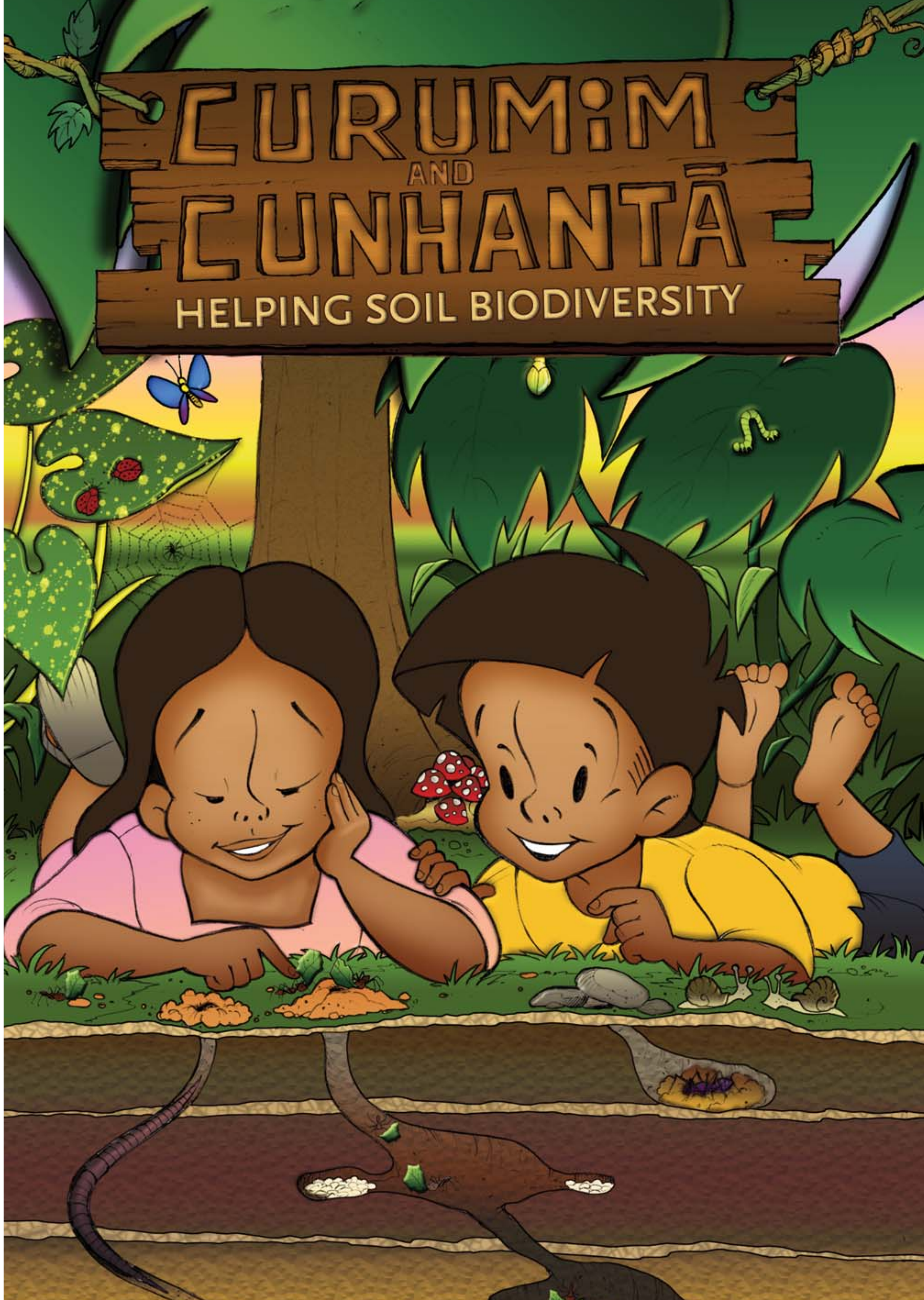
CURUMIM
AND
CUNHANTÃ
HELPING SOIL BIODIVERSITY

CURUMIM AND CUNHANTÃ

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Presentation

Soil organisms play an important role in several natural processes responsible for the sustainability of ecosystems. These processes are influenced by the complexity, heterogeneity, dynamics, and interaction of several physical, chemical, and biological factors of the edaphic system. Thus, the study of the soil microorganism must be conducted in an integrated context, aiming at the application of acquired knowledge to the development of sustainable agricultural and forest production associated with environmental conservation.

The Project "Conservation and Sustainable Management of Below-Ground Biodiversity" (CSM/BGBD) is coordinated by the "Tropical Soil Biology and Fertility Institute" (TSBF) of the Centro Internacional de Agricultura Tropical (CIAT); it is sponsored by the "Global Environment Facility" (GEF), implemented by the "United Nations Environment Programme (UNEP)" and conducted in seven countries: Brazil, Ivory Coast, India, Indonesia, Kenya, México, and Uganda. In Brazil, the project is called BiosBrasil and is coordinated by Universidade Federal de Lavras (UFLA) and is jointly conducted with the following institutions: Instituto Nacional de Pesquisa da Amazônia (INPA), Universidade Federal do Amazonas (UFAM), EMBRAPA – Solos, Universidade Regional de Blumenau (FURB), Universidade de Brasília (UnB), Centro de Energia Nuclear na Agricultura (CENA), Centro de Ensino Universitário Luterano de Manaus (CEULM/ULBRA), Comissão Executiva do Plano da Lavoura Cacaueira (CEPLAC), and Universidade Estadual do Sudoeste da Bahia (UESB).

In Brazil, its nearly 100 participants include researchers, undergraduate and graduate students, technicians, and scholarship holders who work in the project. Another four institutions participate in Phase 2 of the project: Universidade Federal do Piauí (UFPI), Universidade Federal de Campina Grande (UFCG), Universidade Estadual do Norte Fluminense (UENF), and Universidade Federal de Mato Grosso (UFMT).

Its objective is to raise the awareness, and further the knowledge and understanding of soil biodiversity, which is important for sustainable agricultural production in tropical environments, and to divulge the scientific knowledge by demonstrations of methods of sustainable conservation and soil management.

The project explores the hypothesis that the conservation of biodiversity may be achieved by appropriate management of the topsoil and belowground biota, bringing national and global benefits through mosaics of land use with different intensities of management, and besides this, result in simultaneous gains in sustainable agricultural production and food safety for the local populations.

The project study area is located in the municipality of Benjamin Constant, which lies in the Alto Solimões region of the Amazon State. It involves the indigenous communities of Nova Aliança and Guanabara II.

This booklet presents the results found by the project researchers during Phase 1 (July 2002 to June 2005). Mingling fiction and reality in language accessible to the general public, it explains the importance of soil biodiversity for the sustainability of ecosystems and how its conservation depends on all of us.

The sky and the earth were sad about human beings losing the capacity to live in harmony with each other and with nature. Fish and other animals were disappearing. The lush trees, the queens of the forest, had been cut. Pests and diseases were appearing, caused by animals and microorganisms that used to be harmless, but now their natural enemies had also disappeared. The soil itself was losing its capacity to produce. This is the reason why the sky and the earth decided to restore the purity of humanity. To this end, they bore a son and a daughter and sent them to live among the humans.

When they arrived on the planet, both of them forgot where they had come from, but their purity remained so that men and women could discover it again. Members of an Amazon community found them wandering in the forest and adopted them. They called them Curumim and Cunhantã[1]. They were happy and curious children and touched everyone with their good feelings and values.

[1] TN: Curumin and Cunhantã are Tupi-guarani words for boy and girl. Tupi-guarani is spoken by the indigenous people of the central South America rainforest.

One day at the community school, Ms. Flora, the teacher, mentioned the biodiversity of Amazon to the students. She said that the Amazon has the greatest biodiversity on the planet and that it is very important for human beings. She also said that, unfortunately, many people are destroying the forest, the rivers and the animals.

Curumim and Cunhantã were intrigued, because although they had heard the same on television, they did not know what biodiversity was, nor what its importance was to human beings. Could it be that the forest is biodiversity? Everybody talked about it, but they just couldn't understand it well. And why was it so important?

Ms. Flora said that biodiversity was so big that it was impossible for only one person to understand everything about it and that there were science specialists for each group of organisms. Ms. Flora said that the scientists were studying the biodiversity of the forests and small farms near her community and that they could explain it better.

The two kids were very excited! It was their chance to ask the questions they had, and they decided to act. They invited other children to come with them and learn more, but all the others wanted to do was watch television. The boys just wanted to fight like the super heroes who did things that none of the tribe warriors could do, and the girls wanted to learn how to make themselves up and dress like soap-opera stars. The two decided, then, to go by themselves.

Very early the next morning, Curumim and Cunhantã took their loyal companion, a small monkey named Mico, and went to the place where Ms. Flora had told them the scientists were working. When they got there, they saw many strangers and many people they knew, too, parents of some of their buddies, and who were helping the scientists. The children asked who could respond to some of their questions, and the answer was that everyone had something to teach them and that all that they had to do was to ask.

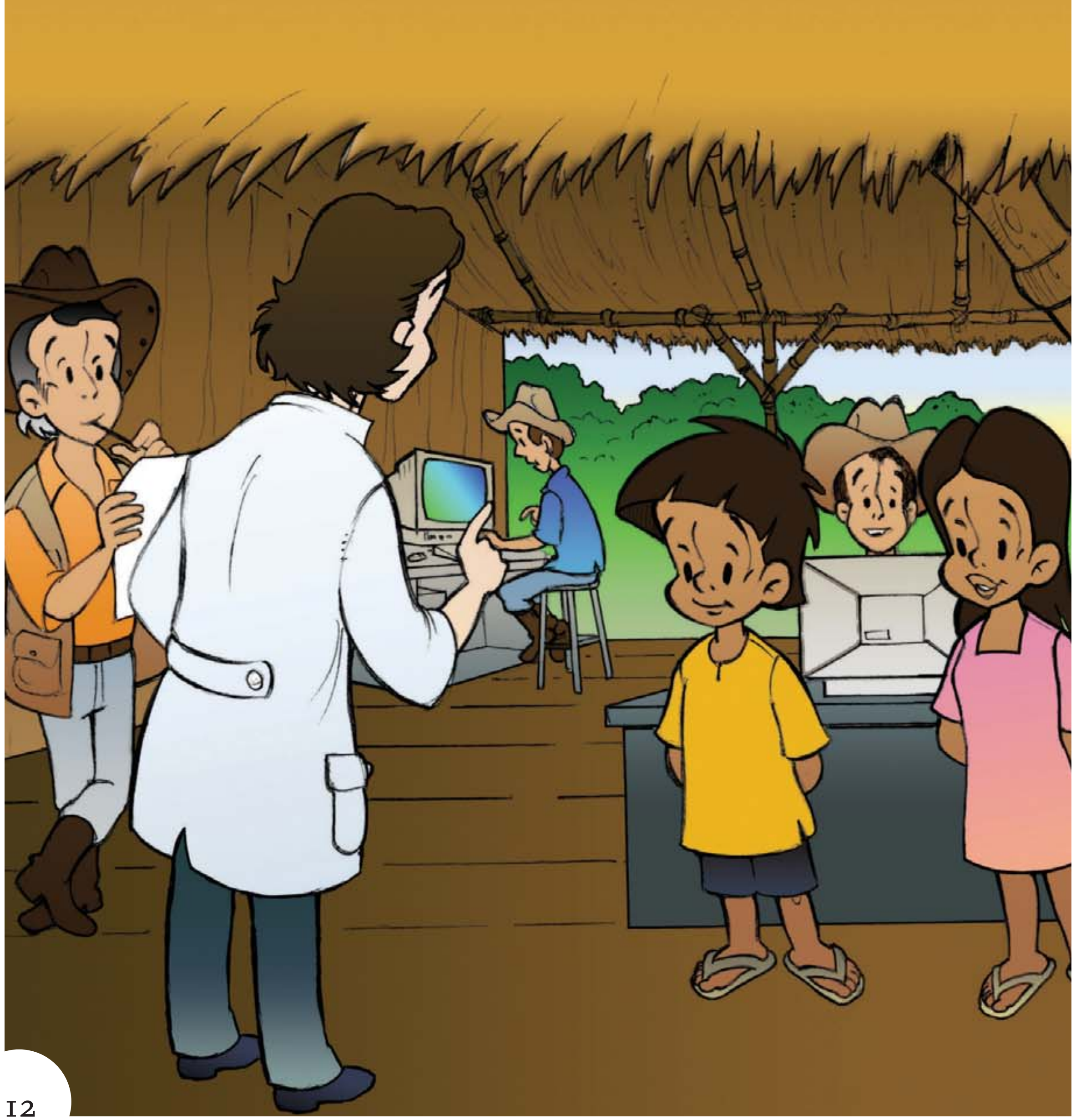
A scientist spotted them in the midst of the other researchers and introduced himself:

– Hi, can I help you?

– Hi, my name is Cunhantã and this is Curumim. Our teacher talked about something called biodiversity and we became curious to know what that is. Where does it hide? I've never seen one.

– She also said that the forests are being destroyed and that if we helped this biodiversity thing, we could save the forests – said Curumim.

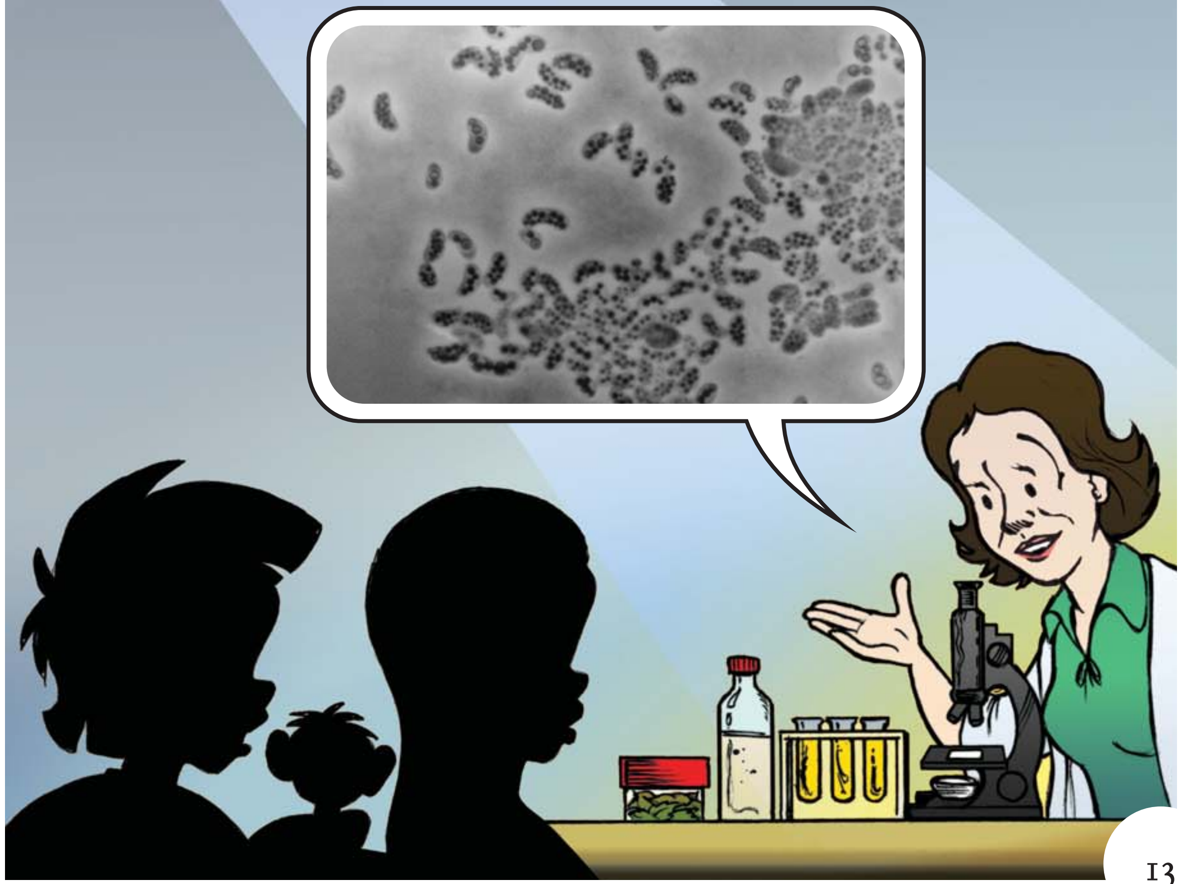
– I'm the project coordinator. We'll all be very pleased to show you and your friends what biodiversity is and why it is important.



The scientist then explained:

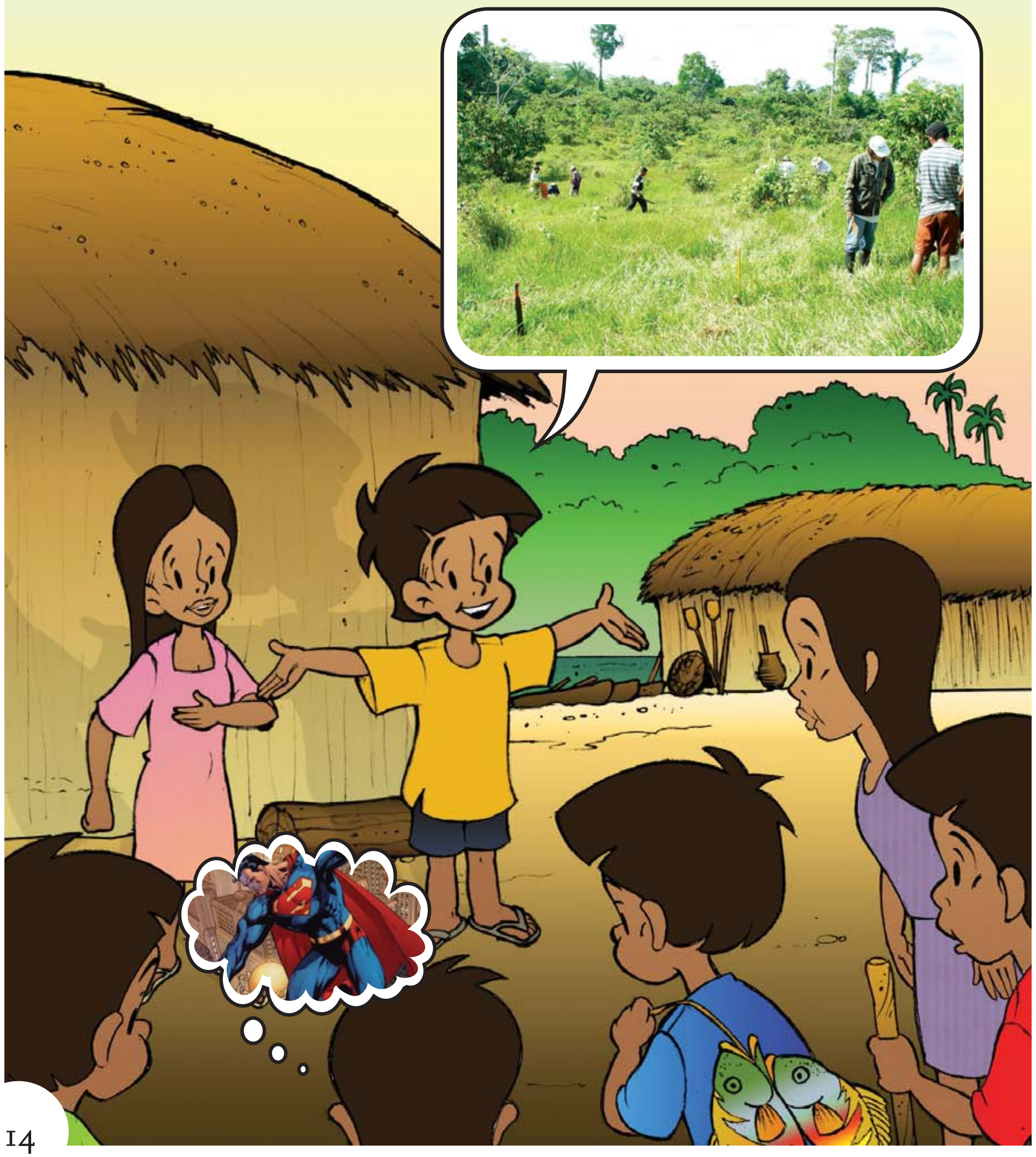
– Biodiversity is all the living organisms, of all shapes and sizes that live in a certain place. Without even being aware of it, we're all surrounded by it, even more so here in the Amazon, which is the biodiversity paradise of the world. All these organisms live in different ecosystems. An ecosystem is the combination of an environment, with all its characteristics, like the amount of rain, the temperature, the kind of soil, and so forth, plus all the organisms that live there. For example, an igarapé, a small river, is an ecosystem, just as the forest is another.

– In the case of our group, for example – she continued –, our main interest is to study the biodiversity of organisms that live in the soil of different environments in this region: forests, *capoeira*s, that is, land cleared for crops where the forest later grew back, crop patches, small farms, and pastures. The organisms vary in size, from worms to others, like bacteria, that can only be seen with the help of a microscope. They are all affected by the way we use the soil to produce food, for example. As they are very important for nature functioning, if we lose them, we may not be able to produce food in the future as we do today. It is very important that the people of the forest know what these organisms do, because then they will understand the importance of conserving the organisms.



The scientist agreed that Curumim and Cunhantã would return the next day, together with their friends, to learn a little more about biodiversity from the scientists involved in the project.

They went back home very happy with this idea and called their friends to visit the project the next day. Their friends wanted to find out what this biodiversity was, but they did not want to miss the super heroes, actors, and singers on television. Nevertheless, Curumim and Cunhantã's enthusiasm was contagious, and many of the kids ended up accepting their invitation.



The next day, they went with their friends, ready to ask questions.

– Good morning, everyone! – said the coordinator.

– Good mooooorning!!!!! – they answered, full of excitement.

She started by explaining that in other countries with forests like the Amazon, researchers were also doing the same kind of study and that there were several specialized scientists in each country.

– I'll start by introducing you to our map specialist.

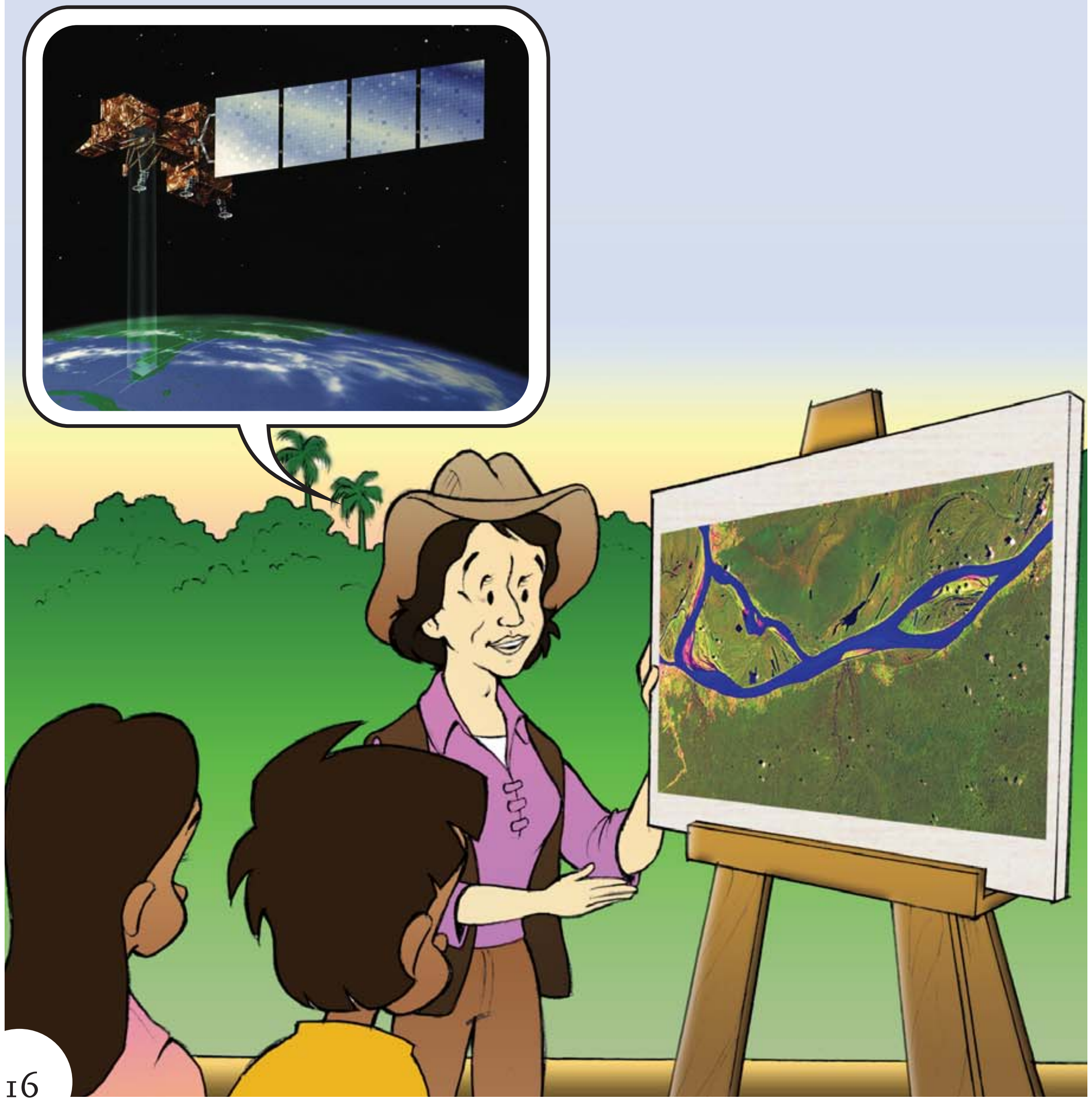
At this, Curumim couldn't contain himself.

– Then a map also is biodiversity?

– No it isn't! – answered the scientist who made maps, happy that he had asked that question. – I'll show you the importance of maps.

– The different ways we use the land affects biodiversity. So first, we need to make a map to show how the land is used and how much of it is used in the region. The map is important for us to locate the forests, the *capoeira*s, the crop patches, the small farms, and other places where biodiversity can be found. It is easier to do this with satellite images. The satellite is up in the sky orbiting around the Earth and takes pictures like this one of the Benjamin Constant municipality with the Solimões River.

– And speaking of land use, we will study the several species of plants involved in each use of the land. I'll introduce you to the botanist, who specializes in plants, and to the agronomist, who knows how to take care of plants that can be cultivated. They will tell you what they have found here in Alto Solimões.

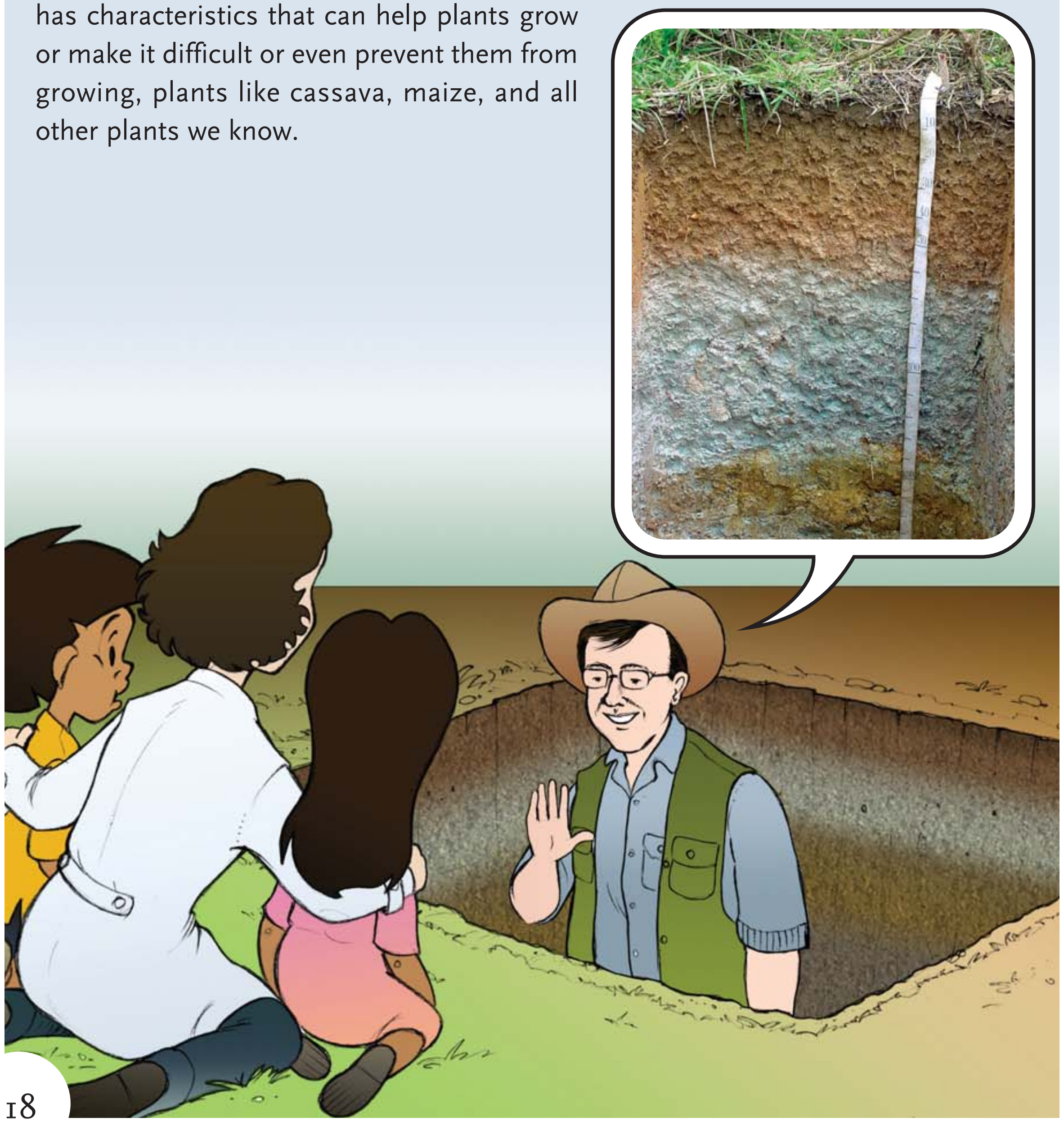


– Shall we get started then, children? – says the botanist. – In this region, we have found 599 plant species in the forest and 69 species in the pastures. These two land-uses are very different. In the forest, we found mainly tall trees with large trunks. Below them, there are some plants that grow in the midst of the leaves, twigs, flowers, and fallen fruit. In the other hand, the pasture has mainly grass, weeds, and some trees. The reason is that the cattle farmer wants to have only grass in the pasture to feed the cattle, and some trees for shade in the hottest time of the day. You could say that this land-use has poor biodiversity. This is not only because there are few plant species, but also because there are few species of other organisms, as the other specialists have observed.

– In the crop patches – says the agronomist – we found 187 species of plants, some of which are from the year's harvests, like cassava, maize, and squash. Fruit trees, such as papaya, cupuaçu, pejibaye palm, banana, and others, are also grown in these areas. The majority, however, are weeds that appear spontaneously and have to be weeded out two or three times a year.

– When the crop patch is abandoned, the forest grows back – says the botanist – and the number of species increases. *Capoeira*, as these areas are known, or secondary forest growth, are formed by several species that grow spontaneously where the forest had been cut down. We have found 291 species in the young *capoeira*, and 255 in the old one. The number of plant species in the old *capoeira* are similar to those of the home gardens. Did you know that in the old *capoeiras*, there are fewer small plants because of the shade? In the home gardens, we have found 196 species of plants, mostly the ones that give the fruit you love so much, and under them, plants that can stand the shade.

– Kids, I'll call the pedologist now. He is the specialist that studies the soils.
– Hi! – he said from inside a hole.
– Hi! – answered the kids, curious and excited about so much knowledge.
– Well, the soil is the very top, soft part of the surface of the planet Earth. It is like the peel that covers the orange. The plants grow on the soil; we get our food from it and build our houses and roads on it. We depend on it to live. There are several types of soils. Scientists can distinguish and classify them with specific names, just like people. Just as Peter and John are names of people, Oxisols, Cambisols, Ultisols, Gleysols, and several other words are names of soils the pedologists have made up. It is important to know the soil names to identify them in the field. Each type of soil has characteristics that can help plants grow or make it difficult or even prevent them from growing, plants like cassava, maize, and all other plants we know.



– In the case of the biodiversity of soil organisms – he went on –, it is also important that we know the types of soils in a given place. The soil is like a home for the organisms. That is why its characteristics are very important. For example, some places have darker soils, others, lighter, and yet others, very wet or dry. It can also be deep or shallow. In shallow soils, like this one here, the hard rock is very close, just a few centimeters from the surface. Other soils have more sand, and others, more clay, which is a grain much smaller than the sand grain. These characteristics and many others help us sort out the field soils and name them, just as they can make it easy or difficult for plants to grow and for organisms to live in them.
– One soil characteristic is very important – remarked the pedologist. – It can be richer or poorer in nutrients, the food that makes plants grow in soil, and that is also important for the organisms that live in it. That is why the amount of nutrients in the soil has a very important role in biodiversity.
– The "terra firme" soils here – he said – are very acid and have a lot of clay. They have large amounts of some nutrients, such as Calcium, Magnesium, Sulphur, Zinc, Manganese, Iron, and Copper, but low amounts of others, such as Potassium, and mainly Phosphorus, and Boron. There are several other elements in soils that are not good for plants, for example, Aluminum, that can poison them, and Hydrogen, that together with Aluminum, make the soils acid, as the soils are here. When this happens, we need to use lime to correct these problems. Acidity makes it difficult for plants to grow or can even stop them from getting the nutrients that they need to grow and bear fruit. When the soil is closer to the river or in some flooded places, it is soaked with water most of the time. This can prevent the roots of some plants from growing or make them rotten because of the excess water and the lack of oxygen for them to breath.

– Kids, I'll introduce you to another specialist, an ecologist. He can tell you about the relationships between the plants and the organisms.

– Hi, kids! Did you know that the plants are also important for the organisms in the soil? They provide these organisms with food while they are alive and also when they are dead. They also release several types of food through their roots that the soil organisms love. Each organism has its own food preferences. Some organisms feed on plants, and others are predators, that is, they eat other organisms. There is also a large group of organisms that eat the different kinds of forest leaf-litter, or debris. A spider web is a good example of the many kinds of relationships between all the soil organisms. So let's call them food webs.

– All right! Now it is easier to understand. What about the soil biodiversity? What is it like? – Cunhantã asked.

– In this case – he answered –, the people who work with soil organisms can explain it very well. These are the various kinds of organisms, like animals, that live in the soil. Are there animals in the soil?

– Are there animals in the soil? – Curumim asked.

– Yes, and many of them. There are so many creatures in the soil that the folks that work with them usually divide them in groups: the larger ones are called macrofauna, the medium-sized ones, mesofauna, and the tiny ones are called microfauna; there also are microorganisms, many of them! The soil has trillions of macro – and microorganisms per square meter and there may be tons in an area the size of a soccer pitch! We do not know the total number of species yet, but certainly, there are millions.

– Gee! – the kids said in amazement.

– We don't get to see this huge diversity because most of the organisms hide in the soil. In addition, many cannot be seen with the naked eye because they are microscopic, such as the bacteria. We can only see a small number of species, the macroscopic ones, that visit or live on the soil surface – he explained.

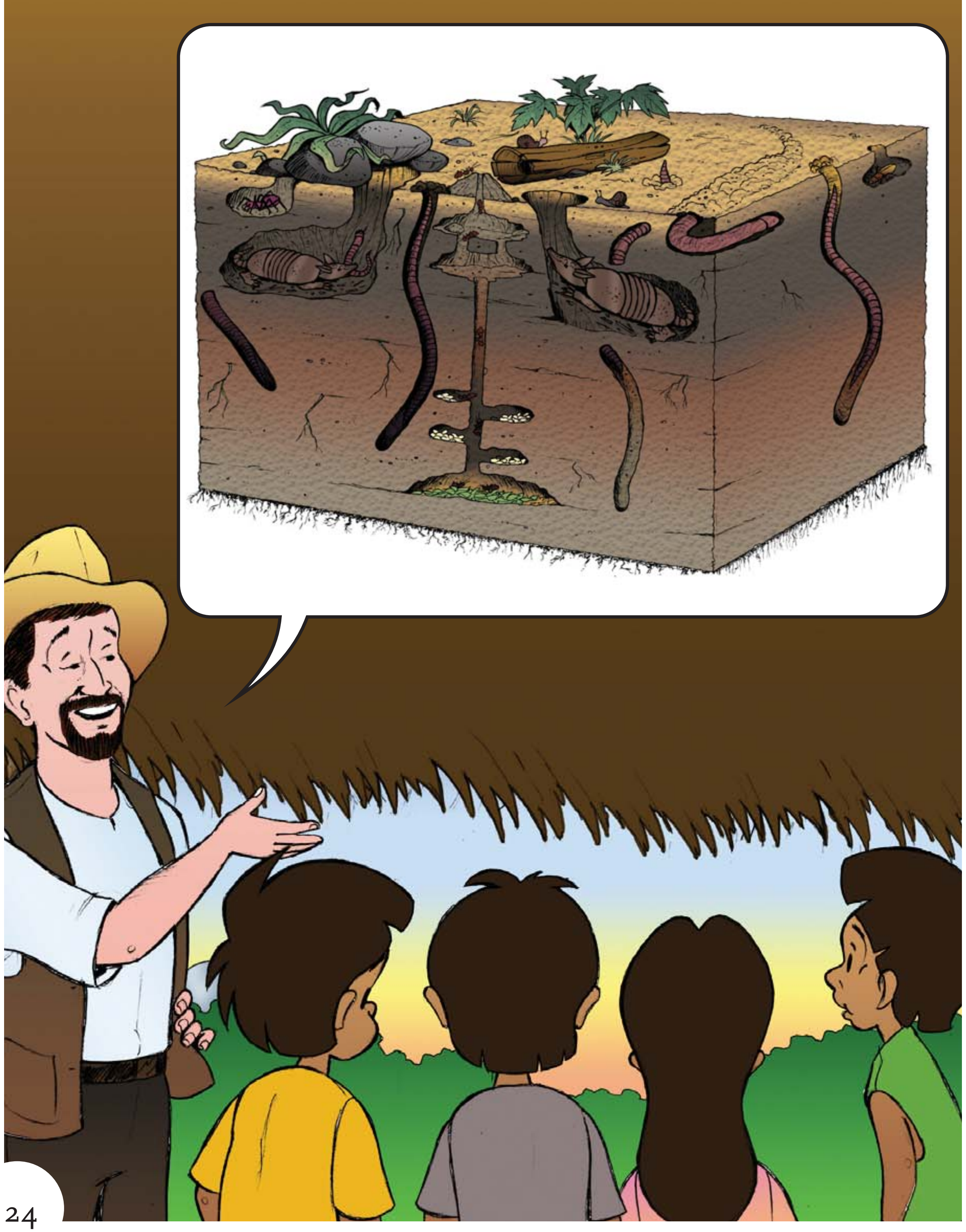
– What is part of the macrofauna, a capybara, a parrot? – Cunhantã asked.

– No, no! – the scientist who specializes in fauna answered.

– They are not part of the soil macrofauna – an entomologist said – The macrofauna is formed by organisms larger than 1 centimeter, organisms like beetles, earthworms, ants, termites, spiders, snails, and many others. Both zoologists and entomologist have found many macrofauna species here, such as 239 of ants, 75 of termites, and 53 of beetles. We are still identifying other groups, because unfortunately the specialists that study them are rare. This is why most of the soil diversity is unknown.

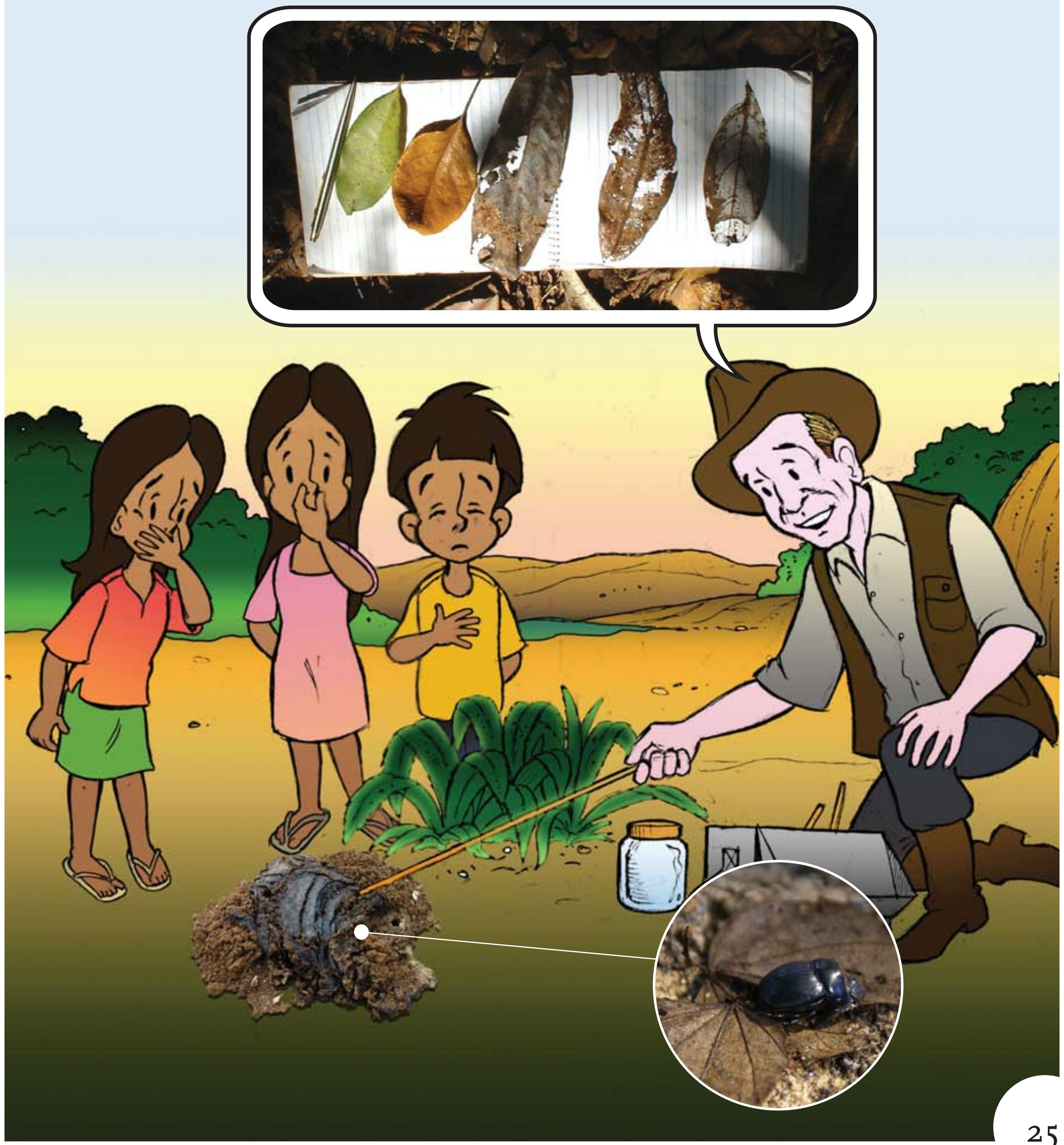
– All these macrofauna groups are badly affected when the forest is burned for crops, and mainly for pasture – the entomologist added – Luckily, as happens with the plants in this area, the restoration of the diversity in the *capoeira*, or forest which has recovering, is very good, because the organisms that were in the part of the forest that wasn't burned, return.

– The macrofauna, like the worms, termites, beetles, and ants, dig tunnels, or galleries, that help water and air get into the soil. The roots of the plants and many of the soil organisms breathe, too, and so they need air. All of them, just like us, need water.



– The macrofauna also helps in the initial phases of decomposition of the organic matter, which is then completed by the microorganisms. Organic matter is all the dead organisms, animals, or plants. Have you ever thought about what would happen if the leaves, branches, dead animals, feces, and all other kinds of waste, didn't decompose? We'd be buried in our own waste! Besides the decomposition process, some organisms, such as beetles, bury the feces of other animals in the soil. In doing this, they help to fertilize the soil and prevent pollution. That is why they are called the "garbage collectors" of the ecosystems.

– Wow! – the kids all said together.



– Hi, kids! – The soil fertility specialist arrived – Completing what my colleague has said, when the organic matter is decomposed, it releases nutrients that the plants had taken from the soil. These nutrients will increase the fertility of the soil and will be used by other living organisms, such as plants themselves, to grow and reproduce. The soil is like a huge machine that digests all organic matter and then releases both nutrients, and organic matter, which we call humus.

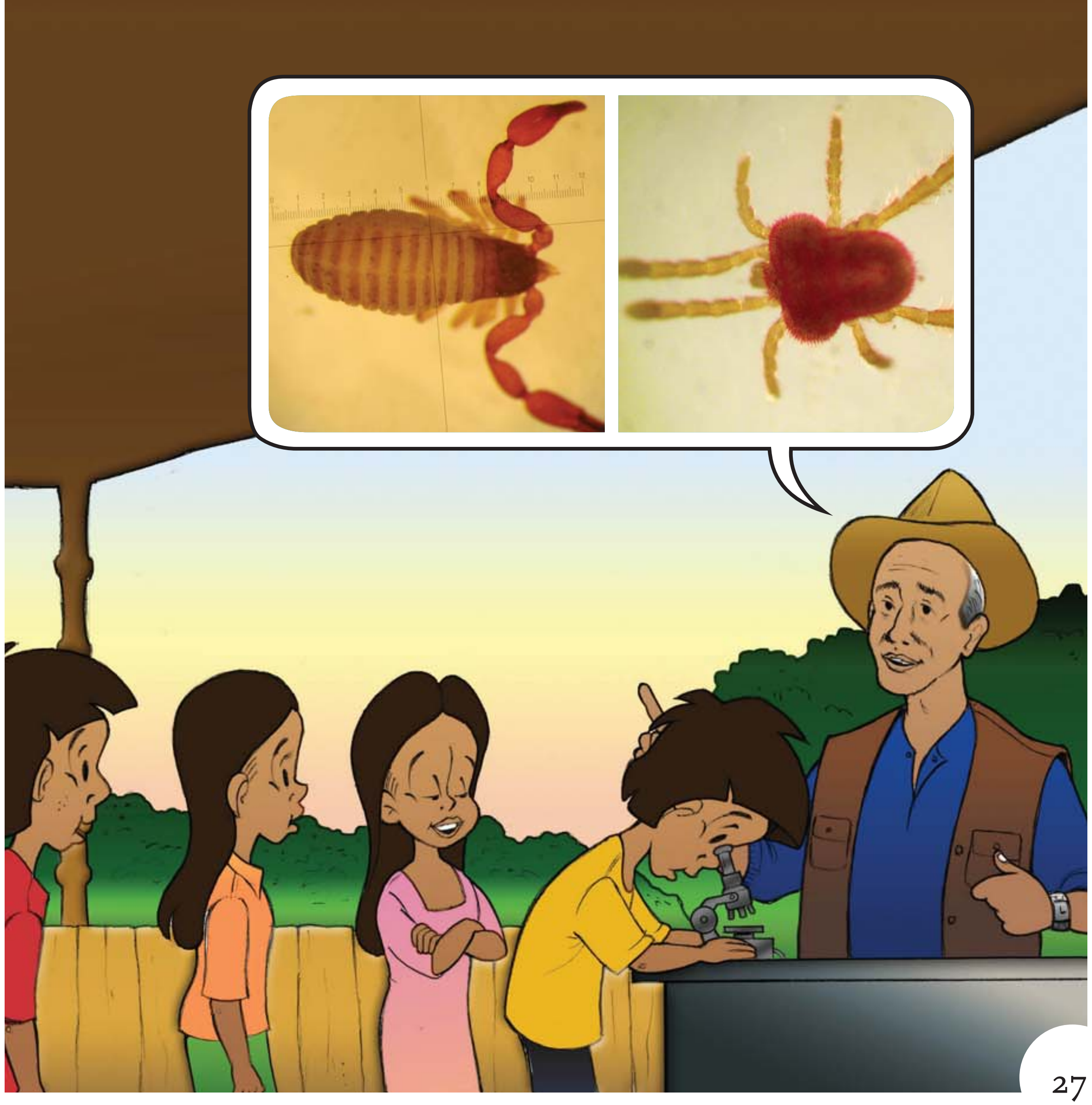
– The amount of nutrients in the soil varies – she continues – depending on the way it is used. For example, when you use manure or fertilizer, it gets more nutrients and the plants grow better. Another thing that changes the amount of nutrients is forest slashing and burning. In this case, all the nutrients from the leaves and trunks are turned into ashes on the ground. The ashes are nutrients for the plants and also help to correct the acidity and the aluminum, which is harmful to plants. However, the ashes are used up fast when we plant cassava right after cutting and burning the forest. This happens because the cassava roots absorbs the nutrients while growing. After 2 or 3 years, the ash nutrients will have all been used up by the cassava plant or carried away by rain water. Then the soil will be as if it had not received any ashes at all. This is why we let the *capoeira*, or the young forest, grow back. As the years pass, the soil becomes similar to the way it was in the original, native forest.

– So when dad does mulching, he is helping to increase the nutrients and the fertility of the soil for the plants to grow, isn't he?

– Exactly, Cunhantã!

– Wow! So this biodiversity does really important things that we need to be able to live!

– Hi, how's it going? I'm an entomologist too. I'll tell you about another important group, the mesofauna. Have you heard about mesofauna? Have a look at the microscope. Mesofauna is made up of animals measuring from 0.2 to 10 millimeters, such as the springtail and the mites, which you already know. Like the macrofauna, they are important to keep the populations of several species under control, because they prey them, and also help in the decomposition of wastes. Also like the macrofauna, the mesofauna helps to disperse the microorganism that would take years to move from one place to another far away; for them one meter is like from here to the moon for us. In contrast, the macrofauna also helps to disperse some mesofauna species, such as the pseudoscorpion and mites. They can hide under the wings of large beetles or stick to the legs of moths and travel long distances.



– Gosh, if this is mesofauna, I guess I have never seen the microfauna – one of the kids said.

– That's right! – said the specialist in nematodes, the phytopathologist. – Usually, you can only see the microfauna through a microscope. Can you see the photo of this root gall? There are thousands of parasites inside it called nematodes. We can only see them in the microscope. They are parasites and they make the plant sick. But there are other species that do good things in nature. Some eat other microorganisms and control their populations. They limit the number of microorganism individuals so that they do not compete with other species and some of them do cause diseases to plants. Have you ever seen a disease or a pest to kill at least a part of the forest?

– Yes, we have, the pest called human beings!!

All the scientists laughed!

– You are right, kids, but we are talking about pests and diseases caused by other organisms.

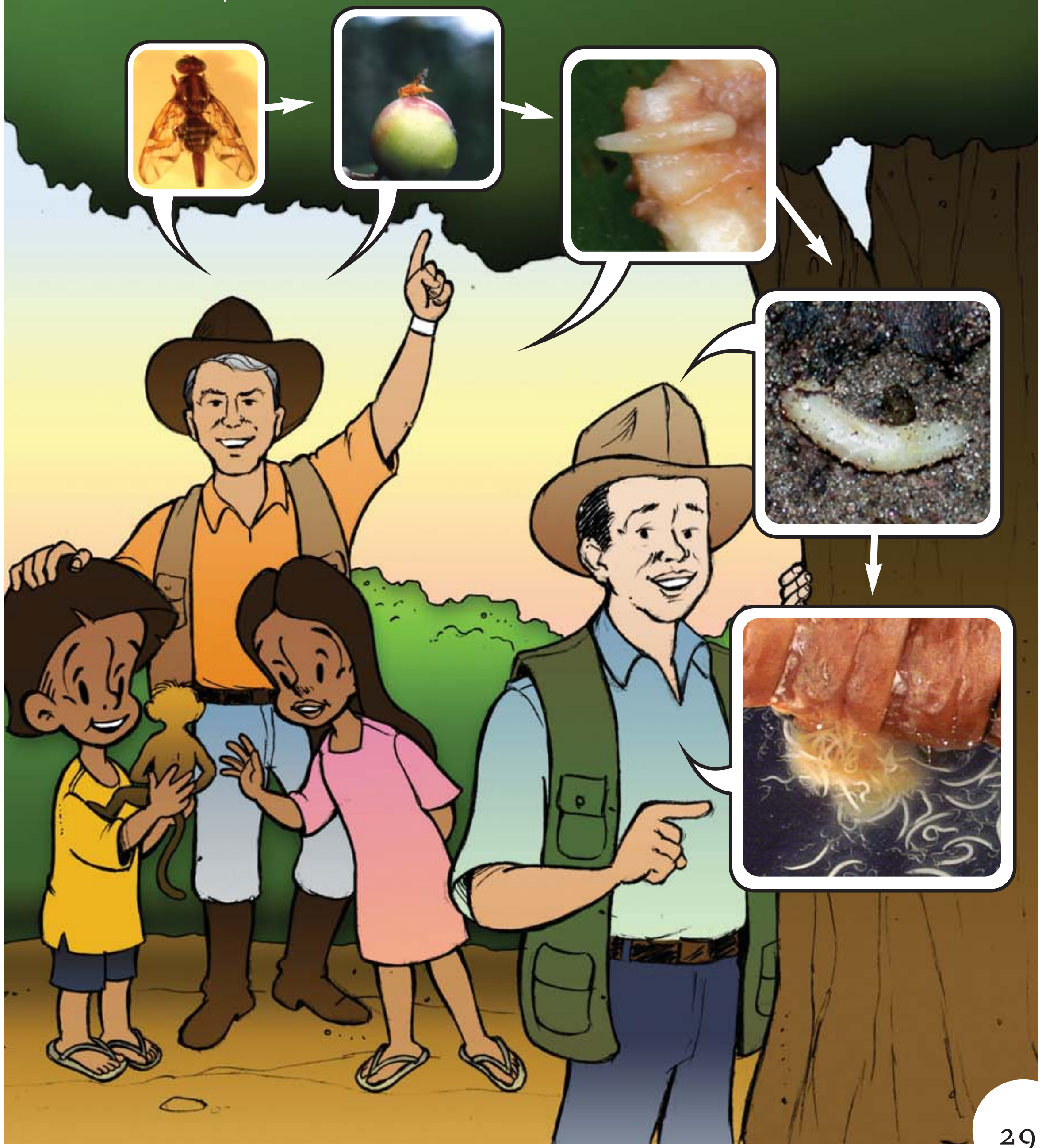
– All right! We have never seen this kind.

– The thousands of relationships between microorganisms allow them all to survive harmoniously and prevent any one population from becoming so numerous as to cause harm to another.

– Cool! We should learn from them, shouldn't we?

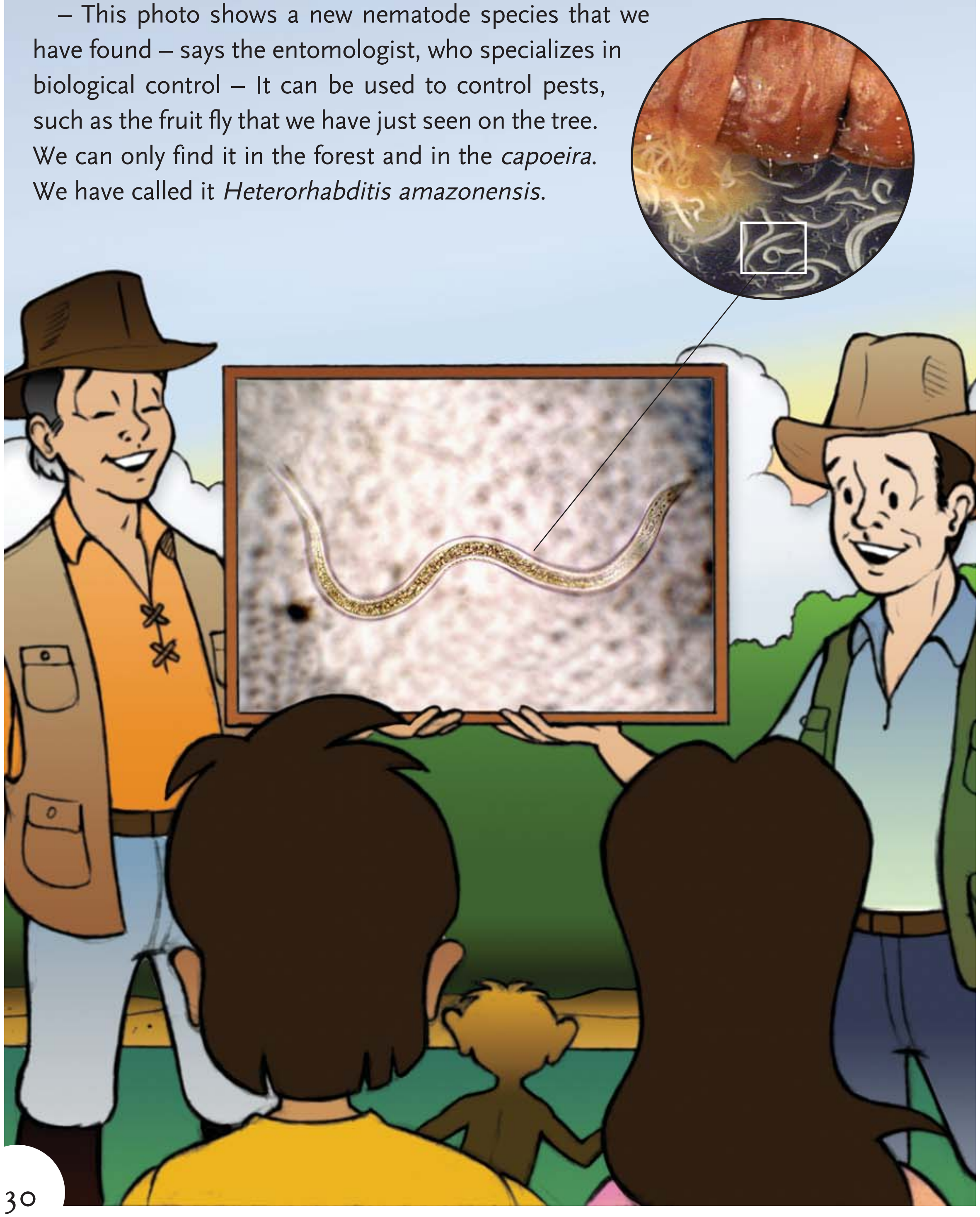
– Yes, nature has important lessons to teach and human beings can learn a lot from it.

– We can even use biodiversity to our advantage. For example, many nematodes can be parasites on insects that are pests, such as the fruit flies that attack guavas and other fruit species.



– In these cases, they can be used in the biological control of these insects, instead of using insecticides, which are poisonous and can harm other animals, including human beings. As these insects spend part of their lives underground, we can increase the number of good nematodes that live there and that will cause diseases in the larvae and pupae of flies in the soil.

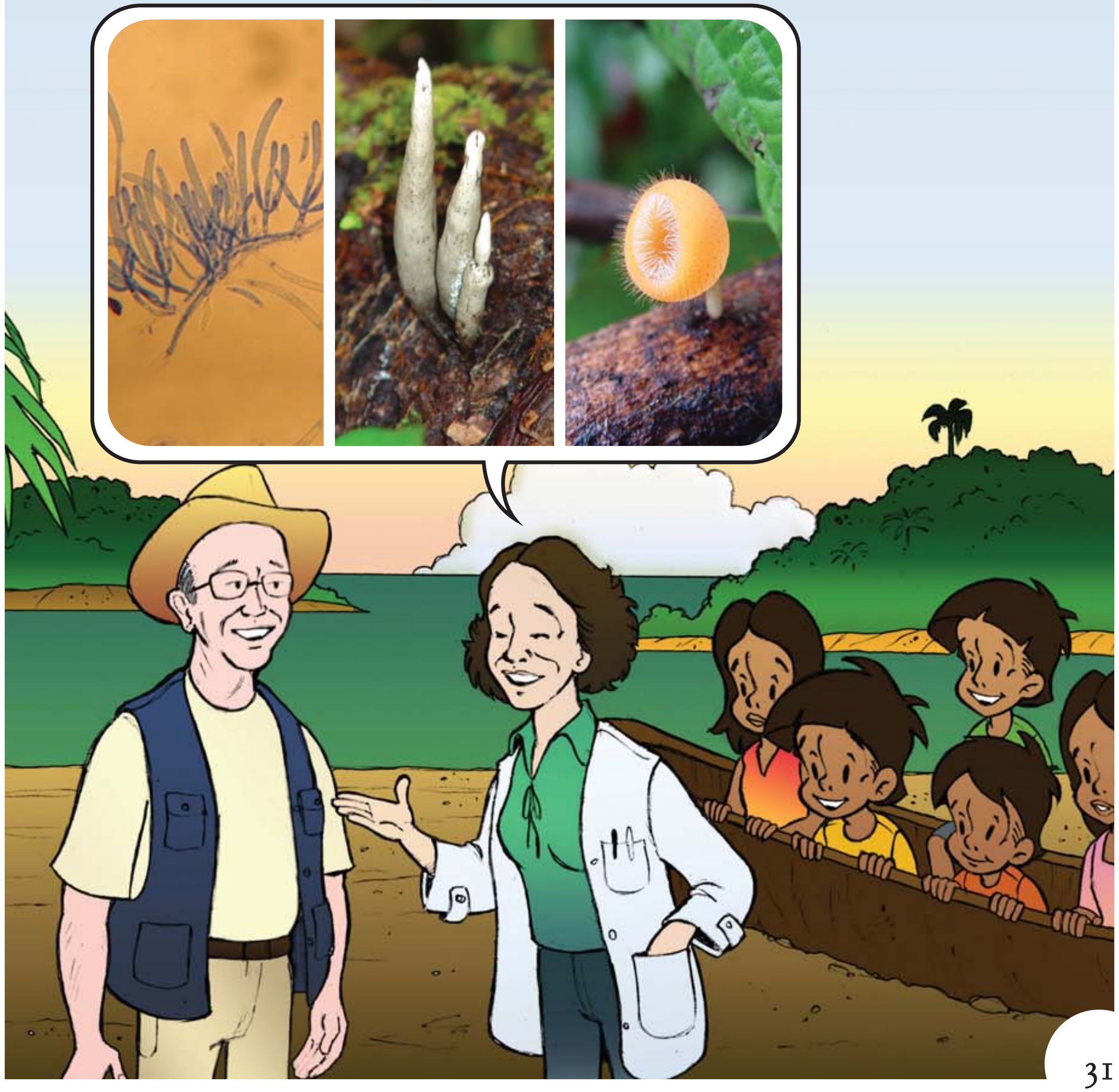
– This photo shows a new nematode species that we have found – says the entomologist, who specializes in biological control – It can be used to control pests, such as the fruit fly that we have just seen on the tree. We can only find it in the forest and in the *capoeira*. We have called it *Heterorhabditis amazonensis*.



– I'm back, kids – said the coordinator.

– Now we will get to know other organisms that cannot be seen with the naked eye; so we will need a microscope. They are the fungi and the bacteria. These organisms are small and there are trillions in each tiny lump of dirt. They have important functions in nature. Some fungi grow so much that they become visible to the naked eye, that is, they become macroscopic. As in every organism group, it has good and bad microorganisms. That is, from our point of view, because in nature, they are all in equilibrium. There is no disease or pest capable of killing off other organisms. They control each other so that they do not become too numerous, nor become pests or cause diseases to plants. Let's start talking to one of our mycologists.

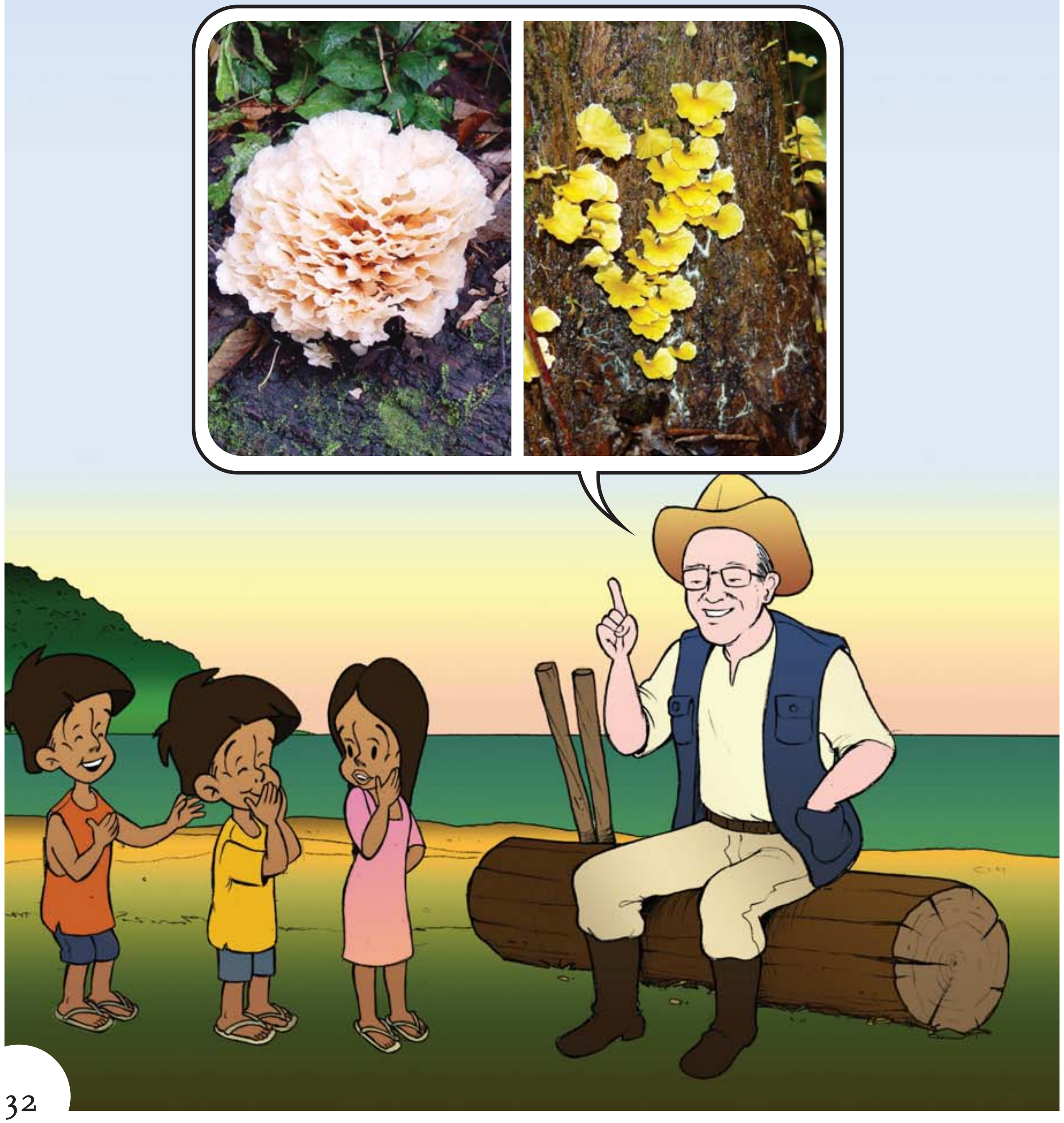
– Hi! – the kids shouted in excitement.



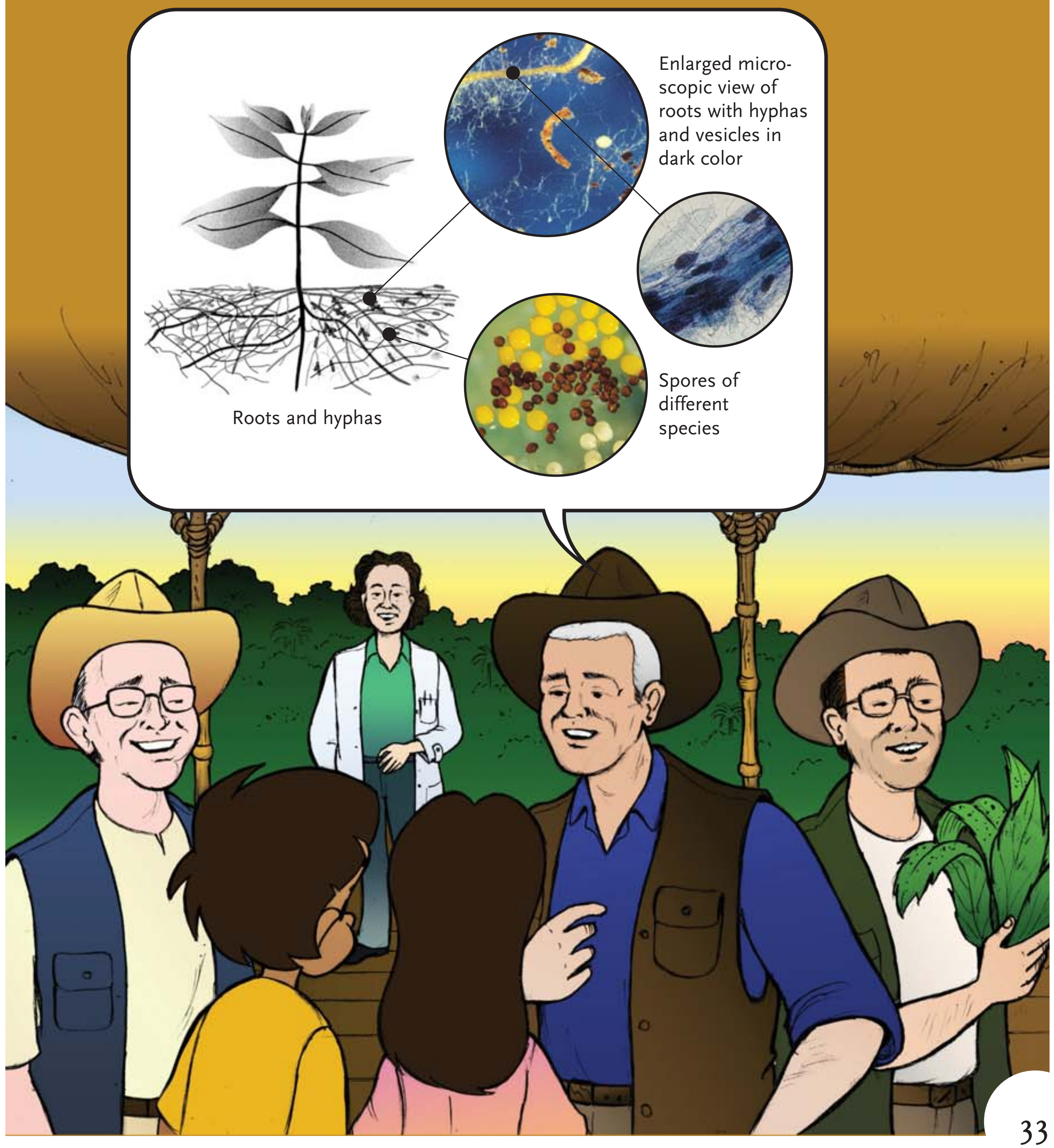
– Hi, folks! I'm a mycologist.

– Do you study our monkey friend Mico? – Cunhantã asked. Everyone laughed.

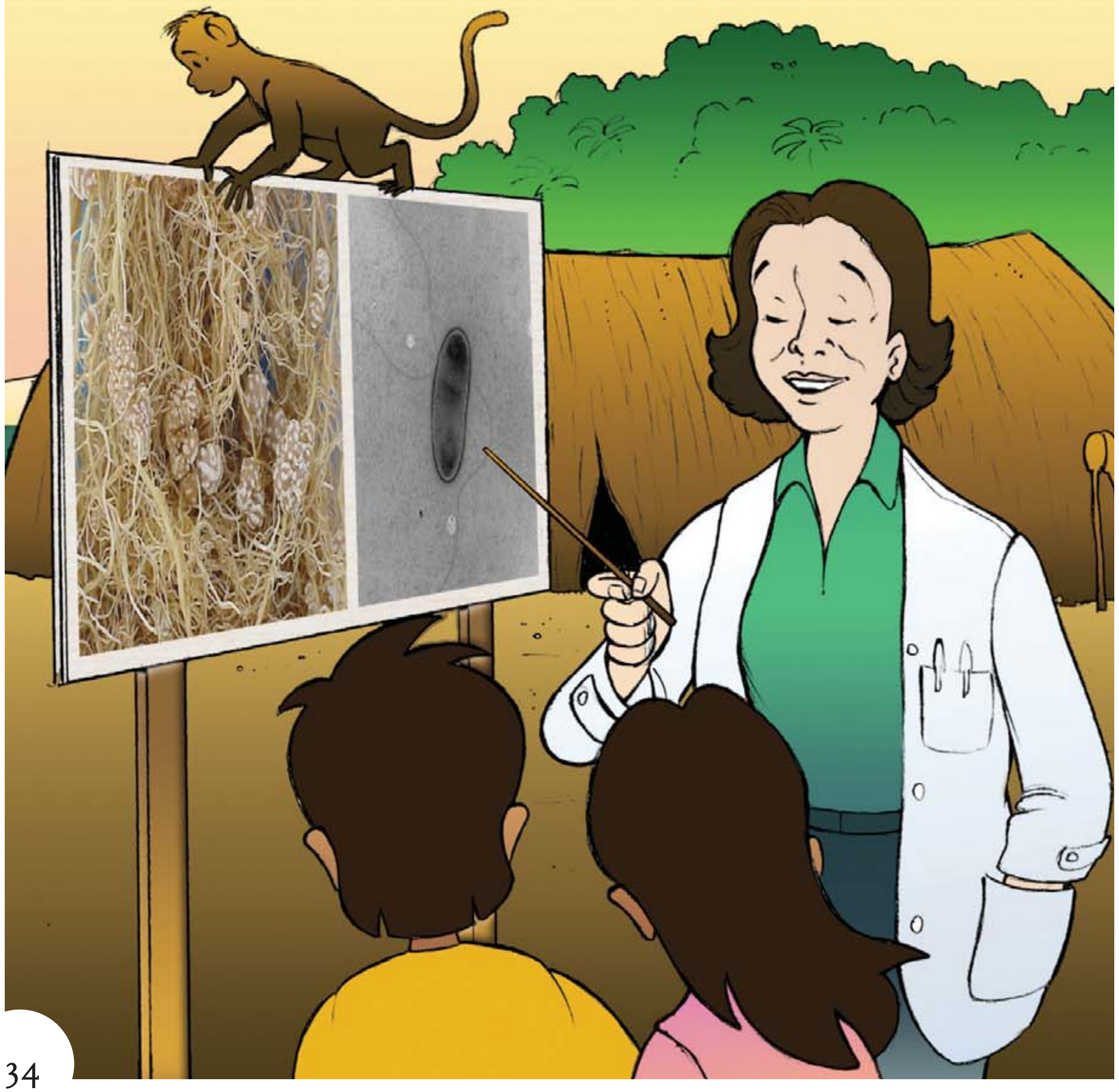
– No, mycologists study fungi. Fungi are very important, because they transform plant wastes, such as leaves, trunks, and other organic materials, such as dead animals, into humus and nutrients for the living plants. There are also some kinds of fungi that can infect other organisms. We call them antagonists. They can be used as the nematodes we have talked about to control pests caused by insects and diseases caused by other fungi.



– Other microscopic fungi ensure the support of plants – added another mycologist –, as they help the roots fetch nutrients out of their reach. They also help fetch water and protect the roots from other organisms that cause diseases. We call them mycorrhizal fungi because they live close to the roots of almost all plants. Fungus hyphae, hair-like threads, reach out from the roots. When we examine these roots under the microscope, besides the hyphae, we also see the fungus vesicles. The fungus spores, which look like and have the same function as plant seeds, sprout and produce new hyphae.



– There are other even smaller organisms that do things that no others do. For example, we study the bacteria that turn the nitrogen from the atmosphere into a form that the plants can use – said the coordinator, who also was a microbiologist.
– Many of these bacteria live in small balls on the roots of leguminous plants like ingá, cowpea, pod tree, and many others. By the way, this family has the largest species diversity in the Amazon – said the scientist – Most of them can have these little beads, which we call nodules. In Brazil, these bacteria already substitute nitrogen fertilizers, such as urea, in soybean fertilization, saving billions of dollars.



– As all of these organisms are very important, we need to guarantee that the action of human beings in nature does not threaten them. Also, we can use the good things they do to help us produce food without harming the environment. When we produce cassava, we need to cut and burn the bushes, overturn the soil, hoe, and do a lot of other things that may harm some or even all of them. As a result, we also eliminate the plants that serve as food for several organisms, which in turn are food for others. Do you remember the food web?

– This is the objective of the project – she explains. – Despite the risk of altering biodiversity, we need to produce food, right? This project, then, will try to answer what the form of food production is that harms nature the least and that takes advantage of the free work the soil organisms do for us. We also want to find out which organisms can help us produce more land-use systems. We call this 'ecosystem services'. The different ways of production are called 'systems of soil use', such as the forest, old *capoeira*, new *capoeira*, home gardens, the crop patch cultivated land, and the pasture. We know that the forest is the best preserved system and the one that has the largest biodiversity. The fewer species in an area, the less preserved it will be, like the pastures. Other systems are at a halfway point.

– So our crop patches and our home gardens are better than the pastures, but worse than the forest? – the little indian asked.

– It all depends on how we use the soil to cultivate plants. What we have observed here is that to leave the soil with the *capoeira* after the crop patches and the home gardens are gone increases the biodiversity. But it is different from other places in the Amazon. Large forest areas are preserved and help to preserve the biodiversity. After the burning, the organisms can return to these areas from the preserved forest areas. Does the way of planting here have different consequences from the soybean and maize plantations in the south of Brazil? Does the way we plant here preserve the soil biodiversity better than the way they do it in the South? To answer these questions, we count the number of species of organisms in the soil, determine their types, the number of individuals of each one in all the systems of soil use, and then we compare them. Of course, we also identify the plant species and the characteristics of the soils, which are related to it all.

– Gosh!! It is really important to know about biodiversity. The soil organisms are true super heroes!

– They truly are, Curumim. Now, the ones you watch on television doing amazing things are make believe. That is all special effects. In nature, the activities of the organisms are real and they help the plants, the ecosystems, such as the forest, and us, the human beings, to exist. This is why we have to help preserve them and let them keep working.

Curumim, Cunhantã, and the other kids asked all at the same time:

– Can we also help the biodiversity??

– Of course, you can. You can learn more about it, as you have done today. This is the first step. Who knows there are future scientists among you who will help to do that? The next steps are to preserve the biodiversity, as you already do here to some extent, and to use it to our benefit, but always respecting nature.

The kids got up all excited and said:

– We're going to get started right away.

Mother earth and father sky smiled in their own way, very happily.

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Glossary, notes, and photos

Page 13 | Photo of the air nitrogen-fixing bacterium *Azospirillum lipoferum*, which measures 0.6 micrometers in diameter. It occurs mainly on the roots of grasses and palm trees.

Page 16 | Image of the Landsat 7 satellite.

Page 18 | Photos of Cambisol profile from dry ground area of the Guanabara II community, Benjamin Constant Municipality.

Pages 22 and 23 | Photos, from left to right: Larva of fruit fly of genus *Anastrepha*; beetle species of genus *Canthon* with others of the same kind, they are called "crap-rollers" because they live in feces; earthworm of the species *Pontoscolex corethrurus*, it occurs widely in Brazil; termite soldier of genus *Nasuitermes*, and soldier and worker of species *Syntermes molestus;* ants of genus *Azteca*, which live in soil, mulch, and on trees (at fruit trees such as the guava tree it attacks the fruit flies and prevent them from laying their eggs on the fruit.)

They have been found in dry land areas studied in the project. 239 species of ants, 75 species of termites, and 53 species of crap-roller beetles. In the world, have been known 12,000 species of ants, 2,800 species of termites, 350,000 species of beetles, and 8,800 species of earthworms.

Page 25 | Sequence of photos of leaves illustrating the different stages of degradation of organic matter by the joint action of macro – and microscopic organisms from soil.

Photo of the crap-roller beetle from genus *Dichotomius* burying feces in the soil.

Page 27 | Photos, from left to right: *Pseudoscorpion* and chigger, both about 2 mm long.

Page 28 | Photos of papaya tree root attached by nematode from species *Meloidogyne mayaguensis*. Roots affected by the nematode with thickenings called "galls" that house the nematodes. The female of the *Meloidogyne* species measures 0.75 X 0.35 mm. It causes the galls in the roots of plants of several species. The nematode from the genus *Miconchus* (0.91 mm) is a predator of other nematodes in soil.

In Benjamin Constant, we found 82 genera of soil nematodes, including both parasites and predators. In the world, it has been known about 1,000 genera that live in several habitats, including the soil.

Page 29 | Photos, from left to right: Life cycle of fruit fly from species *Anastrepha obliqua*, shown laying eggs on mapati fruit and fruit with fly larvae. Larva of fruit fly in soil and after infestation by parasite nematode.

Page 31 | Photos, from left to right: Microscopic fungus from species *Fusarium solani*, which causes diseases in tomatoes, pepper, and in other cultured species from the *Solanaceae* family; macroscopic fungus from species of genera *Xylaria* and *Peziza*.

We have identified about 120 species of microscopic filamentous fungi from the *Ascomycota* phylum in the Benjamin Constant area. There are 69,000 species of microscopic and macroscopic fungi in the world.

Page 32 | Photos of macroscopic fungi decomposing vegetal wastes.

Page 33 | The photo shows spores of mycorrhizal fungi from species *Scutellospora heterogama* (brown), *Gigaspora gigantea* (yellow), and *Gigaspora margarita* (white), which have approximate diameters of 150, 250, and 300 micrometers.

In Benjamin Constant, we have identified 70 of the 200 species of phylum *Glomeromycota* known in the world. Most microscopic species cannot be cultured in laboratory (for example, the bread mould is a microscopic fungus that became visible after multiplying into billions of individuals. The bread served as a "culture medium". Arbuscular mycorrhizae are among the non-culturable fungus species. They grow close to tree roots (in symbiosis)

Page 34 | Photo of air nitrogen-fixing bacterium *Azorhizobiuim doebereninerae*, which measures 1 micrometer in diameter and lives in nodules (beads) in leguminous plant species and also in the soil outside the roots. The nodules in the beach bean roots are induced by bacteria of species from genus *Bradyrhizobium*.

The nodules are easy to distinguish from the nematode galls, as they easily detach from the roots, while the galls are impossible to detach. Seventy species of these bacteria are known in the world. In Benjamin Constant, we have found 30 species so far.

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