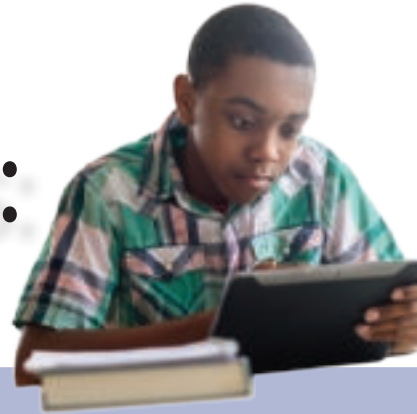


Cells and Systems:

How do living things heal?



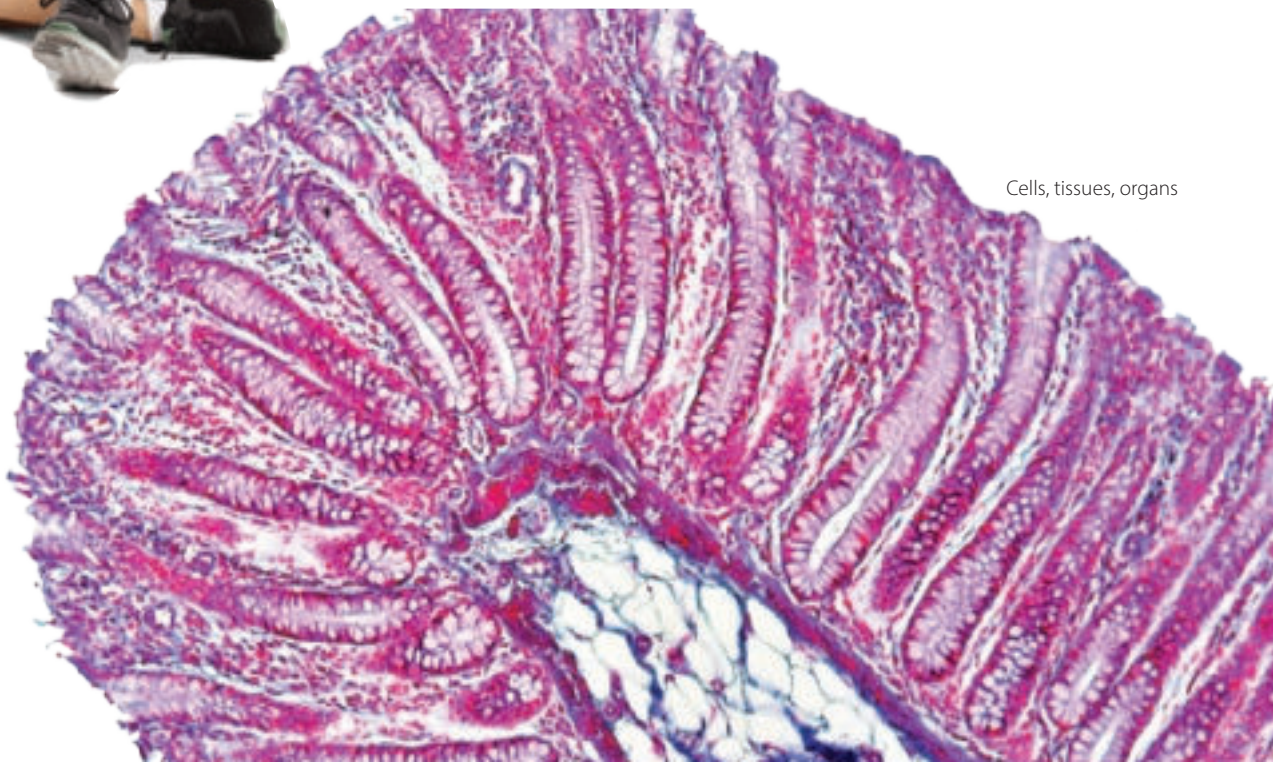
Science Literacy Student Reader



Injury and healing



Medical imaging



Cells, tissues, organs

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Cells and Systems

Science Literacy Student Reader



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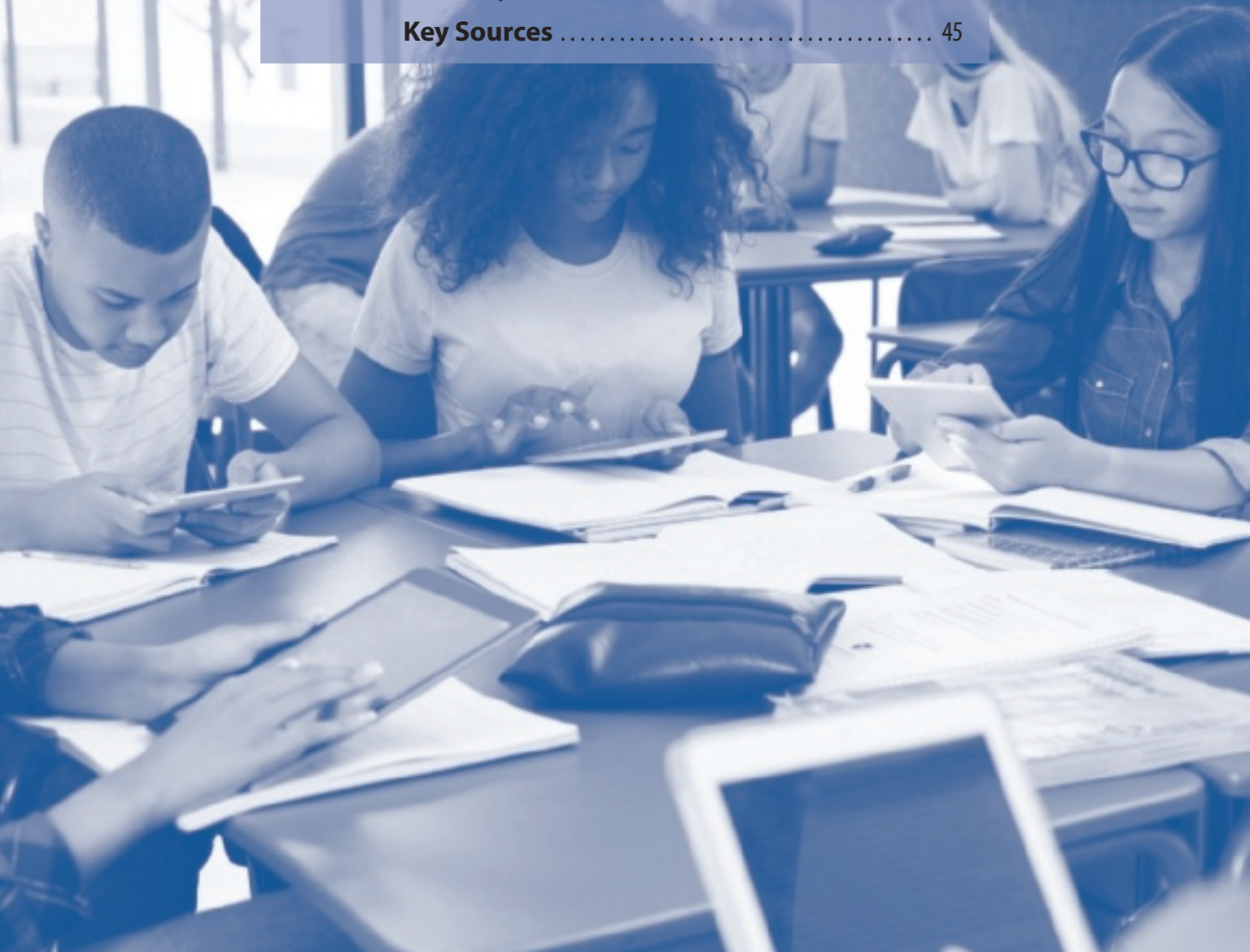
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Cells and Systems

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Put Yourself in This Scene

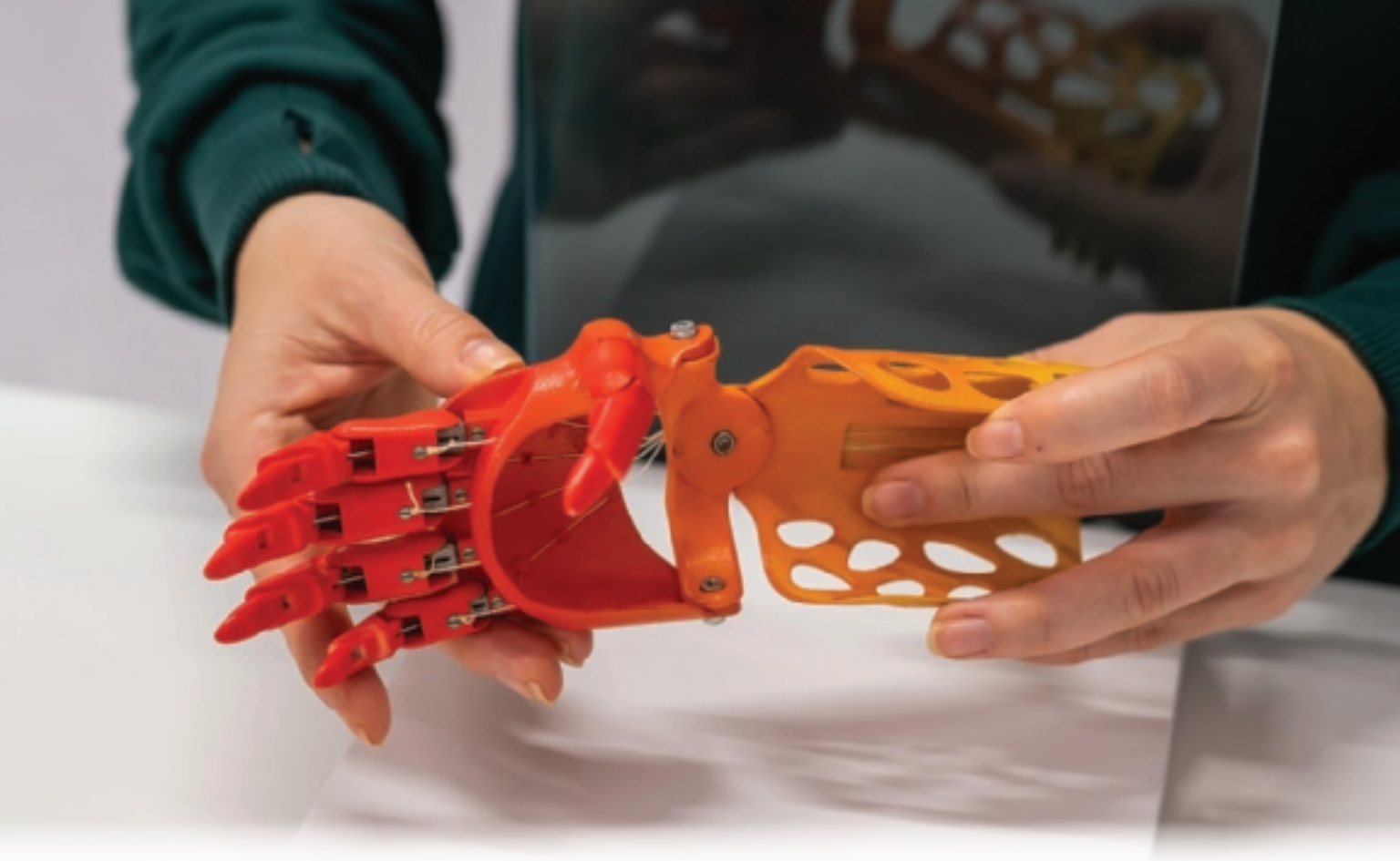
August 17, 2022

Hi. I'm Maddy's dad. Maddy turned eight the other day. She's been watching a lot of baseball and softball this year, and she's now the biggest fan in the house. When we were at Grandpa's last weekend, we found my old baseball bat and a tee. We set it up in the yard, and she's been out there every day after school, hitting tennis balls, hardballs, softballs—anything she can find that looks like a ball—off the tee. It's a bit tough for her because she doesn't have a left hand, but she's already quite strong with her right, and she's just so determined. She can throw well, too. She does not yet have a glove, and I'm trying to figure out how to handle that. Catching and throwing a ball with the same hand is doable when the ball is soft or moving slowly. It's pretty much impossible when the ball is moving at high speed.

We could simply let her adapt to the game as she's adapted to everything else as a one-handed human. I know there have been successful one-handed athletes, even in professional baseball. And of course, she is free to try to enjoy anything she wants to, including getting a college scholarship or turning pro. We could go a few different routes, though. Some of the technology in prosthetic limbs and even robotic options are truly mind-blowing now and getting better every year.

We could stay the course and have her learn to play ball with one hand. Or we could have her fitted with a prosthetic hand that could hold a glove but without any kind of mechanical, pseudomuscular movement. Or we could investigate a robotic hand that could respond to commands from her brain, via a neural link.

Right now, I'm inclined to just let her keep doing what she's doing, but with prosthetics and robotics getting more accessible to regular people like us, who knows? We're taking it one year at a time, I guess.



Maddy's father is weighing options for his eight-year-old daughter, who was born without a left hand. He could let Maddy continue to grow and develop without the aid of an artificial hand, or he could embrace modern technologies that could help Maddy do what she would like to do. Which path should he choose? And how should he and his daughter figure it out?

That's what this book is about—scientific literacy, which means knowing how to think about science topics that you read or hear about. Our world has 24–7 news, social media, and too many websites to count. The amount of information we must sort through is overwhelming, and all the information

is not reliable. In the internet age, sources of information are often obscure or not trustworthy. It is good to process information with a healthy degree of skepticism.

We will make our way back to this human body topic by the end of the book. Along the way, the series of reading selections and the writing exercises that go with them will help you flex your mental muscles and sharpen your science literacy skills. The ability to read about science, understand the information, and tell truth from fallacy or misrepresentation is important. Science literacy helps you as an individual and as a consumer, and it shapes the ways you affect the community in which you live.

Robots: Helpers or Competitors?



Videos of this dancing robot dog have gone viral. The coordination and agility of the robot, which is designed by a company in Boston, is striking. Some viewers wonder if the videos were in fact real. Others are both delighted and disturbed. We've all seen enough movies about a future in which robots take over the world and wage war on their makers. Others note that we've already seen many jobs get taken away from humans and given to robots. There's a sense of "Wow, that's so cool!" that quickly gives way to questions like "Is this thing going to take my job?"

These robots are sophisticated designs made of interacting systems. Sensors tell the computer in the robot about its balance, position, and location. The computer then coordinates movements of limbs, which have supple joints that would make many elderly humans green with envy. Hydraulics power the movements of the limbs, and a skeleton made of 3D printed parts serves as the framework. Electricity is the blood for these bots. Electrons are stored in a high-capacity battery, similar to the stores of sugar and fat that humans rely on.



Like humans, robots need lots of inputs, such as energy and matter, but they aren't very good at acquiring those things on their own. Battery-powered robots need to be recharged with human help and with electricity provided by human technologies

such as generators and circuits. Humans program safeguards into the computers of robots so they can be shut down remotely in the event that they are working improperly—or trying to take over the world!

Skeleton Diversity

Hydrostatic Skeletons



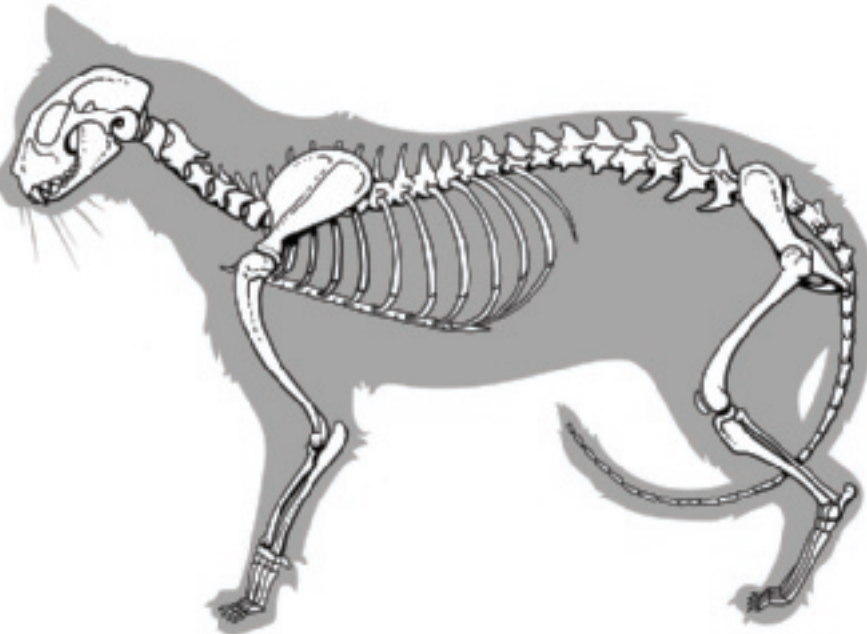
Instead of having bony skeletons, many worms maintain their shape by pressurized fluid. This is called a hydrostatic skeleton.

Exoskeletons



Many invertebrates have exoskeletons. Platelike structures made of chitin surround the animals' muscles and other tissues, providing protection and support.

Endoskeletons



This illustration shows the skeleton of a cat. Bony internal skeletons, called endoskeletons, are one of four types of skeletons in the animal kingdom. Skeletal muscles attached to the bones allow for movement.



Humans have bony endoskeletons. Rays, sharks, and skates have endoskeletons made of cartilage. Skeletal muscles allow these animals to move like bony fishes.

Living with Ehlers-Danlos

I'm staying in tonight. "My bones go out more than I do" is a common refrain among people like me who have Ehlers-Danlos syndrome. My family first noticed something was unusual about me when I took longer than most babies to take my first steps, and then when I fell down, I seemed to bruise very easily. My parents noticed my skin seemed to be unusually stretchy, like the latex in a popped balloon. A genetic test confirmed what the pediatrician suspected: EDS. I was less than two years old. Ten years later, we've all learned to live with my condition.

Having EDS means my body has a hard time making collagen, an important protein that helps form connective tissues. In the skin, collagen makes skin plumper and denser. That's why you see some people in Hollywood get collagen injected directly into their lips. It's also important for maintaining joints. And that's why I'm staying in tonight. My joints are often very sore, and sometimes they can get dislocated. I play basketball, but I wear braces on both knees to keep my kneecaps in place and add a bit of stability. At practice today, my kneecap nearly slipped out of place, and my entire knee joint seemed to bend the wrong way. Ouch. I'll be missing the next few practices for sure. It stinks, but it's something I'll be dealing with for the rest of my life.

The body's difficulty in making collagen can result in joints that are unusually flexible. One danger is that joints can become more easily dislocated.



No Pain, No Gain

Vocabulary

healing, n. the process of becoming healthy again

Spot the BS

Heads up! There is some **bad** science in this conversation. Can you spot who has their scientific facts straight and who doesn't?

GW Grant Wheaton

Football tryouts are coming up at the end of August. We should use the summer to get strong. Anybody want to come to my basement to lift? We set up a squat rack, and we've got enough bars and plates to keep three or four of us busy.

KJ Keenan Johnson

I'm in. But I think we should start with body-weight exercises before we hit the free weights. Maybe a week of just push-ups, pull-ups, dips, air squats, box jumps, and lots of sprints?

MW Mike Wise

Keenan just wants to take it easy. LOL.

KJ Keenan Johnson

Bro, I just want to ease into it so we don't blow out our knees or backs throwing tons of weight around. You can't make the team if you're on crutches or laid up in bed with a back injury.

GW Grant Wheaton

Come on . . . your muscles don't care whether you ease into your training or jump right into the tough stuff. But whatever, let's do this. I'm opening my basement gym starting next week. Anyone who wants to come lift weights and get stronger can join me. No pain, no gain. If anyone wants to take it slow and not get as strong, they can go with Keenan to a field and do calisthenics. LOL.

KJ Keenan Johnson

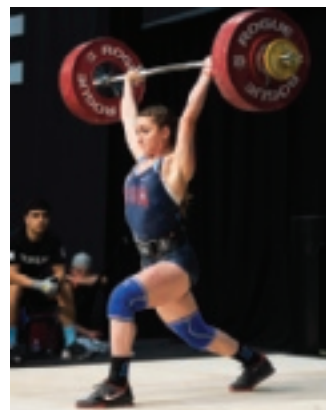
I'm coming to your basement after a week of my warm-up program. I'm stronger than all y'all anyhow, so I'm not worried about any of this. I just want to actually be able to try out and play instead of being on the sideline. Too much pain, no game!

Who's Right?

- The number of muscle fibers you have is based heavily on genetics. Someone who is naturally, genetically slender and not heavily muscled may have fewer muscle fibers than someone who looks bigger and stronger. Some people are, in that sense, born stronger than others.
- Human skeletal muscle has a mix of fast- and slow-twitch fibers. Someone with lots of slow-twitch, or Type I, muscle fibers might be naturally good at endurance events such as running long distances or swimming across lakes, though not necessarily at maximum speed. Someone with lots of fast-twitch (Type II) muscle fibers might jump higher or be able to lift more weight, but they are more likely to get tired sooner than a person who is endowed with slow-twitch muscle. Having a sense of your ratio of muscle fiber types can help you develop an exercise regimen that makes the most sense for you.
- The thickness and length of muscle fibers can be altered through diet and exercise, particularly a protein-rich diet and resistance exercise. Weight lifting offers resistance to your muscles, because your muscle fibers must pull with greater force. Repeated exercises of this type produce small tears in the muscle fibers. If well nourished, the person's fibers will be repaired and will also grow as a result of **healing** these small-scale injuries.
- However, excess strain on muscle fibers can lead to tears that are larger and more severe. Instead of producing small tears in some fibers, too many fibers—or even the whole muscle—can be torn, leading to a major injury that requires extended rest or even surgery. Resistance training also puts stress on other tissues, including tendons, cartilage, and ligaments.
- Easing into a resistance training program can help your muscles prepare for greater challenges, including more repetitions or taking on heavier loads.

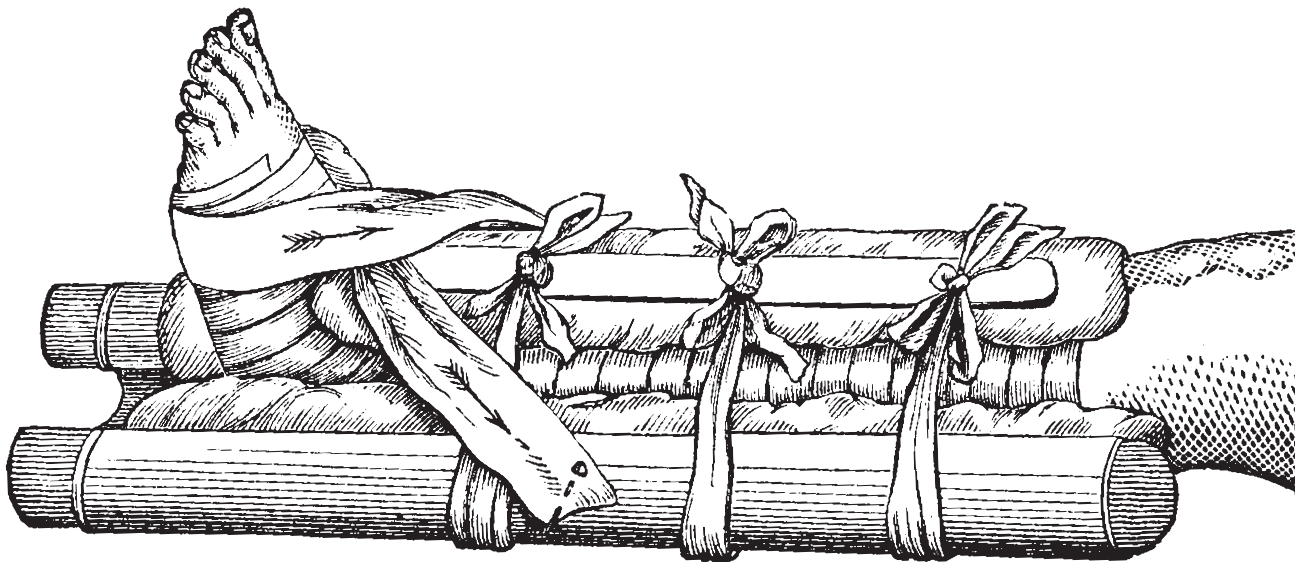


Marathon runners' muscles are likely to have a high proportion of slow-twitch fibers.



Someone who competes in weight lifting is likely to have a high proportion of fast-twitch muscle fibers.

Mending Broken Bones



For a broken bone long ago, a splint made of sticks or slats of wood and ties would keep a broken bone somewhat immobile. Splints are still used in a pinch if someone is hurt in a remote location and cannot be given a proper cast. Setting the broken bone is important for encouraging healing and avoiding a misshapen limb.



The typical hard cast that is formed around limbs with broken bones is based on centuries-old techniques and materials. The mineral gypsum was mined in Europe and mixed with water to form a paste that could be molded or cast into walls. By the mid-1800s, physicians had developed a recipe for casts made of this "plaster of Paris" and bandage rolls of linen that would set quickly but remain hard for weeks.



When bones are severely fractured, resetting and immobilizing them may not be enough. In these cases, surgery can be required to put in plates and screws to keep the fragments of bone together and encourage healing. Sometimes this hardware is left in forever, and sometimes it is removed later on.

If bones completely fracture, the sharp ends or fragments can break through the overlying tissues. This increases the chance of infection. Without proper treatment of such wounds, tissue can die, and limbs can require amputation. This occurred to thousands of soldiers during the U.S. Civil War.

Imaging Injuries



We were in a bad car accident last week. Dad was driving, slid on some black ice, and lost control of the car. We hit a tree at fairly high speed. The airbags deployed, but Mom's head snapped back pretty hard against the headrest after she bounced off the airbag. She felt dizzy and confused as we waited for an ambulance to arrive. My dad's left knee felt like it had twisted when the front left end of the car crumpled while his left foot was braced against the floor. My seatbelt prevented me from colliding with the back of his seat, but my left collarbone really hurt where the belt had yanked against me. When we arrived at the hospital, the team of ER doctors assessed our injuries.

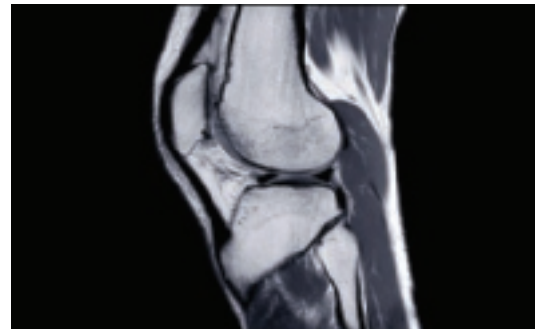
My dad and I were given **X-rays** to check for fractures. Dad's X-ray was negative—no obvious fractures in his knee—but there was a lot of swelling. He was given a referral to get an **MRI** at a nearby orthopedic hospital two days later. My X-ray showed a hairline fracture of my left clavicle, or collarbone. This meant the bone hadn't fully broken. They prescribed an arm sling so I would avoid use of my left arm for a few weeks. The ER doctors seemed most concerned about my mom because of her head injury. They gave her a **CT scan** to check for a brain injury. The scan showed slight swelling at the back of her brain. This was probably from her head striking the headrest. They diagnosed her with a concussion but kept her overnight for observation.

Dad's MRI showed a strain, or partial tear, of his left ACL, a ligament in the middle of the knee. He'll avoid surgery for now and hope the ligament heals on its own. Because of Mom's concussion, she needs to avoid bright lights and get plenty of rest over the next week or two. The soreness in my collarbone has declined, and I should be able to get back to swimming in about a month.

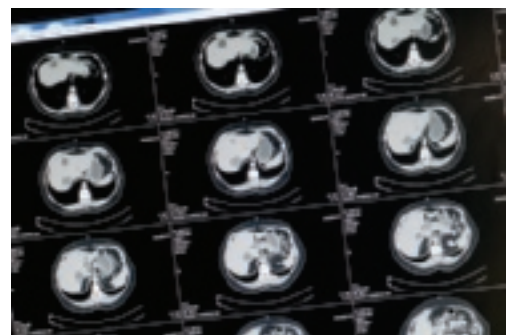
X-rays are on the electromagnetic spectrum. They have short wavelengths. They can pass through low-density materials, like skin and muscle and other soft tissues. They do not pass through bones or teeth. An X-ray renders bones and teeth as white on a black or gray background. The high contrast of the white and black makes it easy to spot fractures, and trained eyes can also spot dislocations and other bone issues. X-ray technology is common and works quickly, especially now that the images can be produced digitally and do not require film and printing. X-rays are regarded as “first-line images” because they are fast and can help diagnose injuries or rule them out so other tests can be prescribed.



MRI stands for magnetic resonance imaging. MRI employs powerful magnets and radio waves. The resonance, or way that particles in the body vibrate in response to the radio waves, produces detailed pictures of many different tissues, including muscle, cartilage, tendon, ligament, and nerve. MRI machines are not as common as X-ray machines, so getting an MRI image usually takes more time to schedule, and the procedure itself is not as quick.



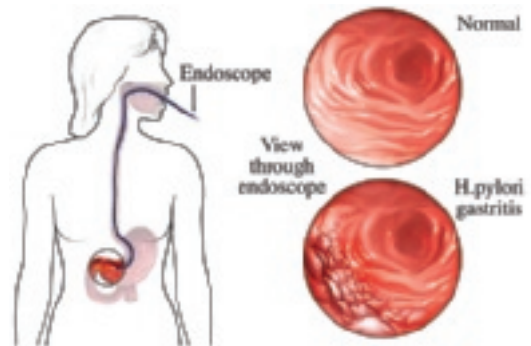
CT scans send radiation through the body, but unlike X-rays they produce three-dimensional, detailed images that show soft tissues. A CT scan is slightly slower than an X-ray, but it is quicker than an MRI. CT scans are usually used in emergency situations, such as an apparent blood clot in the brain or an injury to an internal organ. CT scans can also be used instead of MRIs on patients who have metal implants in their bodies. The magnet in an MRI machine is so powerful that such patients are at risk of injury if they are exposed to it.



Ultrasound provides another way to look inside the body that is not invasive. The probe slides painlessly across the exterior of the body area being imaged. Ultrasound waves penetrate the tissue and bounce back to the probe. The different makeup of the tissues the waves pass through are detected and processed by a computer to generate pictures, called sonograms, that can show tears, tumors, or other problems with body structures. Ultra sound is also commonly used to produce images of the heart and of unborn fetuses inside the womb.

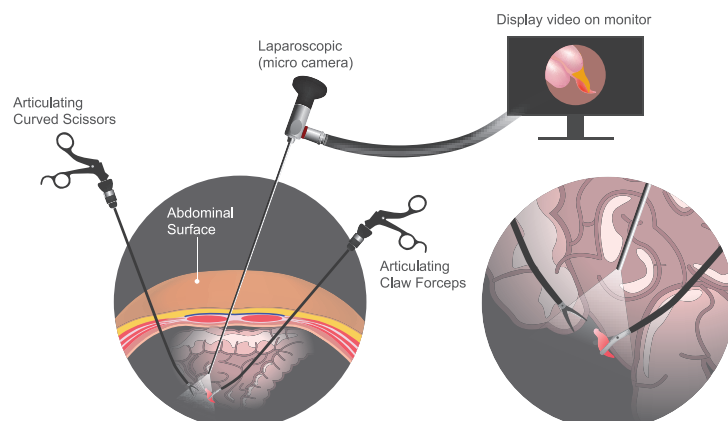


Sometimes looking at the inside of the body using scanning technology from outside the body doesn't provide a clear enough look. Endoscopy allows a look inside the body with a camera inserted through a body opening. A tiny wireless camera can even be swallowed like a pill to image the inside of the gastrointestinal tract.



Laparoscopic surgery

Laparoscopy allows a look inside the body through a camera inserted through a very small surgical incision.



Threatened—and Saved—by the Cold

I was enjoying a day of snowboarding on the slopes when an avalanche decided to follow me downhill.



I heard and felt the snow envelop me. Then it went dark. I don't remember much after that.



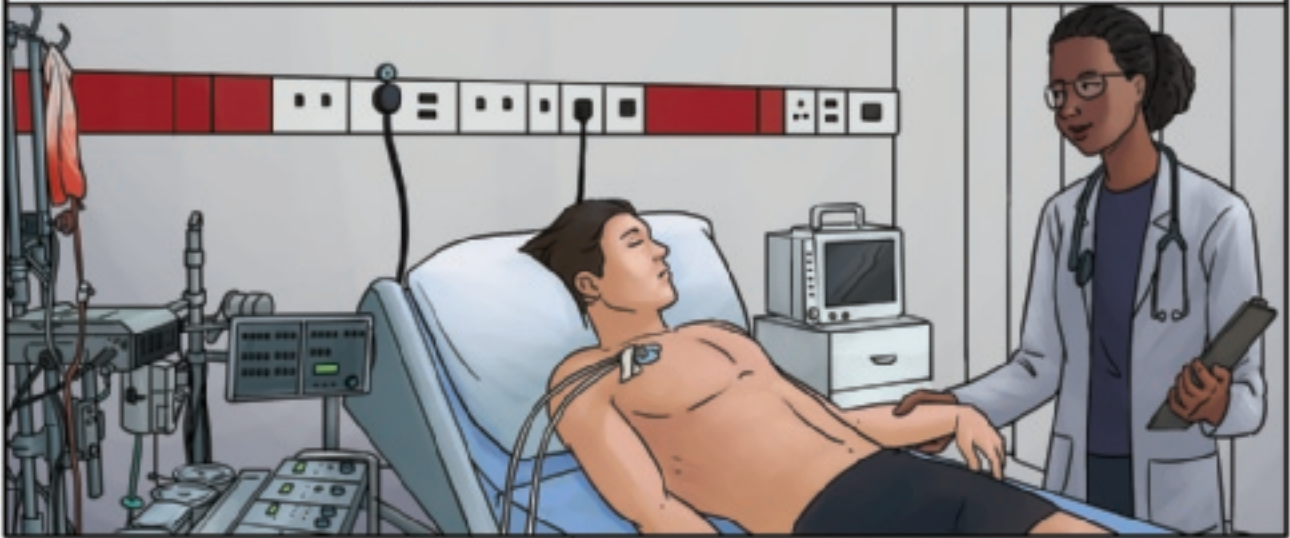
A rescue dog detected my scent under the snow. Twenty minutes after I was buried, I was freed. But my body temperature was very low.



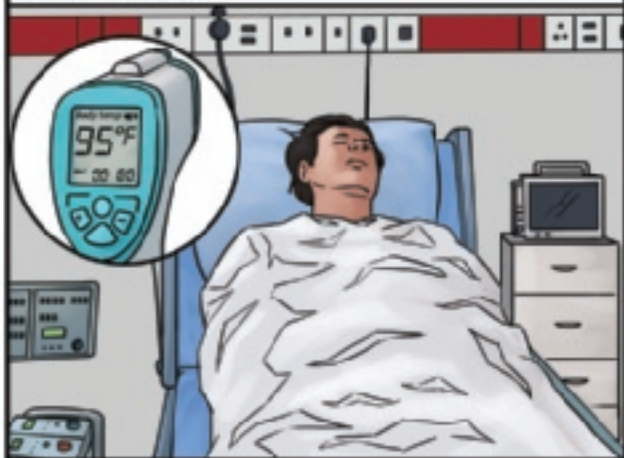
My heart had stopped, probably just a few minutes after being buried. You might think I needed CPR and heated blankets to save my life. Or maybe a jolt of electricity. Actually ...



... being buried in the snow saved me, after basically killing me. The body's metabolism slows way down when it's very cold. This means it uses less oxygen, which is good because while I was buried it wasn't getting any. A machine warmed and oxygenated my blood while letting my heart's temperature slowly get back to normal.



Once my body was warmed up, the heart-and-lung machine was disconnected, and my heart was revived. With warm blood to pump, my heart could work again while the rest of me began to recover from oxygen deprivation.



The dive my body's temperature took also helped to limit the damage my brain suffered from the many minutes without oxygen, but I don't remember much from that day, and I have had to relearn a lot of things.



Word to Know

Metabolism is all the chemical processes that sustain the life of an organism.

Blood Doping

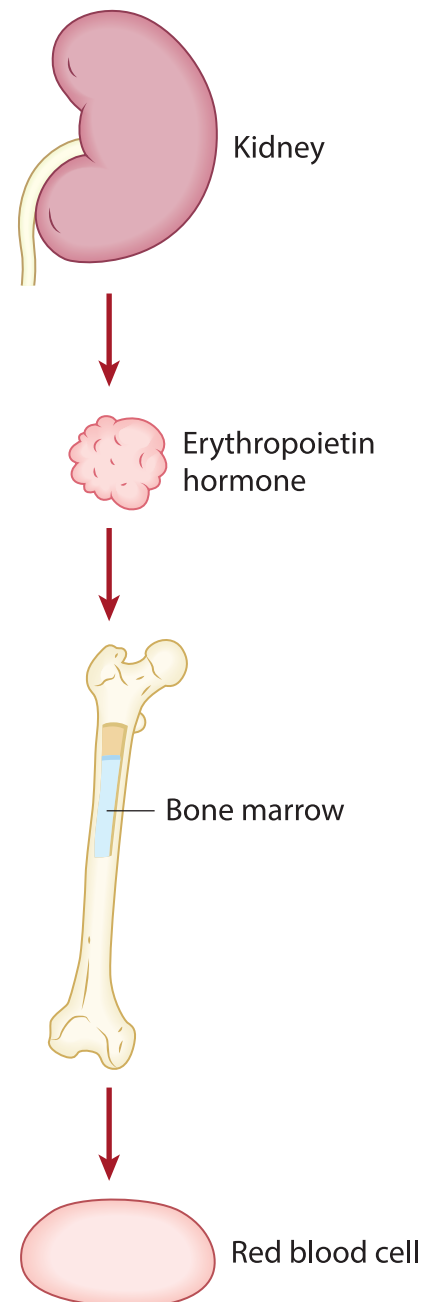
Blood doping is the use of techniques or substances to artificially increase the number of **red blood cells** in the user's body. Some athletes do this because more red blood cells means more oxygen delivered to muscles, which means more endurance, which can mean faster times, victories, gold medals, prize money, endorsement money, and fame.

EPO and ESAs

A person can stimulate the production of red blood cells in their own body by taking a substance called EPO, which stands for erythropoietin. EPO is a hormone produced by the kidneys that stimulates the production of red blood cells. Athletes can take EPO directly and get a boost in the number of red blood cells as a result. The production of EPO itself can be stimulated by taking erythropoietin-stimulating agents, or ESAs.

Vocabulary

red blood cells, n. structures that deliver oxygen to tissues via blood flow through the circulatory system



Medications

Heart disease is a leading killer of humans, and people can suffer from other heart ailments, such as malfunctioning valves or chambers that pump out of sync. There are many heart medications to treat these issues. Some athletes have found some such medications useful for boosting the performance of their healthy hearts. In 2022, a Russian figure skater name Kamila Valieva appeared to be on her way toward an Olympic gold medal in the winter games in Beijing, China, before she tested positive for a heart medication called trimetazidine.

Valieva, just 15 years old, pleaded innocence and suggested that she had accidentally ingested a trace amount of the medication from a glass of water she'd shared with her grandfather.

A lot of controversy surrounded Kamila Valieva. But what could trimetazidine have done to boost Valieva's performance, in theory? The World Anti-Doping Agency bans its use because it can improve the body's ability to use oxygen and increase the flow of blood to the heart. Other medications are on the banned list, too.



The controversy surrounding the use of banned substances in the Olympic Games was of worldwide interest.

Transfusion

In the early days of blood doping, particularly in the world of professional cycling, the way to increase the number of red blood cells in an athlete's blood was to transfuse that athlete's blood back into the athlete after storing it in a refrigerator for a few days. Some cyclists went back to this method of doping after testing for banned substances got better, because if someone finds that your blood contains your own blood, it's much harder to say that's a problem or a sign of cheating.



Risks of Blood Doping

Aside from the risk of getting caught and banned from the sport, what are the risks of blood doping?

The use of transfusions and EPO greatly increases the number of red blood cells in the user's blood, which also means the blood gets thicker. The body's organs and blood vessels are made to move blood that has a normal consistency. When blood is thicker, it is more difficult for the heart pump it out of its chambers, and it is more likely to "gunk

up" blood vessels, forming clots. Such clots can lead to heart attack and stroke, or the deprivation of blood and oxygen to the brain. Blood doping experts estimate that at least 20 cyclists have died from blood doping over the last 25 years.

If an athlete transfuses someone else's blood into their own bloodstream, the transfusion can introduce viruses such as hepatitis or HIV to the athlete. If the blood was not stored properly, bacterial infections are another risk.

Copper as Pain Reliever

Spot the BS

Heads up! There's some **bad science** in this ad. Can you detect the fishy claims being made?

CopperAge!

Tired of aching knees? Is arthritis bringing you down? Do you wish you had more energy? Then it's time for you to join the CopperAge! Our special compression-sleeve technology blends the elastic snugness of latex with the healing properties of copper, a magical metal used by humans for millennia! Copper, when isolated, is a positively charged ion. These ions draw out negatively charged ions that can accumulate in your joints and cause swelling. The compressional effect of the CopperAge sleeve also fights swelling, regulates blood flow through the joint, and improves athletic performance.

Try CopperAge sleeves for 60 days. If you're not completely satisfied, we will give you your money back, no questions asked.



The Truth About Copper and Compression

Written by: Dr. Edith Gould

Millions of people suffer from chronic joint pain. I see it all the time in my orthopedic practice. That means there are millions of potential customers of businesses that sell pain-relieving products. For some people suffering from arthritis, which is a disease of the joints, spending some money on something that promises pain relief is money well spent. However, the logic behind the pain-relieving properties of copper-infused compression braces is hard to find, and the science supporting such claims is even flimsier.

Compression is used in medicine when someone suffers a certain type of traumatic joint injury, such as a sprained ankle. It is the third part of the RICE approach: Rest, Ice, Compression, Elevation. Compression helps to limit the swelling around the injured joint, which can make recovery quicker. It is possible that the compression offered by the sleeve advertised on the previous page could help someone recover from a knee injury, but there's very little evidence in our field of medicine that compression boosts athletic performance.

The alleged role of copper in this type of item is basically bunk. Copper being ionic or, specifically, positively charged in a given form does not mean it can actually attract and draw out negatively charged ions. If it worked that way, the withdrawal of those ions from the user's knee would be extremely painful! That particular claim seems designed to take advantage of confusion over positive and negative *magnetic* charges, which are transferred without moving matter. Or perhaps the idea is to make people think that the stuff that makes a joint hurt is "negative" as in "bad" and that therefore the "positive" copper will somehow cancel out the negative and make the user feel better.

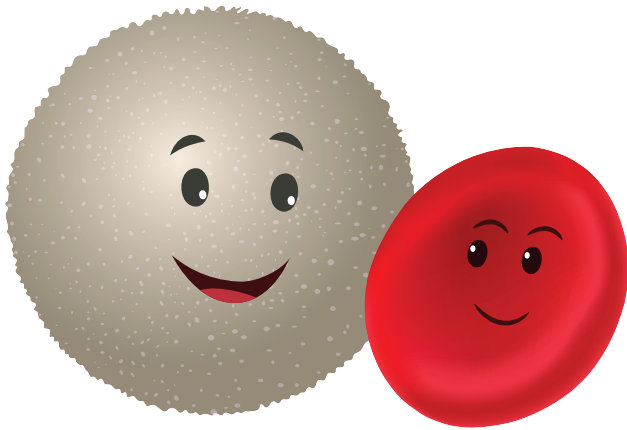
Studies have been conducted using copper-infused sleeves and other items on one set of people with arthritis and a placebo for another group with arthritis, and the copper products did no better than the placebos in relieving pain. Because of the unsupported claims, one major manufacturer was fined millions of dollars by the Federal Trade Commission, a governmental agency that monitors advertisements for fraud.

Word to Know

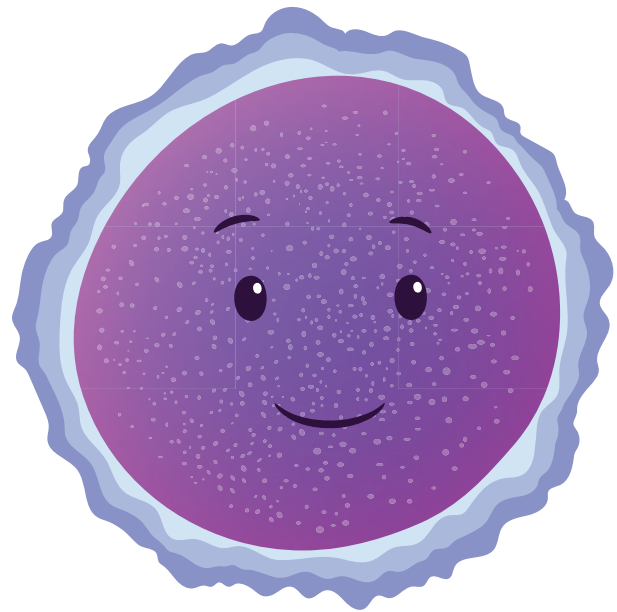
A *placebo* is a neutral substance that is used in scientific investigations to test whether a given substance or solution actually works.

Cell Types

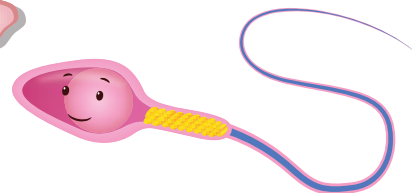
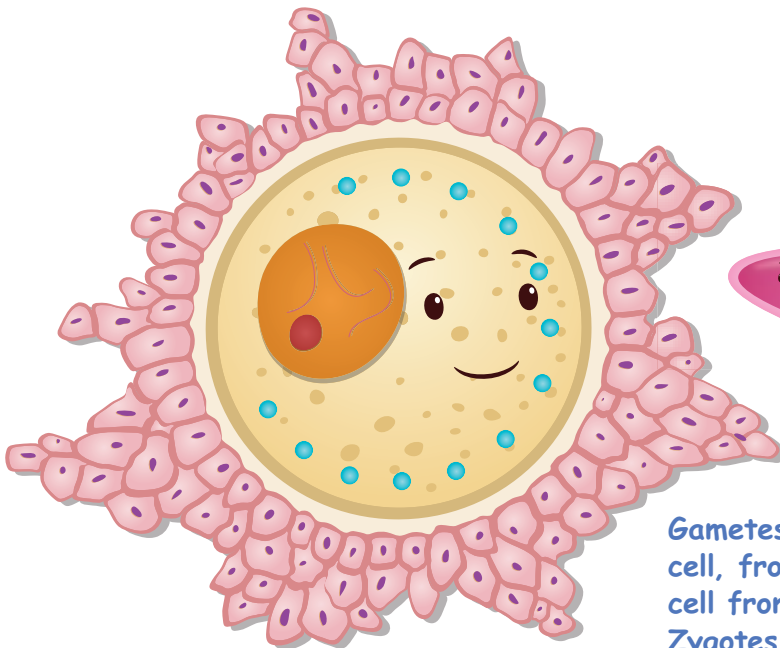
There are about 200 different types of cells in the human body. Meet a few of them here!



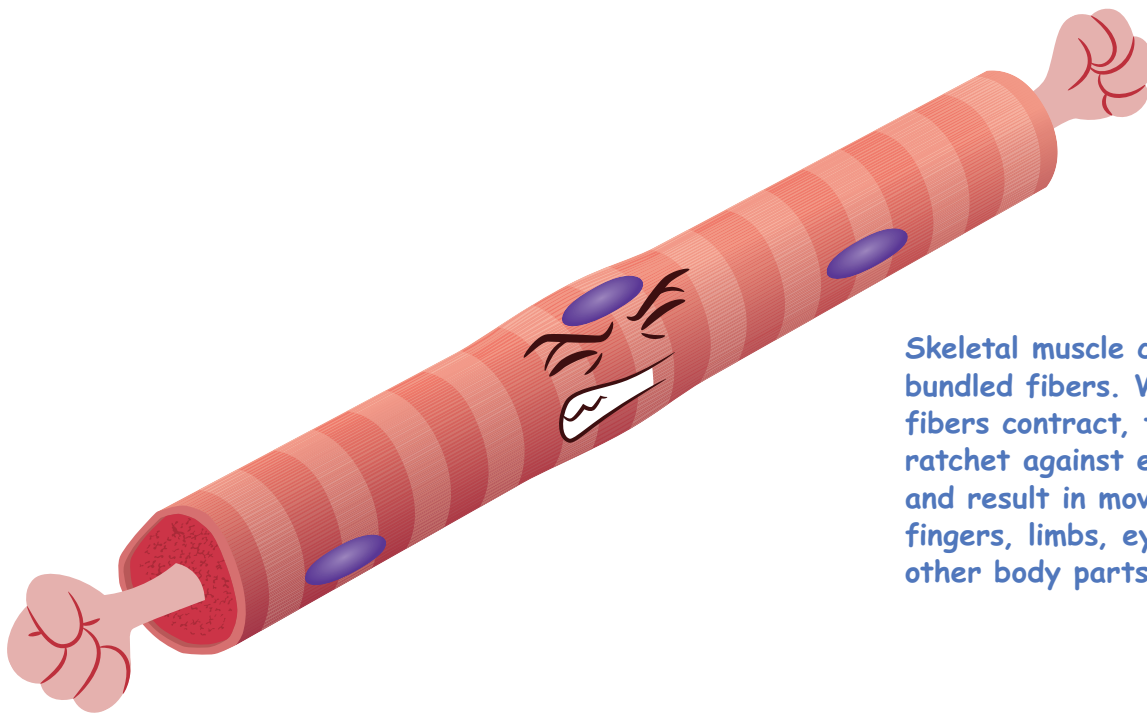
White blood cells go after invaders, such as bacteria and viruses. Red blood cells, which lack a nucleus or any internal structures, carry oxygen.



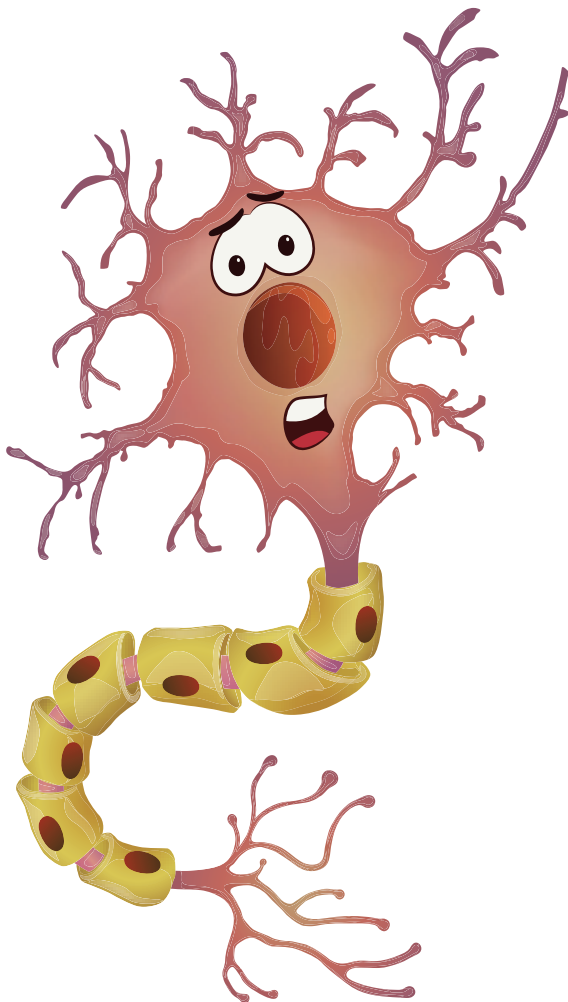
A hemocytoblast is a type of stem cell. Stem cells can develop into many different types of cells. A hemocytoblast morphs into different types of blood cells. Hemocytoblasts are found in bone marrow.



Gametes are sex cells. The ovum, or egg cell, from a female fuses with a sperm cell from a male. This produces a zygote. Zygotes contain DNA from both parents. A zygote divides and divides and becomes an embryo, which develops into a fetus.



Skeletal muscle cells form bundled fibers. When fibers contract, they ratchet against each other and result in movement of fingers, limbs, eyelids, and other body parts.



A neuron is a nerve cell. These make up the nerves, the spinal cord, and most of the brain. They are very connected to other neurons, and they send signals to and receive signals from each other.



An adipocyte, or fat cell, stores fat to be used later on as a source of energy.

The Rise and Fall of Cells

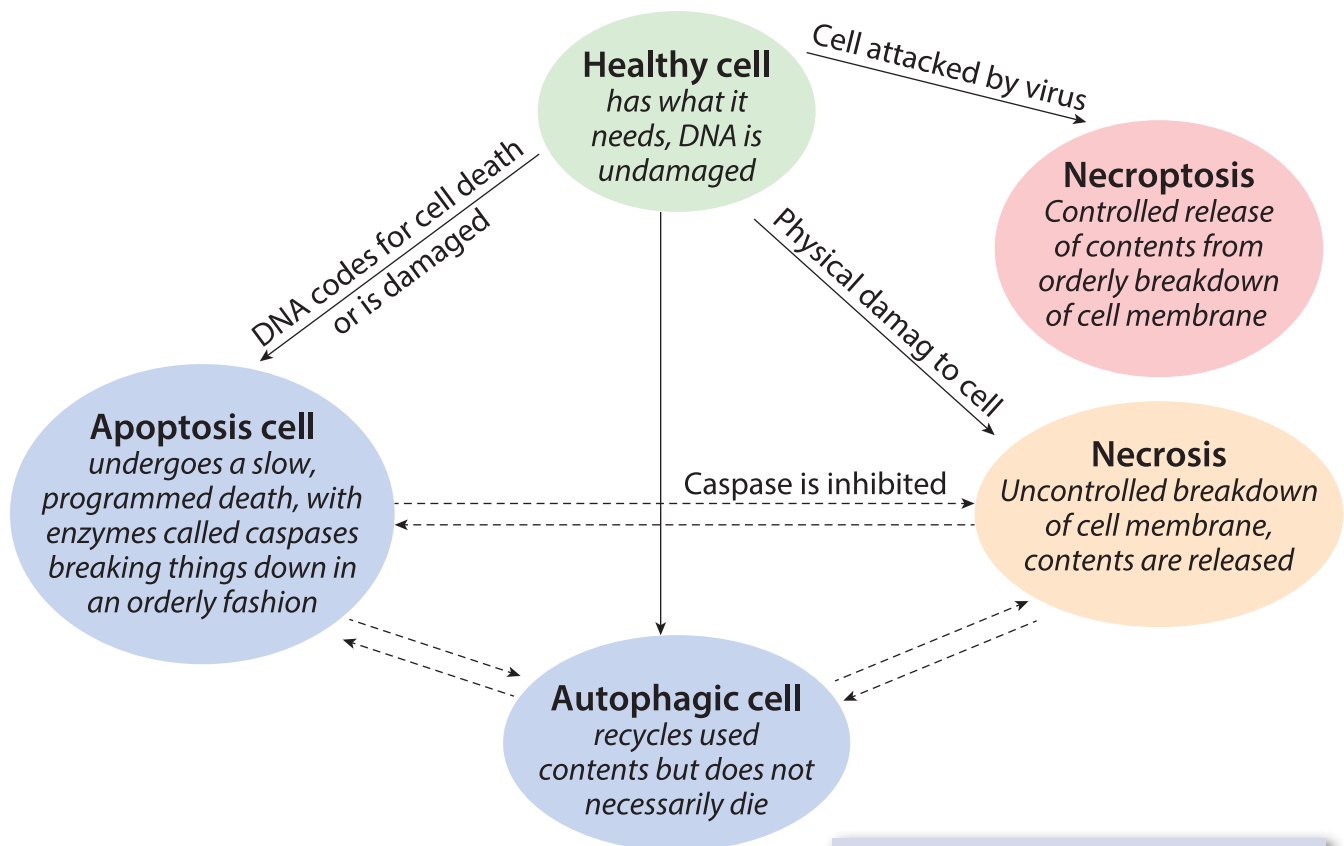
Many, if not most, cells are programmed to die.

Cells have certain processes that control the overall rise-and-fall, life-and-death rhythm of the cells and the organism itself. Sometimes, cell death helps an organism take shape.

Let's take fingers, for example. In early development, a person's fingers are webbed.

A programmed cell death, called **apoptosis**,

removes the webbing from the fingers to separate each finger. Sometimes, one type of cell death can turn into another. It all depends on what's happening to the cells, what their DNA determines, and whether anything has happened to their DNA.



Vocabulary

apoptosis, n. the preprogrammed death of a cell

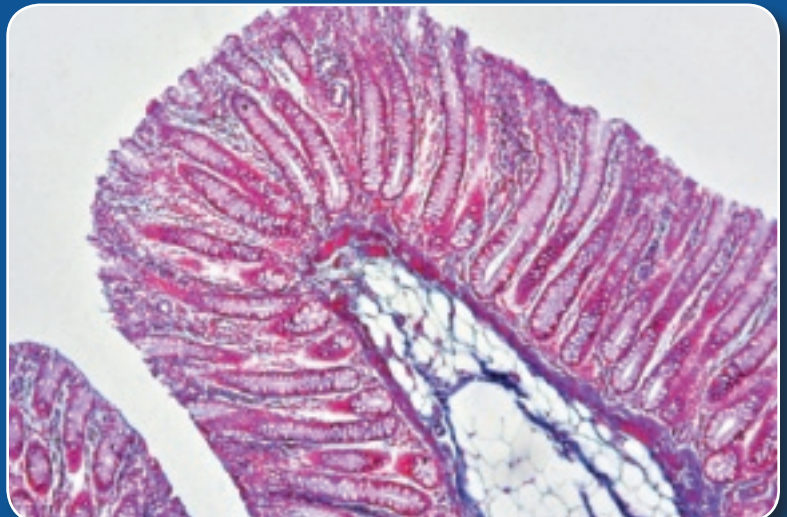
Extreme Cells



The most massive single cell in nature is probably the ostrich egg, which can weigh about four pounds.



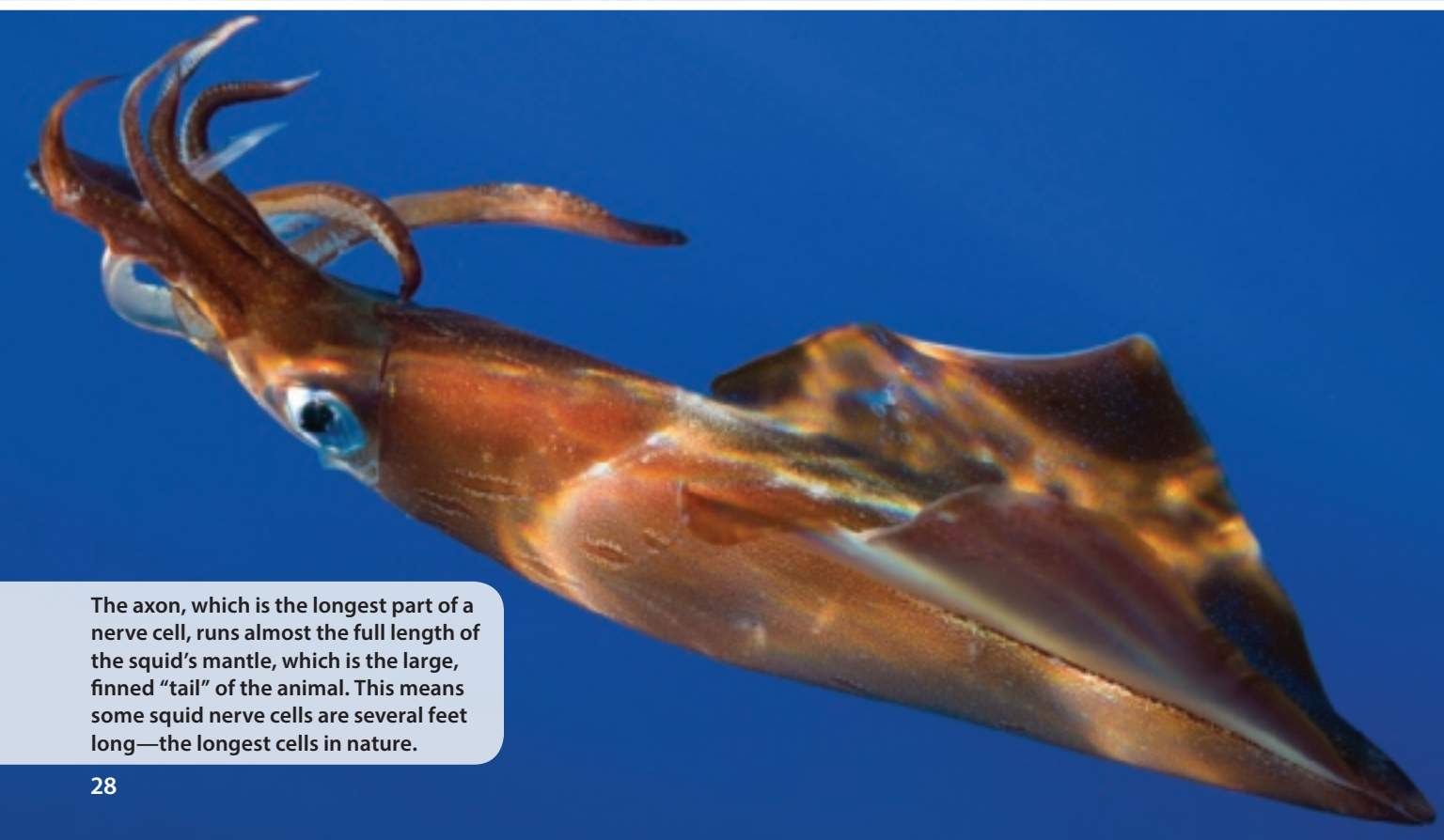
Cells of the human brain may last a lifetime. Degenerative brain diseases, however, can cause these cells to die prematurely, resulting in the loss of memory and other functions.



The human body cells with the shortest lives might be the epithelial cells of the intestines. These cells help absorb nutrients from food. They last about three days on average, after which newer epithelial cells take their place.



Caulerpa taxifolia is a marine alga that grows up to a foot in length, despite being unicellular, meaning the whole organism can consist of just one cell with many nuclei.



The axon, which is the longest part of a nerve cell, runs almost the full length of the squid's mantle, which is the large, finned "tail" of the animal. This means some squid nerve cells are several feet long—the longest cells in nature.



For bacteria, a single cell comprises the whole organism, and bacteria reproduce very rapidly. Some bacteria can double from one cell to two as quickly as every four minutes. *E. coli*, which causes food poisoning, can double in number about every 20 minutes.



Phagocytes are cells that are capable of engulfing and absorbing other cells and particles. White blood cells engage in phagocytosis when they attack bacteria in the body. Amoebas, like bacteria, are composed of single cells. Amoebas like this one consuming several parametia could be characterized as tiny predators.

Healing Tissues and Replacing Cells

The Medicine Man of Mango Island

When I was getting ready for my time in the Peace Corps, I didn't think much of buying six tubes of antibiotic ointment and some bandages. They're so widely available in the United States, it felt like packing a pair of socks or a spare toothbrush. But since arriving here on this island and letting someone use some of the ointment and some proper bandaging to treat an infected hair follicle—a boil—of a neighbor, word has spread of my "special medicine," and I have had complete strangers show up at my door seeking it.

The most recent case involved my colleague and neighbor, Sammy. He's 43 and diabetic. He's often massaging his toes and feet to improve circulation. A few Sundays ago, he spilled some boiling water on his big toe. The lack of adequate circulation of blood meant that damaged cells weren't healing well, and dead cells—the ones destroyed by the burn—were not being broken down and cleaned out as well as they should be. And because Sammy has diabetes, his high blood sugar inhibits the immune system that is trying to repair the wound. In about a week, he had a dime-sized gouge in the fat part of his toe. He went to the local medical clinic, but they just looked at it and suggested that his toe would probably need to be amputated to prevent infection from spreading to the rest of his foot.

I applied antibiotic ointment and wrapped clean gauze and bandages around his toe twice a day for about a week. The bandage was snug enough to pull the wound closed but loose enough to allow circulation in the toe. This was the only way to encourage healing. The antibiotic ointment helped kill bacteria in the wound and prevent more from taking hold. Now, Sammy's toe is actually healing, and the doctor at the clinic said amputation won't be necessary.

I'm now going to focus the rest of my service here on improving awareness of proper treatment of these kinds of wounds, especially among the many diabetic people here. I'm also writing a grant proposal to have more antibiotic ointment and bandaging materials shipped here. There's no reason for people to be losing toes, fingers, or limbs to infections like this.

Healing in *Arabidopsis thaliana*

Abstract

We investigated healing in the roots of thale cress, *Arabidopsis thaliana*. A laser was used to cut into the roots of multiple plants. First, we observed how fluid pressure in the cells next to the wound increased, to help bring water and nutrients to the site for new cells to grow.

Next, we adjusted the amounts of auxin, a plant hormone important in triggering growth, in the roots. A higher level of auxin resulted in a tumorlike overgrowth of tissue at the wound site. When auxin levels were very low, the wound did not heal as quickly.

We also experimented with the role of fluid pressure, also known as turgor pressure, in the root tissue. When we applied mannitol, a substance that draws water out of tissues, to the roots after wounds were made, the wounds did not heal well.

Our results suggest that the hormone auxin and high turgor pressure are important components in a plant's response to trauma and a plant's ability to heal damaged tissues.



Wellness and Health

Spot the BS

Heads up! There's some **bad science** in on this page. Which of the claims about the products seem hardest to believe?

Wellness Gifts for Your Beloved

Wellness World's editors and experts have compiled a list of must-have gifts for the smart, wellness-minded person in your life, just in time for your next special day!



Himalayan sea salt is a quarter billion years old. Its age means it has none of the impurities or toxins found in rock salt or sea salt from the modern age. \$69 (two-pound box)

The ancient Greeks thought amethyst gemstones helped their wearers maintain their wits. Keep your head clear with this amethyst crystal-infused water bottle. \$59



Jade has been an important part of traditional Chinese healing and wellness for 4,000 years. Use this jade roller to release toxins and body heat from your skin before bed. \$79



Newburyville Gazette

Wellness Is Whatever People Want It to Be. And That's Not Good.

Editorial

The wellness industry sells about \$1.5 trillion worth of products every year. What is wellness? If you're not sure, or it's a term you'd never heard of five years ago, you're not alone. Analysts and the industry itself seem to define wellness as a general focus on health, fitness, nutrition, appearance, sleep, and mindfulness. The health care provided by your family physician or a surgeon would not really qualify as "health" in this case, but the herbal supplements and vitamins and other things you might ingest or otherwise use on your own would qualify, as long as you think you are doing it for health. "Mindfulness"? This seems like a flimsier way of saying "thoughtfulness" without requiring actual

thought. Or maybe it is meant to suggest a vague feeling of being connected to . . . something? The vagueness itself seems to be the selling point, because a consumer can see or hear whatever they want to when language is so wishy-washy.

One of the other signs that you've stumbled into a wellness store, either real or virtual, is the abundance of claims about seemingly nonreactive materials working wonders on your skin, brain, or other body parts, as well as your soul. Various jade trinkets are meant to be worn or rubbed on one's face or back to help with "healing" and "energy." Glass bottles containing trace amounts of gemstones are supposed to help you "connect with yourself," but the cause-and-

effect relationship between the liquid you ingest and the solid, nonreactive material that held it is unexplained. Perhaps it's just supposed to feel better to drink water from a pretty glass?

Scientific analyses of the claims made by the wellness industry have already resulted in fines and legal settlements, yet these are a drop in the bucket, so the industry keeps chugging along. There is simply too much money to be made.

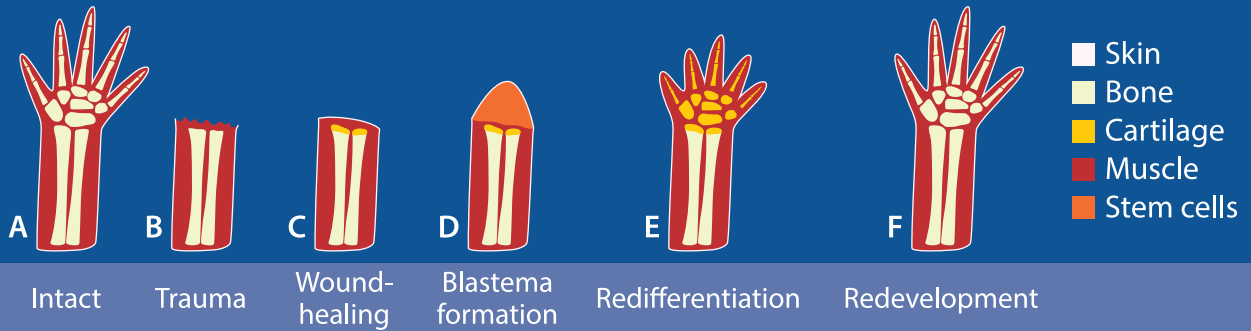


Will Humans Be Able to Regrow Limbs?



In a sci-fi comic book, anything is possible, including the regeneration of a missing limb and the unfortunate side effect of turning into a half-human, half-salamander!

Axolotl Limb Regeneration



When an axolotl salamander loses a limb, the wound-healing phase is followed by the formation of a blastema. The blastema consists of cells that had been parts of the skin, muscle, cartilage, bone, nerve, and other tissues of the now-missing limb, but they have regressed to less-defined forms. It's almost as though they have gone back in time to what they were like when the axolotl was developing in an egg. Over time, these cells differentiate again into the specialized cells they used to be so that bones, muscles, and other parts of the **regenerated** limb can take shape and grow. The growth of nerves into the blastema seems to be particularly

important. When nerve growth is prevented, the blastema does not develop into a limb.

If human cells could be programmed to dedifferentiate and form a blastema instead of forming a scar at the site of a major trauma, it is possible that regeneration of human limbs and other body parts could one day become a reality. But little is understood about how this process occurs, including how the DNA of the axolotl and similar organisms directs and conducts the process. Even if regeneration of human limbs became possible, the process would probably take years, not the mere seconds or minutes like in movies or comic books.



Vocabulary

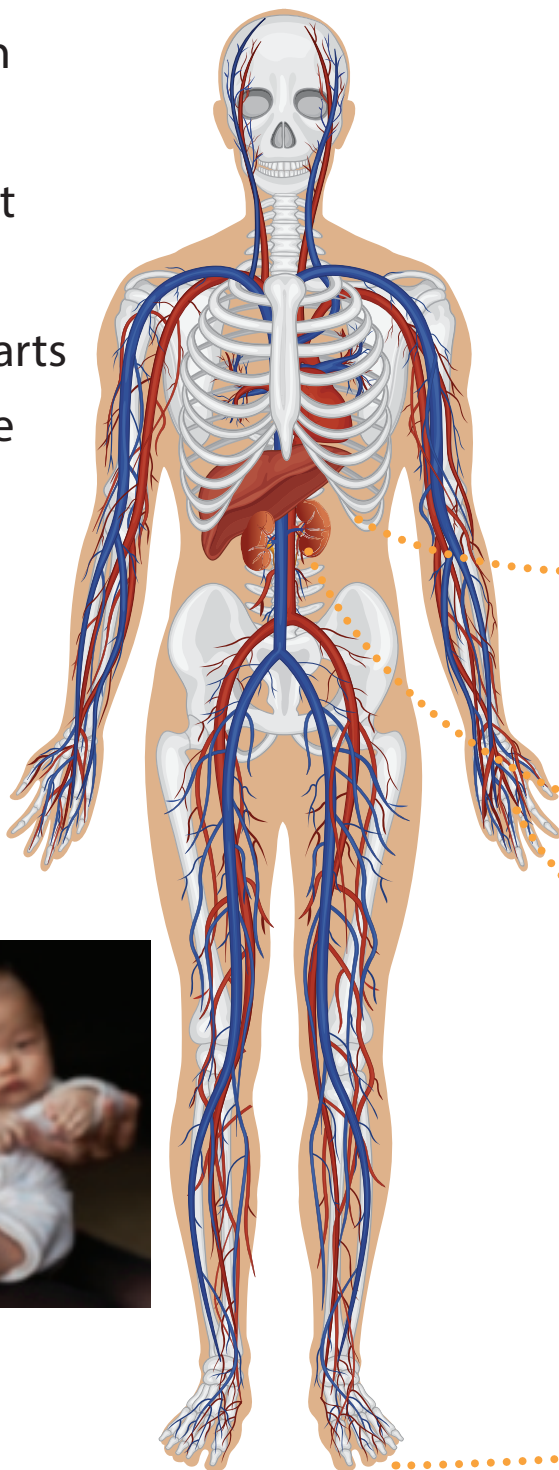
regenerate, v. to replace lost or injured tissue

Word to Know

In organisms, *cell differentiation* is the transition from a generalized cell into a cell of a specific type.

Spare Parts

It is not uncommon for a human body to have a spare part or two. The typical body has several parts that people can live without. And some people's bodies grow additional extra parts, as well.



Sometimes a person can have two sets of DNA in their bodies, especially their bloodstream. This can occur when a mother has a fetus and some of the fetus's cells end up in the mother's bloodstream. If the cells survive for years, this can actually lead to confusing DNA test results. In other cases, fraternal twin embryos form in the mother's womb, one of them dies, and some of its cells end up being absorbed by the surviving twin. That twin can end up having two sets of DNA as a result. This condition is known as chimerism. If a person receives a bone marrow donation, they will likely have many blood cells with the DNA of the donor.

Most humans are born with 24 ribs, with 12 on each side of the torso. Some people are born with extra ribs, called supernumerary ribs. These can develop near the neck or at the bottom of the rib cage. In most cases they are harmless, but in some cases they can pinch nerves.

Some organs come in pairs, such as the kidneys. A healthy person can donate a kidney to another person without jeopardizing their own health. A lobe of the liver can also be donated to someone in desperate need of a new liver.

Polydactyly is a condition resulting in extra fingers or toes. About 0.1% of the general population has this condition at birth. In many cases, the extra digits are removed because they are not functional. Polydactyly also occurs in cats.

There are structures in the human body that appear to serve no purpose. For example, the smallest toes of your feet most likely do not help you with movement or balance. Likewise, the coccyx, or tailbone, does not seem to serve a purpose in humans or closely related primates. These are called vestigial structures. They are basically leftovers from our ancestors who did use their fifth toes and had functional tails.

Bum Ligament:

Reconstruction or PRP?

Not even five minutes into the first game of the season, and I blow out my knee! Went up for a dunk, got fouled, came down at a slightly wrong angle, and my knee buckled. I felt and heard the “snap” in my knee and knew my season was over five minutes later when our head trainer jostled my lower leg side to side and nodded grimly. “ACL. We’ll get you an MRI tonight, but I’m pretty sure your ACL is fully torn.” I’ve had my leg in a soft cast since then. And the MRI confirmed the trainer’s fears.

I’m on the last year of my contract, so the timing could not be worse for me. But my agent has some of the best orthopedic doctors’ phone numbers in his phone for moments like this, so he’s been asking what the best options are so I can possibly be ready for the end of the season and be at full strength going into free agency. ACL reconstruction has been around for years, and I know a lot of players who have had that surgery and ended up bouncing back from it, but it seems to take a while. Another option is something called PRP. I guess it involves taking out your blood and processing it so it contains the stuff that helps healing, and then they inject it into the knee so the ligament is better prepared to heal and scar tissue doesn’t build up. I guess part of the problem with ligaments is they don’t get a lot of blood, so when they’re torn, they are kind of ignored by the body’s repair system.

Surgery seems inevitable if I want to keep playing ball, but this PRP stuff is something I’ll need to look into more deeply.

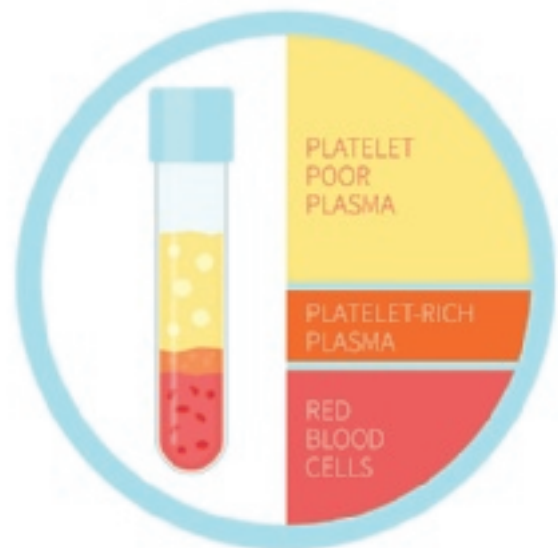
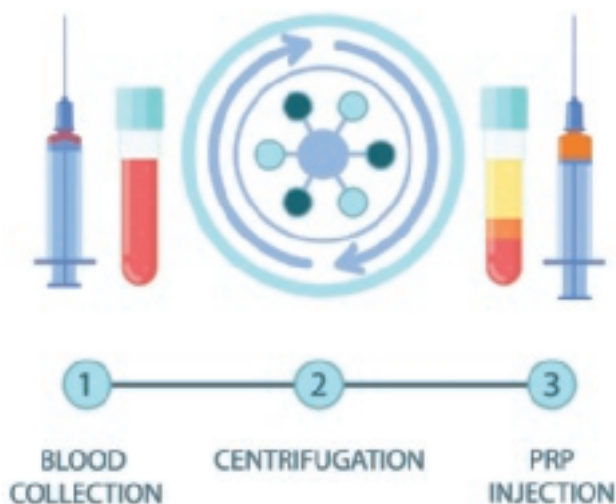
I know Kobe used it when he was banged up toward the end of his Hall-of-Fame career.



Reconstruction of ligaments often involves taking a portion of a tendon from the patient's body, making a new ligament from that piece of tendon, and fixing it in place in the damaged joint. In the case of a torn ACL, or anterior cruciate ligament, a piece of tendon from the same knee is often used as the graft tendon. The grafting process involves drilling holes in the thighbone and shinbone, passing the graft tendon through both holes so the tendon takes the place of the ruptured ACL, and then screwing the ends of the tendon in place. The rehabilitation process from the surgery can take months. The holes in the bones heal, and the tendon effectively becomes a new "ligament."

PRP stands for platelet-rich plasma. Platelets are the specialized blood cells that are delivered to a site of trauma, such as an open cut, to form blood clots so bleeding doesn't continue. Plasma is the fluid that makes up most of the volume of blood. PRP is basically plasma with about four times as many platelets as you would find in normal blood. It also contains white blood cells, also known as leukocytes. PRP can be injected into a joint with a strained (partially torn) ligament. The leukocytes clear out bacteria and other things that might interfere with healing, and the platelets encourage healing. Platelets also provide growth factors that help with cell division and tissue regeneration. So far, PRP therapy has had promising results, but it cannot make a fully torn ligament regrow.

PLATELET-RICH PLASMA



Living and Thriving with Physical Disadvantages

Rick Allen

Rick Allen has been the drummer for rock band Def Leppard for over forty years. In 1984, after the band had already achieved tremendous success, Allen lost his left arm in a car accident. He learned to drum with one hand and help from an electronic drum kit that allowed for greater use of his feet. The band has sold tens of millions of records and was inducted into the Rock and Roll Hall of Fame in 2019.



Stevie Wonder

Stevie Wonder was born blind. Despite this disadvantage, he learned to play piano and many other instruments and is a master vocalist and songwriter.

Dr. Stephen Hawking

Dr. Stephen Hawking lived with a rare, slow-progressing form of amyotrophic lateral sclerosis (ALS) from 1963 until his death in 2018. A professor of mathematics, Hawking developed detailed theories on the origins of the universe and was widely regarded as one of the most brilliant people on Earth. After he lost the ability to speak with his voice, he used a computer that he could control with his cheek to write and speak.



Bethany Hamilton

In 2003, Bethany Hamilton was a 13-year-old aspiring professional surfer when her left arm was bitten off by a tiger shark. Rather than give up her dream due to her physical disability or out of fear of sharks, she continued to surf and won her first national title two years later. "To lose your everyday life of surfing and being creative on waves, enjoying the ocean—that's scary to me," she says. "It was essential to at least try surfing again and get out there and see how it went." By 2007, she was a pro. Bethany got an assist from her dad, who fashioned a handle onto her surfboards so she could push the board under unwanted waves.



Jim Abbott was born without a right hand. He learned to throw a baseball—and do pretty much everything else—with his left hand and became a phenomenon as a teenager. On every pitch, Abbott used his right arm like a hanger on which his glove would sit as he threw the ball with his left arm. As the ball sailed toward home plate, he would slip his left hand into the glove in case the batter hit the ball toward him. If he fielded a groundball, he would tuck the glove and ball under his right armpit and then reach into the glove with his left hand to throw the ball to first base. He pitched for the United States in the 1988 Olympic Games and went on to pitch for ten years in the major leagues. Over 300 no-hitters have been pitched in the majors, but Abbott is the only player born with one hand to have such a performance.

Back to Maddy's Story

Maddy just had her first real taste of organized ball, on opening day of tee-ball. She had a couple nice line-drive hits and fielded two balls pretty cleanly in the outfield. She's been watching old videos of Jim Abbott, who pitched in the big leagues for a decade with one hand. Abbott's routine with his glove is what Maddy is trying to copy. His story is so inspiring. We also just watched a movie about Bethany Hamilton, the surfer who lost an arm to a shark attack and then went on to become a champ. Incredible. There are so many role models for Maddy to look up to.

For now, Maddy seems happiest to just be who she is and not use any kind of prosthesis. And frankly, I think she's going to do awesome at whatever she does, even without a left hand. But I am keeping my ear to the ground about advances in robotics. If she could eventually have a hand that she could use just by thinking, maybe it would be worthwhile. To see some of the robots that are being made these days—dancing, providing protection from threats, performing surgeries—we just can't rule out that some solution might suit her at some point.

Tee-ball today, and her first drum lesson tomorrow. I'm so proud of her!

Glossary

amputation, n. a surgical procedure in which a limb is removed

analogous, adj. referring to structures that have similar functions

apoptosis, n. the preprogrammed death of a cell

bone cell, n. living structural units that make up bones

cell, n. the smallest structural and functional unit of an organism

cell differentiation, n. the transition from a generalized cell into a cell of a specific type

cell membrane, n. the semipermeable membrane surrounding a cell's cytoplasm

cell wall, n. the rigid layer outside the plasma of plant, fungal, and bacterial cells

chromosomes, n. threadlike structures in the nucleus of most living cells that carry genetic information in the form of genes

collagen, n. a structural protein in skin and connective tissue

compression, n. the act of placing under pressure or being compressed

connective tissues, n. tissues, such as tendons and ligaments, that connect or support other tissues, organs, or body structures

cross section, n. a view of something that would be exposed by making a straight cut through it

CT scan, n. a medical X-ray image produced by computed tomography

cytoplasm, n. the fluid within a cell surrounding the nucleus

exoskeleton, n. the rigid external structure that provides support and protection to invertebrates

focus, n. the center of interest or attention

function, n. the purpose for which or particular way a thing works

gamete, n. a reproductive cell

healing, n. the process of becoming healthy again

hydraulic, adj. operated by liquid contained under pressure

metabolism, n. the chemical processes that sustain life in an organism

MRI, n. magnetic resonance imaging; a technique used to image internal structures in the body

multicelled organism, n. a living thing composed of more than one cell (multicellular)

muscle cell, n. a living structural unit that makes up muscle tissue

muscle fiber, n. a muscle cell, generally cylindrical, that makes up skeletal muscle tissue

nerve cell, n. a living structural unit that conveys electrical signals between the brain and other structures in the body

nucleus, n. the organelle within a cell that contains genetic material

placebo, n. a neutral substance used in scientific investigations to test whether a tested substance works as designed

plasma, n. the colorless fluid part of blood

platelet, n. a structural component of blood involved in clotting

prosthetic, adj. related to prostheses, artificial limbs

red blood cells, n. structures that deliver oxygen to tissues via blood flow through the circulatory system

regenerate, v. to replace lost or injured tissue

science literacy, n. the ability to read, hear, and comprehend information about scientific topics and demonstrate understanding in discussion and through writing

sensory system, n. the collection of neurons and parts of the brain that contribute to vision, hearing, touch, taste, smell, and balance

single-celled organism, n. an organism that consists of a single cell (unicellular)

skepticism, n. doubt about the truth of something

skin cell, n. a living structural unit that makes up the tissue covering an organism's external surface

sperm cell, n. the male reproductive cell (gamete)

stem cells, n. undifferentiated cells from which all other specialized cell types are generated

structure, n. the way the parts of something are arranged

tissue, n. a grouping of cells that perform a specialized function together

white blood cell, n. a type of blood cell, made in bone marrow, that helps the body fight infection and disease

X-ray, n. a wavelength of electromagnetic radiation that is used to produce medical imaging of structures inside the body

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