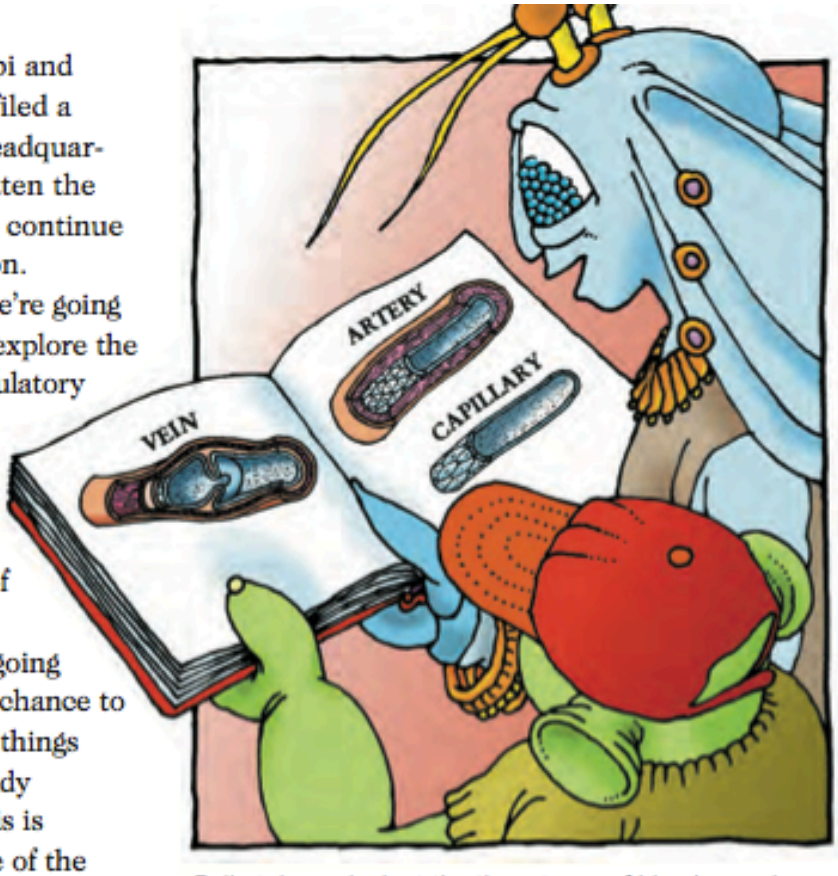
Back in Circulation

Agents Peppi and Bollo have filed a report to headquarters and gotten the go-ahead to continue their mission.

"Today, we're going to begin to explore the human circulatory system," says Peppi. "You're going to learn a lot of new things. You're also going to have the chance to apply some things you've already learned. This is because one of the remarkable things about human body systems is that everything is related. The more you understand one system, the better prepared you are to explore the next one."

"Sounds good to me," says Bollo. "Where's the door?"

"No door!" exclaims Peppi. "There is no entry or exit point to the circulatory system. No mouth, no nose, no anus. The circulatory system is a *closed* system. It consists of the heart, arteries, veins, capillaries, and blood.



Bollo takes a look at the three types of blood vessels.

"If something breaks this closed system—for example, if a human gets injured and bleeds heavily—it could mean serious damage. The body needs about 5 liters of blood to stay alive. And that blood has to stay in its place—within the closed circulatory system. External bleeding, which happens when a human is cut, and internal bleeding, which happens when blood leaks beneath the skin, can be dangerous."

Super Transport

"Some people compare the circulatory system with a transportation system. The heart is the hub. It's an important organ, and the human body is designed to offer it protection. The heart is nestled in the chest cavity, cushioned by the soft, spongy lungs and surrounded by a sac called the pericardium.

"Large, one-way vessels carry blood from the heart. These are the arteries. The arteries branch out

into smaller vessels called arterioles. Eventually, the 'passengers'—red and white blood cells as well as cell fragments—pass into the smallest, thinnest-walled vessels along the line."

"The capillaries, right?" asks Bollo, remembering their experience in the respiratory system.

"Right. Once a drop of blood has reached its destination, unloaded oxygen and nutrients, and picked up some carbon dioxide and other waste materials, it's ready to go back to the heart, by way of the veins. The veins, too, are one-way streets.

"It's an amazing transportation system. If placed end to end, the blood vessels in a human adult would be about 96,000 kilometers long—enough to stretch around the Earth two and a half times! It's efficient. The human heart pumps about 7200 liters of blood daily. And the time it takes for one blood cell to enter the heart, move through the body, and return to the heart is—well, just guess!"

Aboard a red blood cell

"Five minutes?" says Bollo.

"No. Just 60 seconds when the person is resting," replies Peppi.

"Wow. I'm impressed. Let's go inside and watch this transport system in action," says Bollo.

"Great. To enter, we'll attach ourselves to an oxygen molecule again. All aboard!"

Twin Pumps

"Time for a quiz," says Peppi as they sail down into the lungs. "Do you remember what happened when we traveled on a red blood cell after leaving the lung?"

"Sure thing."

"You might have expected that we'd head straight for the body cells that needed a fresh supply of oxygen, right? Instead, we went . . . "

"To the heart!" says Bollo.

"Good for you. And after we had delivered our oxygen to the body cells and were ready to go back to the lungs, we went through the heart a second time."

"Yes. I was wondering about that," says Bollo. "Why couldn't we just head straight back to the lungs? After all, we didn't have any oxygen with us anymore. I was wiped out."

"Keep your eyes open. You'll see," says Peppi.

Peppi and Bollo move through the cells making up the wall of an alveolus and into a capillary. Their oxygen molecule latches on to a red blood cell and heads for the left side of heart.

"Now we're in a pulmonary vein," says Peppi. "The heart is right ahead."

They enter the left atrium of the heart from the back. Squish! The walls of the chamber contract, and they shoot downward through a valve.

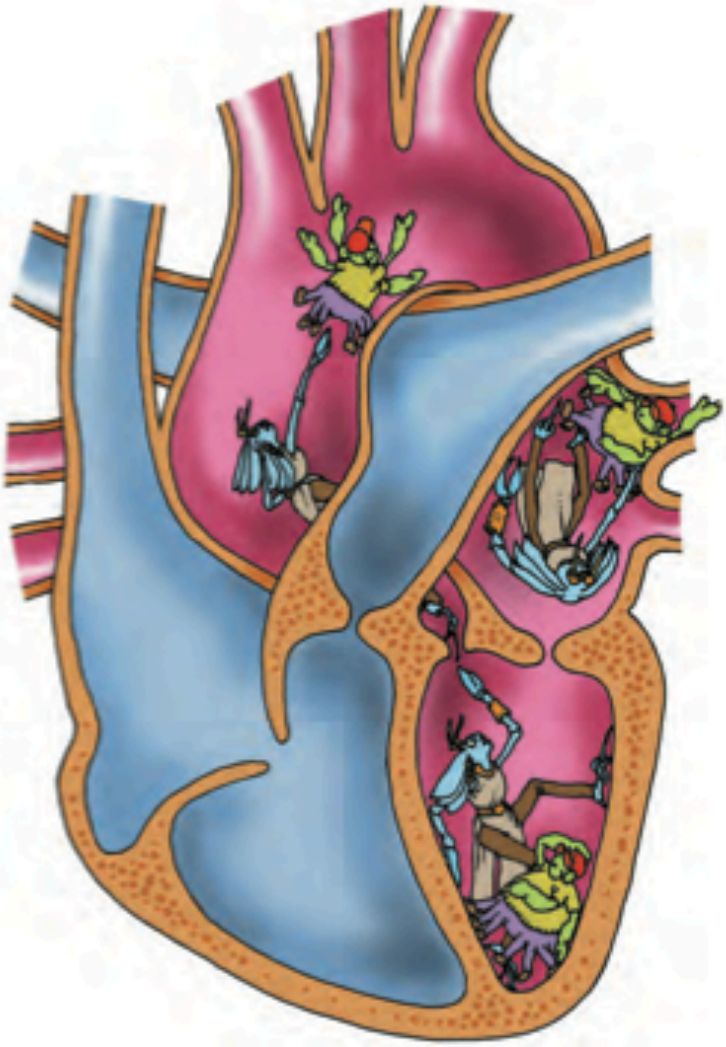
They arrive in another chamber. Its walls are much thicker than those of the atrium. Peppi and Bollo take a seat on a muscle fiber at the bottom of the heart.

"Let's stop for a moment," says Peppi. "Now tell me what's happening."

"The heart is beating regularly," says Bollo. "There's a

squeeze at the bottom, then a squeeze at the top. Lub-dub, lub-dub, lub-dub." He checks his stopwatch. "A little more than one beat per second. How does the heart know when to beat?"

"Heartbeats are caused by electrical impulses that come from a small area in the upper right corner of the heart. These impulses make the heart muscles contract. This pocket of specialized muscle cells is called the pacemaker. Some people with heart trouble have to get artificial pacemakers to keep their heart beating properly."



Inside the heart. It's one squeeze after another!

Moving On

The break is over. Whoosh! Blood moves up and out of the heart, carrying Peppi and Bollo with it.

"This must be a major highway," says Bollo. "It's broad. Room for lots of traffic."

"Yes, this is the aorta. It's a superhighway as far as human blood vessels go—about 3.5 centimeters in diameter."

Peppi and Bollo head out via the aorta. It soon divides into smaller arteries that branch out to various parts of the body. The spies go with the flow, heading north to the brain.

Peppi and Bollo watch some oxygen being delivered to the cells of the brain and see some carbon dioxide being picked up in exchange. This all happens through the walls of the capillaries.

They soon find themselves in a vein and heading back to the heart. But this time, they're traveling a different route. They're still entering from the top, but now they're on the right side of the heart. They enter. A moment later, they are being squeezed downward. Another contraction, and up again.

The journey continues. "We're now in the pulmonary artery," says Peppi. "We're moving out of the heart and back to the lungs."

Four Rooms, Two Pumps

"Hold on. I'm confused," says Bollo. "We've been in four chambers. We started on the left side and we ended on the right. I feel like I've really been shuffled around."

"Here's why. The heart is not just a pump. It's really like two pumps that are side by side. The pumps do different things, but they work 'in synch.' Each of these pumps has an upper chamber, called the atrium, and a lower chamber, called the ventricle. The left and right sides are separated by a thick, muscular wall called the septum.

"The atria (that's the plural of 'atrium') contract at the same time. Blood in both sides of the heart moves through valves to the ventricles. The

blood on the left side of the heart has come from the lungs. It's bright red, loaded with oxygen, and ready to go to work. The blood on the right has come from elsewhere in the body. It's done its job. You can tell, because it's got the 'blues.' It's carrying less oxygen and more carbon dioxide and other wastes.

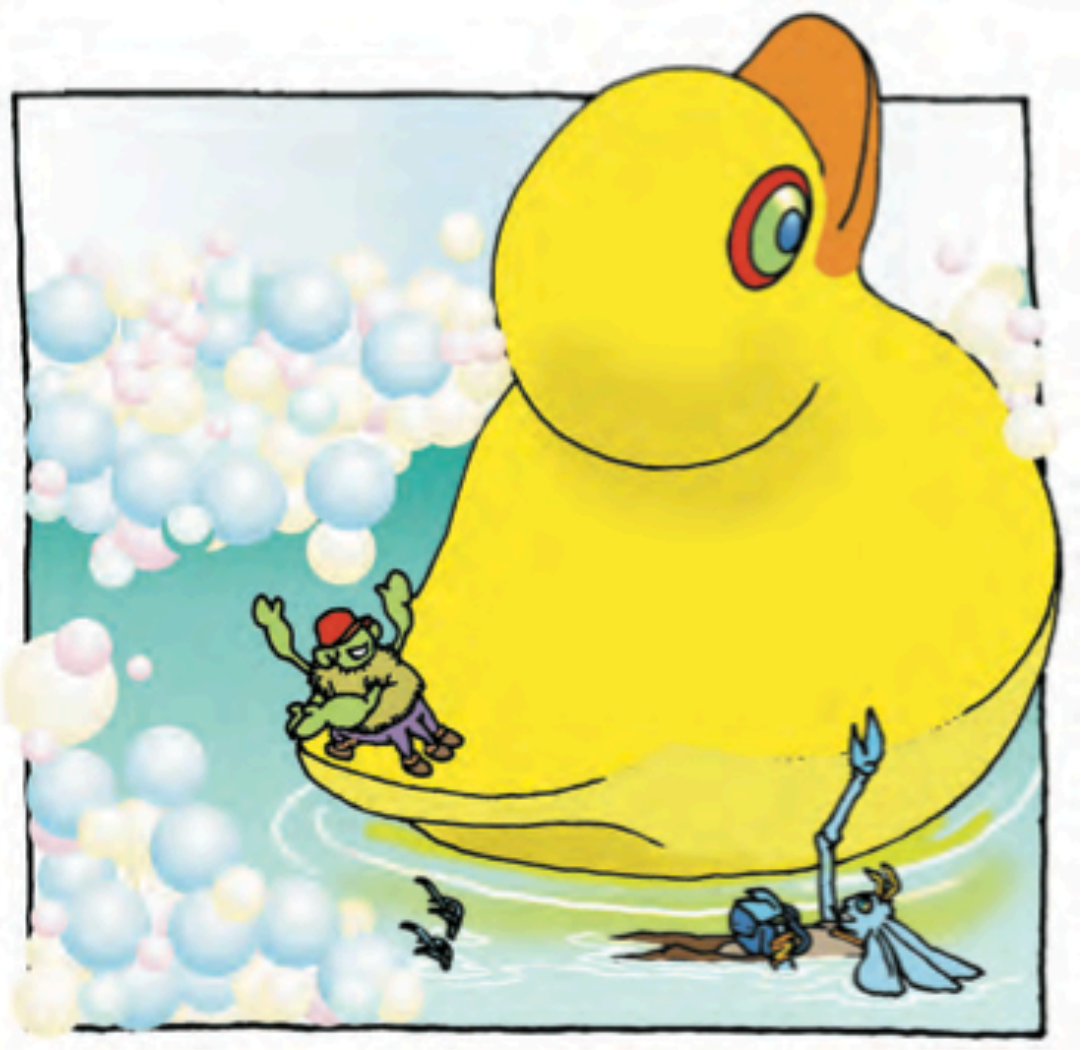
"The ventricles contract. Blood in both sides of the heart moves into arteries. The bright-red blood moves into the aorta. The tired, dark-red blood moves into the pulmonary artery. It's headed for the lungs and a fresh dose of oxygen."

"Two systems in one!" says Bollo.

"Exactly. Humans have pulmonary circulation between the heart and the lungs *and* systemic circulation between the heart and the rest of the body. And the systemic circulation has many smaller divisions, such as those to the liver and kidneys. Quite a big job for an organ that's no bigger than a human fist and that weighs only about half a kilogram," says Peppi.

"Now, guess what!" Peppi continues. "Our voyage through Joanne's circulatory and respiratory systems is over. I'm in the mood for a swim. How about you?"

"Great idea. Just let me get my rubber duck," says Bollo. □



Peppi and Bollo take a dip.