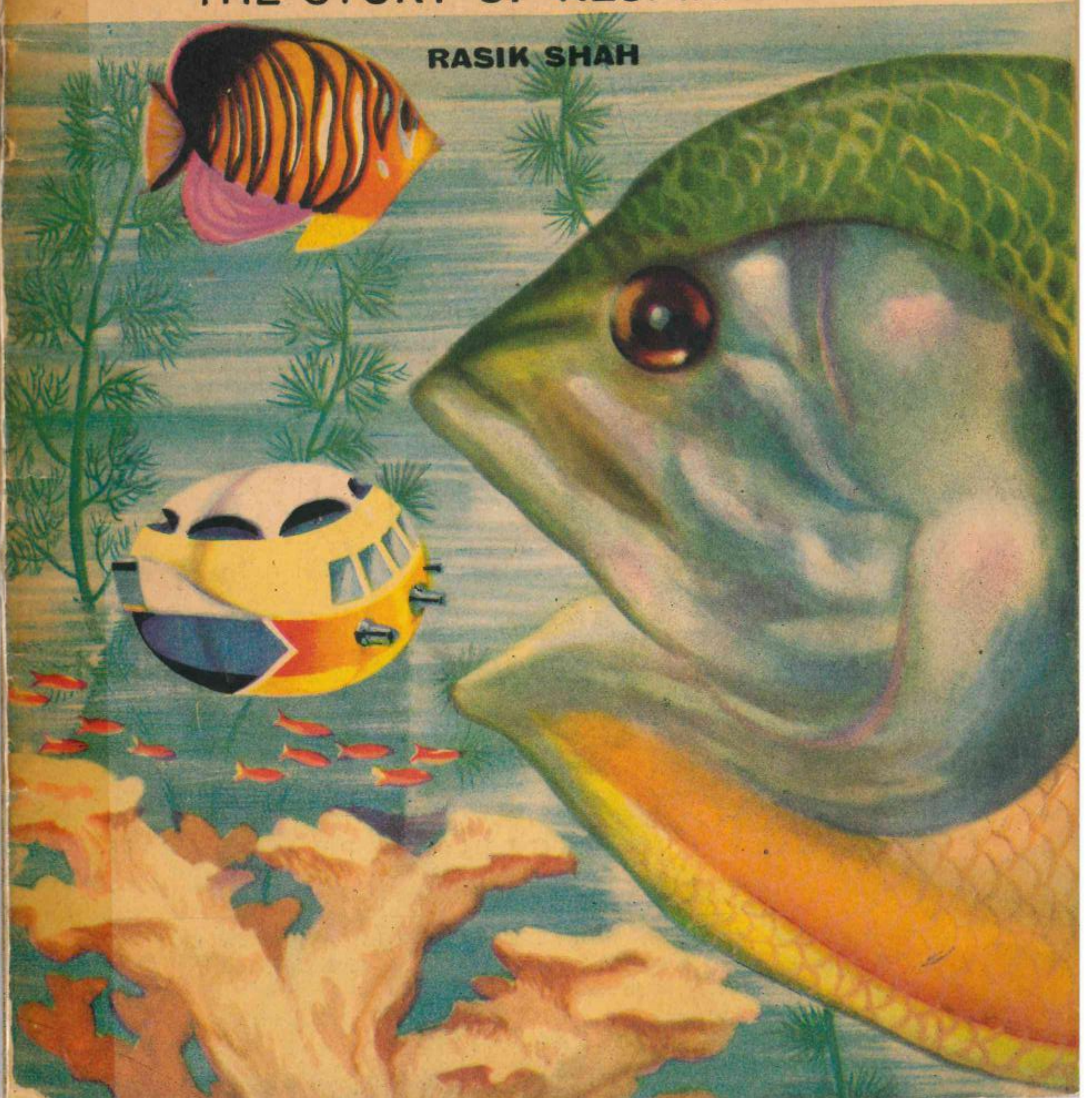
LANDS OF THE LIVING FURNACES

THE STORY OF RESPIRATION

RASIK SHAH



CITIZENS OF TOMORROW SERIES, 17

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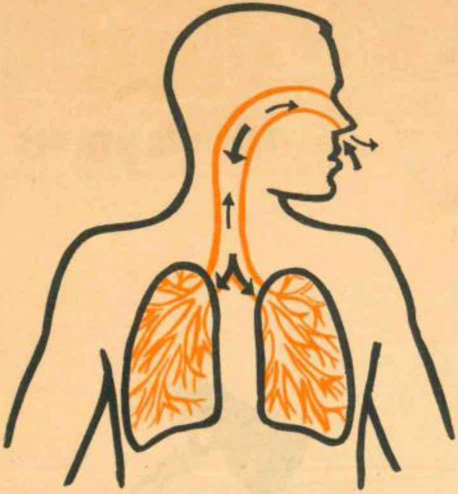
PREPARATIONS

AMI WAS hard at work preparing a lesson on Respiration. Students' Day was fast approaching and on that day Ami was to teach Respiration to Standard X. He was very tired and fell asleep over his books and began to dream.

He was with Professor Knowall who had promised to take him to the Lands of the Living Furnaces where, the professor assured Ami, he would learn all he needed to about Respiration. His sister, Gira, asked if she could join them and the professor and Ami readily agreed.

"We cannot visit the Lands of the Living Furnaces unless we make ourselves much smaller than we are, much smaller indeed. Fortunately, I know how we can manage this but, before we start on the first of our trips, let us see how much we already know about Respiration."



The professor turned to Gira and said, "Gira, you know what oxygen is, don't you?"

"O, yes! It's a gas. In science-class my teacher performed an experiment which showed that a candle can't burn without oxygen."

"Did she tell you anything else about oxygen?"

"Well," she said, "we all need oxygen to live."

"I know all about the main uses of oxygen. All living things need oxygen. Moreover, nothing burns without oxygen," interrupted Ami.

"But are these two quite *different* uses of oxygen?" asked the professor.

"No, not quite. I think I remember," said Ami, "I read in the science textbook that the cells in our bodies use oxygen to produce heat and energy. Is not that also a kind of burning?"

"Well, in a sense, it is," replied the professor with a smile.

"We don't burn though, do we?" asked Gira. "And what about light?"

"We don't produce any light either, as far as I know. Not even with all the oxygen we take in. The candle flame did give light when it burnt," she added.

" Silly, the oxygen that we breathe in goes through a slow burning process, and so there is no light," said Ami showing off his superior knowledge. "When you burn coal in a furnace it produces energy very rapidly. On the other hand when a living thing uses oxygen, it uses it gradually and produces energy very, very slowly. We can very well say that all living things have furnaces inside them which produce energy but very, very slowly."

"Ah, so now we know what you meant by Lands of the Living Furnaces!" exclaimed Ami.

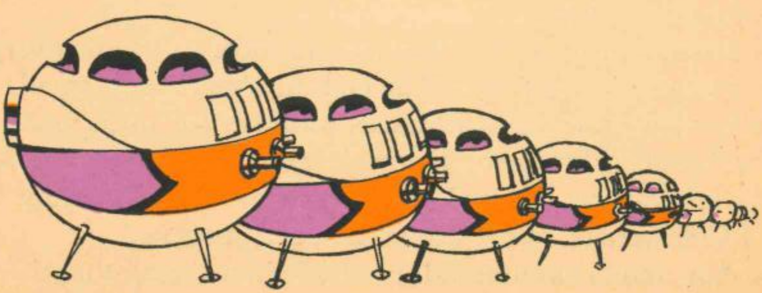
"Yes, indeed! The cells of the body behave just like furnaces. In an ordinary furnace we burn coal and produce heat. The living furnaces within the body 'burn' food to produce the energy that we need," explained the professor.

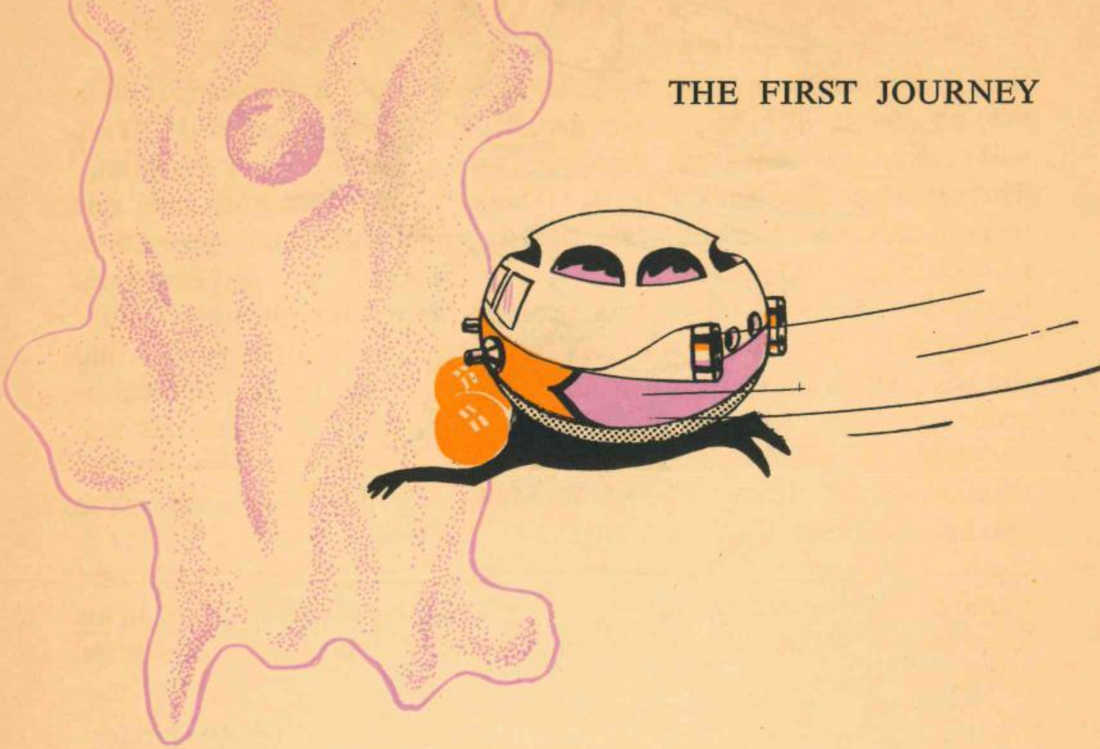
"Now I realize why you said we would have to become very small for this journey," said Ami. "The cells are very, very small, and if we want to visit these small furnaces we have got to be small too."

"Right," replied Professor Knowall, and then added, "come with me to my laboratory. There I have a special vehicle waiting for us. I call it a Cellosphere. We'll use it for our journeys."

When Ami and Gira entered the vehicle they found that the vehicle had glass windows on its sides. Inside there were four seats. In addition to a number of other gadgets, there was a small screen and a film projector. Pointing to the projector, the professor said, "This will help us to see the living furnaces as we would normally see them." The professor then took three small pills from a box and gave one to each child. He himself swallowed the third and asked the children to do the same. He said, "The effect of these pills will last for about four hours. So, we'll have to be rather quick on our journeys." After a short while the pills started taking effect. Professor Knowall and the two children started becoming smaller. Now the professor proceeded to press certain switches on the switchboard beside his seat and said, "You'll see the cellosphere getting smaller and smaller and smaller." And, presto ! The whole vehicle was reduced to a size much smaller than that of a speck of dust.

"Now we are ready for our first journey," smiled the professor and immediately directed the cellosphere towards an aquarium tank in his laboratory. Noiselessly, the vehicle entered the tank. And so started the first journey.





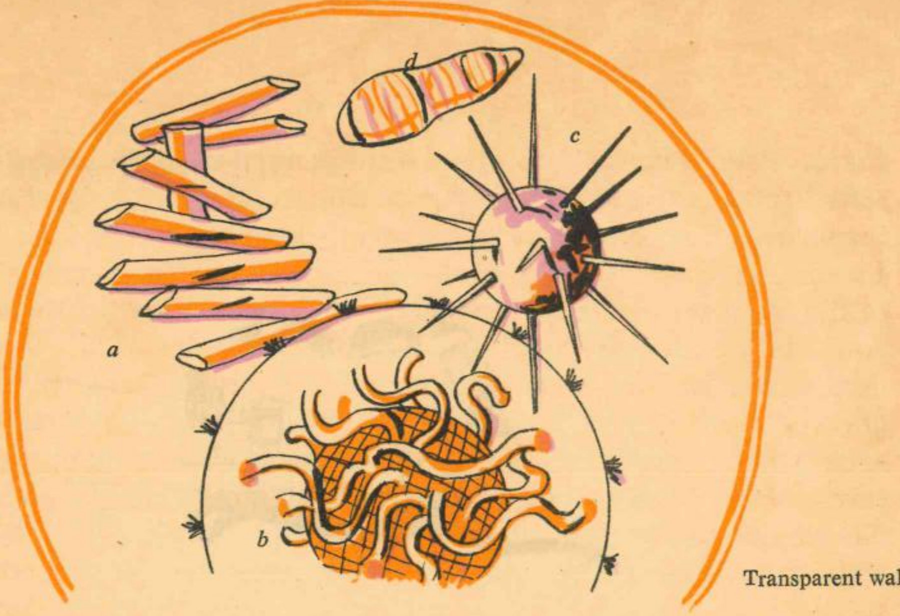
GIRA JUMPED to the window. "I've never been out on such a wonderful journey!" she cried with excitement. "This cellosphere is just like a submarine, isn't it?"

Professor Knowall smiled and, pointing to an oxygen molecule said, "That is only an oxygen molecule. There is nothing to be alarmed about. We are going to travel with it for some time."

"I know where it is taking us," said Gira. "It must be leading us to a living furnace."

"You are right. Look here! That huge transparent wall you see is the boundary of a living cell—a single-celled animal."

The oxygen molecule stuck to their cellosphere and moved rather slowly towards the cell. Gira became impatient. "Why doesn't our friend the oxygen molecule move faster?" she kept asking. The



a : Reticulum *b* : Nucleus *c* : Centrosome *d* : Mitochondrion

cellosphere together with the oxygen molecule approached the wall of the cell and then passed through it with ease.

"What is that ladder-like thing?" asked Ami.

"It's called the *reticulum*. It's actually more net-like than ladder-like and the sphere you see there is the most important part of this cell we are in. This sphere is called the *nucleus* of the cell. It controls all the activities of the living cell."

"Look there!" shouted Gira, "do you see that ball with spikes all round it ? My, it's really lovely, isn't it!"

"The scientists use a big word for it. They call it the *centrosome*. It plays an important role when the cell divides into two." Then the professor added, "Do you see that structure high up above the centrosome? That's the place we are going to visit."

"There's a similar structure on the right as well," cried Gira.

"If you look around you'll even find some more of them. Why, sometimes a single cell may have hundreds of them. Again the scientists call each of them by a big word *mitochondrion*. These are the furnaces and now we'll visit the one high up above the centrosome," said Professor Knowall. "Now, while our cellosphere is approaching the furnace, I'll do a simple experiment with a stove right here. Ami, I want you to weigh out one gram of this glucose. It's a simpler form of the sugar we eat daily. Now I'll burn this gram of glucose which Ami has weighed. Gira, please look at the pointer of this machine here. It will tell us the amount of heat produced when I burn this gram of glucose."

So, when the professor burned the sugar Gira watched the pointer carefully and when it stopped she read the number carefully and said, "3·8 calories."

"You are indeed a very good observer," the professor said. "When you leave school and join college you must go in for science. Indeed, one gram of glucose when burnt gives us 3·8 calories of heat. But in the case of the furnace we are to enter, things are slightly different. As a matter of fact, most of the energy that is liberated there is not in the form of heat at all."

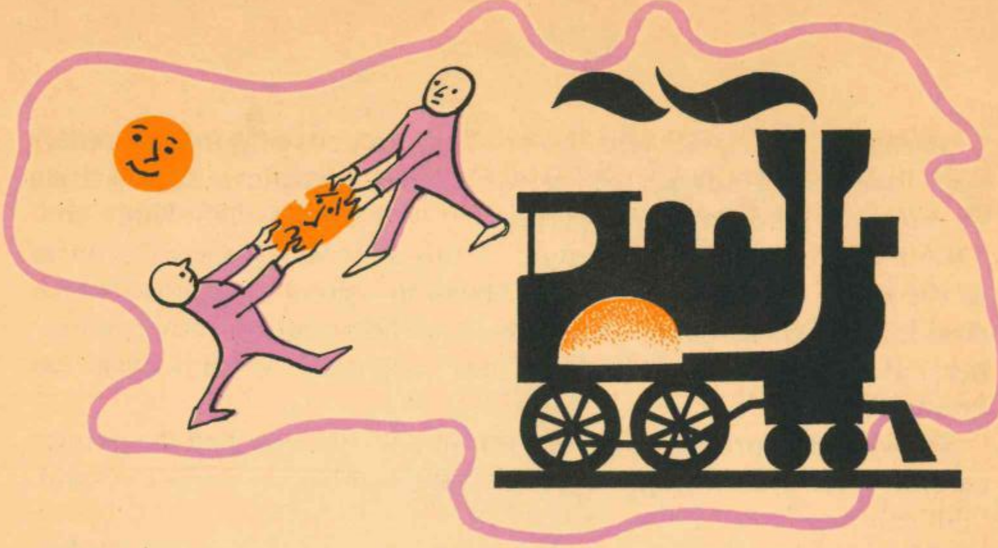
"I wonder what those tiny creatures are doing there outside the furnace. What a funny shape they have!" exclaimed Gira. "It appears as if they are trying to tear that poor fellow apart."

The professor laughed and said, "That poor fellow is none other than Mr. Glucose Molecule of whom we were talking and those tiny, odd-shaped creatures tearing them apart are the enzymes."

"And what are these enzymes?" asked Ami.

"Well, these are helper substances. They help to break up food into smaller and simpler units. Here they are breaking up the glucose molecule into two smaller units. Only after this is done, can Mr. Glucose enter the furnace."

By this time the cellosphere had reached its destination. As soon as they entered the furnace they found that things were happening at a tremendous speed. The oxygen molecule and the two parts of



glucose had been taken away by some of the enzymes.

"I wonder what they are going to do with Mr. Glucose," said Ami, puzzled.

"Well, your friend Mr. Glucose is a big hoarder of energy. The army of enzymes here will see to it that they get from him all the possible energy. They'll break down Mr. Glucose step by step. The oxygen, with whom we travelled will also be used. As the ultimate result, we'll have carbon dioxide and water," concluded Professor Knowall.

"Then what will happen to the energy?" asked Ami.

"That's a good question. Though we have used the words 'living furnace' for the mitochondrium, it would be more appropriate to compare it to a power-station. As a matter of fact, scientists sometime call this mitochondrium 'the power-house of the cell' because it obtains power or energy from glucose and other substances and then packs it up in small packets which can be easily used by living things to carry out different life processes like moving, eating and so on."

"But you didn't tell us the name of these energy packets," complained Ami.

"Well, they have a pretty long and complicated name but when they are still full of energy scientists call them the ATP, in short. But when the energy is used up, these packets, so to say, become empty and are known as ADP."

"ATP and ADP? Funny names!" exclaimed Ami.

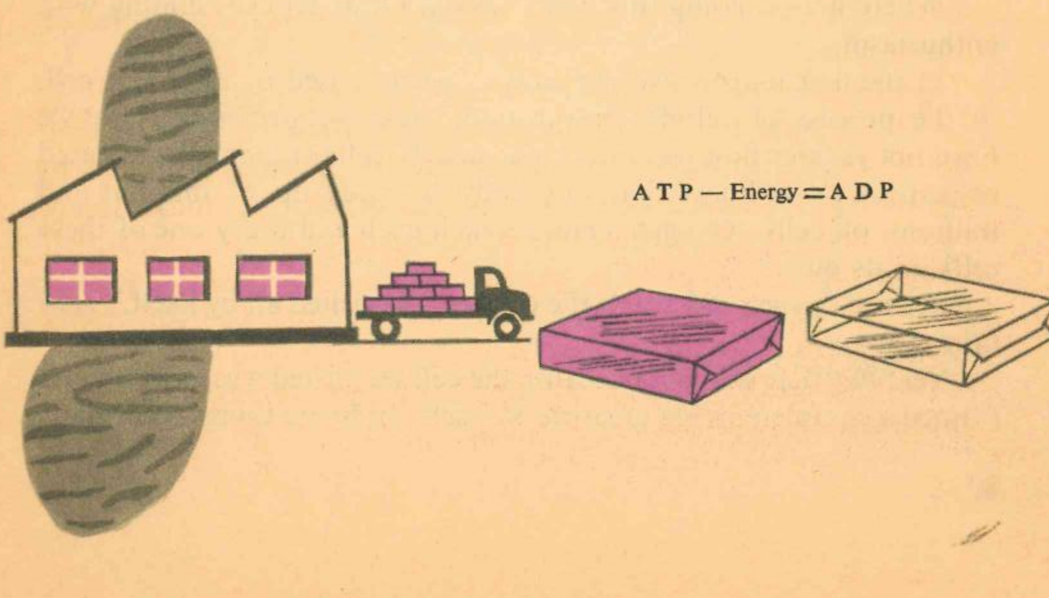
"But easy to remember," chimed in Gira.

During all this talk, the army of enzymes in the mitochondrium was busy breaking up the glucose and water and making the energy packets, viz. the ATPs, with the help of the energy released.

"That one there is a molecule of carbon dioxide," said the professor, pointing to a moving molecule. "You see it leaving the power-house. Let us also leave the cell," said the professor.

"We entered the cell with an oxygen molecule and we are now leaving it with a carbon dioxide molecule. Why, this sounds bit familiar," mused Ami.

"Don't you think that this is all connected with the lesson on respiration you have to prepare for Students' Day?" asked the professor, with a twinkle in his eye.



"Ah! So, that's how we use oxygen during respiration," said Ami.

"Yes, but there's a special name for this process. Scientists call it *cellular respiration* because each and every cell of the body respires," said the professor.

"This means that the oxygen that we breathe in ultimately goes to these power-houses. So does the food that we eat. If the power-houses stop supplying power, even for a minute, we die. Now, except for the red blood cells, all the cells of our body have these tiny power-stations which supply energy round the clock."

"I would like to know one thing," said Ami. "How big are these power-houses?"

"Indeed, they are very, very small, so small that more than five thousand would be needed to arrange them in a line just one centimetre long! Here is a photograph of mitochondria taken with a special instrument known as an electron microscope," explained the professor.

"Well, sir, they may be insignificant in size but not in work!" exclaimed Ami.

"Indeed so, Ami. And now it's time for us to start on our second journey," said Professor Knowall.

"Where are we going this time?" asked Gira, her eyes shining with enthusiasm.

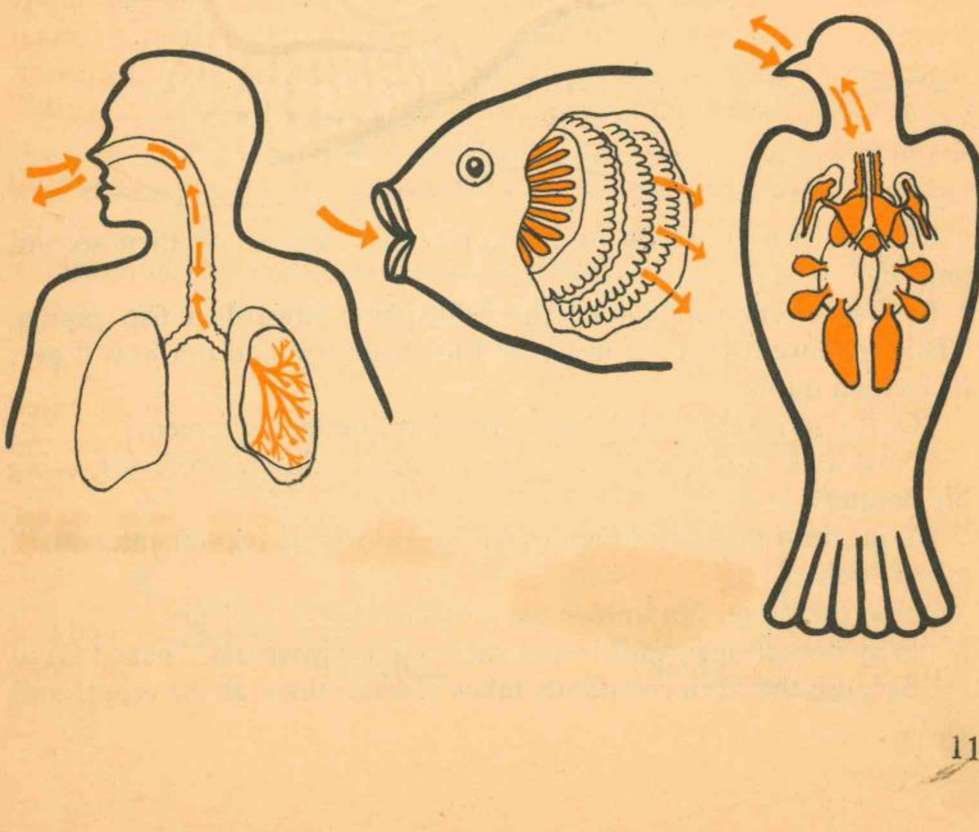
"In the first journey we saw how oxygen is used by the living cell, in the process of cellular respiration," said the professor. "But we have not yet seen how the oxygen reaches the cells of more complicated organisms. You know that our body is made up of millions and millions of cells. Oxygen cannot reach each and every one of these cells on its own."

"But the oxygen did reach the cell we just visited all by itself," said Gira.

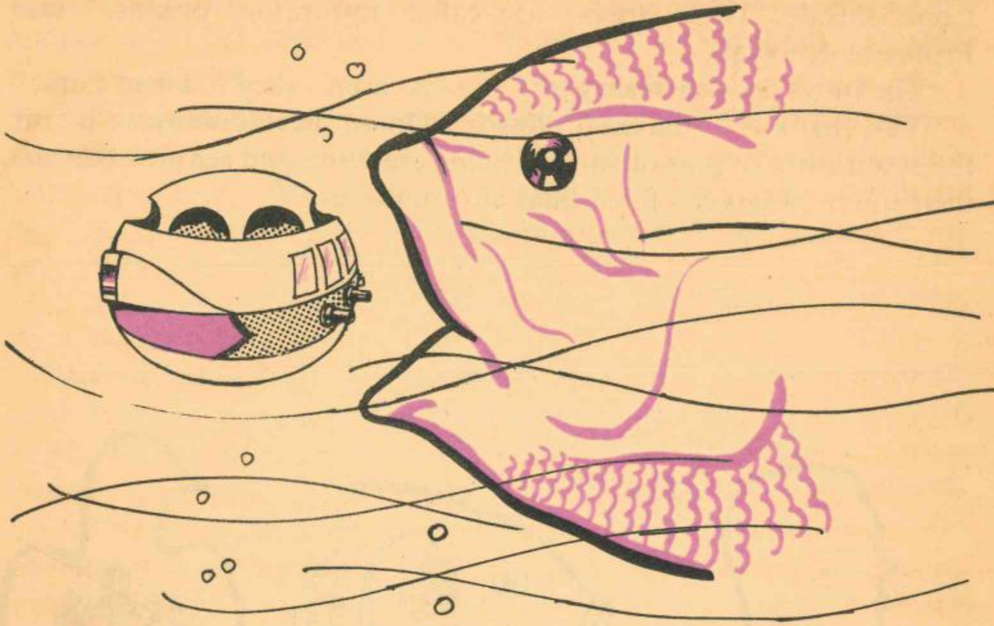
"Yes, but that was only because the cell we visited was isolated and formed a complete living creature in itself. In living things with many cells, special organs have been evolved to take in the needed oxygen from outside. These organs are called respiratory organs," said Professor Knowall.

"The lungs are our respiratory organs, aren't they?" asked Gira.

"Yes, that's so," said the professor. "On our next journey we'll visit the respiratory organs of various living creatures and see how they get their quota of oxygen from their surroundings."



THE SECOND JOURNEY



SO THE PROFESSOR and Ami and Gira started on their second journey.

Professor Knowall guided the cellosphere towards a fish saying, "This time we'll visit the inside of this trout and find out how it gets its oxygen quota."

"O, it's so lovely!" exclaimed Gira looking at the screen.

"Now look at this semi-circular opening," said the professor, using his pointer.

"You mean that flap which opens and closes at regular intervals?" asked Ami.

"Yes, the same. It's known as an *operculum*."

"Why does it open and close at such regular intervals?" asked Gira.

"Because the trout constantly takes in water through the mouth and the operculum lets that water out," Professor Knowall informed them.

"Does the fish feel that thirsty? I don't drink that much water!" exclaimed Gira.

"You do breathe that often though, don't you?" asked the professor and then, without waiting for an answer, continued, "Just as we cannot live without air the fish cannot live without water. Of course the fish does not drink the water but merely inhales it. Then, it exhales the 'used' water through the operculum, just as we breathe out air."

"Now I remember," said Ami. "The fish 'uses' water to get from it the oxygen that it needs."

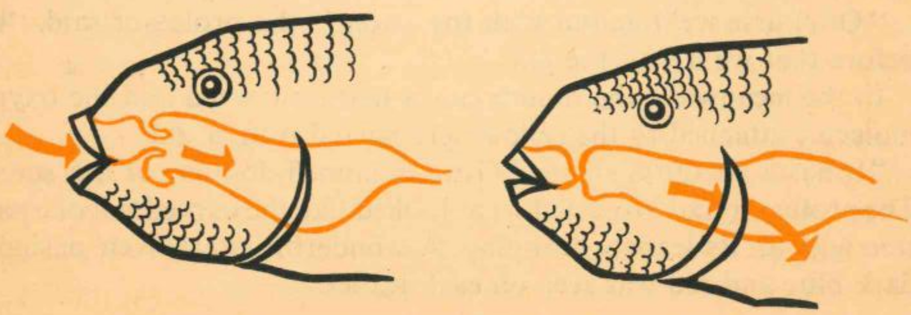
"Does that water then go into its lungs?" asked Gira.

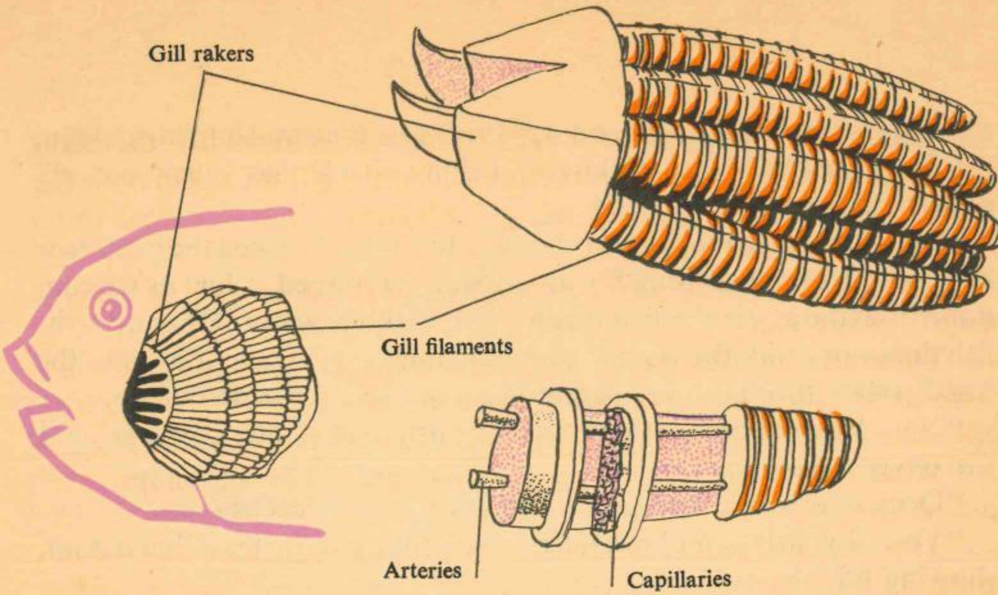
"You silly, fish don't have lungs! They have gills instead," said Ami, showing off.

"What are gills?" asked Gira.

"Gills are the breathing organs of the fish," said the professor. "Some oxygen in a dissolved state is usually present in water. When water is taken in by a fish, it first passes over the gills and then comes out through the operculum. We'll again take a dissolved oxygen molecule as our guide."

Gira and Ami were now anxiously watching the screen. When the oxygen molecule came near the mouth of the fish, the fish sucked in





water and, together with many other oxygen molecules and the cellosphere also, the oxygen molecule entered the fish's mouth. The professor drew a very simple diagram to explain the movement of the water. He said, "When we entered the mouth of the fish just now, the operculum was closed. Now, the mouth cavity will become smaller because of the contraction of the muscles. Hence the water will be forced out through the operculum."

"I hope we also will go out with that water," said Gira. "I don't like the idea of being in the mouth of a fish. It makes me feel so small."

"Of course we'll go out with the water," the professor said, "but before that we'll visit the gills."

In the meanwhile the mouth cavity had contracted and the oxygen molecule attached to the cellosphere passed over a gill.

"It has a beautiful shape!" Gira exclaimed, looking at the screen. The professor had projected what looked like the curved leaf of a palm tree with all its leaflets drooping. A wonderful interwoven design in dark blue and red was seen on each leaflet.

"This is a gill," the professor said. "That which looks like the main vein of a palm leaf is bony structure called the gill-arch. On both the sides of this gill-arch you see the gill filaments. These appear to be like the leaflets of a palm-leaf."

"And what are those spike-like things on the other side of the gill-arch?" asked Ami.

"These are the gill-rakers," said the professor. "You can easily see how these rakers strain out solid particles, which come in along with the water, and stop them from reaching the gill filaments."

"What are those pretty designs in blue and red on the filaments?" asked Gira.

"They are not really designs," smiled Professor Knowall. "Let's magnify a gill filament and see what the blue and red lines really are, shall we?" He adjusted the projector.

"My goodness, now these lines look like pipe-lines!" exclaimed Gira excitedly.

"Indeed they are just like pipe-lines, and do the kind of work pipe-lines do," said the professor. "These pipe-lines are the arteries. They bring blood from the fish's heart."

"But my teacher told me that the arteries carry bright red blood. Many of these fish arteries are blue. Why?" asked Gira.

"Your teacher is right. Most of the arteries do carry bright red blood. You'll notice that the arteries that are taking the blood away from this gill are indeed bright red. Here, our guide oxygen is now entering the filament along with our cellosphere. Now, let's see what happens to it," said the professor, and once again he adjusted the projector so that they could have a very close look into the gill filament. Then he continued, "The artery coming from the heart, on entering this filament divides and sub-divides into a very fine network of tubes known as the capillaries. Look here, our oxygen molecule is crossing the very, very thin wall of the capillaries of the gill filament."

"It appears as if it is boarding a ship," said Gira and all of them laughed.

"In a way it does. What appears to be a ship is only a red blood corpuscle. The red blood corpuscles serve as carriers of oxygen," the professor told Gira and Ami.

"We too have red blood cells in our blood. Are they similar to these red blood cells in the fish?" asked Ami.

"Yes, they are similar, except for the fact that these red blood corpuscles in the fish carry much less oxygen than the red blood corpuscles in our bodies," the professor replied.

Gira nodded, "Then these red blood cells must be like delivery vans."

"Rather like delivery ships. For they move in streams of blood," said the professor. "When these ships or red blood corpuscles are fully loaded with their cargo of oxygen, they are bright red and when without it they are rather dull coloured or blue."

"How about the carbon dioxide? Do these red blood cells bring it back from the different parts of the body?" asked Ami.

"No, the carbon dioxide comes along the stream of blood. Actually, you can see that carbon dioxide molecule right now crossing the gill filament and entering the water," said the professor pointing to it.

"Now it's time for us to go out," he added, and steered the cellosphere out of the filament.*

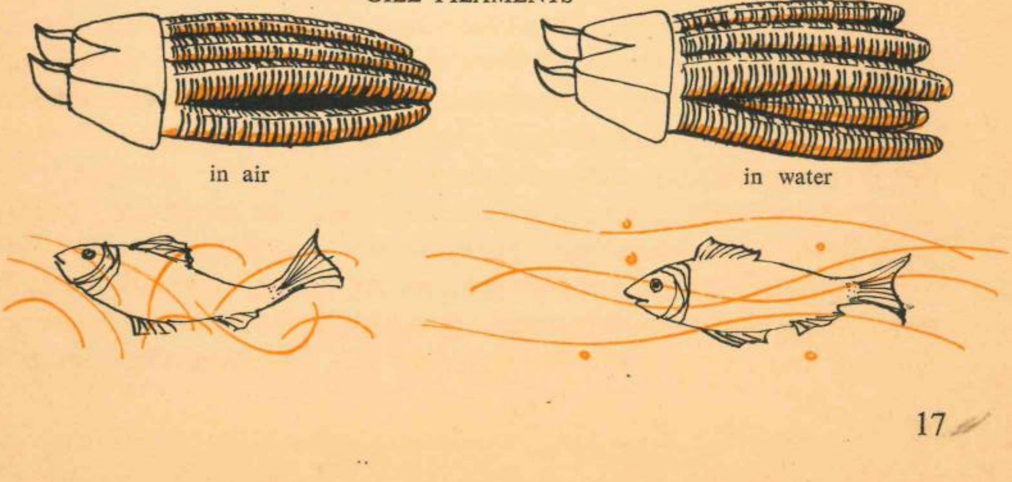
"So, in the gill filaments an exchange of gases takes place. The oxygen, dissolved in water, enters the blood and carbon dioxide from the blood enters the water. That is why we can call these gill filaments exchange stations."

"I don't understand one thing. If oxygen does and can enter the gills, why does a fish die when it is out of water but is still surrounded by the oxygen-giving air?" asked Ami.

"There is no doubt that there is oxygen in air. Actually in 100 parts of air there are 21 parts of oxygen. On the other hand, in water there is just one part of dissolved oxygen in 2000 parts of water. And yet, when a fish is on land surrounded by air it dies of suffocation, lack of oxygen. The reason is that the filaments of the exchange station, the gills, become dry and stick together. When the filaments are dry, the oxygen *cannot* pass through their walls. The oxygen has got to dissolve in water before it can enter the gill filament wall. Therefore, the fish does not get enough oxygen and it dies," explained the

*You can read more about the role of blood in respiration in THIS RED RED BLOOD, No. 6 in the Citizens of Tomorrow Series.

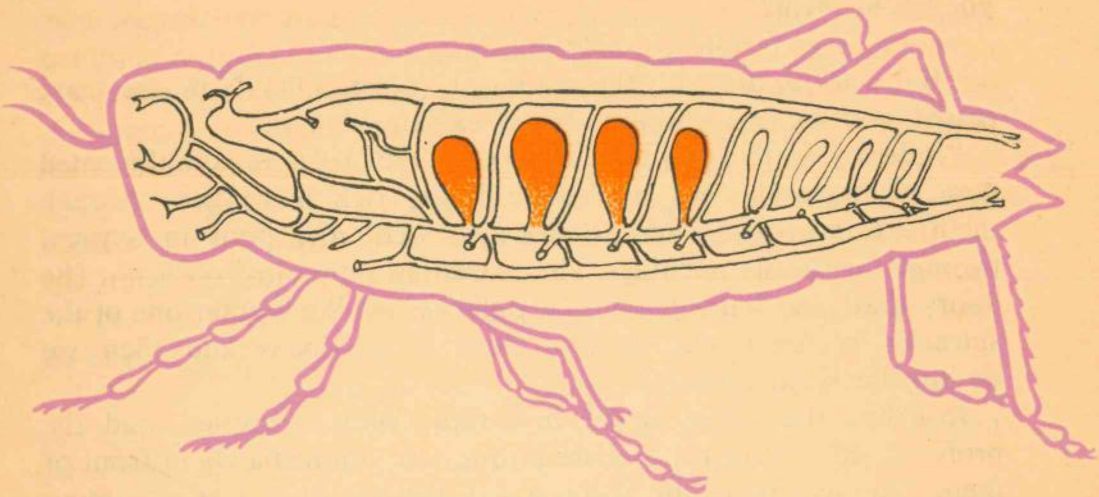
GILL FILAMENTS



professor. "However," the professor continued, "there are some varieties of fish which can use open air, besides water, to obtain their quota of oxygen. For example, when the pond in which the common carp lives runs short of oxygen or dries up in the hot summer months, the fish pokes its head out, takes in a bubble of air and holds it in its mouth near its moist gills. Other kinds of fishes like the climbing perch, the snake-head and the Indian catfish have special chambers that hold air which is passed over the gills. There are lung-fishes which can breathe open air with perfectly good lungs. But such fishes are quite rare."

"Anyway we'll now let this fish remain in water and we will go back to land and air," said Professor Knowall, patting Gira on the head. Shortly afterwards the cellosphere came out of the fish tank.

THE THIRD JOURNEY



"FROM A SUBMARINE to an airplane!" exclaimed Gira as, on its third journey, the cellosphere rose into the air. "Indeed Professor Knowall, your cellosphere is a wonderful invention. Where do you plan to take us this time?" she asked.

"Now, we are going into the wind tunnels supplying oxygen to living organisms which breathe in air," said the professor.

"Do you plan to take us into the human body then?" asked Gira, who was somewhat taken aback by the idea.

"Well, Gira, most living things that live on land breathe in air. All insects, birds, reptiles, and mammals, including human beings, breathe in air," said the professor.

"Are we going to visit all of them?" asked Gira, happy at the exciting thought.

"No, we have only three more visits to make. We'll visit an insect, a bird and a human being," replied the professor. Just then he saw a grasshopper on the screen. "That's our friend," he remarked.

"Look at the screen, do you see those openings on the side? Can you count them?"

"O yes, there are ten," said Gira.

"But I notice that only the last six are open. Oh! Now they are closed, and the first four are open!" exclaimed Ami.

"Indeed you are a very good observer," the professor complimented Ami. "The grasshopper inhales fresh air, rich in oxygen, through the first four openings and exhales the 'used' air, poor in oxygen, through the last six openings. These openings are called *spiracles*. The doors that guard the spiracles are the *valves*. We'll enter one of the spiracles as soon as this valve in front of us opens and then we go into the wind tunnel!"

Just then the valves of the first four spiracles opened, and the professor guided the cellosphere into the one immediately in front of them. The opening of this spiracle was guarded by bristles. Pointing to these bristles, the professor remarked, "Do you remember the gill rakers on the other side of the gill-arch?"

"Yes, they stopped the useless particles from going over the gills," replied Ami.

"Yes, that's right. Now, these bristles do a similar job. They do not let the dust particles enter into the tunnels. These tunnels are actually called the *trachea*," said the professor.

"But it seems as though these tubes are becoming smaller and smaller," said Gira.

"Yes," the professor smiled, "towards the ends they become so narrow that you could arrange about ten thousand of them side by side on a line only one centimetre long!"

"My goodness!" cried Gira.

"Now, we are at just such a narrow end. Look out from the window and tell me what you see," said the professor.

"I see some liquid there, and beyond I see a cell. Oh! And inside that cell there is that power-station which uses oxygen." Gira was quite excited, as she had been able to recognise the mitochondrium.

"You are quite right!" exclaimed the professor. "There are no red blood cells, so you can say that, in a sense, insects are 'bloodless'. The oxygen from the air dissolves in this liquid and then enters the cell."

On their way out, Ami and Gira saw a huge bellows-like structure at the end of one of the main tracheal tubes. "What is that?" Ami asked the professor.

"That is called the air sac," replied the professor. "It makes the air circulation easier."

In the meanwhile the cellosphere had come to the end of the main tracheal tube, and its valve opened and the cellosphere was thrown out through the eighth spiracle along with the 'used air'.

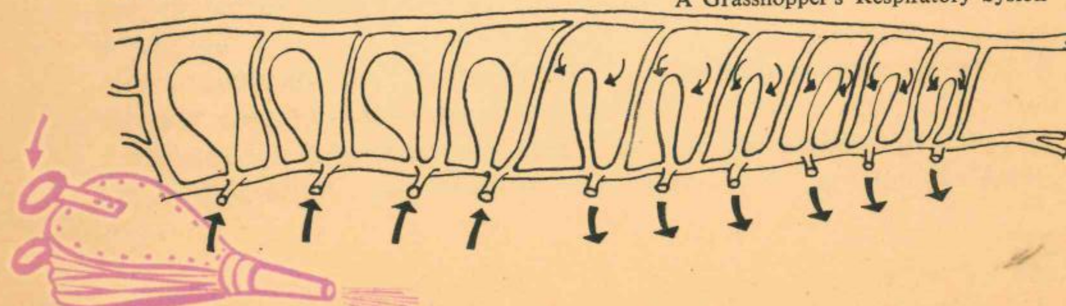
"Let us now pay a flying visit to a bird. There is one important thing that I want you both to note about its lungs."

The cellosphere entered through the hole in a pigeon's beak and went directly into its lungs.

"The same design in the reds and blues," observed Gira.

"Yes, these are again the bird's exchange stations. Here we call them lungs. Do you see those bag-like things surrounding the lung?" asked the professor.

A Grasshopper's Respiratory Sysion

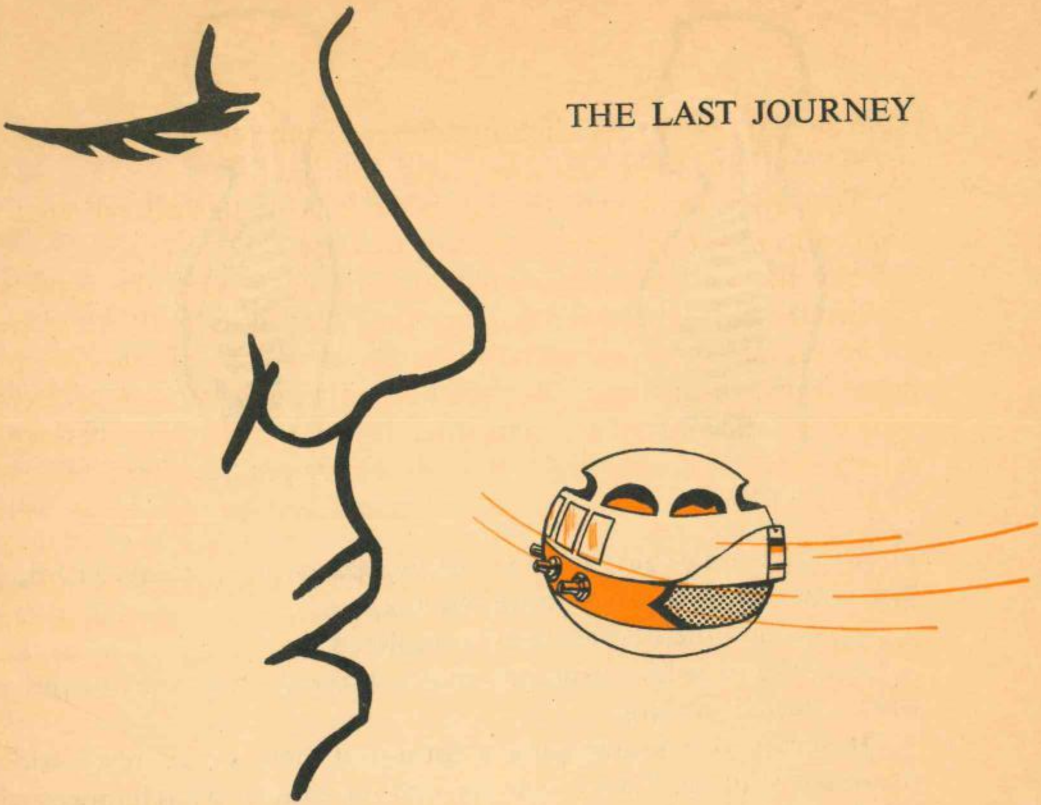


"Yes, but aren't they slightly different from our lungs. There are no red and blue lines on them," said Ami.

"They seem to be very similar to the bellows-like air sac that we noticed in the grasshopper," remarked Gira.

"Yes, there are air sacs in the bird's lungs," said the professor. "When the bird inhales air through the holes in its beak, some fresh air enters into these air sacs. When the bird exhales, this fresh air passes through the lungs. So, the lungs get fresh air full of oxygen both when the bird inhales and when it exhales. This is necessary for a bird because, during flight, it needs a very great amount of energy to work its muscles. Moreover, these sacs help to reduce the weight of the bird's body."

While Prof. Knowall was explaining the function of the air sacs, the bird exhaled and, together with the 'used air' full of carbon dioxide, the cellosphere came out. And this ended their visit to the tunnels and the bellows.

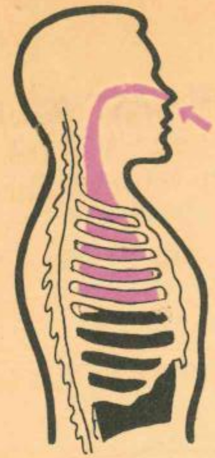


THE LAST JOURNEY

"NOW CHILDREN, before we start on our last journey, I would like to show you how we breathe. I have here a movie which will show you the breathing process of man as seen on an X-ray screen," said Professor Knowall. He then darkened the cabin and projected the movie.

The movie showed the movement of a human being's lungs and the surrounding organs while breathing.

The professor began explaining, "As you are looking at the film I'll tell you about respiration in man. Now, in the process of inhala-



INHALING

EXHALING

tion, special note must be made of two parts of the body. The dome-like structure at the bottom of the lungs..."

"...is called the diaphragm," completed Ami.

"And the cage-like structure that surrounds the lungs is the rib-cage," butted in Gira.

"It seems you know quite a lot about these structures," said the professor smiling. "Now, can you tell me exactly what happens when inhalation takes place?"

"Well, for one thing, the rib-cage expands and the diaphragm goes down," said Ami.

"As a result, the volume of rib-cage increases, and the pressure in the chest cavity is lowered, and the outside air, under greater pressure rushes into the lungs. Do you know how much air we can take in during one inhalation?" the professor asked.

"No, that I don't know," replied Ami.

"Neither do I," said Gira.

"We can take in about half a litre of air during one inhalation."

"But what exactly happens when we take a really deep breath" asked Ami.

"Oh, in that case we take in about seven to eight times the air we generally take in during an inhalation or inspiration," said the professor. "That is why we are advised to take deep breaths. For then, we get more oxygen from each inhalation."

"Why do we pant or breathe quickly after running?" asked Ami.

"You don't even know that! Because we need more oxygen of course," said Gira, triumphantly.

"And my wise little sister, how does my diaphragm know that I need more oxygen, may I ask?" countered Ami.

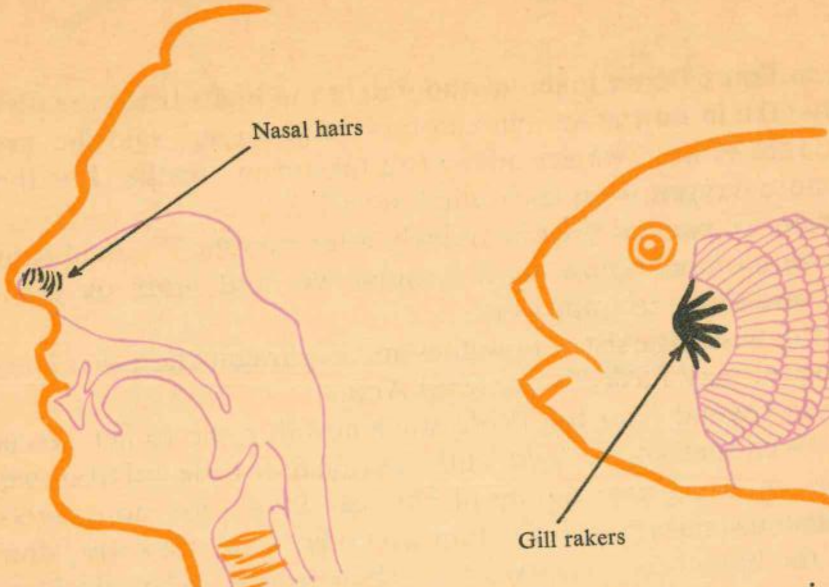
This was beyond Gira but Professor Knowall came to her rescue. He said, "Well, that's rather a difficult question for a little girl to answer. Whenever we do a great amount of physical work a lot more carbon dioxide than usual is produced within the body. Now you know, don't you that the blood carries away this carbon dioxide. When the blood full of carbon dioxide passes through the brain, the brain comes to know about this short supply of oxygen. So, it sends an instant command to the rib muscles and the diaphragm to work faster. As a result, we breathe faster than usual and the body gets the required amount of extra oxygen."

"So, in a way, it's the carbon dioxide that controls our breathing!" exclaimed Ami.

"You can say that, yes," said the professor. "During expiration or exhalation, the reverse is the case. The rib-cage and the diaphragm return to their normal positions. As a result, the pressure of the air inside the chest-cavity increases and, the air sacs being elastic, the 'used air' with the unused oxygen and carbon dioxide is forced out."

Just then the film came to an end. Professor Knowall, Ami and Gira prepared for their last journey into the lungs of a human being. A person was sitting and dozing under a tree and the cellosphere entered his nose.

"The poor man doesn't even know that at this very moment three



people are entering his body," giggled Gira. Then, more seriously, she said, "But Professor, please see that we do not disturb him. It's not nice to wake up a sleeping person."

"We'll try our best not to wake him," replied the professor.

In the nostrils, something like a huge jungle of trees surrounded the cellosphere.

"Professor Knowall, what are these huge trees we see?" asked Gira. "Will we ever get through this dense jungle?"

"Don't you recognise the hair in the nostrils? These hairs which seem to you so like a dense jungle of trees filter out the larger dust particles and other impurities."

"Just like the gill-rakers in the fish and the bristles in the grass-hoppers," showed off Ami.

"In this nasal cavity, three things happen to the air. The dry air is moistened with the help of a secretion from the cells which line the cavity. Secondly the temperature of the air is brought close to the body temperature. Lastly, the air is purified by removal of large dust particles as I mentioned earlier," said the professor.

"So the 'Hair Jungle' is really useful," said Gira jocularly.

"What are those two deep valleys?" asked Ami.

"Well, if you want to go into the stomach and get digested," said the professor, "you must jump into the second valley. But as we plan to visit our friends, the lungs, we'll plunge into the first. This part of the passage above the wind-pipe is called the *pharynx*."

"What is that slit-like opening?" asked Gira.

"That's the place where your voice is produced," the professor informed her.

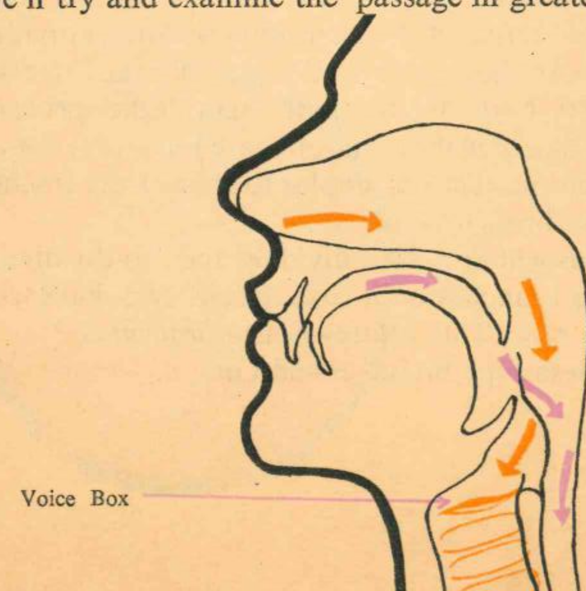
"I know what this is. It's the voice-box," said Ami.

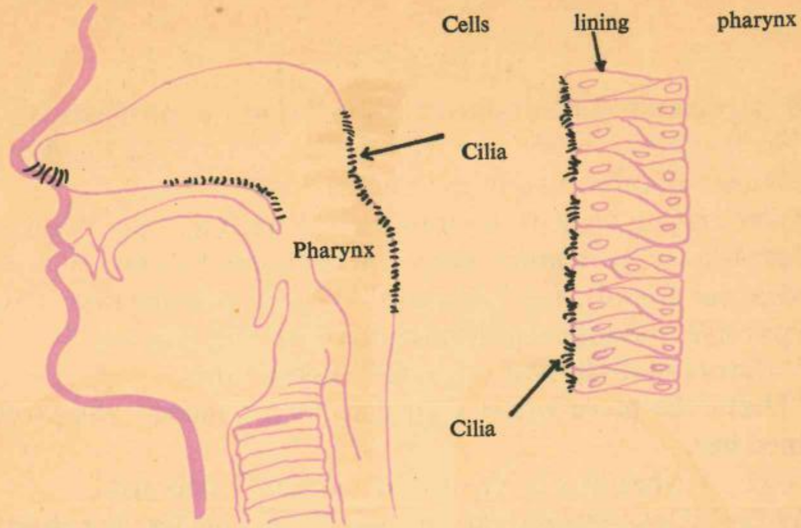
As the cellosphere passed through the wind-pipe, the children were looking at the screen to examine the structure of the passage. They saw that the wind-pipe was made up of small horse-shoe shaped sections.

"You see that the wind-pipe is made up of small pieces of soft bone called cartilage. These prevent the wind-pipe from collapsing. You know how important the wind-pipe is, don't you?' asked Professor Knowall.

Ami nodded. "If it collapses we are done for."

"Now, we'll try and examine the passage in greater detail." The





professor adjusted the projector and a magnified view of the wind-pipe passage was seen on the screen.

"Oh! Hair in the wind-pipe, too? And all waving as it were! Are there really so many of them?" asked Gira.

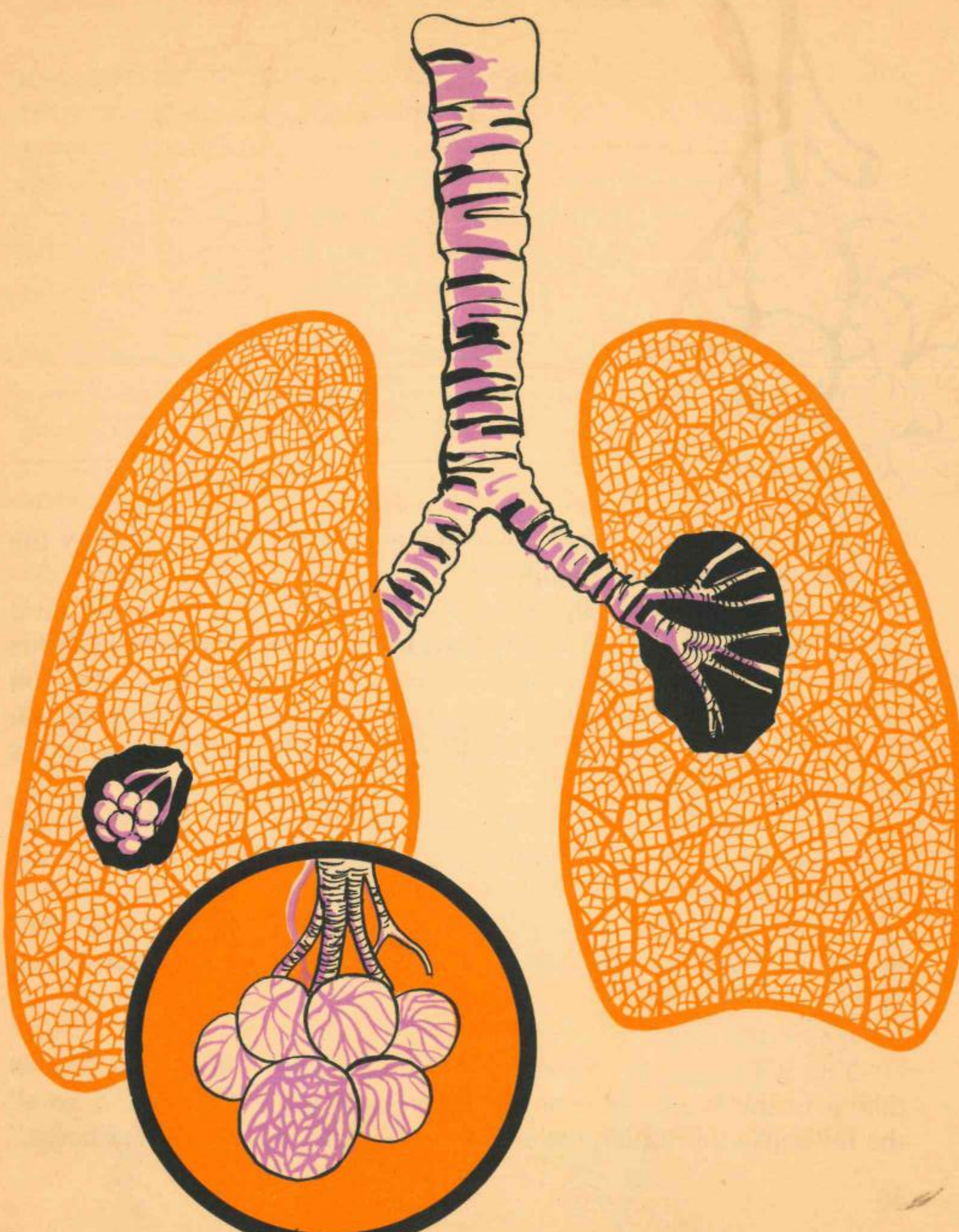
"Not hair, Gira, these are the cilia," the professor explained. "These cilia are always bent upward and so prevent tiny dust particles from entering the lungs. Now, when enough dust is so filtered, it is pushed up to the region of the pharynx and we remove it either by coughing it out or by swallowing it."

"O look!" cried Gira. "The wind-pipe is getting divided into two parts. I know where they lead to—the right lung and to the left lung."

"You are right, Gira. Quite, quite right," the professor smiled. "These two divisions of the wind-pipe are known as the *bronchi*. The structure of each bronchus is similar to that of the trachea. Let's go into one of these bronchi, shall we?"

"The bronchus will now start dividing and sub-dividing and further dividing like the branches of a tree. Look! We have come to the smallest branch now. This is known as a *bronchiole*."

"What are these pipe lines," asked Gira.



"Don't you know, Gira? They are blood vessels. They carry the red blood and the blue blood."

"The artery carrying the blue blood comes from the heart, and carries the blood full of carbon dioxide. Now let's see what happens to this blood," said the professor. "At the end of the bronchiole you see a grape-like cluster. This grape-like thing is called the *alveolus*. It is the exchange station where the blood in the artery gives up its carbon dioxide."

"Look, there's our friend the oxygen molecule!" exclaimed Gira. "It's coming out from the grape-like alveolus and now it's boarding that ship, the red blood cell."

"Remember, it has first of all to dissolve in the fluid at the walls of the alveolus," said the professor. "Mark the colour of the blood as it leaves the alveolus."

"It's bright red," said Gira.

"Yes, it's bright red because it's full of oxygen. This vein will now take it to the heart and that pumping station will then send it to all the millions and millions of power-stations in the cells of the body," the professor explained. "In the lungs of a single individual, there are as many as about 300 million alveoli. This means that there are as many alveoli as, let us say, about two-thirds the population of India ! If we merely consider what the total surface area of these alveoli is, we would arrive at the surprising fact that it is about forty times the surface area of the whole body!"

"Unimaginable!" exclaimed Ami.

"Yes, but very, very true, all the same," said the professor. Then he glanced at his watch and, greatly alarmed, he ran towards the switchboard and started turning off the switches as if something terrible was in the offing. "I forgot to keep looking at my watch. There are hardly four seconds left for the effect of the pills we took to wear off !"

"Good gracious! What happens if we cannot go out of this poor man's wind-pipe in just four seconds from now?" shouted Ami.

Gira was too much shaken to say anything. The cellosphere was rushing at great speed towards the pharynx. Professor Knowall was

anxiously looking at the seconds hand on his watch. He said almost in a whisper, "Only one second left now! Only one!..."

Suddenly there was the sound of a big sneeze and Ami sat up wide awake in his bed. His mother and Gira came running into the room.

"What happened, Ami?" asked his mother.

"I only sneezed," Ami replied.

"Well, the sound you made was terrible—I wondered what had happened to you. And, O yes, don't you remember that tomorrow you have to teach the lesson on respiration?" said his mother.

It was then that Ami remembered the whole wonderful dream. It had solved his teaching problem. He needed no preparation for that lesson, not he! He said aloud, "I know all about respiration. Professor Knowall taught me everything."

At this, both Ami's mother and his little sister, Gira, looked at him with astonished faces but *we* know all about it, don't we?

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