the golfer hopes or curses). As a result, aerodynamic optimization—achieved through dimple-pattern design—is critical.

Air exerts a force on any object, such as a golf ball, moving through it. Holding your arm out of the window of a moving car easily illustrates this phenomenon. Aerodynamicists break down the force into two components: lift and drag. Drag acts to oppose motion, whereas lift acts in a direction perpendicular and upward to motion.

A speeding golf ball has a high-pressure area at its front. Air flows over the front contours and eventually separates from the ball toward the back. The ball also leaves behind a turbulent wake region, where the airflow is fluctuating or agitated, resulting in lower pressure at the rear. The size of the wake affects the amount of drag. Dimples create a thin, turbulent boundary layer of air that clings to the ball's surface. This design allows the smoothly flowing air to follow the ball's shape a little farther around the backside, decreasing the size of the wake. A dimpled ball thus has about half the drag of a smooth ball.

Most golf balls have between 300 and 500 dimples, which each have an average depth of about 0.010 inch. The lift and drag forces are very sensitive to dimple depth: a difference of as little as 0.001 inch can produce radical changes to trajectory and travel distance. Dimples have traditionally been spherical, but other shapes can also optimize aerodynamic performance; the HX golf ball by Callaway, for example, uses hexagons.

Dimples also affect lift. A smooth ball with backspin creates lift by warping the airflow such that the ball acts like an airplane's wing. The spinning action makes the air pressure on the bottom of the ball higher than the air pressure on the top; this imbalance creates an upward force on the ball. Ball spin contributes about one half of a golf ball's lift. The other half is provided by the dimples, which allow for optimization of the lift force. [For more on golf-ball lift, see "Flight Control," by Mark Fischetti, Working Knowledge; Scientific American, June 2001.]

Q How does club soda remove red wine stains?

—K. Hug, New Bern, N.C.

Biochemist Pete Wishnok of the biological engineering division at the Massachusetts Institute of Technology provides an answer:

There is no particularly good chemical reason why club soda should remove stains: it is essentially water with carbon dioxide and salts dissolved in it. It is weakly acidic, so it might decolorize stains that can act as acid-base indicators.

Club soda does seem effective on occasion. It has worked dozens of times for wine spills on our living room carpet (which probably says more about our lifestyle than it does about club soda). But it did not work at all on the tablecloth during Christmas dinner (the laundromat did the trick the next day).

A common theory suggests that the secret ingredient is the bubbles, and there may be something to that. Probably more important, however, is the fabric involved and how fast you can run. If your carpet is a synthetic that absorbs stains slowly—and if you arrive quickly with lots of paper towels—the club soda may simply act as a carrier in blotting everything up. It may also dilute the wine and help keep the color from setting so that a detergent can finish the job later. A particular stain remover might work better with certain fabrics, so it is a good idea to keep a few cleaning agents, other than club soda, handy. My conclusion: if club soda works, plain water probably works as well. SA

SARA CHEN

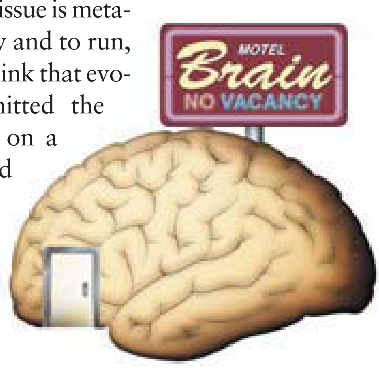
ASK THE EXPERTS

Do we really use only 10 percent of our brains?

Barry L. Beyerstein of the Brain Behavior Laboratory at Simon Fraser University in Vancouver offers this answer:

Perhaps it is unwelcome news, but neuroscience has found no vast, unused cerebral reservoir for us to tap. In addition, a study of self-improvement products by a National Research Council panel found that no "brain booster" is a reliable substitute for practice and hard work when it comes to getting ahead in life.

Why would a neuroscientist immediately doubt that 90 percent of the average brain lies perpetually fallow? First of all, it is obvious that the brain, like all other organs, has been shaped by natural selection. Brain tissue is metabolically expensive to grow and to run, and it strains credulity to think that evolution would have permitted the squandering of resources on a scale necessary to build and maintain such a massively underutilized organ.



SARA CHEN

Moreover, doubts are fueled by ample evidence from clinical neurology. Losing far less than 90 percent of the brain to an accident or disease has catastrophic consequences. There does not seem to be any area of the brain that can be destroyed by stroke or other trauma without leaving the patient with some kind of functional deficit. Likewise, electrical stimulation of points in the brain during neurosurgery has failed so far to uncover any dormant areas where no perception, emotion or movement can be elicited by applying these tiny currents. (This can be done with conscious patients under local anesthetic because the brain itself has no pain receptors.) With the aid of tools such as EEGs, magnetoencephalographs, PET scans and functional MRIs, researchers have succeeded in localizing a myriad of psychological functions to specific centers and systems in the brain. With nonhuman animals, and occasionally with human patients undergoing neurological treatment, recording probes can even be inserted into the brain itself. Despite this detailed reconnaissance, no quiet areas awaiting new assignments have emerged.

The 10 percent myth has undoubtedly motivated many people to strive for greater creativity and productivity in their lives—hardly a bad thing. The comfort, encouragement and hope that it has engendered help to explain its longevity. But like so many uplifting myths, the truth of the matter seems to be its least important aspect.

How can the weight of Earth be determined?

—A. Thor, San Diego, Calif.

Michael Wysession, associate professor of earth and planetary sciences at Washington University, explains:

I think the reader is really asking about the mass, rather than the weight, of Earth. But we can still solve this problem using a bathroom scale, which you might typically use to weigh something.

As is often the case in physics, fairly complicated things can be described very well with a simple equation. To determine Earth's mass, we can use the formula $g = G \times$ (mass of Earth)/distance to Earth's center^2. The rate at which an object accelerates as a result of the force of gravity, called g, depends on the mass of the object doing the pulling. From many decades of careful experiments we know G, the gravitational constant, 6.67×10^{-11} ($m^3\ kg^{-1}\ s^{-2}$), where m is meters, kg is kilograms and s is seconds. And we know how far a person standing on the surface is from the planet's center (6,371 kilometers).

To solve the problem, you can drop your bathroom scale out the window and count how many seconds it takes to hit the sidewalk. Then measure the distance from the window to the ground, and you can compute the acceleration of the scale. The answer you will get is 9.8 meters per second per second. Knowing this value of g, along with the constant G and the distance to Earth's center, you can then calculate Earth's mass to be 6×10^{24} kilograms. (You also won't be bothered by bad news from your scale anymore.) SA

ASK THE EXPERTS

What causes hiccups?

—J. Nowak, Torrevieja, Spain

William A. Whitelaw, a professor in the Respiratory Research Group at the University of Calgary in Alberta, explains:

Scientists have an incomplete understanding of what causes hiccups; they also do not know what purpose hiccups serve. A long list of medical disorders seems to be associated with hiccups. By far the most common are distension of the stomach and the resulting reflux of stomach acid into the esophagus. A disease or an irritation in the chest could be to blame. Hiccups may arise from a variety of neurological abnormalities, many of them involving the brain stem. Metabolic and other disorders, as well as medications that cause acid reflux, have also been linked to hiccups.

Several things happen in quick succession when a person experiences a hiccup. First the roof of the mouth lifts, as does the back of the tongue, often accompanied by a burp. Then the diaphragm and the entire set of muscles used for inhaling come together in a sudden, strong contraction. Just after that contraction begins, the vocal chords clamp shut, making the "hic" sound. The heart slows a bit. Hiccups tend to recur every few seconds, sometimes continuing for hours.

These observations imply that somewhere in the brain a central pattern generator, or CPG, exists for hiccups. In other words, we have a neural circuit designed for generating hiccups similar to those for actions such as breathing, coughing and walking. The hiccup CPG is most likely left over from a previous stage in evolution. A search through the animal kingdom for activity that resembles a hiccup turns up a few candidates. One is the CPG for gasping, a sudden intake of breath that can occur in rhythmic succession. In a recent paper, our research team argued that a better candidate is the CPG used by tadpoles for gill ventilation. Halfway through its development, a tadpole has both lungs that breathe air and gills that extract oxygen from water. The pressure-pump action of the tadpole's mouth at this stage is nearly the same action as hiccuping.

According to evolutionary theory, the CPG probably would not be preserved unless it served some purpose. One possibility is that the hiccup CPG directs suckling in infants, to ensure that milk does not get into the lungs. Another possibility is that the CPG controls burping to clear gas from an overfilled stomach.

How do sunless tanners work?

—F. Georgina, Fairbanks, Alaska

Randall R. Wickett, professor of pharmaceutics and cosmetic science at the University of Cincinnati College of Pharmacy, offers this explanation:

Sunless tanners dye skin darker by means of several chemical reactions. The active ingredient is the compound dihydroxyacetone (DHA). DHA is a sugar that reacts with proteins on the top layer of the skin, turning that layer brown. This process, known as the Maillard reaction, occurs frequently in food preparation and is responsible for the caramelization of sugars and the golden-brown color of beer. The tan formation sometimes emits a starchy odor that is difficult to mask with perfume.

The products of sunless tanning absorb a little less red light than skin pigments do when reacting with the sun, which can lead to orange coloration. Newer formulations use lower DHA concentrations, creating a tan that is more natural-looking. A number of products contain the sugar erythrulose, found in red berries, which adds a bit of red to the tone.

Sunless tanners are not without drawbacks. Color can be inconsistent if the product is applied unevenly. They offer no protection against sunburn and do not last as long as a real tan. Because only the uppermost layer of skin is stained and this layer is continually shed, it takes about three weeks for the tan to slough off; the use of exfoliating products speeds this process. SA

SARA CHEN

Why is the fuel economy of a car better in the summer ?

—C. Staf, New York City

Harold Schock, professor of mechanical engineering and director of the Automotive Research Experiment Station at Michigan State University, explains:

Temperature and precipitation affect the inner workings of a vehicle and the actions of its driver, both of which have an impact on the mileage. In cold, snowy weather, the fuel economy during trips of less than 10 minutes in urban stop-and-go traffic can easily be 50 percent lower than during operation of the same vehicle in light traffic with warm weather and dry roads.

Auto components such as electric motors, engines, transmissions and the axles that drive the tires consume more energy at low temperatures, especially during start-up. Oil and other fluids become more viscous as temperatures drop, which means that more work—and thus fuel—is required to overcome friction in the drive-train components. In addition, the initial rolling resistance of a tire is about 20 percent greater at zero degrees Fahrenheit than it is at 80 degrees F. This rolling resistance decreases as the vehicle starts to move, and in trips of a few miles the temperature rise—and its effect on mileage—is modest.

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The aerodynamic drag acting on a vehicle increases in colder weather as well. Air density is 17 percent lower on a hot, 80-degree day than it is on a cold, zero-degree day. This percentage makes little difference in city driving, but on an open highway the colder temperature reduces mileage by about 7 percent, even taking into account the improvement in fuel efficiency that cars typically experience during highway driving.

Personal driving habits can also have a major effect on the efficiency slide. In winter, we use heater motors, defrosters and windshield wipers to keep our fingers warm and our sight line clear. We often bring the automobile interior to a comfortable temperature before driving and then keep our engines idling to maintain that temperature when we have to wait in the car.

In any season, you can improve your mileage with a few simple steps: Keep tire pressure at the recommended level (lower pressure reduces mileage). Avoid storing excessive weight in the car and driving in heavy stop-and-go traffic. Finally, courteous, careful motorists have lower gas-pump bills than those who employ frequent acceleration and braking.

Why does inhaling helium make one's voice sound strange?

—C. Graves, Renville, Minn.

Craig Montgomery, chair of the chemistry department at Trinity Western University in British Columbia, provides an answer:

The culprit is the difference between the density of the helium in one's larynx and that of the nitrogen and oxygen that make up most of the air a person normally breathes. Per given unit of volume, any type of gas contains the same number of particles. But because helium atoms have approximately one seventh the mass of nitrogen molecules, the density of helium is about one seventh that of air.

To explain how the voice change happens, we first have to discuss some basics about sound. Sound waves form when something, such as vocal cords or a drum skin, vibrates in a medium, such as air. As the skin of a drum moves upward, it compresses the gases above it. Each successive down-up motion of the skin creates additional compression, and this series of moving compressions constitutes sound waves. The frequency is the number of compressions created in a given period.

Like that of a drum, the vibration frequency of vocal cords is independent of the type of medium through which the waves pass. Because the pitch of a tone depends on the wave frequency, inhaling helium does not alter the pitch of the voice. Rather the density of the medium affects the velocity of the sound waves, as well as the timbre of the tone. (The timbre is what makes middle C on a piano sound different from middle C played on, say, a cello.) That's why, if you listen closely to a person who has just inhaled helium, you will notice that his or her voice is not squeaky but instead sounds more like Donald Duck's. SA

ASK THE EXPERTS

Why do some expectant fathers experience pregnancy symptoms?

—D. Barrera, McAllen, Tex.

Katherine E. Wynne-Edwards, a professor of biology at Queen's University in Kingston, Ontario, who studies hormonal changes in expectant fathers, offers an answer:

Many factors—from social to hormonal—could play a role when an expectant father experiences pregnancy side effects such as nausea, weight gain, mood swings and bloating. The condition is called couvade, from the French verb *couver,* which means "to hatch" or "to brood."

The prevalence of couvade is difficult to measure because of its varied definitions and the skewed rates of symptom reporting. In modern Western populations, estimates of couvade's frequency range from less than 20 percent to more than 80 percent of expectant fathers.

Only recently has this phenomenon received attention from biologists, spawning a variety of hypotheses. For one, change in one partner's lifestyle can affect the other's: the cravings and increased appetite of a pregnant woman may pave the way for the father's weight gain, heartburn and indigestion. The mother's feelings can range from frustrated incapacitation to boundless anticipatory joy, fostering in the father jealousy of the ability to carry a child, guilt over having caused this sometimes unwelcome transformation in his partner and selfish attention seeking. Changes in sexual activity, shifts in social priorities, time off from work, or the arrival of a relative for a potentially stressful extended visit may also contribute.

Recent studies have shown that some of the same hormones that fluctuate in pregnant women may be affected in future fathers, making male hormones another factor. Men with higher levels of prolactin, which causes lactation in women, report more couvade symptoms, and their paternal prolactin peaks just before delivery. Levels of cortisol (a steroid hormone secreted in response to stress) and the sex steroids estradiol and testosterone also change in the father, though not as significantly as those in the mother.

Unfortunately, we don't yet know whether such hormonal changes and behaviors are cause-and-effect patterns or just coincidental. It is certainly tempting to look to hormones as the definitive root of couvade, but social and emotional factors could be equally influential. Either way, questions in this area have quietly expanded the horizons for research on male hormone levels—testosterone alone is clearly no longer the sum of the man.

Why does a shaken soda fizz more than an unshaken one?

—P. Biesemeyer, Malone, N.Y.

Chemist Chuck Wight of the University of Utah explains:

The short answer is that shaking = bubbles = fizz = sticky mess on your floor. But there's more to it than that. Creating bubbles in a soft drink takes a surprising amount of energy, and the turbulence caused by shaking a can or pouring it quickly into a glass speeds up their formation.

The tingly texture of a soft drink comes from dissolved carbon dioxide molecules that escape as bubbles from an open can, causing the soda to go flat. Forming bubbles requires the gas to overcome the surface tension of the liquid and part its surface molecules, a feat that requires a relatively large amount of energy. Once a bubble is formed, a smaller amount of work is needed to expand the bubble by vaporizing additional carbon dioxide molecules. (Less energy is needed because as a bubble grows, its volume increases faster than its surface area.)

Shaking the can introduces lots of small bubbles into the liquid, allowing the dissolved gas to vaporize more easily by joining existing bubbles. Having circumvented the difficult step of bubble formation, the gas can escape more quickly from shaken soda, resulting in more fizz. SA

SARA CHEN

ASK THE EXPERTS

How do scientists know the composition of Earth's interior? —J. Gerber

Arthur Lerner-Lam, associate director for seismology, geology and tectonophysics at the Lamont-Doherty Earth Observatory at Columbia University, explains:

Because we cannot extract samples directly from the deep Earth, we must deduce its composition. Scientists look at the clues hidden in rocks that are igneous (volcanic) or metamorphic (those that have changed after exposure to high pressures and temperatures underground). They also examine proxies for composition and structure, such as the three-dimensional variation of the velocity of seismic waves produced by earthquakes, which are sampled by networks of seismometers on the surface of the planet.

The late Francis Birch, the eminent Harvard geophysicist, and his colleagues and students worked out the basic methodology that brings these distinct observations together. Birch showed how the stiffness of rocks changes under the extreme conditions of pressure and temperature deep within planets. Because the speed of seismic waves depends on the stiffness of the medium through which they propagate, it is possible to calculate temperature and composition from maps of seismic velocity. Most current research is based on Birch's work, and it has even been extended to the most extreme temperature and pressure conditions of Earth's core. For example, much of our understanding of the large- and small-scale convection patterns driving plate tectonics has come about by using Birch-type proxies for temperature and composition.

How can we improve our knowledge of the other planets? Manned and unmanned missions to the moon and Mars deployed seismometers, which provided tantalizing, but ultimately limited, information before they stopped operating (although the Spirit and Opportunity rovers continue to transmit chemical analyses and pictures of the Red Planet back to Earth). Almost all planetary landing missions now in the design stage include seismological instrumentation, and some even plan to return rock samples to Earth. We hope the best geoscience is yet to come.

How does decanting red wine affect its taste? And why not decant white? —J. Eastley, Pittsburgh, Pa.

Andrew L. Waterhouse, a professor in the department of viticulture and enology at the University of California at Davis, provides an answer:

Decanting—simply pouring wine into another container—can mellow the flavor of harsh younger red wines by exposing them to oxygen; it also serves to remove sediments in older vintages. White wines, which are aged for shorter periods, do not benefit from decanting.

Some young red wines—between three and 10 years old—can be astringent if consumed directly after opening the bottle because they are maintained in an environment relatively free of oxygen during aging. Over time, these conditions result in a "closed" character for the wine that comes from the accumulation of particular compounds. A wine's aroma changes during the first 10 to 30 minutes after opening. Decanting accelerates this so-called breathing process, which increases the wine's aroma from natural fruit and oak, by allowing a few volatile substances to evaporate. Decanting also appears to "soften" the taste of the tannins that cause harshness and astringency, although chemists have not detected noticeable changes to the tannins. Less dramatic changes result from just uncorking the bottle 15 to 60 minutes before pouring. In older wines, decanting also serves to remove sediments, which are harmless but make wine look cloudy and taste gritty. Unlike younger wines, older wines should be served immediately after decanting—the "bottle bouquet" can be fleeting.

The author would like to thank Kay Bogart for her help in preparing this answer. SA

MATT COLLINS

ASK THE EXPERTS

Q Why is life expectancy longer for women than it is for men?

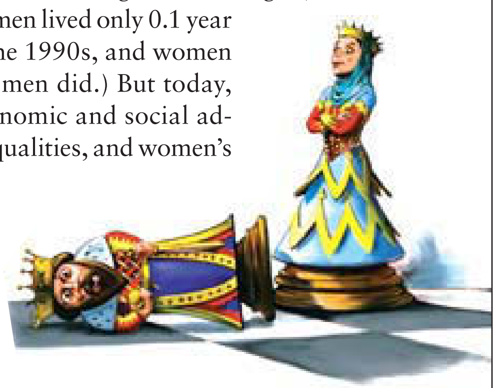
—E. Baierl, Lake Elmo, Minn.

Bertrand Desjardins, a researcher in the demography department of the University of Montreal, explains:

Both biological and social factors affect life expectancy. Biology strikes first: during the 12 months of infancy (in the absence of any outside influence), male mortality is typically 25 to 30 percent greater than female mortality. Some 105 males are born for every 100 females, ensuring that the number of men and women will be about the same at reproductive age. Hormones also play a role in longevity. The female hormone estrogen helps to eliminate "bad" cholesterol (LDL) and thus may offer some protection against heart disease. In contrast, testosterone, found in greater amounts in males, may make men more likely to engage in violence and risk-taking behavior. The female body's ability to adapt to pregnancy and breast-feeding appears to help women manage excess calories more easily than men do. Finally, women gain an additional biological advantage because of their two X chromosomes. If a gene mutation occurs on one X, women's second X chromosome can compensate. In comparison, all the genes on men's sole X chromosome are expressed, even if they are deleterious.

Biology is not the whole story, however: social factors contribute a great deal to longevity. Although male and female life habits have been converging in the industrial world, this convergence is not absolute. Females tend to smoke fewer cigarettes, drink less alcohol and drive more carefully. On average, their professional activities are less prejudicial to their health.

In the past, women's social status and life conditions, such as the hardships associated with childbirth, nullified their biological advantage. (In some countries, this effect continues today. Women lived only 0.1 year longer than men in Bangladesh in the 1990s, and women in India lived 0.6 year longer then men did.) But today, at least in industrial countries, economic and social advances have largely erased status inequalities, and women's life expectancy is longer than that of men. For example, in the 1990s U.S. women lived 6.7 years longer than U.S. men, and women in the U.K. and France lived 5.3 years and 7.8 years longer, respectively, than the men in those countries. SA



MATT COLLINS

ASK THE EXPERTS

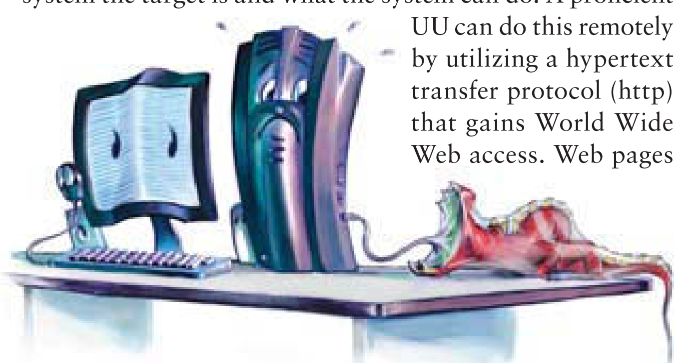
How do computer hackers "get inside" a computer?

—D. Ikavuka, La Mirada, Calif.

Julie J.C.H. Ryan, assistant professor at George Washington University and co-author of *Defending Your Digital Assets against Hackers, Crackers, Spies, and Thieves*, explains:

Essentially, hackers get inside a computer system by taking advantage of software or hardware weaknesses that exist in every system. Before explaining how they do this, a few definitions are in order. The term "hacker" is fairly controversial: some use this word to describe those whose intrusions into computer systems push the boundaries of knowledge without causing intentional harm, whereas "crackers" want to wreak havoc. I prefer "unauthorized user" (UU) for anyone who engages in unsanctioned computer access. "Getting inside" can mean one of three things: accessing the information stored on a computer, surreptitiously using a machine's processing capabilities (to send spam, for instance) or capturing information being sent between systems.

So how does a UU get inside a computer? The easiest weakness to exploit is a poorly conceived password. Password-cracking programs can identify dictionary words, names and even common phrases within a matter of minutes. Many of these programs perform a "dictionary attack": they take the encryption code used by the password system and encrypt every word in the dictionary. Then the UU plugs in the encrypted words until the password match is found. If a system has a complex password, the UU could try a "technical exploit," which means using technical knowledge to break into a computer system (as opposed to nontechnical options such as stealing documentation about a system). This is more challenging, because the UU must first learn what kind of system the target is and what the system can do. A proficient UU can do this remotely by utilizing a hypertext transfer protocol (http) that gains World Wide Web access. Web pages usually record the browser being used. The UU could write a program that takes advantage of this procedure, making the Web page ask for even more information. With this knowledge in hand, the UU then writes a program that circumvents the protections in place in the system.



Although you cannot eliminate all possible weaknesses, you can take steps to protect against unauthorized access. Make sure you have the latest patches for your operating system and applications. Create a complex password with letters, numbers and symbolic characters. Consider installing a firewall program, which blocks unwanted Internet traffic. Make sure your antivirus software is up-to-date and check frequently for new virus definitions. Finally, back up your data, so you can recover important material if anything does happen.

Why do traffic jams sometimes seem to appear out of nowhere?

— H. Smith, New York City

Benjamin Coifman, assistant professor of electrical and computer engineering at Ohio State University who studies traffic patterns, offers this answer:

Drivers encounter the end of the line in a traffic jam seemingly out of nowhere because the number of waiting cars could stretch several miles away from the original bottleneck. The bottleneck could have arisen because of an accident or because of features in the roadway, such as a sharp curve, where drivers must slow down. The difference between the bottleneck's capacity and the demand upstream determines how fast the line grows. The end of the line typically has the worst conditions because cars there suffer from accumulated delays caused by the original obstruction, especially since vehicles entering from ramps worsen the problem by occupying additional space. Speeds tend to improve as drivers progress, making it easy to miss the actual trouble site when you finally pass it. SA

MATT COLLINS

Why do bags form below our eyes?

—K. Davin, Juneau, Alaska

Rhoda S. Narins, clinical professor of dermatology at New York University Medical Center and president of the American Society for Dermatologic Surgery, explains:

Dark circles and bags under the eye occur for several reasons: the skin there is much thinner than it is elsewhere on the body and becomes looser as we age. This very thin skin also sits on top of underlying purple muscle and blood vessels and therefore appears darker. In addition, some people have hereditary pigmentation in this area. As we age, fat comes out of the space enclosed by the eye socket, called the orbit, and forms a puffy area under the eye. This fatty tissue can fill with water, making the hollow appear even deeper. The condition becomes even more noticeable when water is retained in the fat pad, which can occur for a variety of reasons, including eating too much salt, lying flat in bed, not getting enough sleep, allergies and monthly hormonal changes.

Treating the hollow space under the eye is straightforward and can be done by injecting a filler such as Restylane. Immediately after this procedure, the so-called tear trough is softened, and any visible pigmentation becomes noticeably lightened. A carbon dioxide (CO_2) laser also can be used to resurface the skin, which tightens and thickens it as well as lightening the coloring. For hereditary pigmentation, CO_2 laser resurfacing and bleaching creams are sometimes helpful. As an option, a surgeon can perform blepharoplasty to fix the fat pad under the eye.

Simple, nonsurgical measures to reduce the puffiness and darkness of under-eye circles include avoiding salt, using cold compresses on the eyes, getting enough sleep, treating allergies, as well as sleeping with your noggin higher by resting it on two pillows or raising the head of the bed.

How are the abbreviations of the periodic table determined?

Michael R. Topp, professor of chemistry at the University of Pennsylvania, offers this answer:

Although some of the symbols in the periodic table may seem strange, they all make sense given a little background information. For example, the symbol for the element mercury, Hg, comes from the Latin word *hydrargyrum,* meaning "liquid silver." Many other elements that were known to the ancients also have names derived from Latin.

The rare (or inert) gases were discovered more recently and tend to have classical-sounding names based on Greek. For example, xenon (Xe) means "the stranger" in Greek and argon (Ar) means "inert." Helium (He) is named after the Greek god of the sun, "Helios."

So far 110 elements have been formally named. The "new" elements are synthetic, and each one's detection needs confirmation. After the finding is confirmed, the discoverers may propose a name, and then the moniker is officially determined jointly by the International Union of Pure and Applied Chemistry (IUPAC) and the International Union of Pure and Applied Physics (IUPAP).

The proposal to name element 111 roentgenium (Rg), for instance, has been recommended for approval by the Inorganic Chemistry Division Committee of IUPAC. As it states: "This proposal lies within the long-established tradition of naming elements to honor famous scientists. Wilhelm Conrad Roentgen discovered x-rays in 1895."

As yet undiscovered elements with higher atomic numbers receive so-called placeholder names, which are simply Latinized versions of their atomic numbers. Thus, element 111 was formerly designated unununium, literally "one one one" (Uuu), and element 112 has been given the temporary name of unbiunium (Uub). SA

MATT COLLINS

ASK THE EXPERTS

How long can a person survive without food?

—Carlos Santiago, Dominican Republic

Alan D. Lieberson, an M.D., attorney and the author of *Treatment of Pain and Suffering in the Terminally Ill and Advance Medical Directives*, explains:

The duration of survival without food is greatly influenced by body weight, genetic variation, other health considerations and, most important, the presence or absence of dehydration.

Without liquids or food, people typically perish after 10 to 14 days. (Depending on whether the individual is dehydrated or overhydrated at the outset, the time may range from approximately one to three weeks.) This situation comes up frequently in two medical groups—the incompetent, terminally ill patients for whom artificial maintenance of life is no longer desired and the individuals who, though not necessarily terminally ill or incompetent, decide to refuse food and hydration to end their own lives.

MATT COLLINS

In cases where healthy individuals are receiving adequate hydration but no food, reliable data on survival are hard to obtain. Mahatma Gandhi, the famous nonviolent petitioner for India's independence, survived 21 days of complete fasting while allowing himself only sips of water. A 1997 article in the *British Medical Journal* by Michael Peel, senior medical examiner at the Medical Foundation for the Care of Victims of Torture, cites well-documented studies reporting survivals of other hunger strikers for 28, 36, 38 and 40 days. But most such reports have been poorly substantiated.

Unlike total starvation, near-total starvation with continued hydration has happened frequently. Survival for many months to years is common in concentration camps and during famines. The body can moderate metabolism to conserve energy. The alteration of metabolism is not well understood, but it occurs at least in part because of changes in thyroid function. This ability may help explain the evolutionary persistence of genes causing diabetes, which in the past could have enabled survival during famine by fostering more economical use of energy.

Medical practitioners encounter cases of near-total starvation in patients suffering from, among other conditions, anorexia nervosa and end-stage malignancies, as well as in those adhering to "starvation" diets. Death may result from organ failure or heart attack when a person's weight corresponds to a body mass index (BMI) of approximately half of what is normal, or about 12 to 12.5. Normal BMI is 18.5 to 24.9, and many fashion models have a BMI of around 17.

How do scientists detect new elements that last only milliseconds?

—J. Adams, Jesup, Ga.

Todd M. Hamilton, associate professor and chair of the department of chemistry at Adrian College, provides an answer:

Even elements that exist only briefly before decaying leave behind a calling card, in the form of an energy signature. The challenge for researchers is detecting that fleeting signal.

When a heavy element disintegrates, or decays, it gives off a unique radiation signature. Alpha-particle (essentially a helium nucleus) emission is the type most commonly used, because it gives off distinct energies.

Scientists make heavy elements by smashing together two elements that add up to the mass of the desired new element. One element, the projectile, is sped up in a cyclotron or other particle accelerator and shot at the second, the stationary target. Sometimes it takes millions of collisions and several weeks of bombardment to generate one atom of the new element.

In addition to using the unique energies of emitted alpha particles to identify new elements, heavy-element hunters turn to a cascade of alpha emissions to confirm their existence. Assembling all of this information is tricky business, but it can serve as convincing evidence that a new element was, in fact, created. SA

ASK THE EXPERTS

What is the fastest event that can be measured?

—R. Mitchell, Melbourne, Australia

Scott A. Diddams and Thomas R. O'Brian of the Time and Frequency Division of the National Institute of Standards and Technology offer an explanation:

The answer depends on how one interprets the word "measured." Both the accurate measurement of fleeting events and the recording or inference of such occurrences are of interest. So we suggest rephrasing the original query into two new ones: "What are the shortest time spans that can be measured with a particular accuracy?" and "What are the briefest happenings that can be recorded or inferred?"

Currently cesium atomic-fountain clocks are the best way to measure time with a certain accuracy. These "clocks" are actually frequency standards rather than timekeeping devices, and they achieve the defined cesium standard frequency with the exceptional precision of about one part in 10^{15}. Put another way, in 30 million years of continuous operation, they would neither gain nor lose more than a second. Yet these frequency standards are rather "noisy," and to achieve such impressive results requires averaging many thousands of separate frequency measurements over a period of about one day. So fountain clocks are not generally useful for timing short-duration events.

Among the shortest-period events that can be directly created, controlled and measured are quick bursts of laser light. These pulses occur on timescales of femtoseconds (10^{-15} second) and, more recently, attoseconds (10^{-18} second). Femtosecond pulses can function in a manner similar to the flash on a camera used to "freeze" events that are too fast for the eye to register. A source of femtosecond-order light pulses is a mode-locked laser, in which many optical waves cooperate to produce a pulse. It is yet another problem, however, to accurately measure that pulse's duration. No photodetectors or electronics are fast enough, so scientists commonly employ correlation techniques that translate a temporal measurement into a distance measurement. To date, pulses as short as a few hundred attoseconds have been generated and measured.

Now let us consider the second question, regarding the most transitory episodes that we can record or infer. Events as short as about 10^{-25} second have been indirectly inferred in extremely energetic collisions in the largest particle accelerators. For example, the mean lifetime of the top quark, the most massive elementary particle so far observed, has been inferred to be about 0.4 yoctosecond (0.4×10^{-24} second).

Why is normal blood pressure less than 120/80? Why don't these numbers change with height?

Jeffrey A. Cutler, senior scientific adviser for the National Heart, Lung, and Blood Institute at the National Institutes of Health, responds:

The origin of the designation of 120/80 as the threshold for "normal" blood pressure is unknown. (The top number is the systolic pressure, which is the pressure in the arteries while the heart is pumping; the bottom is the diastolic pressure, a measure of pressure in the arteries while the heart is resting and refilling with blood.) It may have come from data available early in the 20th century from life insurance physical exams. In any case, epidemiological studies confirm that the risk of a heart attack or stroke begins to increase in adults when the systolic is 115 or greater or the diastolic is 75 or more. The risk steadily increases with higher and higher readings, so the traditional 120/80 level remains a reasonable guideline for getting a doctor's attention, with the main goal of preventing your pressure from continuing to rise in subsequent years.

Blood pressure does in fact increase with height, ensuring that the brain, located at the uppermost point of the circulatory system for most of the day, gets sufficient blood flow and oxygen. But the effect is fairly small, which is why the 120/80 figure is not adjusted for taller people. SA

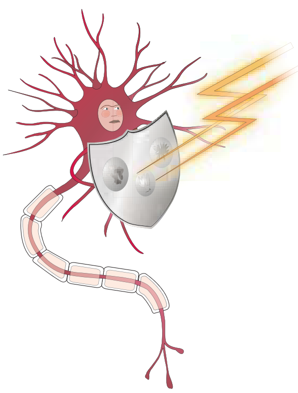
MATT COLLINS

How does anesthesia work?

Bill Perkins, associate professor of anesthesiology at the Mayo Clinic College of Medicine, explains:

Local and general anesthetics work by blocking nerve transmission to pain centers in the central nervous system, although the exact mechanisms for general anesthetics are not well understood, despite use of such pharmacological agents for more than 150 years.

Local anesthetics, such as Novocain, bind to and inhibit the function of the sodium channel in the nerve cell membrane, a type of ion channel required for the propagation of nerve impulses. This action obstructs the movement of nerve impulses from tissue innervated by nerves at the site of local anesthetic injection but causes no changes in awareness and sense perception elsewhere in the body.



In contrast, general anesthetics provide overall insensibility to pain. The most commonly used such agents are inhaled, and they are structurally related to ether. Their primary site of action is in the central nervous system. Unlike local anesthetics, the general anesthetics reduce nerve transmission at the synapses, the sites at which neurotransmitters are released by neurons and adjacent nerve cells respond. General anesthetics affect the response of receptors and ion channels to neurotransmitters, thereby decreasing nerve cell activity.

General anesthetics bind only very weakly to their sites of action and interact with proteins in a lipid environment, factors that together make it difficult to determine their exact binding structure. Despite such limitations, researchers are taking advantage of various methods to better discern how anesthetics work at the molecular level.

Genetic tools, for example, enable researchers to alter specific protein function and then determine whether this protein can be linked to sensitivity or resistance to anesthetic action in lower organisms. Other approaches, including sophisticated structural modeling of anesthetic binding to protein targets, are also showing promise. The targets for different agents do not appear to be the same, so there is probably no single molecular mechanism of action for all anesthetics.

Are one's fingerprints similar to those of his or her parents?

—Eric C., Lakeland, Fla.

Glenn Langenburg, a certified latent print examiner at the Minnesota Bureau of Criminal Apprehension, offers this answer:

Yes, we inherit the overall size, shape and spacing of so-called friction ridge skin (FRS)—fingerprints. The individual details that make a fingerprint unique are not genetically determined, however. Made up of a series of ridges and furrows that aid in grasping, FRS is unique and permanent. No two individuals—including identical twins—have the same arrangement, which also does not change throughout life (except in the case of significant damage that creates a permanent scar).

Why are the general patterns but not the identifying ridge features inherited? The reason is in the timing of aspects in fetal development. Fetuses acquire smooth volar pads—raised pads on the fingers, palms and feet—because of swelling mesenchymal tissue, which is a precursor of blood vessels and connective tissues. Around week 10, the fetus's volar pads stop growing, but the hand continues to enlarge. Over the next few weeks, the volar pads are absorbed back into the hand. During this stage, the first signs of ridges appear on the skin of the pads. The shape of the volar pads at the time the first ridges appear will dictate the general pattern that develops.

Once the overall pattern has begun to take shape within its confines, the exact arrangement of the identifying ridge features is dictated by random, localized stresses on the skin. The timing of these two events—volar pad regression and primary ridge appearance—is genetically linked. The precise locations of the ridges and other features, however, are random. SA

LUCY READING-IKKANDA

ASK THE EXPERTS

How are past temperatures determined from an ice core?

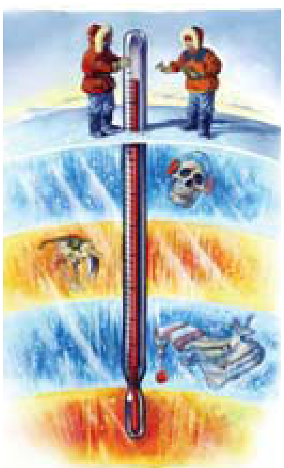
—G. Spencer, Longwood, Fla.

Robert Mulvaney, a glaciologist with the British Antarctic Survey, offers this answer:

Temperature is not measured directly but is inferred from the levels of certain isotopes (chemically identical atoms with the same number of protons but differing numbers of neutrons) of water molecules released by melting the ice cores.

Water is composed of molecules comprising two atoms of hydrogen (H) and one of oxygen (O). The isotopes of particular interest for climate studies are ^{16}O (with eight protons and eight neutrons); ^{18}O (eight protons and 10 neutrons); ^{1}H (with one proton and no neutrons); and ^{2}H (one proton and one neutron, also known as deuterium, D).

Using mass spectrometers, researchers measure the ratio of the oxygen and hydrogen isotopes in ice-core samples and compare the result with the isotopic ratio of an average ocean-water standard known as SMOW (standard mean ocean water). The water molecules in ice cores contain slightly less of the heavy isotopes than SMOW, and the difference compared with the standard is expressed as delta (or change of) ^{18}O or D. Both these values tell essentially the same story—namely, that there is less ^{18}O and D during cold periods than during warm ones. Why? Simply put, it takes more energy to evaporate the water molecules containing heavy isotopes from the surface of the ocean. As the moist air is transported poleward and cools (loses energy), those water molecules containing heavier isotopes are preferentially lost in precipitation.



Plotting either delta ^{18}O or delta D with depth along the length of an ice core can reveal seasonal oscillations in temperature and longer-term shifts in the climate. From the very deepest ice cores, reaching depths of more than three kilometers in the Antarctic ice sheet, we can clearly see the steady pulsing of the ice ages on a period of about 100,000 years. From a site called Dome C in Antarctica, we have recently reconstructed the climate spanning the past three quarters of a million years and have shown seven ice ages, each interspersed with a warm interglacial climate, such as the one we are living in today.

Why do people have different blood types?

—Nichole, Detroit, Mich.

Harvey G. Klein, chief of the department of transfusion medicine for the National Institutes of Health, explains:

The short answer: blood types can aid survival under certain conditions. The specific proteins, glycoproteins and glycolipids found (or expressed) on the surface of red blood cells define blood types, which are inherited. In 1900 Karl Landsteiner described the original classifications—A, B and O—and doctors now recognize 23 blood-group systems with hundreds of different subtypes.

Most such molecules do not seem to be essential for blood cell operation, but some have specific jobs on the red cell membrane. Blood-type factors may be transporters, for instance, allowing materials to enter and exit the red cell, or receptors that permit the binding of certain substances to the cell surface.

Environmental selective pressures clearly play a role in the persistence of some blood types. For example, a "Duffy" blood-type receptor enables certain malarial parasites to enter the red cell. Thus, in some malarial areas of Africa, populations who lack the Duffy blood factor gain a measure of protection against malaria, a distinct survival advantage.

We do not yet know the functions of the A and B blood-group factors. (O blood does not contain A or B factors.) They are probably important in some way, because they appear on many cells and tissues in addition to blood cells and circulate in plasma as well. Also, statistical differences in the frequency of certain malignancies associated with a given A, B or O group suggest that these factors play a role in these diseases. SA

MATT COLLINS

ASK THE EXPERTS

Q Why do flowers have scents?

—H. James, Woodbridge, Va.

Natalia Dudareva, associate professor in the department of horticulture and landscape architecture at Purdue University, offers an answer:

Scent is a chemical signal that attracts pollinators to a particular flower in search of nectar or pollen, or both. The volatile organic compounds emitted play a prominent role in the localization and selection of blossoms by insects, especially moth-pollinated flowers, which are detected and visited at night. Species pollinated by bees and butterflies have sweet perfumes, whereas those pollinated by beetles have strong musty, spicy or fruity smells.

To date, little is known about how insects respond to the individual chemical components, but it is clear that they are capable of distinguishing among complex aroma mixtures. In addition to attracting insects and guiding them to food resources within the bloom, floral volatiles are essential for insects to discriminate among plant types and even among individual flowers of a single species. For example, closely related plant species that rely on different types of insects for pollination produce different odors, reflecting the olfactory sensitivities or preferences of the pollinators. By providing species-specific signals, the fragrances facilitate an insect's ability to learn particular food sources, thereby increasing its foraging efficiency. At the same time, successful pollen transfer (and thus sexual reproduction) is ensured, benefiting the plants.

Scent outputs tend to be at the highest levels only when the flowers are ready for pollination and when potential pollinators are active. Bees and butterflies tend to plants that maximize their output during the day, whereas flowers that release their fragrance mostly at night are visited by moths and bats. During development, recently opened and young buds, which are not ready to function as pollen donors, produce fewer odors and are less appealing to pollinators than older flowers are. Once a flower has been sufficiently fertilized, its bouquets are again reduced, encouraging insects to select other blossoms instead.

Q How are tattoos removed?

—T. Durkee, Berkeley, Calif.

Dermatologist Joshua L. Fox, director of Advanced Dermatology's Center for Laser and Cosmetic Surgery in New York City, explains:

Industry experts say that 50 percent of people with tattoos will someday consider getting rid of their body art. Doctors remove the markings using three types of lasers: alexandrite, YAG and ruby. Each works on different pigment colors and compounds, so the dermatologist will use one or a combination of lasers depending on the nature of a given tattoo. (It follows that you would want to select a dermatologist who has the specific laser necessary for removing your tattoo.) Tattoo pigment is inserted into the dermal layer of the skin through ruptures in the top layer, or epidermis. To remove that pigment, the laser emits very short pulses, which are selectively absorbed by the color of the tattoo ink. This high energy fragments the pigment into smaller particles that are then removed by the body's immune system. In most cases, a series of laser treatments can remove 90 to 95 percent of the original design.

Patients who want a tattoo removed should seek a dermatologist with experience and equipment specific for the procedure. Good questions to ask include how many such procedures the practitioner has done and whether he or she owns the lasers or leases them. Doctors who own their lasers typically do more tattoo removals and as such have more practical experience. SA

MATT COLLINS

ASK THE EXPERTS

What causes headaches?

—Mike A., Wilmington, Del.

Dawn A. Marcus, associate professor at the University of Pittsburgh School of Medicine's department of anesthesiology, offers this answer:

Although they may feel as if they emanate from the brain, headaches actually arise as a result of irritation in nearby structures: skin, joints, muscles, nerves or blood vessels. Brain tissue, encased in the protective coating of the skull, has not evolved the ability to respond to pressure sensations.

Clinicians classify all headaches as either secondary or primary. Secondary headaches, which appear as symptoms of an underlying disorder, have no uniform cause. Anything from a pinched nerve to a sinus infection can lead to secondary head pain.

Most headaches, however, are primary, meaning that the headache is not a symptom of another condition but the problem itself. Research suggests that this type—which includes tension headaches and migraines—may derive from a single, identifiable pathway.

The chain begins when pain centers in the brain are activated, at which point they produce neurotransmitters such as serotonin and norepinephrine. These chemicals call for expansion of meningeal blood vessels enveloping the brain, resulting in increased blood flow. As the vessels swell, they stretch the nerves that surround them. These nerves, in turn, convey signals to the trigeminal system, an area of the brain that relays pain messages for the head and face, and we perceive pain.

Why the pathway is initiated at all is still an open question, although some circumstances seem to make headache onset more likely. These triggers may be internal (for example, hormonal changes during menstruation) or environmental (such as stress or sleep deprivation). So far, however, most evidence for what factors are directly responsible is anecdotal, and the mechanism by which the triggers are converted to chemical signals is little understood.

How can a poll of only 1,004 Americans represent 260 million people?

—C. Bures, Wellesley, Mass.

Andrew Gelman, professor in the departments of statistics and political science at Columbia University, explains:

You can learn a lot about a large population from a smaller cross section—but that does not make the technique flawless.

Mathematically, the margin of error depends inversely on the square root of the number of those sampled; however, the margin of error is an abstraction based on tacit assumptions. In practice, actual errors may be larger than advertised.

One assumption is that the queried group is truly random—that respondents have been chosen one at a time, with everyone in the U.S. equally likely to have been picked. To approximate this ideal, polls use telephone numbers generated randomly by a computer. But if you do not have a phone, you will not be in the survey, and if you have two lines, you have two chances to be included. Another confounding factor is that women, whites, older people and college graduates are more likely to agree to be interviewed. Statistical weighting helps pollsters match the sample to the population, but they can counter only known biases.

Finally, any margin of error is an understatement, because opinions change. For instance, surveying 4,000 people would improve the margin of error to 1.5 percent. Although this sounds appealingly precise, it is generally a waste of time, because public views vary enough day to day that it is meaningless to attempt too exact an estimate. It would be like getting on a scale and measuring your weight as 173.26 pounds; after you drink a glass of water five minutes later, your precise weight would have changed but to an unimportant degree. SA

MATT COLLINS

ASK THE EXPERTS

Are food cravings the body's way of telling us that we are lacking nutrients?

—J. Shelton, Ogden, Utah

Peter Pressman of the Cedars-Sinai Medical Center in Beverly Hills, Calif., and Roger Clemens of the University of Southern California School of Pharmacy explain:

A hankering for particular foods is not linked to any obvious nutrient insufficiency. But other biological factors appear to be at work.

Researchers have employed functional magnetic resonance imaging (fMRI) to explore the neural basis of such appetites. The images suggest that when somebody is pining for a certain fare, brain components in the amygdala, anterior cingulate, orbital frontal cortex, insula, hippocampus, caudate and dorsolateral prefrontal cortex are activated. A network of neural regions may be involved with the emotion, memory and chemosensory stimuli of food yens.

Desire for chocolate offers an example. The treat's constituents may influence satiation or alter our longing for it by affecting mood-influencing chemicals in the brain, such as phenylethylamine, tyramine, serotonin, tryptophan and magnesium.

Additional factors such as simple carbohydrate content may amplify a food's appeal or even attenuate depression. More support for a nutrition-neurological connection comes from research that shows that administration of naloxone, an agent that blocks opiate receptors in the brain, appears to inhibit the consumption of sweet, high-fat foods—chocolate among them. Studies of cannabinoids, which commonly occur in marijuana, have shed more light on the neurochemistry of selective appetite. In addition, research has identified an entire spectrum of gut neuropeptides with elaborate central nervous system feedback and influence on satiety.

Some studies suggest that chocolate craving, especially among women, may partly result from a sense of deprivation or a reaction to stress, hormonal fluctuation and modulation of neuropeptide concentrations. Culture has an influence as well. Spanish women, for example, eat relatively large quantities of chocolate and exhibit limited craving for that sweet. In contrast, American women consume less yet present a strong "chocophilic" tendency.

What causes feedback in a guitar or microphone?

Robert L. Clark of the Pratt School of Engineering at Duke University offers this answer:

Several mechanisms can lead to the unpleasant shriek known as feedback. Let us deal first with the simple case of a microphone and an amplified speaker. Feedback occurs when a "loop" closes between an input (the microphone) and output (the amplified speaker). The sound radiated from the amplified speaker reaches the microphone and is subsequently amplified again and again, until it saturates and can no longer amplify the input. This excessive ratio of output to input, called gain, occurs at a particular frequency and arises from many factors. These can include the distance between the microphone and the speaker, the directional design of the microphone and speaker, the influence of reflective surfaces within the acoustic environment, and the presence of additional microphones and amplified speakers. To reduce gain, an equalizer can adjust the signal amplification.

When a microphone is used with an acoustic guitar, the amplified speaker closes the loop between the input and output when the radiated sound from the speaker reaches the guitar. In such cases, the guitar starts vibrating excessively at a particular frequency (typically between 100 and 200 hertz), or the room itself can begin to resonate, producing an audible tone. A similar mechanism occurs in electric guitars. Structural vibrations induced by acoustic feedback can magnify the signal generated by sensors embedded in the guitar to "pick up" its sound, leading to the instability of feedback. SA

MATT COLLINS

ASK THE EXPERTS

What causes shin splints?

—E. Bachman, Austin, Tex.

Claude T. Moorman III, director of sports medicine at Duke University Medical Center, offers an answer:

"Shin splints," the layman's term for the painful sensations felt at the front of the shinbone (tibia) after exercise, occur when the constant pounding and stresses placed on the muscles, bones and joints overwhelm the body's natural ability to repair damage and restore itself. We commonly see shin splints in athletes, military recruits and even in middle-aged weekend warriors, especially at the beginning of milder weather.

Overworked muscles are one major source of the aches. The muscles that connect the tibia to the ankle are held together by fascia—a tough, inelastic covering like a sausage skin. When the muscles naturally expand as a result of exercise, the resulting pressure can cut off blood flow, causing pain. This form of shin splints, known as exertional compartment syndrome, appears in athletes who play field sports such as soccer or who often run on hard surfaces.

Pain can also stem from injuries to the bone, ranging from stress reactions to full-blown fractures. The continual pounding endured during running, for example, can cause many microscopic cracks to develop in leg bones. Normally, with rest, the body easily fixes the tiny fissures. Without sufficient mending time, however, they can coalesce into a stress fracture—a hairline crack—or even a complete fracture, in which the bone breaks all the way through.

People can prevent shin splints by simply adding extra arch support to shoes to redistribute weight or changing to softer running surfaces. Doctors also recommend "active rest," which means that a runner, for instance, should take up swimming or biking for a while. The change of pace gives the affected areas time to heal but maintains the cardiovascular benefits of exercise.

Warming up muscles before exercise to prevent injuries is a controversial subject, with smart people on both sides arguing for and against it. We at Duke, based on research conducted at the university, recommend a slow warm-up period. We believe that about 10 minutes of graduated activity is the best way to prepare the body for working out more strenuously. For shin splints, as with most things in life, moderation appears to be the best medicine.

Why do bees buzz?

—M. O'Malley, Newton, Mass.

Gard W. Otis, a professor of environmental biology at the University of Guelph in Ontario who studies bee behavior, ecology and evolution, explains:

Bees produce their distinctive "zzzz" in two ways. First, their wing beats create wind pulses that people hear as a buzz. This sound is not exclusive to bees—most flying insects produce a similar hum. The pitch of the sound produced is a function of the flapping rate: the faster the wings, the higher the pitch.

Second, some bees, most commonly bumblebees (genus *Bombus*), vibrate their wing muscles and thorax (the middle segment of their body) while visiting flowers. These movements make the pollen fall off the flower's anthers onto the insect's body. Some of that pollen gets deposited when the bee alights on the next bloom, resulting in pollination. The bee also grooms pollen onto basketlike structures on its hind legs, taking it back to the nest to feed to the larvae.

When bumblebees vibrate blossoms to release pollen, the noise is quite loud. Honeybees (genus *Apis*) are incapable of such "buzz pollination" and are usually quiet when foraging. Some plants are adapted to buzz pollination: Tomatoes, green peppers and blueberries all store pollen inside tubular anthers. When the bee shakes the flower, the pollen falls out. Consequently, bumblebees pollinate these crops much more efficiently than honeybees do. SA

MATT COLLINS