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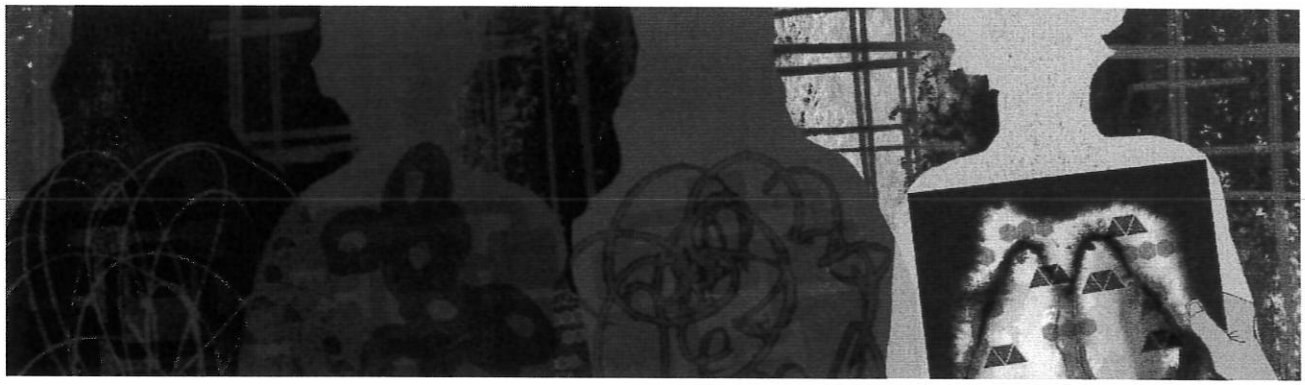

Metabolism:

Making the Diagnosis

Article Compilation

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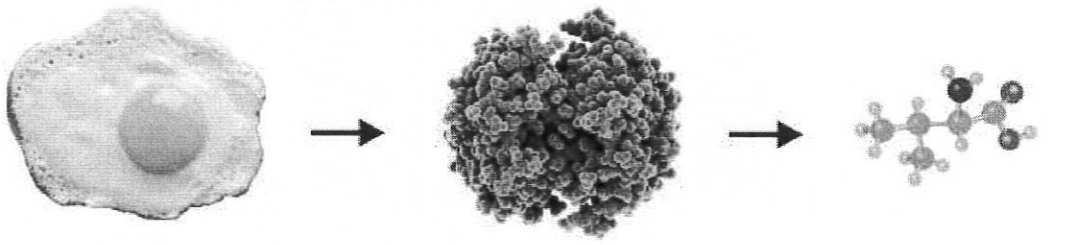
Molecules Cells Need

When your body is healthy, it runs so smoothly that you probably don't even notice it: without thinking about it, you can get up in the morning, breathe, laugh, dance, grow, fight off diseases, and live your life! But what makes a body healthy, and how does it stay that way? In a healthy body, all the systems work together to make sure every cell gets the molecules it needs: oxygen, glucose, and amino acids. Metabolism is the body's use of these molecules for energy and growth.

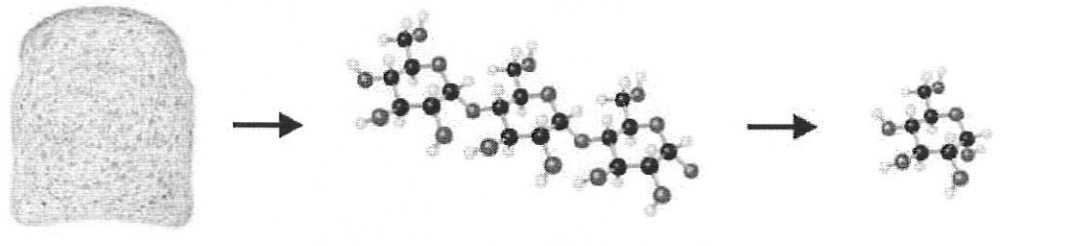
We need to breathe in oxygen molecules from the air around us to keep our bodies alive. Our bodies get other important molecules, such as amino acids and glucose, from the food we eat.

Amino acid molecules are the building blocks of proteins, and we get them from protein-rich foods like beans, meat, and eggs. We get glucose molecules mainly by breaking down foods that contain starch, such as fruits, vegetables, and grains.

The oxygen, glucose, and amino acid molecules you get from air and food are the fuel your body needs to function every day. Without these molecules, your cells can't do what they need to do to keep your body healthy. Many medical conditions cause problems because they can keep these molecules from reaching your cells consistently.



Many foods, such as eggs, contain protein. Large protein molecules are made up of smaller molecules called amino acids.

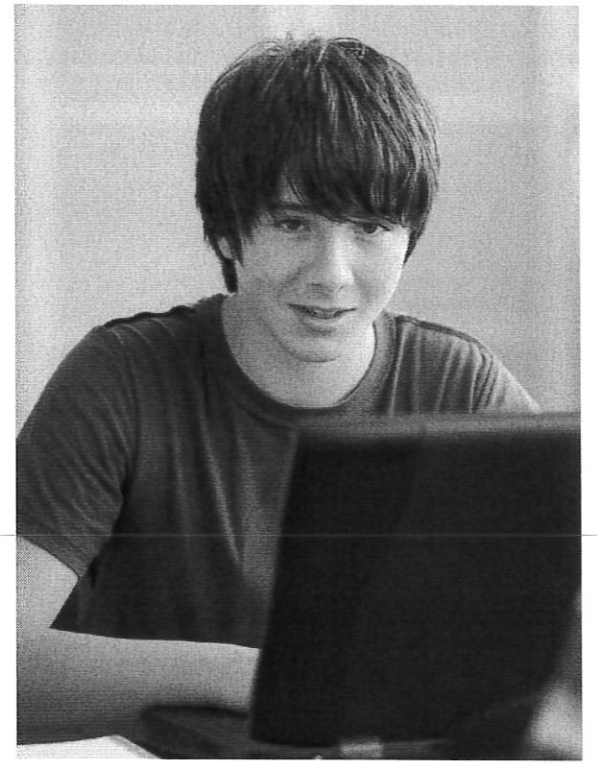


Many foods, such as bread, contain starch. Large starch molecules are made up of smaller molecules called glucose.

Patient Stories: Problems with Body Systems

With every breath and every bite of food, the human body takes in millions of molecules. These molecules are so small that they can't be seen under a common microscope, but the body can't live without them. How can something so tiny be so important to the health of the whole body? When everything works properly, the body gets certain molecules from food and from the air. The molecules enter the cells of the body and provide everything the cells need to be healthy. Healthy cells make up healthy organs, and healthy organs work together in systems to keep the body breathing, moving, thinking, and releasing energy. The relationship between molecules and health isn't just a cool idea: tiny molecules can actually make a person feel better or worse!

Sometimes people get sick because their cells aren't getting the molecules they need. When this happens, we say the person has a medical condition. Doctors often look for medical conditions when a patient's symptoms don't seem to be caused by something like bacteria or a virus. In many cases, people can manage medical conditions by taking medicine to make sure their bodies get the molecules they need. Read the following story to find out about a person whose body systems didn't provide his cells with everything they need.



Anemia can make patients feel very tired.

Anemia: Red Blood Cell Shortage

My Story

A few months ago, I was feeling tired all the time. I tried taking it easy and getting extra sleep, but that didn't help. I even started feeling like I was going to faint sometimes. My dad took me to the doctor, and she tested my blood. She said my red blood cell count was lower than normal, and the amount of oxygen in my blood was also lower than normal. Based on the blood test, the doctor gave me a diagnosis: anemia. I asked the doctor about anemia—I wanted to know what it was and how I got it! She said anemia means having fewer red blood cells than a healthy person does.

How Anemia Affected My Body

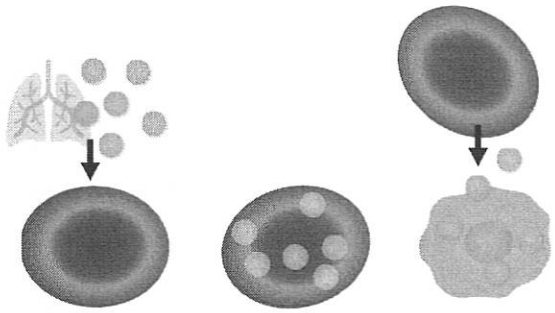
With each breath, oxygen molecules go into our lungs, which are part of the respiratory system. The oxygen molecules move from the lungs through tiny structures called alveoli (al-VEE-oh-lie) and into the circulatory system. The circulatory system is filled with red blood cells, and these red blood cells quickly pick up the oxygen from the lungs and move it all around the body. Through this process, oxygen molecules are delivered to cells all over the body. Cells need oxygen to function well.

My anemia was affecting my red blood cells. Even though my respiratory system was taking in plenty of oxygen, I didn't have enough red blood cells to carry the oxygen around in my circulatory system. Because I had fewer red blood cells to carry oxygen, there was less oxygen in my circulatory system. Because of this, my cells were not getting as much oxygen as a healthy person's cells. My cells were not getting enough oxygen, so they were not doing well—and neither was I!

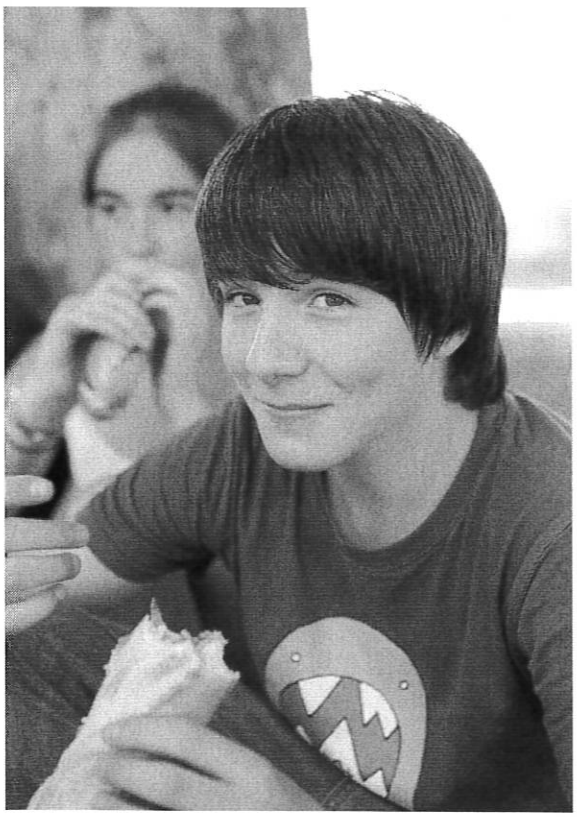
The doctor said my anemia was probably caused by not getting enough iron in the food I was eating. Not getting enough iron is the most common cause of anemia. Your body needs iron to make red blood cells: if your body doesn't have enough iron, it won't have enough red blood cells.

How I Stay Healthy

The doctor must have been right about the iron, because as soon as I started taking iron pills, I started feeling more energetic. Now I feel fine! I don't need to take iron pills anymore, because I'm making sure to eat plenty of beans, meat, and greens like spinach—those are all foods with lots of iron in them. With these changes, I have plenty of energy.



Oxygen molecules pass from the lungs into the blood, where they are picked up by red blood cells. The red blood cells carry the oxygen to body cells, which can use it to release energy.



Eating plenty of iron-rich foods can help cure and prevent anemia.

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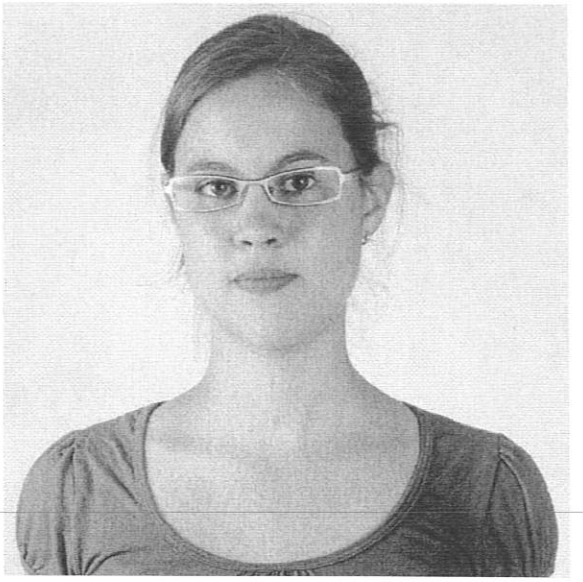


Asthma is a condition that makes it difficult to breathe.

Asthma: Struggling to Breathe

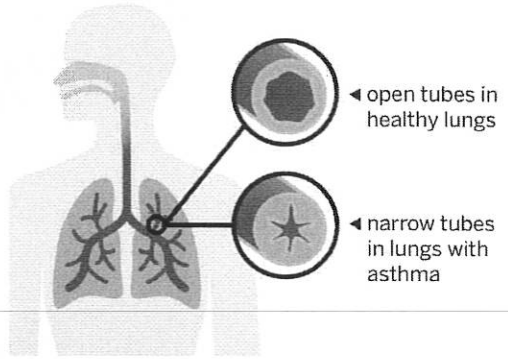
My Story

I found out I have asthma. I would sometimes have trouble breathing, especially when I exercised during PE class. If I ran home from the bus stop, I would have trouble catching my breath afterward. It felt like my chest was tightening up, and it was hard to breathe. I would make a noise when I was trying to breathe, and my mom told me that was called wheezing.

I went to the doctor and she listened to my lungs, did some other tests, and asked me a lot of questions about when I have a hard time breathing. She said I have asthma. This diagnosis means that if something like exercise or dust irritates my lungs, the tubes inside my lungs swell up. When the tubes swell, they get narrow and not as much air can get through. That can make it hard to breathe.

How Asthma Affects My Body

The doctor explained that asthma affects more than just your breathing. She said that when you breathe in, you pull oxygen molecules from the air into your respiratory system. In your respiratory system, the oxygen moves through smaller and smaller tubes deep into your lungs. Inside the lungs are tiny structures called alveoli (al-VEE-oh-lie). In the alveoli, oxygen molecules move from the respiratory system into the blood of the circulatory system. Your blood carries those oxygen molecules throughout your circulatory system, delivering oxygen to all the cells of your body.

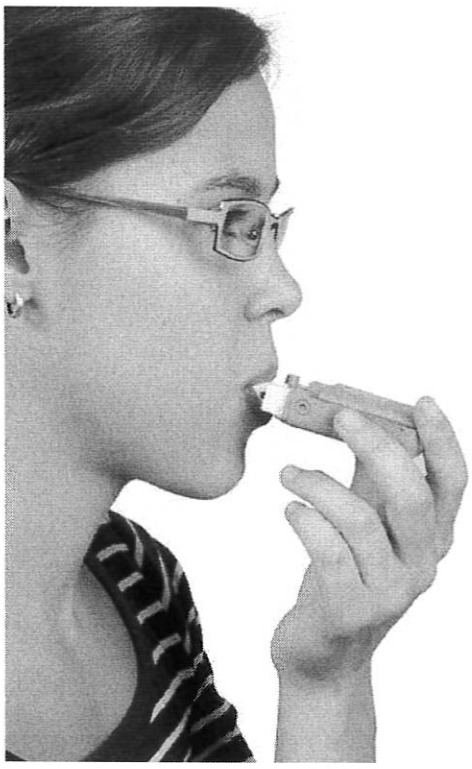


Asthma causes the tubes in the lungs to close up, so that air cannot pass through.

Because of asthma, the tiny tubes in my lungs were squeezing shut, and I wasn't getting as many oxygen molecules into my respiratory system as a healthy person would. Because there was less oxygen in my respiratory system, there was less oxygen moving into the blood in my circulatory system. With too little oxygen in my blood, not enough oxygen was getting to my cells. Cells need oxygen! Without oxygen, cells can't do any of the things they need to do for the body to function. I wasn't doing well because my cells weren't doing well.

How I Stay Healthy

The doctor gave me an inhaler to help me breathe when I have an asthma attack. The inhaler stops the tubes in my lungs from swelling, keeping the tubes wide and letting me breathe in more oxygen. The doctor also told me to be careful of certain things, like lots of dust. For instance, the playing fields at my school can get really dusty. When that happens, I should try not to play sports outside. I still participate in PE class, but I tell the teacher when I need to use my inhaler or take a short break. Now I know what causes my asthma attacks and how to take care of myself so they don't happen as often.



People with asthma can use inhalers to keep the tubes in their lungs open.

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Diabetes prevents the cells in the body from getting the glucose they need.

Diabetes: Glucose Locked Out

My Story

I was diagnosed with type I diabetes when I was five years old. You may have heard of the phrase "blood sugar." When people talk about blood sugar they really mean blood glucose. Glucose is a kind of molecule that cells need in order to release energy, and all people have glucose in their blood. If you have diabetes, your level of blood glucose can get too high.

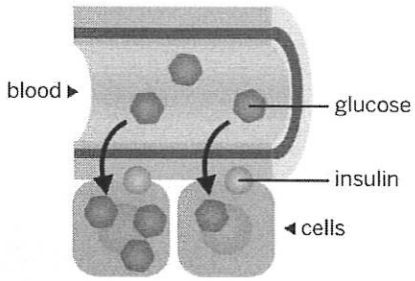
Where does that glucose come from? When you eat starch and other carbohydrates, your digestive system breaks them down into glucose. Then the glucose moves into your blood, and your circulatory system carries it throughout your body. If you don't have diabetes, that glucose moves from your circulatory system into all of your cells. For a person with diabetes, it's not that simple.

How Diabetes Affects My Body

Glucose doesn't just go into your cells automatically. Cells are actually very picky about which molecules are allowed to cross the cell membrane and enter the cell. In order to get glucose into a cell, the cell membrane needs to be unlocked. A molecule called insulin acts like a key to unlock the cell membrane and let glucose inside. Insulin is a protein molecule made in special cells and released into the blood of the circulatory system, which carries the insulin to every cell in the body. People with diabetes have trouble making insulin. Since I have diabetes, my body is not making enough insulin.

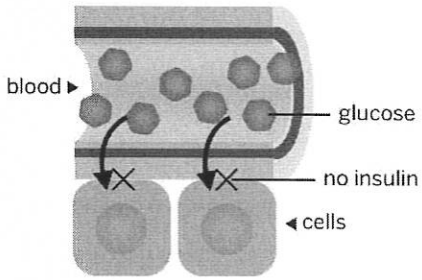
Without insulin, glucose is locked out of my cells. The glucose molecules can't get through the cell membranes—they just get stuck in my circulatory system. When that happens, the amount of glucose in my blood gets higher than normal. More important, my cells don't get as much glucose as they need. Other molecules can get into my cells just fine, but not glucose. When my cells aren't getting enough glucose, they can't function—and that can become very dangerous!

No Diabetes

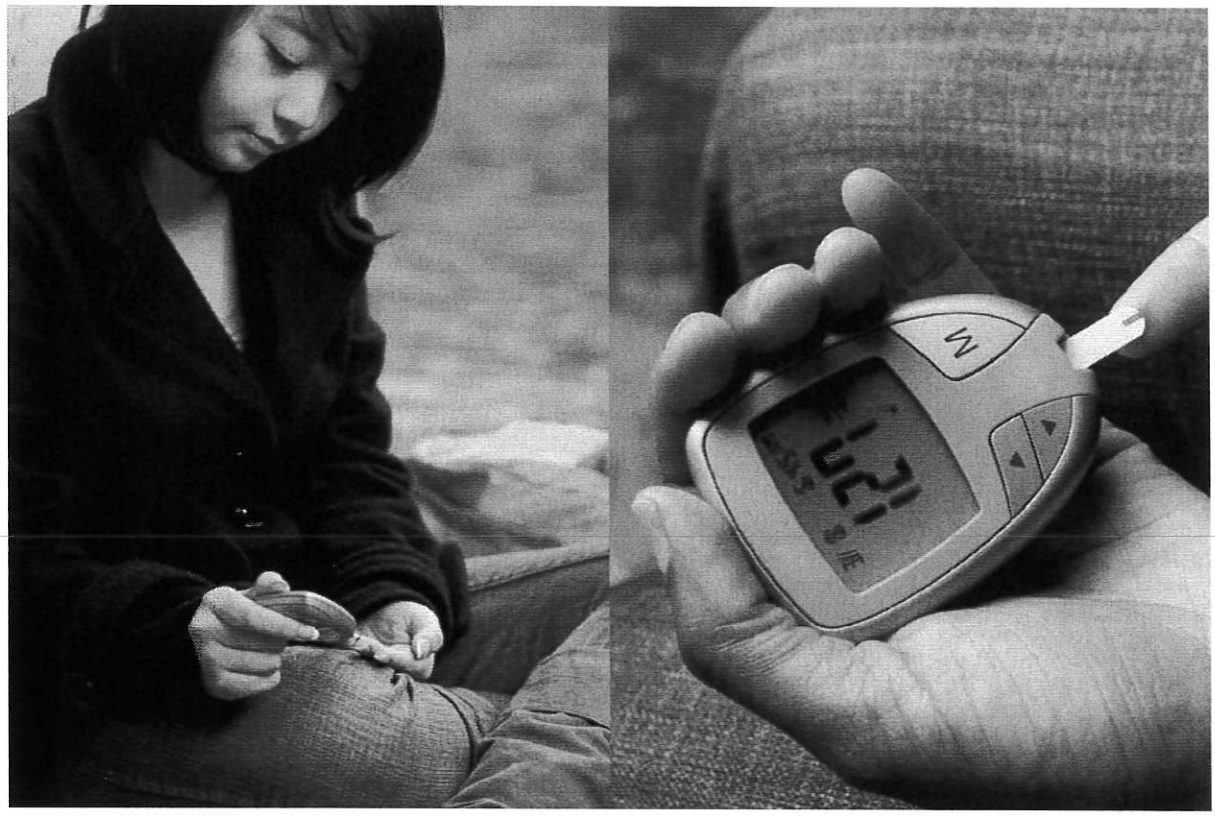


In a person without diabetes, insulin allows glucose to enter the cell, where it can be used to release energy.

Diabetes



In a person with diabetes, there's no insulin to "unlock" the cells and allow glucose to go in. Because the glucose cannot leave the blood, there is too much glucose in the blood.



People with diabetes must test the levels of glucose in their blood.

How I Stay Healthy

To keep myself healthy, I've learned how to control the amount of glucose in my blood. I measure my blood glucose several times a day, and use the test results to decide what to eat and when. I also take a kind of insulin that is made in a lab. When I take insulin, my circulatory system carries the insulin to all the cells in my body. The insulin unlocks my cell membranes so that glucose molecules can move from my circulatory system into my cells. That way, my blood glucose doesn't get too high, my cells get enough glucose, and I stay healthy.

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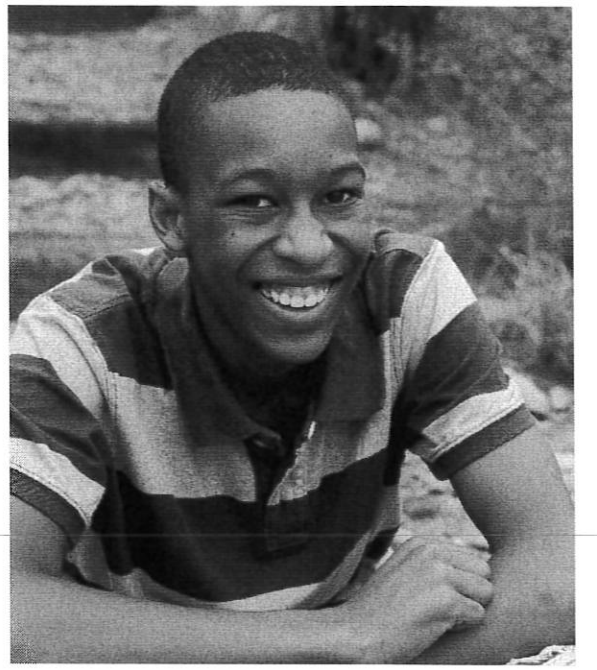


An injury to the pancreas keeps the body from digesting food properly.

Injury to the Pancreas: Trouble Digesting

My Story

When I was a little kid, I got hit by a car when I was riding my bike. Luckily I was wearing my helmet, so I survived. Still, I was pretty badly injured where the car ran into my body. I had to go to the hospital and have some operations. I seemed fine for a long time after that, but then I started to get sick. It felt like I wasn't digesting my food right. My insides usually hurt after I ate, and I had diarrhea. I also felt tired a lot.

My parents took me to see the doctor. After a bunch of tests, the doctor said that my pancreas must have been injured in the bike accident. He said I have chronic pancreatitis, which means that my injured pancreas isn't

working as well as it should. I'd never even heard of a pancreas! The doctor explained that it's a small but important organ that's part of the digestive system. He said injury to the pancreas is a really unusual diagnosis, and that may be why no one figured it out earlier.

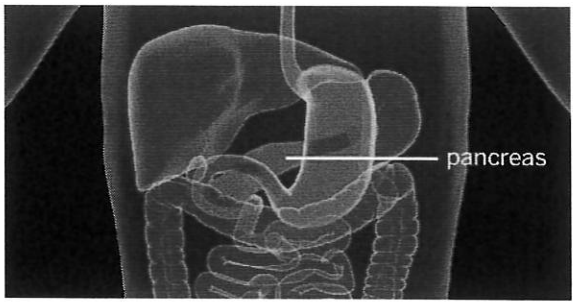
How My Pancreas Injury Affects My Body

The pancreas is part of the digestive system and makes lots of digestive enzymes. These enzymes help break down food into smaller molecules, like glucose and amino acids, that are tiny enough to pass from the digestive system into the circulatory system. Because my pancreas was damaged, it wasn't making as many digestive enzymes as a healthy pancreas would.

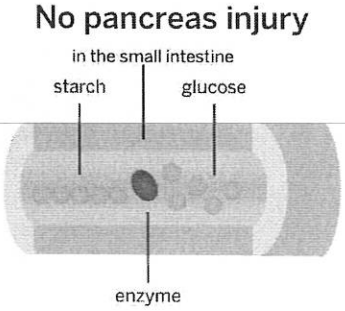
Without enough enzymes, my body was having trouble digesting food—that's what was making me feel sick. Most of the food wasn't breaking down into molecules like glucose and amino acids, so not as many of those molecules were entering my circulatory system as they would in a healthy body. The undigested starches and proteins were just moving right through my digestive system and leaving my body as waste. My cells weren't getting as many glucose molecules as they needed, which was making me feel tired all the time.

How I Stay Healthy

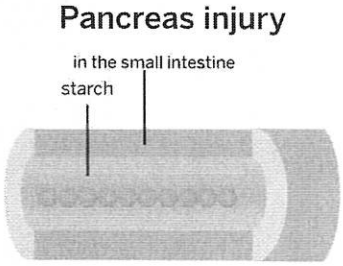
The good news is that scientists have figured out how to make most of the enzymes that a healthy body needs. To stay healthy, I've been taking medicines with enzymes in them, and they are helping my body digest food much better. Now my cells are getting all the molecules they need. I still have a damaged pancreas, but I'm feeling much better.



The pancreas is an organ located underneath the liver and near the stomach.



The pancreas makes enzymes that break down food into smaller molecules.



Without the enzymes made by the pancreas, starch molecules aren't broken down into glucose molecules.

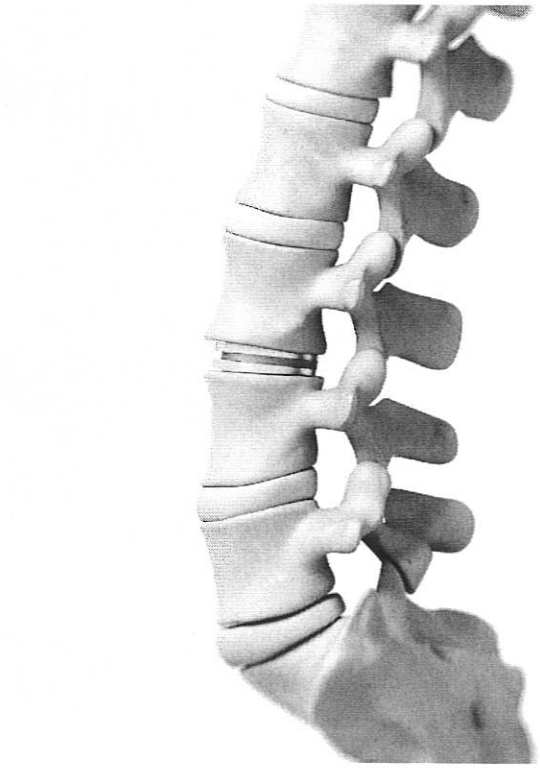
Medicines with enzymes in them can help people with pancreas injuries stay healthy.

Meet a Scientist Who Grows New Cells

When parts of the body get old or injured, they sometimes stop working the way they should—and cause pain, sickness, or worse. In many cases, doctors can help patients by replacing a part or a whole organ with a machine or a mechanical version, like an artificial heart or a knee joint made from plastic and metal. But what if scientists could grow brand-new organs and use them instead of the mechanical versions? Dr. Grace O'Connell, a researcher at the University of California, Berkeley, is trying to do just that.

O'Connell and the students in her lab study the soft tissues in the spine—specifically the squishy discs of tissue between the vertebrae, or bones, of the spine. Because these discs are between the vertebrae, they're called intervertebral discs. The discs act like cushions between the vertebrae, allowing the spine to bend and keeping the vertebrae from touching. The discs in the spine sometimes begin to wear out with age, or squeeze out from between the vertebrae, so they don't offer as much cushioning. That's a sore spot: vertebrae rubbing together or discs putting pressure on the spinal nerves can cause back pain. In most cases, doctors don't replace discs when they wear out; instead, they remove the worn-out or injured disc and glue the vertebrae above and below it together, forming one longer bone. The glued bone doesn't cause as much pain, but it's also less flexible than two vertebrae with a healthy disc between them.

Dr. Grace O'Connell is working to grow new tissue for spinal discs, which could help people with back problems.



The discs between vertebrae (shown here in white) allow the spine to bend and keep the vertebrae from touching or rubbing against nerves in the spine.

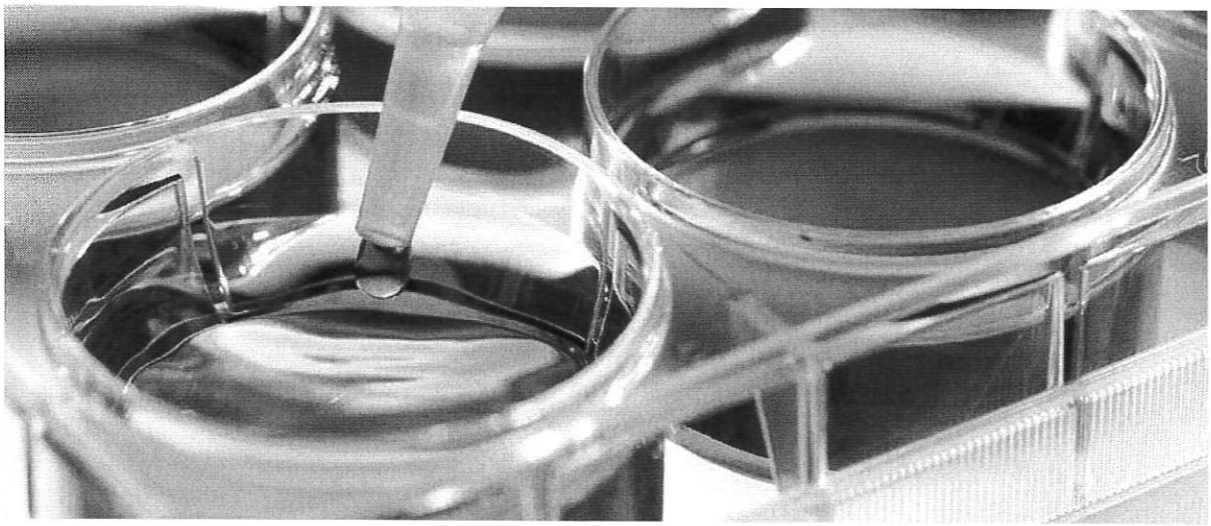
O'Connell hopes to change the way doctors treat damaged or worn-out discs. Instead of gluing the vertebrae together, she hopes to grow brand-new disc tissue to replace old or injured discs! Her lab has two main goals: to study healthy intervertebral discs and to grow new intervertebral disc tissue that behaves just like healthy discs.

Because tissues are made of cells, O'Connell is really working with cells. She begins with a small sample of disc cells and encourages them to reproduce and form new disc tissue. To make the tissue perform exactly like healthy disc tissue, O'Connell and her students look at the cells and how they behave. "The cells create the tissue, which gives the joint its function," she says. "So we look at the way the whole disc works, but we also keep in mind that the cells are really responsible, and we look at how the cells are changing things." Some of the cells O'Connell and her students study come from human medical patients: "Patients sign a release that says they're willing to donate their cells to science, and we get to grow their cells," she says. But sometimes O'Connell and her students study cells that aren't human—and they come from the butcher down the street!

"We get the oxtails," she says. "If they're fresh, the cells are still living, and we can use them."

Growing up near Philadelphia, O'Connell wanted to fly and design airplanes. She even took flying lessons in high school! In college, she studied aeronautical engineering—the study of engineering for flight—but decided to use her engineering knowledge to help people with health problems instead, and studied the way engineering relates to the body. Along the way, she says, "I studied math. Lots of math." She still hopes to earn her pilot's license someday.

Today, she enjoys the challenges of trying to grow new disc tissue from just a few cells—even when her work doesn't go as planned. "One of the biggest challenges of this kind of research is that the cells don't always do what you want them to," she says. "But sometimes that leads to new questions and new learning." In fact, she says one of the hardest parts of the job is finding out that there are some things nobody knows. "You're told 'this is how things are,' when this really isn't how things are in reality. There's a lot that nobody knows, and you have to find out. It's challenging, but it's very exciting when you do learn something that nobody else knew before."



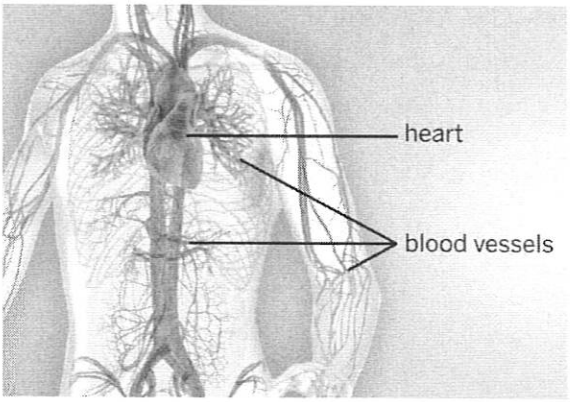
The scientists at Dr. O'Connell's lab grow new cells in dishes of cell culture medium, which helps support cellular growth.

Systems of the Human Body: The Circulatory System

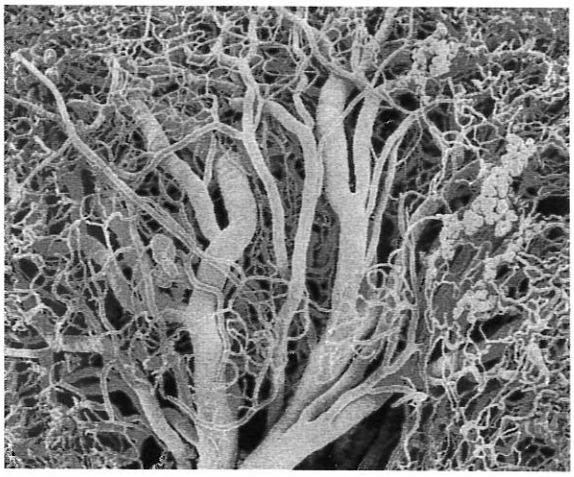
When blood travels through the body, bringing important molecules to cells that need them, it doesn't just flow anywhere and everywhere. Blood flows through a complex system that takes it where it's needed. The circulatory system is made up of blood vessels that extend throughout the body, the blood that moves through the blood vessels, and the heart. It's called the circulatory system because the blood circulates—flows around and around. Blood circulates through the blood vessels to and from the heart and every cell, organ, and system in the entire body. The circulatory system connects the cells to the other body systems, transporting molecules between those systems and the cells. Without the circulatory system, cells could not get what they need from the respiratory system or the digestive system.

Transporting Molecules to and from Body Cells

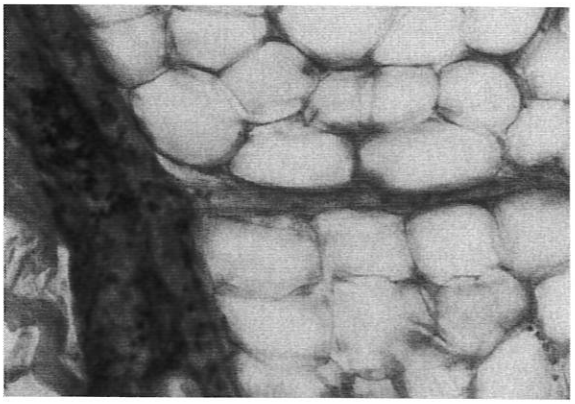
Your body cells need certain molecules—oxygen, glucose, and amino acids—in order to function. These molecules are carried in the blood, which is part of the circulatory system. As the heart pumps, it moves the blood through blood vessels that become narrower and narrower and branch out in all directions. These blood vessels extend to every part of your body, bringing blood to every tiny cell. The blood delivers molecules like oxygen, glucose, and amino acids to the cells. Blood also carries away molecules that the cells don't need, like carbon dioxide.



The circulatory system includes the heart, blood vessels, and the blood itself. It transports molecules to and from body cells.



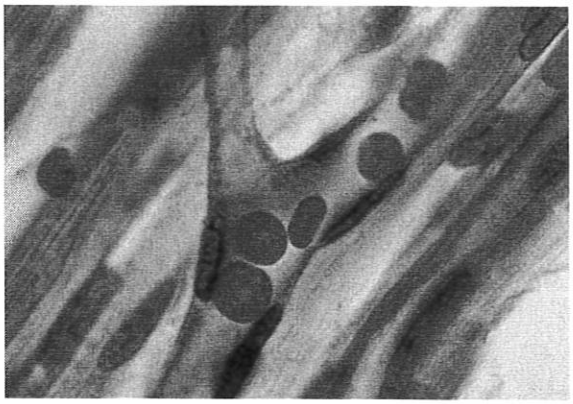
This photo was taken through a powerful microscope. It shows tiny blood vessels branching out in all directions to reach every body cell.



This microscope photo shows body cells and the tiny blood vessels that carry molecules to and from those cells.

Red Blood Cells Carry Oxygen

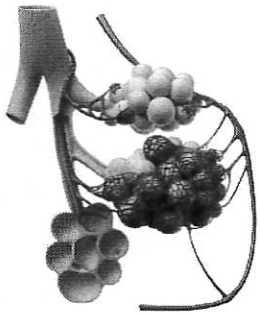
Blood is liquid, but it is partly made up of cells—mostly red blood cells. The red blood cells transport oxygen throughout the body, delivering the oxygen to all the other cells in the body. A special protein called hemoglobin (HEE-moe-globe-in) gives red blood cells their ability to pick up oxygen. Red blood cells contain lots of hemoglobin. Hemoglobin is reddish in color, which is why red blood cells (and blood) look red!



Taken through a microscope, this photo shows red blood cells moving through tiny capillaries in single file. Red blood cells carry oxygen to the rest of the body cells.

Picking Up Oxygen in the Respiratory System

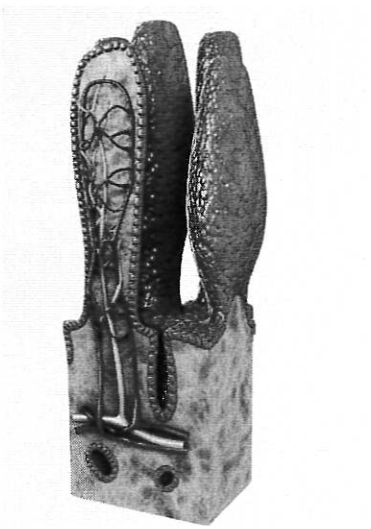
Your circulatory system gets its oxygen from your respiratory system. These body systems connect inside your lungs, at the tiny air sacs called alveoli (al-VEE-oh-lie). It's in your alveoli that the oxygen you breathe moves from your lungs to your blood. The alveoli are surrounded by tiny blood vessels called capillaries, which have very thin walls and are so narrow that red blood cells have to move through them in a single-file line! As you breathe in, your alveoli fill with air. Oxygen from the air passes through your alveoli and enters your capillaries. As red blood cells move through your capillaries, they pick up the oxygen. At the same time, carbon dioxide leaves your blood and goes through your alveoli into your lungs, where you breathe it out.



This diagram gives a cutaway view of the alveoli.

Picking Up Glucose and Amino Acids in the Digestive System

Your digestive system breaks down food into molecules that your cells can use—but it's your circulatory system that actually has to get the molecules to the cells. The circulatory system and the digestive system meet at the walls of your small intestine, where the circulatory system picks up molecules like glucose and amino acids from digested food. This happens in the villi (VILL-eye), tiny finger-like parts that stick out from the walls of the small intestine. Inside the villi, there are capillaries. Glucose

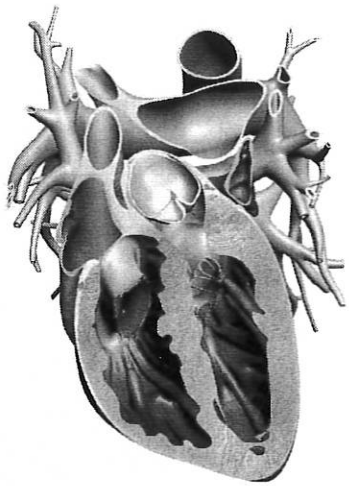


Villi are tiny finger-like parts that line the small intestine. This cross-section diagram shows the tiny blood vessels called capillaries inside the villi. In the villi, molecules pass from the digestive system into the circulatory system.

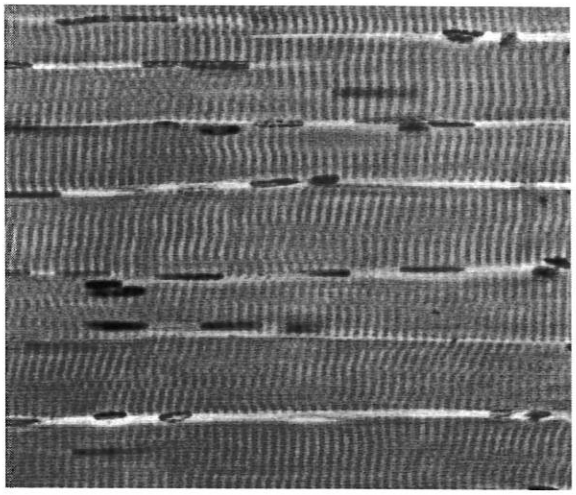
and amino acids pass through the villi and enter the blood in the capillaries. These molecules flow with the blood through blood vessels that branch out to reach every body cell.

The Role of the Heart

Your heart pumps blood through blood vessels all around your body so that your blood can reach every cell. Your heart is made of muscle tissue—a type of muscle that is similar to the muscles in your arms and legs. Of all the muscles in your body, your heart does the most physical work. This is because your heart beats all the time—about 100,000 times each day! Your heart rate (how fast your heart beats) changes depending on what you are doing. On average, the human heart beats about 60 to 100 times every minute. When you exercise, your heart beats faster to deliver molecules to your cells faster. Your exercising heart rate might be twice as fast as your resting heart rate.



An artist created this cross-section image of a heart to show the spaces inside. Blood enters the spaces, and the heart squeezes to pump the blood out into blood vessels.



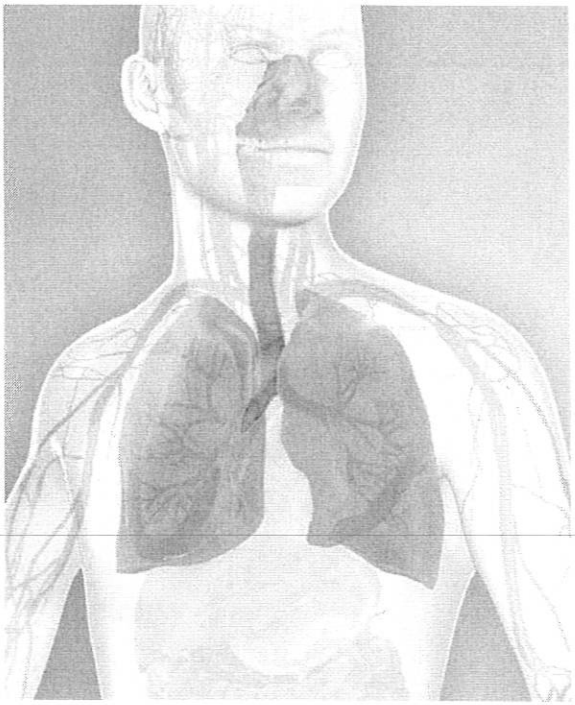
This microscope photo shows muscle cells from a human heart. The heart is the hardest-working muscle in the body.

Systems of the Human Body: The Respiratory System

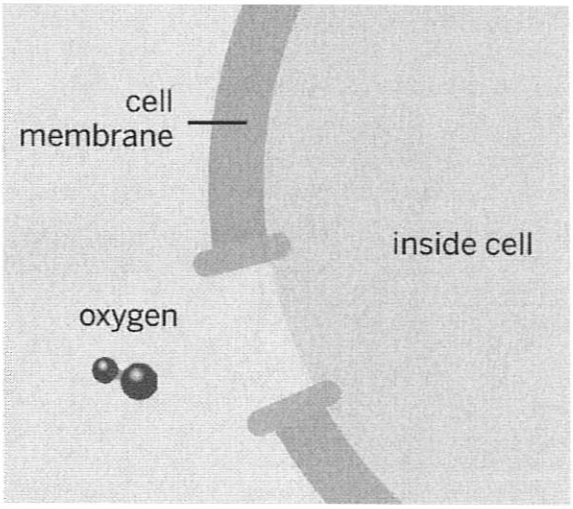
To *respire* means to breathe—the respiratory system is the body system involved in breathing. This body system includes the lungs, the trachea (TRAY-kee-a) (also called the windpipe), and the nose and mouth. Through breathing, the respiratory system brings oxygen into the body and moves carbon dioxide out.

Oxygen in, Carbon Dioxide Out

When you breathe, you take in air that contains molecules of oxygen. The air moves through your trachea, which branches into many narrower tubes inside the tissue of your lungs. These tubes continue branching in all directions, becoming narrower and narrower, until they end in millions of tiny air sacs called alveoli (al-VEE-oh-lie). With each breath, oxygen molecules enter the alveoli—but they don't stay there long. The oxygen molecules are small enough to pass through the walls of the alveoli, entering tiny blood vessels that surround these air sacs. At the same time, carbon dioxide molecules are moving in the other direction, out of the blood and into the alveoli. You release this carbon dioxide when you breathe out.



The respiratory system includes the lungs. As you breathe, this system brings oxygen into your body.



Oxygen molecules are small enough to enter a cell.

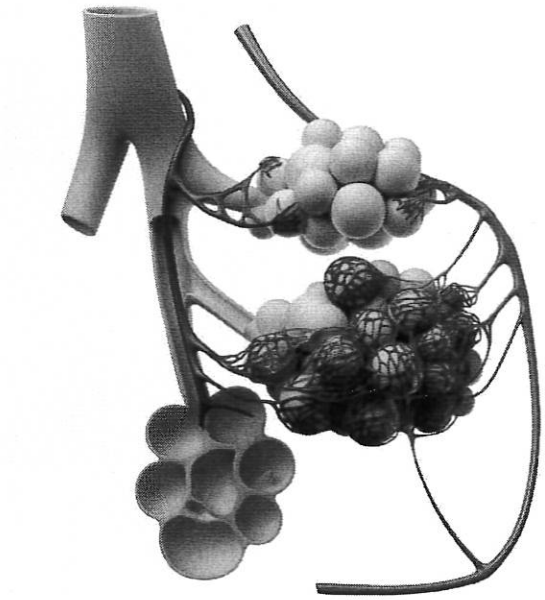
Connecting to the Circulatory System

The respiratory system brings in oxygen molecules that cells need, but those molecules can't get to the cells without the circulatory system. As oxygen molecules pass through the walls of the alveoli and into the blood vessels on the other side, they enter the blood. From there, the blood circulates throughout the body, carrying the oxygen molecules to every body cell. The alveoli are also where carbon dioxide molecules leave the blood and enter the lungs to be released.

Breathing

You take one full breath in and out about 12 to 20 times every minute when you are resting. Nerve cells inside the blood vessels in your neck and chest keep track of the levels of carbon dioxide and oxygen in your blood. When the amount of carbon dioxide gets too high or the amount of oxygen gets too low, the nerve cells in these blood vessels can tell. They send signals to your brain that cause you to breathe faster so that you breathe out the carbon dioxide and bring in fresh oxygen. When you are exercising, your cells need more oxygen and produce more carbon dioxide. Because of this, you breathe faster when you exercise.

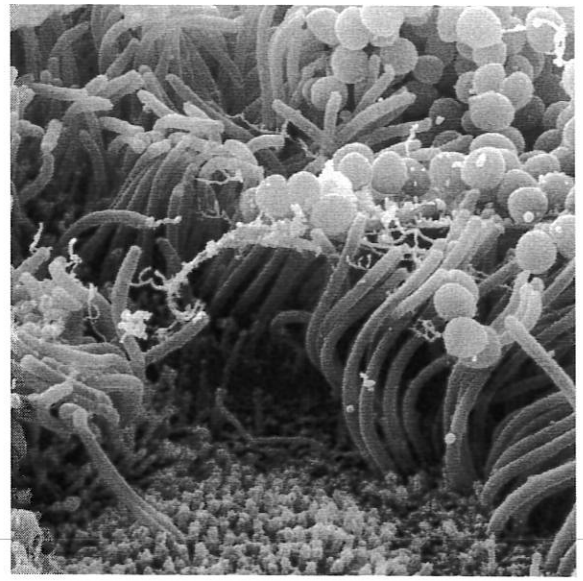
An artist created this illustration of the tiny air sacs in your lungs called alveoli. The alveoli are surrounded by blood vessels, shown here in red and blue.



This diagram gives a cutaway view of the alveoli.

Filtering Out Harmful Particles

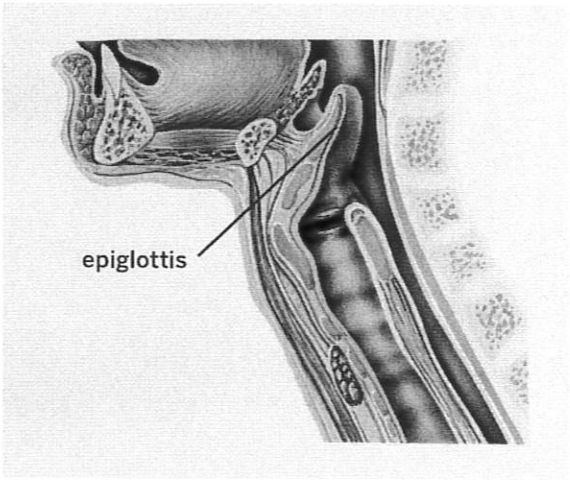
Oxygen isn't the only thing in the air you breathe: dust, pollen, pollution, bacteria, and other small particles are all floating around in the air. These particles can be harmful, and they enter the respiratory system with every breath. The respiratory system has parts that act like filters to keep harmful particles out of the lungs while still letting oxygen in. This filtering is possible because oxygen molecules are so small—they can fit through spaces that larger particles can't. Filtering begins in the nose, where nose hairs and mucus work together to trap large particles and keep them out of the lungs. Smaller particles are filtered by structures called cilia (SILL-ee-ah), which look like tiny hairs lining the walls of your respiratory system. The cilia sway back and forth to trap harmful particles and push them up to the nose, where they can be blown out.



The gray hair-like things in this photo are microscopic structures called cilia, which line the respiratory system. The cilia are trapping harmful bacteria (shown in yellow), keeping these bacteria out of the lungs.

Keeping Food Out of the Respiratory System

You take in both food and air through your mouth, so how does air end up in your respiratory system and food in your digestive system? A small flap of tissue called the epiglottis (epp-ih-GLOT-iss) keeps everything going in the right direction. The epiglottis is open while you breathe, but it closes when you swallow to cover your trachea and keep food out. If food accidentally enters your trachea, it can stop air from flowing—that's called choking. A person who is choking can't breathe because the trachea is blocked. Whatever is blocking the trachea has to be removed or the person may not be able to get enough oxygen to survive.



The epiglottis closes when you swallow to keep food out of your respiratory system. If food accidentally enters the respiratory system, it can lead to choking.