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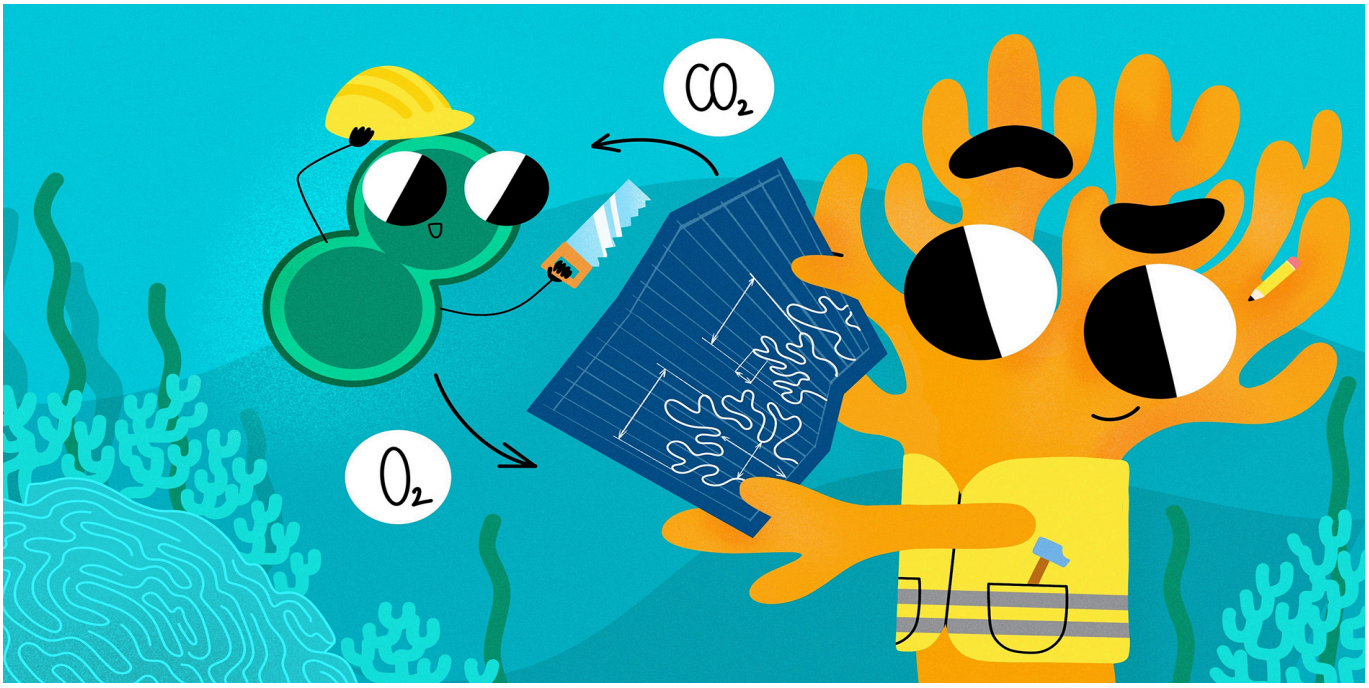

CORAL REEFS: A STORY OF TWO LONGTIME FRIENDS

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YOUNG REVIEWERS:


CHENGKAI
AGE: 11


EMILY
AGE: 12


LUQI
AGE: 15


SUBHANG
AGE: 8

Corals and tiny algae act as a team of engineers to form the building blocks needed to create the amazing coral reef ecosystem, which supports much of the marine life in the tropical oceans. These incredible ecosystems can extend for thousands of kilometers, like the Great Barrier Reef of Australia. Coral reefs would not exist without the help of the microscopic algae that associate with the coral and provide it with important nutrients for its survival. This article features the collaboration of amazing corals and their microalgae partners. You will learn about the processes that support the construction of coral reefs, their abilities to resist the threats that currently affect them (climate change, contamination), and the actions that can be taken to keep them safe and maintain the services that these ecosystems provide to other marine life.

A STRONG, LONG-LASTING FRIENDSHIP: CORALS AND MICROALGAE

Scientists estimate that corals have existed on Earth for around 240 million years. They first showed up in a vast, warm sea called Tethys, in between two supercontinents called Laurasia and Gondwana. We know this because it is when their **fossils** first appeared [1]. While corals can only grow underwater, you can find coral fossils on land, as fossil reefs. These days, there are two main groups of corals: hard corals and soft corals. Hard corals have a solid **exoskeleton**, while soft corals do not. For corals to survive, they need the help of many species, from fish to tiny **microalgae**. In this article, we will tell the story of a hard coral named Sclero (Figure 1A) and its friend Symbia (Figure 1B), a tiny but powerful microalga.

FOSSILS

The remains or impression of an organism preserved in petrified form or as a mold or cast in rock for thousands or millions of years, giving evidence of life on Earth in the past.

EXOSKELETON

An external structure made of calcium carbonate that protects the bodies of some animals, like corals.

MICROALGAE

Tiny single-celled organisms capable of photosynthesis.

ECOSYSTEM ENGINEERS

Any species that creates, maintains, or modifies habitat.

SYMBIOSIS

A longtime relationship between two or more organisms from different species that is usually beneficial.

PHOTOSYNTHESIS

Transformation of light and CO_2 into compounds that can be stored and used as food, mostly sugars.

THE STORY OF SCLERO AND SYMBIA

Sclero is a very cheerful Caribbean hard coral with a spectacular tan. He is part of a large group of **ecosystem engineers** called Scleractinian corals (the hard corals), that slowly build the coral reef, day after day. A coral reef is a large, rocky barrier that supports one of the richest seascapes on the planet in terms of the number of the species living there (Figure 1C). Corals like Sclero protect the coasts and humans from the strong winds of storms and hurricanes, acting as a barrier. At the same time, corals have an important role in the functioning of ecosystems that do not have enough food in them, like the Caribbean Sea.

The ability of Sclero to build the reef only happens because of his great friend Symbia, a microalga. Sclero and Symbia have a very tight relationship and because of that, coral reefs are full of life. Sclero and Symbia's relationship is called **symbiosis**, which is helpful to both of them and vital to their existence in ocean environments with little food [2]. However, this friendship is threatened by climate change and coral diseases.

THE BEGINNING OF A FRIENDSHIP

The ancestors of Sclero and Symbia met ~300 million years ago in the calm and pristine Tethys Sea. Some scientists say that Sclero comes from corals that did not form an exoskeleton made of calcium carbonate, like current corals do. Other scientists say the opposite, they say that Sclero's ancestors always had calcium carbonate armor. Symbia apparently comes from the first microalgae symbionts that ever existed on Earth [3].

Symbia has an extraordinary superpower. Like plants on land, she can perform **photosynthesis** to convert sunlight into food! To do

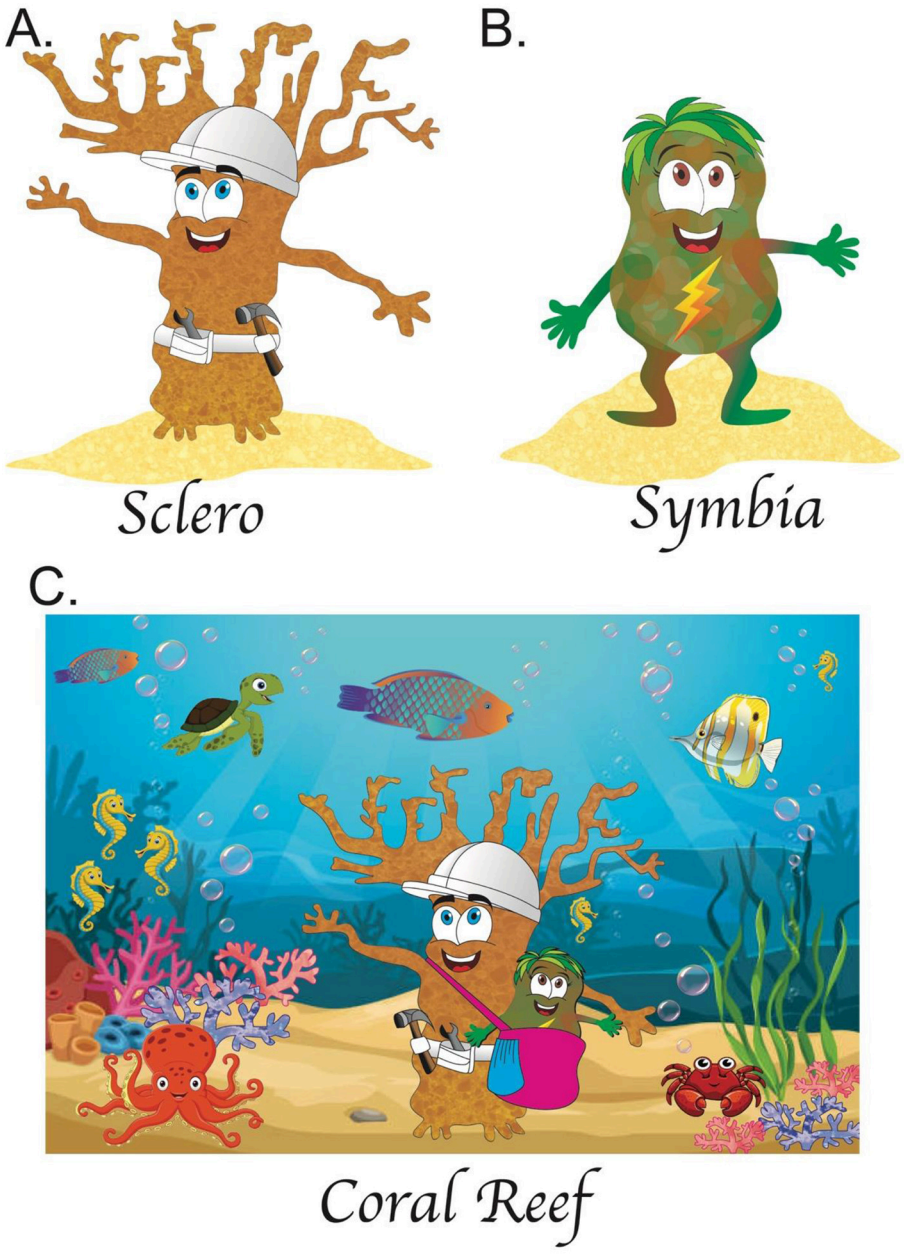

Figure 1

(A) Sclero is an elk-horn coral. **(B)** Symbia is a tiny microalga, thinner than a human hair. **(C)** Sclero and Symbia live in a coral reef that is full of life with thousands of species including fishes, lobsters, turtles, sponges, and crabs.

CHLOROPLASTS

Compartments within plant cells that are responsible for photosynthesis.

this, Symbia uses **chloroplasts** to harvest light and produce food and energy for herself and to share with Sclero. Chloroplasts trap sunlight and use it to transform a gas in seawater called carbon dioxide (CO_2) into sugars. The sugars nourish Sclero, helping him to grow and form his exoskeleton [4]. Sclero also uses nutrients to produce a mucus layer on his skin, to separate him from the ocean environment. In the mucus, Sclero hosts a community of bacteria and other microorganisms that also help maintain his health by guarding against bad bacteria. This friendship between Sclero and Symbia has allowed coral reefs to exist for thousands of years.

Sclero also builds a home for other species, like fish, anemones, crabs, clams, starfish, squid, sponges, lobsters, seahorses, and sea turtles, forming a beautiful seascape. Just as Sclero and Symbia are friends forever, Symbia also has a very good friendship (symbiosis) with other animals, like sponges, clams, snails, anemones, and jellyfishes.

SCLERO AND SYMBIA HELP EACH OTHER

Corals get nutrients by eating tiny, abundant sea animals called **zooplankton**. But corals also get their food from Symbia. As these two friends live in symbiosis, after Sclero digests his food, he gives his waste to Symbia, which she uses to create more delicious food for herself and Sclero in her solar stove (the chloroplast) [5]. The food produced by Symbia is charged with energy for corals to grow strong and healthy, and Symbia has a healthy home to live in: Sclero is Symbia's home.

ZOOPLANKTON

Small aquatic animals (<2 mm long) that include crustaceans, rotifers, fish larvae, and many other organisms. They are food to many marine animals, such as fish, mussels, or whales.

As you now know, Sclero and Symbia exchange and share nutrients, while recycling their waste products (Figure 2) [2]. This is amazing, is it not? For this reason, recycling is a habit that humans should learn from symbiotic relationships like that of corals and microalgae, so that we do not fill the planet with our waste.

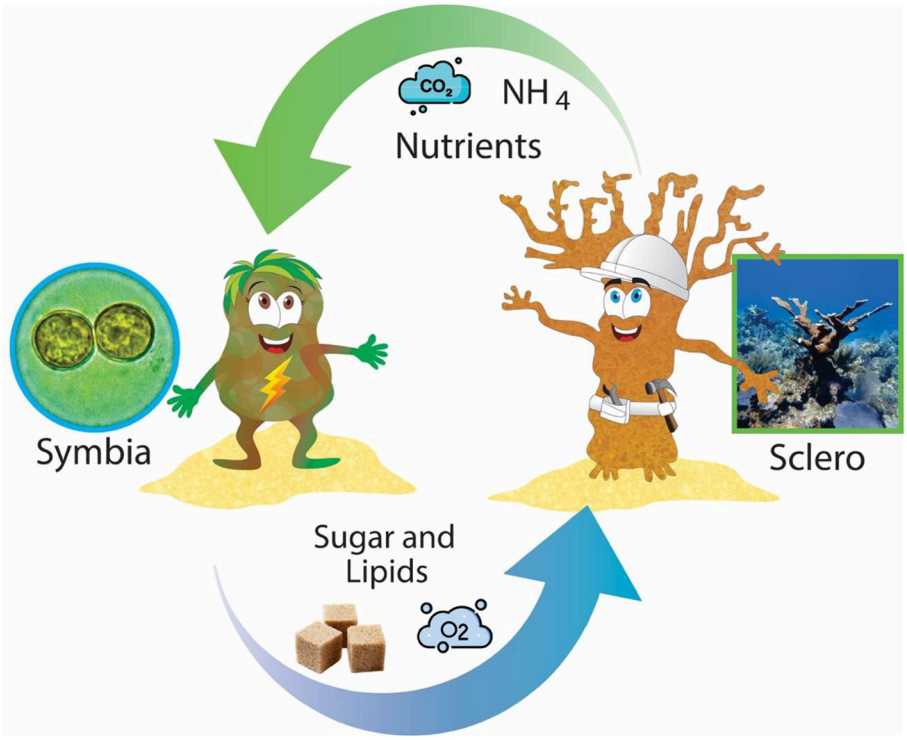

Figure 2

The nutrients that Symbia and Sclero exchange. The nutrients that exist dissolved in ocean water, like nitrogen in the form of NH_{4+} (to make proteins), and carbon in the form of CO_2 (to make sugars), are used by Symbia during photosynthesis to grow strong and healthy. Symbia then transfers foods containing carbohydrates, lipids, and some proteins to Sclero, so he can grow, too. Symbia is only 8 μm long, while Sclero can grow up to 6 m high and 13 m across (photo credits: Sergio Guendulain Garcia).

LONGTIME FRIENDS

Recycling nutrients has been the key for the success for Sclero, Symbia, and their ancestors, and it has kept them alive for millions of years. However, not everything has always been dreamy. They have had to overcome great losses, including **mass extinctions** that dramatically reduced the world's coral communities. Fortunately, corals have resisted and not vanished [1].

MASS EXTINCTIONS

The disappearance of half of the plant and animal species due to catastrophic events that happened 1,000's or several million years ago.

Corals nearly went extinct during a global climate change 65 million years ago. This was caused by a massive meteorite impact, after which dinosaurs disappeared. During that time, seawater became so acidic that it dissolved the exoskeletons of corals. Even worse, the amount of nutrients in the sea was so great that it caused an imbalance in symbiosis, and corals almost vanished. Despite these catastrophic events, the ancestors of Sclero and Symbia survived and gave rise to the species of corals that exist today [1]. The dramatic climate change events that we are now seeing on our planet may push this friendship, once again, to a breakup.

CLIMATE CHANGE IS BREAKING THE FRIENDSHIP BETWEEN SCLERO AND SYMBIA

The close friendship between Sclero and Symbia is facing one of the greatest challenges in millions of years. Climate change is causing the oceans to become warmer and more acidic [6]. Warmer water causes microalgae to abandon the corals they protect and feed, while the more acidic ocean water can also dissolve the corals' exoskeleton. In the Great Barrier Reef off Australia, scientists have been witnessing frequent **coral bleaching**. Huge areas of corals are dying and turning white.

CORAL BLEACHING

The lost color of coral due to the expulsion of their symbionts.

WHAT CAN WE DO TO PROTECT CORAL REEFS?

The temperature of the Earth and the oceans has been increasing due to human activities that produce tons of gasses such as CO_2 and methane. CO_2 emissions also make the oceans more acidic, which damages coral reefs [6]. More acidic ocean waters prevent coral growth, and warmer waters cause coral bleaching. So, do you know how you can start protecting corals from your home? Whether you live near the coast or far away, you can help keep coral reefs healthy. Humans must use fewer gasoline-powered vehicles, and properly separate and recycle their trash, without throwing it into rivers, lagoons, or seas. To help reduce the global effects of climate change, you could bike, walk, or volunteer to clean up beaches. And if you would like to explore coral reefs through diving or snorkeling, you must do so safely and responsibly, without stepping on or touching the corals. Also, use reef-friendly sun protection, to avoid harming

or even killing corals. Share this information with your community, family, and friends to help everyone protect marine biodiversity. It takes more than personal action to save corals: governments must invest more in water treatment plants and create policies that regulate the improper use of natural resources. Only then will Symbia, Sclero, and their other coral friends stay together for many more years in the seas of planet Earth.

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as a potential conflict of interest.

YOUNG REVIEWERS

CHENGKAI, AGE: 11

My name is Chengkai, I am the only child in my family, I am 5th grade. I like to look at maps and I like to draw them. I attend live math meetings. I speak Chinese, English, and a bit of Arabic. I have two bikes, but no pets. I play violin, basketball, and badminton. I learned swimming last summer and I am the only one who can swim in my family. I am proud of myself.

EMILY, AGE: 12

Hi, my name is Emily, and I was born in Hong Kong. I am currently 12 years old and I was born on August 19. I love playing sports and reading different kinds of books. My favorite animals are rabbits because I find them very cute, gentle, and furry. I look forward in knowing all of you soon!

LUQI, AGE: 15

My name is Luqi, and I am currently 15 years old. I like reading scientific articles and playing badminton. Besides, I like watching movies and listening to pop music. I grew up in a multi-cultured environment.

SUBHANG, AGE: 8

Subhang's fascination lies in the world of numbers and outer space. He enjoys learning about the earth, its diverse ecosystems, and the creatures that inhabit it. Maths is his favorite subject. He loves spending time with his LEGO constructions and perfecting his violin skills.

AUTHORS

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My name is Luis Parmenio Suescún Bolívar. I am a biologist and diver from Colombia. I studied at the University of Pamplona in Colombia and got my masters and Ph.D. in marine biology at the National Autonomous University of Mexico. I enjoy learning about the physiology, biochemistry, and communication processes involved in the exchange of nutrients between corals and their symbionts; the possible effects of environmental change on these processes; and how the loss of friendship between

corals and microalgae is associated with the failure in the recycling of nutrients. *lsuescunb@unicartagena.edu.co

PATRICIA E. THOMÉ

I am Patricia E. Thomé. I worked with corals during my master's studies, and their beauty and importance captured my immediate interest. I have a Ph.D. in biology from UCSB. I have worked in Mexico as a professor since 1996, at the Institute of Marine Sciences-UNAM. My interest in corals has been mainly in the symbiosis they maintain with microscopic algae. I study how various types of symbionts benefit corals and other symbiotic animals, like anemones and medusas. I also work with the immune system of corals, because I am concerned by the high incidence of coral diseases.

NATALIA CARABANTES

I am Natalia Carabantes. I am a biologist passionate about studying marine life, from microorganisms to marine organisms, and how to protect them. I have a Ph.D. in marine biology from UNAM, Mexico. Currently, I am a postdoctoral researcher at the Center for Scientific Research, CICESE, Mexico. I study the marine biodiversity that uses the coral reef as its home. We sample seawater to obtain DNA (environmental eDNA) of species in various marine ecosystems, to study how climate change and human activities affect their populations. I like proposing plans to preserve marine global biodiversity.