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MANGROVES: "SUPERHERO" ECOSYSTEMS

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Mangroves are woody trees that can live on the land or in the sea, and they are found in tropical and subtropical coastal regions. Because mangroves live along the land-ocean boundary, they are unique plants that provide several benefits to nature and humans. For example, mangroves provide refuge and food for organisms, hurricane protection, and water filtration; mangroves also promote the release of oxygen into the atmosphere and the uptake and trapping of carbon dioxide, which helps to fight against climate change. To understand mangrove ecosystems, it is important to consider the role of the microorganisms that live there. Although mangrove ecosystems are important, they face several threats, including deforestation and coastal development. Therefore, understanding and communicating about the benefits of mangrove ecosystems is essential to conserving the goods and services they provide.

WHAT ARE MANGROVES?

Mangroves are shrubs or trees that form forests or small patches along tropical and subtropical shorelines (Figure 1). The word "mangrove" comes from the **Guaraní** word *mangal* which means "crooked tree." [Guaraní is the language of the Guarani, one of the main divisions of the Tupi-Guarani language family and a national language of Paraguay. The plural of mangrove ("mangroves") refers to the population or community composed of several individual mangroves of the same species or different species]. Mangroves are plants that live at the boundary between the land and the ocean [1]. For example, while most plants have roots that are entirely underground, mangroves have roots that are partially above ground, called **aerial roots**. Aerial roots serve as "snorkels" for breathing when the soil is flooded or has little oxygen. In addition, mangroves have **salt glandules** that allow them to remove sea salt through the pores of the leaves (Figure 2), which is essential for living in seawater. Mangroves provide multiple benefits or **ecosystem services** to the marine and coastal species around them. Mangroves offer refuge for marine organisms, nursery areas for fish, feeding zones for land and water animals, and hurricane protection. Furthermore, mangroves efficiently filter out water pollutants from coastal waters.

GUARANÍ

The language of the Guarani, one of the main divisions of the Tupi-Guarani language family and a national language of Paraguay.

AERIAL ROOTS

Anatomical structure of mangroves for breathing/gas exchange.

SALT GLANDULES

Set of cells that have the function of excreting salt.

ECOSYSTEM SERVICES

Good or service provided by ecosystems to humans or other organisms.

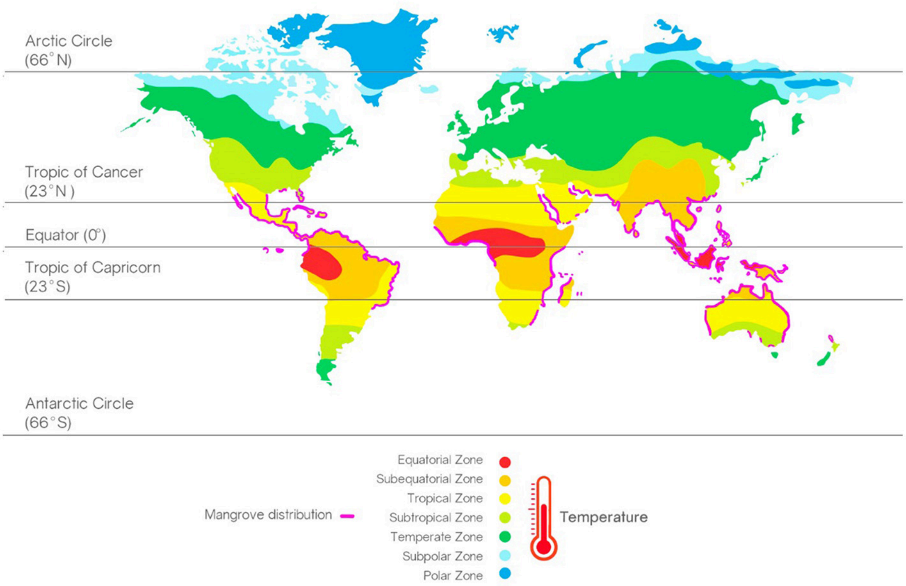

Figure 1

Figure 1

Mangroves (pink line) can be found along the coasts throughout the tropical and subtropical regions of the world.

THE IMPORTANCE OF THE MANGROVES: BIG OR SMALL

When we think about forests on land, we easily picture big pines, grass, bears, and squirrels. Compared to coral reefs, for example, mangrove ecosystems have low biodiversity, but they still harbor a wide diversity of life, such as bacteria, birds, fish, turtles, and crustaceans like fiddler crabs. Some of these species have economic (shrimps, snapper,

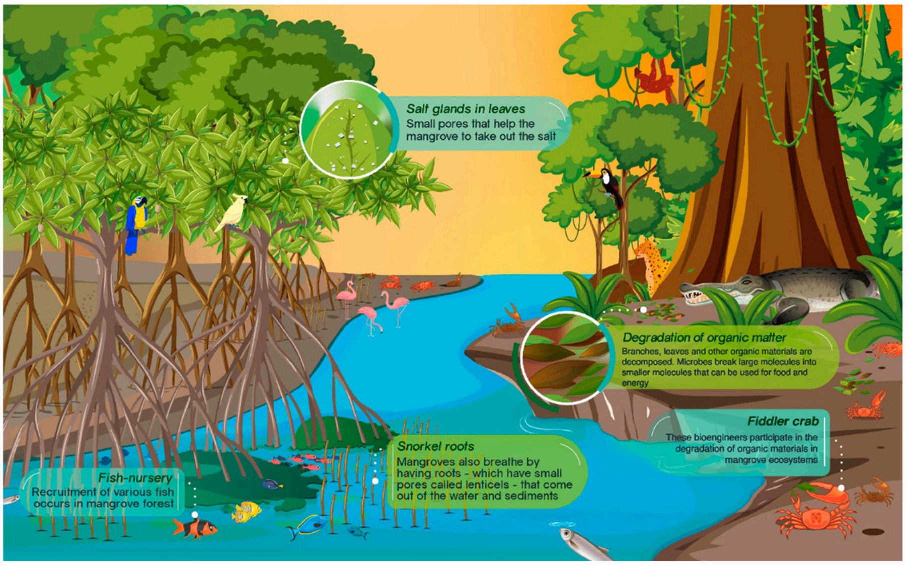

Figure 2

Figure 2

Mangrove forests are unique ecosystems that bridge the land and the salt water of the ocean and are home to many species.

crabs, and others) and social importance (for example, biodiversity as cultural importance).

Mangroves occupy only 0.5% of the world's tropical and subtropical coastal areas, but they are the most significant contributors of terrestrial carbon (the primary element of life and the most significant element on the planet) that is sent to the ocean [1]. This is important because the carbon (dissolved or particulate organic) is transformed into food for organisms such as phytoplankton or enters as part of the coastal carbon budget of the oceans or ecosystems adjacent to mangroves. Like other plants, mangroves build roots, leaves, and stems using sunlight, water, and carbon dioxide (CO_2), which is a greenhouse gas (Figure 3). However, mangroves remove CO_2 from the atmosphere about four times more efficiently than other plants [1]. Thus, mangroves are essential to reducing CO_2 in the atmosphere because they can trap it in the soil around them for extended periods of time. Mangroves also help to reduce erosion and protect the coasts against storm water and extreme weather events, like hurricanes. Because of the mangroves' abilities, the International Union for Conservation of Nature considers mangrove ecosystems to be superheroes in slowing down climate change and reducing its negative effects on the planet.

Compared with forests or jungles, mangrove ecosystems can store a lot of **biomass**. In coastal and ocean ecosystems, ~40% of the biomass is from carbon, which makes up leaves, wood, mud, roots, leaf litter, and organisms [1].

Mangrove ecosystems have a high biomass due to their high **productivity** rate. Productivity is the speed at which carbon is

BIOMASS

The organic matter that comes from biological process (like the growth of plants) and that is usable by other organisms as an energy source.

PRODUCTIVITY

The speed at which carbon is accumulated to generate biomass in a plant.

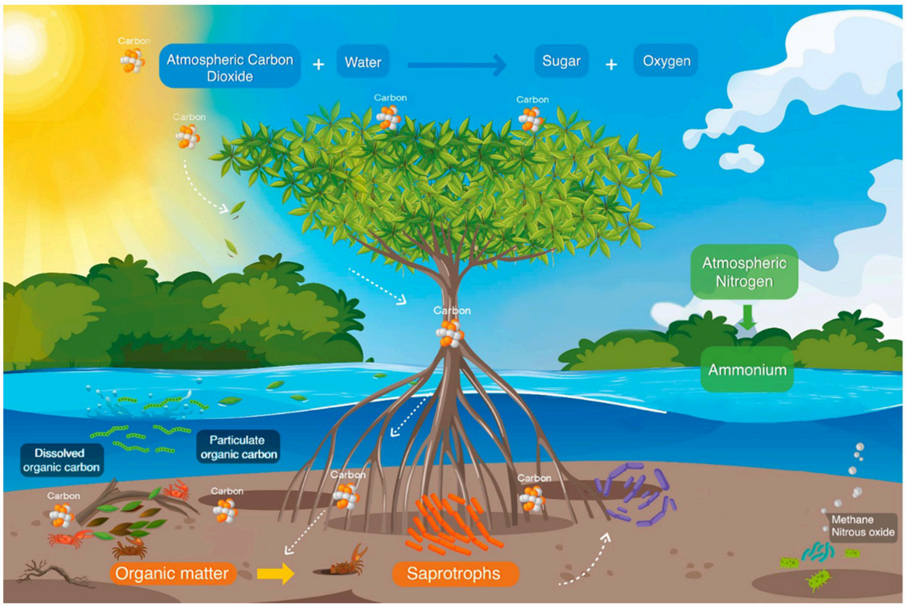

Figure 3

Figure 3

Photosynthesis (blue), nitrogen fixation (green), and degradation of organic materials by saprotrophs (orange) all occur in mangrove ecosystems. Carbon moves from the atmosphere into the mangroves and then into other organisms in the ecosystem, which is shown by the white arrows.

accumulated to maintain a plant and generate biomass. Biomass and productivity are essential measures of how carbon flows through an ecosystem, from the atmosphere to the plant [1]. Additionally, the carbon in organic matter can flow through food webs in the mangrove ecosystem. This flow depends on decomposition. Microorganisms including bacteria and fungi decompose other organisms and take up their carbon. The carbon subsequently proceeds to fish, crustaceans like crabs and shrimp, birds, jaguars, and even humans [2].

The organisms living in mangrove ecosystems can be full-time residents or migratory animals. Migratory animals arrive in the mangroves during a specific stage of their life cycle. For example, the arid mangrove in the Gulf of California is an important North American migratory bird corridor. Although several of these mangroves are small patches, they provide shelter and food for diverse bird species. These small, arid mangroves have the same capacity to remove and trap high amounts of CO_2 from the atmosphere as those mangroves located in tropical regions [3]. Big or small, all mangrove patches are equally important because they provide unique ecosystem services.

MICROORGANISMS: THE SMALLEST CREATURES LIVING BETWEEN MANGROVES

In addition to the animals and plants living in mangrove forests, these ecosystems contain a diverse microbial world. Microorganisms are tiny organisms that are impossible to observe with our eyes. Microorganisms are everywhere, and they are essential to the functioning of the mangrove ecosystem [2]. They are present in the soil and water and help to make certain elements, such as carbon, nitrogen, and phosphorous, available to animals or plants as nutrients. These elements are often contained in big molecules that animals and plants cannot use, and microorganisms transform these molecules into accessible forms. For example, Earth's atmosphere is composed of 78% nitrogen, but most organisms on Earth cannot consume atmospheric nitrogen—only microbes can acquire it and convert it into a form (ammonium) that can be used by other organisms [2]. This process is known as **nitrogen fixation**, and it is performed by bacteria, photosynthetic bacteria called cyanobacteria, and related microorganisms called archaea (Figure 3). Nitrogen fixation helps mangroves to grow and allows them to support a broad diversity of other species.

NITROGEN FIXATION

A process carried out by microorganisms that moves nitrogen from the atmosphere to the soil or water and makes it available to other organisms.

Microorganisms in mangroves also help to break down and recycle organic materials, like leaves and the remains of organisms. These organic materials accumulate in the soil and form what is called **detritus**. Insects, crabs, and worms are detritivores, they slowly consume detritus (Figure 2). Microorganisms in the detritus, known as **saprotrophs**, degrade the smallest particles, breaking them down into their most basic compounds so they can be recycled (Figure 3) [2]. These microorganisms are essential in mangroves because they contribute to the flow of energy from the smallest to the largest organisms [2]. Finally, microorganisms also produce and consume atmospheric gases including methane, CO_2, and nitrous oxide. These gases help keep the atmosphere warmer by trapping the sun's heat. Consequently, the atmosphere makes Earth a temperate place to live.

DETRITUS

Decomposing organic matter of animal or vegetable origin.

SAPROTROPHS

Organisms that break down organic materials from dead/decaying organisms so that other organisms can use them.

MANAGEMENT AND CONSERVATION

Mangrove forests are among the most important coastal ecosystems in the tropics and subtropics. These ecosystems sustain an immense diversity of life, support local fisheries, and have economic benefits for nearby regions. Unfortunately, increased human activities within mangrove forests threaten these ecosystems. Urban development, pollution, overexploited fisheries, agriculture, aquaculture, and deforestation all contribute to the loss of mangroves. It is estimated that 35% of the world's mangrove forest area was lost during the 1980 and 1990's, and this loss will continue in the upcoming years if we do not act now. Currently, the biggest threat to mangroves is not deforestation but rather degradation of mangrove ecosystems; that is, the loss or modification of the ecosystem services provided by these wetlands.

Human population growth in coastal zones is inevitable, and society and industry must manage mangrove forests with more care. Many people are not even aware of the ecological importance of mangroves and the dangers that threaten them. Thus, public information and educational campaigns must be promoted to raise awareness of this issue. Hopefully, once more people are aware of the critical ecosystem services provided by these unique, irreplaceable wetlands, more steps will be taken to protect them. Saving the mangroves will have widespread benefits for our entire planet, perhaps even helping to slow climate change.

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YOUNG REVIEWERS

GEFFEN ACADEMY, AGES: 12–13

The seventh graders at Geffen Academy at UCLA are innovative and creative thinkers. They are creators who explore scientific themes in an experiential way and develop skills and competencies on their way to become expert learners.

YU, AGE: 14

Yu is a young motivated boy who likes playing in the green landscape and mountainous forest. Hobbies are swimming, playing with animals including beneficial insects, pets, and flowers. I am the big fun and voice of agro-ecology, biodiversity conservation, and voice of climate change mitigation and adaptation actions from childhood. I am also an active member of the Climate Environmental Protection Club. I like to pick up plastic waste and put them in their reserved place.

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I am a marine biologist specializing in microbial ecology. I am very interested in geomicrobiology, astrobiology, and biotechnology. I have experience studying the methane and sulfur cycles and analyzing the microbial diversity of marine ecosystems. In brief, I am interested in studying the role of microorganisms in nature and their potential use for biotechnological purposes.

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