frontiers FOR YOUNG MINDS

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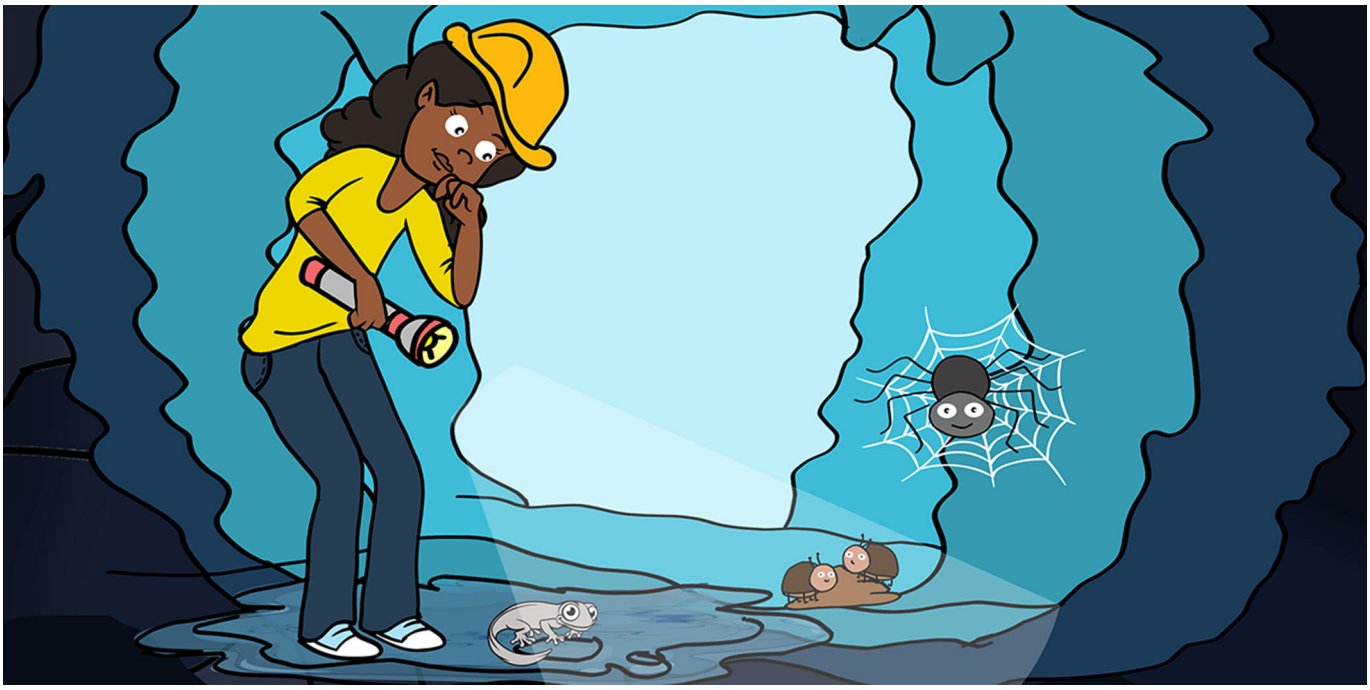

LIFE IN THE DARKNESS OF CAVES

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For humans, caves are dark, moist, and often dangerous places. However, caves are also home to many animals that live strange lives: blind beetles that eat bat poop and appreciate it; tiny spiders that spin webs to catch insects, also known as flying food; and white salamanders that swim in cave ponds without getting lost, at least not all the time. Most of these animals do not have eyes—why would you need eyes when you live in the dark? Instead, they have developed other special senses to "see" in the dark. These animals look nothing like the ones you know, and many of them are endangered because they can only live in caves. Mining, pollution, and climate change are threatening cave animals and all their weirdness. Anyone can study and help them, even you!

LET US START

For us clumsy humans, used to the sun and lots of space, entering a cave is an adventure. Caves are completely dark, constantly wet,

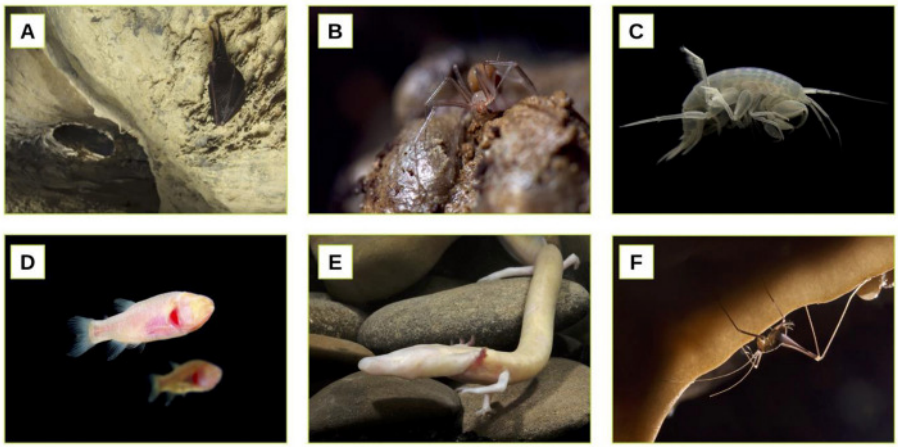

Figure 1

Figure 1

Examples of cave animals. **(A)** During the daytime, bats hang upside down from the roofs of caves. **(B)** A blind cave spider searching for prey. **(C)** A shrimp swims in the dark. **(D)** An eyeless fish from South America. **(E)** The olm, a white and eyeless salamander that lives in subterranean ponds and rivers in Europe. **(F)** A cave cricket uses its long antennae to feel its way around in the dark (Photograph credits: **(A)** Emanuele Biggi; **(B,F)** Francesco Tomasinelli; **(C,D)** Rodrigo Lopez Ferreira [1]; **(E)** Boris Krstinic [1]).

and they contain many obstacles. Still, we should not give up. Even if we only venture a few meters inside, we might encounter strange and fascinating animals (Figure 1). Some of these animals, like bats, sleep in caves during the day and then leave at night to search for food. Other animals, such as spiders, shrimps, fish, and salamanders, survive in caves their entire lives without ever coming out. Let us put on a helmet and some tough clothes, turn on the lamp, and follow their trails.

HOW DO ANIMALS SEE IN THE DARK?

You can use a lamp to see inside a cave, but what about cave animals?! Well, they do not need to see or use camouflage to hide from predators; eyes and fancy body colors are useless in the dark. Over millions of years, many cave animals have lost their eyes and become white or transparent. They have developed special senses to help them move around without banging their heads. These special characteristics are called **adaptations**. There are insects that use very long antennae to feel their way around, a bit like a blind person using a walking cane as a navigation aid. Many insects and spiders can also perceive tiny vibrations and air currents that tell them that food, or maybe a predator, is just around the corner. Bats fly in the dark using **echolocation**. Have you ever heard your echo when shouting in a large empty room? Bats use the returning sound to find out what is around them—is it the cave wall or a small moth? There are even tropical cavefish that produce an electric field that acts as a sort of echolocation in the water, allowing them to sense obstacles, food, and predators. As you see, cave animals are equipped with all sorts of superpowers.

ADAPTATION

Any characteristic that allows organisms to live under specific conditions. Examples are the ability of a bird to fly and the lack of eyes in cave animals.

ECHOLOCATION

An adaptation used by bats and other animals to navigate the environment using reflected sound.

Figure 2

Food sources in a cave. In this example, a spider is about to catch a fly that accidentally entered the cave. Some external detritus (leaves and small pieces of wood) is accumulating on the cave floor and will be decomposed by fungi and eaten by animals. A millepede is feasting on a pile of **guano**—the poo of bats (Image credit: Irene Frigo).

IS THERE FOOD IN CAVES?

Every animal either eats plants or eats animals that eat plants, which means that all animals depend on plants one way or another. But there is no sunlight in caves, so there are no plants. And if there are no plants, there is no food. So, what do cave animals eat? Most of the food in caves comes from outside. Examples of food sources include leaves and small pieces of wood that are transported into the cave by gravity, running water, and wind; flies and other insects that accidentally fall into caves; and moths that sleep during the day on cave walls. Carnivores, such as spiders and salamanders, hunt for prey that comes in from the outside, but they also eat other cave animals. There are even cave animals that eat bat **guano**, the poo of bats. Guano can be abundant in caves that house large bat colonies—there are poo piles as high as a house, and many animals love them (Figure 2).

GUANO

The poo of bats. Guano accumulating in caves is food for many animals.

As food in caves is often scarce, cave animals have developed adaptations to survive long periods of starvation. Some species can live for months without eating! It might be tempting to use this excuse next time you are called to dinner... but think again. To save energy, cave animals move very little and slow down their **metabolism**. It is a bit like if you were always sleeping and only woke up on Sundays to eat some soup. It would not be a very exciting life, would it?

METABOLISM

All the chemical reactions in the body that convert food into energy.

THE SCIENTIFIC STUDY OF CAVE LIFE

Humans have been using caves for millennia. In prehistoric times, we used caves as shelters. Some cave walls still preserve the drawings made by early humans. These cave paintings tell us about how ancient people lived [2]. In recent times, humans started to explore caves for other purposes, and soon cave animals attracted the interest of scientists. The scientific study of cave life is known as **biospeleology.** We can answer many scientific questions by studying cave animals,

BIOSPELEOLOGY

The study of subterranean life. The scientists who study subterranean life are called biospeleologists.

Figure 3

Mining, pollution, and other human activities are all threatening cave animals. In this example, some toxic waste dumped into a cave threatens the animals that live there (Image credit: Irene Frigo).

particularly about how species behave and evolve [3]. For example, cave species that are now blind have descended from ancestors that were able to see. This adaptation to a lightless environment has occurred in cave salamanders, fish, insects, and spiders. The process of different species adapting in similar ways is known as **convergent evolution**. Scientists can study how these unrelated animals became blind, or how long it took them to change.

CONVERGENT EVOLUTION

The process of unrelated species evolving similar body features or other adaptations.

The adaptations of cave animals have inspired new technologies and other useful tools. Some of their adaptations have even helped us to invent new cures for human diseases. For example, cave animals sleep in a different way than animals on the surface do; therefore, they can help us develop treatments for people suffering from sleep disorders [4]. Similarly, by studying how these animals have lost their eyes, we can learn how to cure blindness in humans [5]. Since many cave animals live longer than surface animals, we can even study them to better understand the process of aging, and one day find ways to extend our own lives [6].

CAVES NEED PROTECTION

You have probably heard that humans are destroying nature in many areas of the world. We are polluting the oceans, cutting down forests, hunting wildlife, and changing the global climate [7, 8]. Most of these actions also affect cave animals. The pesticides and insecticides that we use in agriculture drip down into caves with the rain, polluting the groundwater and harming the many animals that live there. Some humans dump garbage, plastic, or even toxic waste underground (Figure 3). Moreover, when we extract rock in mining activities, we often destroy caves that are home to unique species. Maybe some of these species will disappear forever, just like the dinosaurs, but this time it will be our fault.

Conservation biologists, the scientists who study how to protect nature, are working tirelessly to save the world's ecosystems and the species that live in them. There is a famous saying among conservation biologists: "What is out of sight is also out of mind." Given that caves lie below our feet, they are often forgotten in plans to protect nature. Imagine if only *some* of your friends got birthday presents and the others missed out. Not fair, right? Yet, this happens all the time with cave animals. However, it is critical to preserve cave animals and their homes [1]. First, caves and other **subterranean habitats** hold freshwater that we often drink. Second, surface habitats and subterranean habitats depend on each other. For example, many cave bats come out at night to eat flying insects. If there were no bats, these insects would get too numerous and eat the crops that we rely on for food. Third, as we have already mentioned, the study of cave animals can be directly useful to humans. If we lose these species, we also lose the chance to make many scientific discoveries in the future.

SUBTERRANEAN HABITATS

The labyrinth of fissures below the ground where some animals can live. When these fissures are large enough for humans to enter, they are called caves.

However, we should not despair because all of us can help protect caves and cave animals. Learn about the caves in your region. Maybe they are small or maybe they are large, but the more people know about them the better. Learn about their animals and whether they are endangered. It is possible that many of these animals live only in your region and nowhere else in the world. Did you know that anyone can help find new animals and write about them? Many speleology associations explore caves and discover their animals. Maybe you can join them for some of the easier cave explorations and help these organizations protect the caves. Ask your family and friends to join you. Even if they are afraid of the dark and weird animals, they might be interested in hearing that some caves you want to visit contain the strangest creatures in the world.

THE END OF THE JOURNEY

Our journey underground ends here: we can crawl out from the cave and enjoy the sunlight again. Let us reflect on what we have learned. We have discovered animals that can survive in the tough conditions of caves, where humans cannot. These animals have developed adaptations that help them feel their way around in the dark and survive for long periods without eating. Very different animal species, such as fish and spiders, have evolved similar adaptations through the process of convergent evolution. Through studying unusual cave animals, scientists have learned many important things. Cave animals have also helped us to develop useful technologies and medicines! Unfortunately, human activities often threaten caves and their animals. But you can help! You can learn about caves in your own region and alert your family and friends to what is happening. Keep in mind that, below our feet, there is a mysterious world full of wonders that are still largely unexplored.

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We dedicate this work to Diogo, a young explorer of the underground! Stefano and Irene also wish to dedicate this work to their niece Matilde, hoping that in a few years she will be able to join us in some adventures. Thanks to Igor, our young reviewer, and Nathan M. Good, our editor, for very useful suggestions.

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YOUNG REVIEWER

IGOR, AGE: 11

I live in Brazil, on the beach. I like Lego, travel, surf, and love to read. In the future, I will become an architect and I love science. In my house I have a huge yard with a tree house.

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I am a researcher in subterranean biology, which means that I am often exploring caves to search for spiders and other animals. In my free time, I love to play chess, climb, and cook. *stefano.mammola@helsinki.fi; stefano.mammola@cnr.it

IRENE FRIGO

I am an illustrator. My job is to make drawings and pictures for children's stories and school books, and even for scientific articles like this one! I really like to read, travel, walk in nature, and listen to caving stories—even though I am scared of the dark!

PEDRO CARDOSO

I work as the father of Diogo, a 10-year-old kid who already goes to caves and helps me find new animals. I spend my free time at the Finnish Museum of Natural History in Helsinki, Finland, where I take care of our scientific collections. I also like to run, bike, camp, and do all sorts of things in nature.