TROPICAL BIODIVERSITY: WHY SHOULD WE CARE?

EDITED BY: Ana Maria Rocha de Almeida and Chelsea D. Specht
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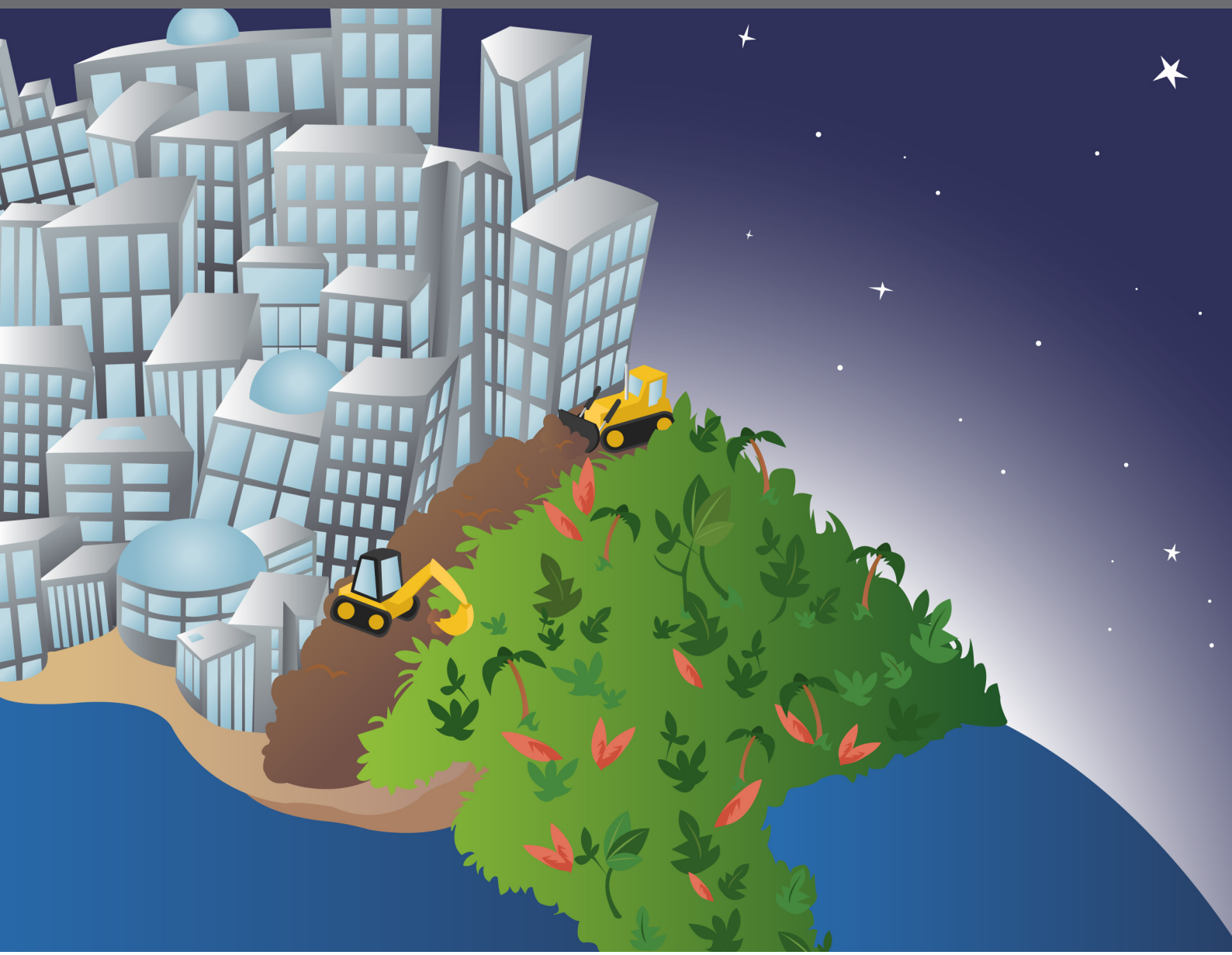

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TROPICAL BIODIVERSITY: WHY SHOULD WE CARE?

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When we look at our planet's species distribution, we observe a very interesting pattern: as we move from the Poles to the Equator, the number of species drastically increases. This is what has been called 'latitudinal gradient of species diversity'. In short, it means that tropical areas, which are located between the Tropic of Cancer and the Tropic of Capricorn, harbor a greater number of species than temperate areas. We still don't know exactly what causes (or have caused) this phenomenon, but we know that it resulted in high endism, that is, a large number of animals and plants unique to these areas.

The tropical areas of the globe are an intricate patchwork of various ecosystems. Tropical ecosystems can vary from rainforests to deserts; from savannahs to mangroves, and we have a lot to learn from them. However, in recent years we have witnessed an increase in rates of habitat destruction, particularly in the tropics. Currently, many tropical ecosystems are under threat, as vast areas are devastated to give space to cities, agriculture, and cattle farms. As tropical areas vanish, so do species previously unknown to us, as well as ecological processed specific to these environments. Moreover, due to its global importance, devastation of tropical areas has potential impacts on other non-tropical ecosystems, and may exacerbate climate change, as well as influence the spread of tropical diseases.

On the other side of this battle, there are many scientists that dedicated themselves to the study of the fascinating tropical biodiversity. This collection of articles aims at highlighting their contributions to our understanding of tropical patterns and processed leading to this incredible biodiversity. It focuses on the wonders of the tropical areas of the globe, by asking, amongst others, the following questions: Which species of plants and animals are found in tropical areas? What can we learn about tropical ecology and how can this knowledge help us conserve these ecosystems for future generations?

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Table of Contents

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BIODIVERSITY
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WHAT ARE BIODIVERSITY HOTSPOTS?

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The image of a tropical forest is likely present in your imagination: green, warm, and wet, with large trees, thick shrubs, and a wide variety of insects, birds, and mammals. This image is accurate: the tropical zone has an incredible abundance of species of plants and animals. Species in tropical regions can account for two-thirds of all known species on earth! Many areas within the tropical zones are considered biodiversity hotspots and are home to the world's most rare and endangered species. Whether we are talking about mountain ranges, islands, or tropical forests, the impressive diversity of life in these areas makes them important places to protect and study. In this article we will discuss the concept of *biodiversity hotspots*, their locations throughout the planet, and their importance for biodiversity conservation.

HOW MANY SPECIES ARE THERE?

Have you ever wondered just how many different species of living things there are on our planet? This is a hard question to answer!

The actual number of living organisms on Earth is unknown to us, but so far, scientists have described up to 1.7 million species of living organisms. Of those, over 1.3 million are animals, 100,000 are fungi, over 300,000 are plants, plus countless species of bacteria, algae, and viruses [1]. This incredible variety of life forms is what we know as *biodiversity*, that is, all kinds of life existing in a certain place.

It is difficult to know the actual number of living organisms on Earth, or what percentage of these organisms are already known to us. In some cases, there is quite a lot of debate. For example, the estimated number of animals varies from 2 to 11 million species. And while the average estimate of *known* plant species is somewhere around 300,000, the predicted number of plants, including yet unknown species, is around 450,000 species [1]. In any case, scientists agree that, despite the great number of species that have already been discovered, it is likely that there is an even larger number of species yet to be discovered.

Now you might wonder, "Okay, that is nice to know, but what difference does it make?" It makes all the difference! When we are trying to protect the biodiversity on our planet, knowing how many species are out there is as important as knowing how and where they are distributed around the globe, so that we can decide which areas of the planet are priorities for **conservation**, especially if we cannot protect every area.

CONSERVATION

Taking care and preserving species and the environment.

BIODIVERSITY IS UNEVENLY DISTRIBUTED AROUND THE GLOBE

With the enormous number of species that exists on Earth, it is remarkable that the distribution of these species is so highly concentrated in specific areas. **Species richness**, the total number of species found in an area, is not evenly distributed around the globe: two-thirds of all known species occur in **tropical areas**, especially in tropical forests [2], even though the causes of such uneven distribution are still a matter of debate.

SPECIES RICHNESS

The number of species living in a specific location.

TROPICAL AREA OR TROPICAL ZONE

Area situated between the Tropics of Cancer and Capricorn. See Figure 1 for the location of the location of the Tropics on the globe.

EXTINCTION

The death of an entire species (like dinosaurs).

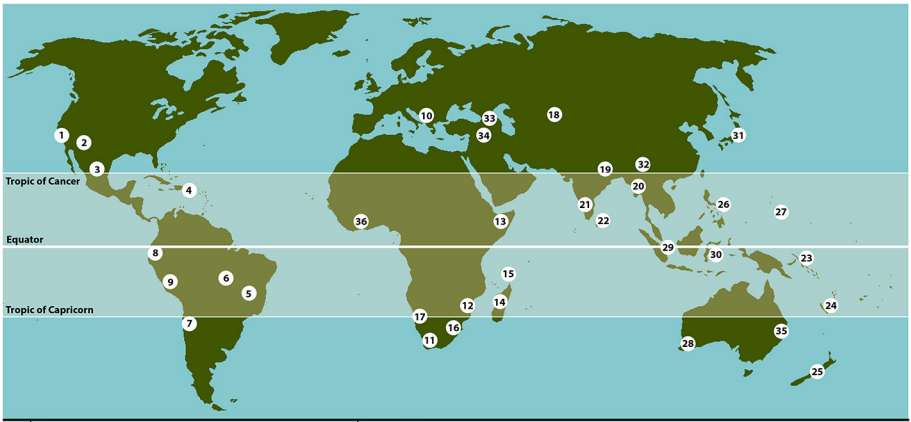
In order to prioritize the areas that should be protected, scientists look for areas that are home to a large number of species, especially those species that are under threat of **extinction** or that are currently being destroyed at a fast pace. These areas that are particularly important for biodiversity conservation are called **biodiversity hotspots**. Two things are crucial when determining that a place is a biodiversity hotspot: (i) the number of different species there; and (ii) whether species in that area are endangered or currently being destroyed. Figure 1 shows the location of 36 biodiversity hotspots, according to the Critical Ecosystem Partnership Fund.

Figure 1

The names and locations of current biodiversity hotspots around the globe [9].

BIODIVERSITY HOTSPOTS

Geographical areas with very large numbers of species that are threatened by destruction.



#	Name	Location
1	*California Floristic Province*	California, USA
2	*Madrean pine-oak woodlands*	Southern USA
3	*Mesoamerica*	Central Mexico, Belize, Guatemala, Nicaragua, and Northern Costa Rica
4	*Caribbean Islands*	East of Central America
5	*Atlantic Forest*	Parts of Brazil, Argentina, and Paraguay
6	*Cerrado*	Central Brazil
7	*Chilean Winter Rainfall-Valdivian Forests*	Central North of Chile, to the Western regions of Argentina
8	*Tumbes-Choco-Magdalena*	Pacific Coast of South America and the Galapagos Islands
9	*Tropical Andes*	Part of the Andes Mountains in South America
10	*Mediterranean Basin*	Surrounds the Mediterranean Sea
11	*Cape Floristic Region*	Southern tip of South Africa
12	*Coastal Forests of Eastern Africa*	Eastern Coast of Africa
13	*Horn of Africa*	Northeastern Africa
14	*Madagascar*	Southeast Coast of Africa
15	*Indian Ocean Islands*	Comoros, Mauritius, and Seychelles, surrounding Madagascar
16	*Maputaland-Pondoland-Albany*	Southeastern coast of South Africa
17	*Succulent Karoo*	Coastal region of South Africa
18	*Mountains of Central Asia*	Central Asia: extends through Afghanistan, China, Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan
19	*Eastern Himalaya*	Parts of China, Bhutan, India, Tibet, and Myanmar
20	*Indo-Burma*	Parts of Bangladesh, India, Myanmar, China, Cambodia, Vietnam, Thailand, and Malaysia, Hainan Island and Andaman Island
21	*Western Ghats*	Indian Peninsula
22	*Sri Lanka*	South of India
23	*East Melanesian Islands*	North East of Australia
24	*New Caledonia*	South Pacific Ocean
25	*New Zealand*	Southwest Pacific Ocean
26	*Philippines*	Southeast Asia
27	*Polynesia-Micronesia*	Southern Pacific Ocean
28	*Southwest Australia*	Southwest tip of Australia
29	*Sundaland*	Southeastern Asia comprising the Malay peninsula, Borneo Island, Java Island, and Sumatra Island as well as their smaller surrounding islands
30	*Wallacea*	Eastern Indonesia
31	*Japan*	Northen Pacific Ocean
32	*Mountains of Southwest China*	Includes Tibet, Sichuan, Qinghai, Gansu, and Myanmar
33	*Caucasus*	Border between Europe and Asia, separating the Black and Caspian seas
34	*Irano-Anatolian*	Parts of Armenia, Azerbaijan, Georgia, Iraq, Iran, Turkey, and Turkmenistan
35	*Forest of East Australia*	Eastern coast of Australia
36	*Guinean Forests of West Africa*	Coastal western africa

Figure 1

Scientists have observed that, even though biodiversity hotspots make up only approximately 1.4% of land on our planet, they are home to 60% of Earth's plant, bird, mammal, and reptile species [3]. Just the *endangered* species in the tropics account for 43% of vertebrates (animals with backbones and its close relatives) and 80% of all amphibians [4]. Species that found only in a certain geographical area are known as **endemic species**, and biodiversity hotspots are full of them! For example, the Banana Tree Frog can only be found in Ethiopia, and you will only find lemurs in Madagascar [5]. Tropical forests are typically biodiversity hotspots *and* are usually filled with endemic species. The Upper Amazonia/Guyana Shield, the Congo Basin, and

ENDEMIC SPECIES

Species that occurs only in a specific geographic region.

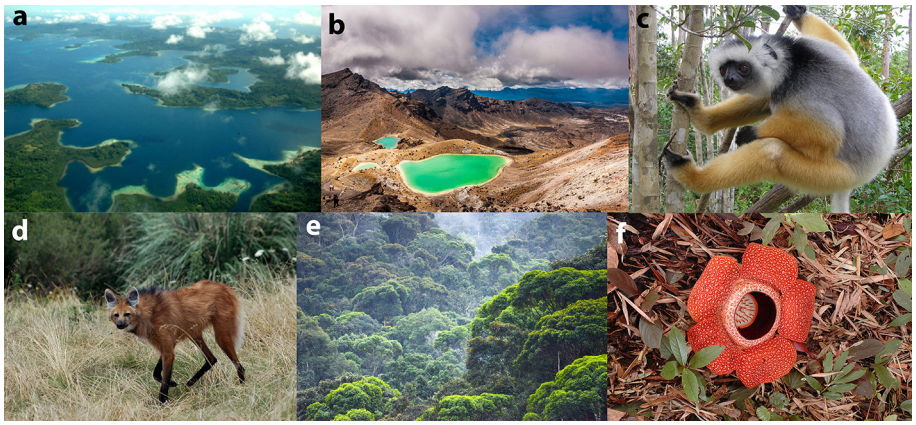


Figure 2

Figure 2

Biodiversity hotspots and some of their endemic species. **(a)** Melanesian Islands; **(b)** Emerald Lakes, New Zealand; **(c)** Diademed sifaca, one of the endemic lemur species from Madagascar. Mantadia National Park, Madagascar; **(d)** Maned wolf, the largest canid of South America, a species from the Cerrado hotspot; **(e)** Atlantic Forest, Caparaó, Brazil; **(f)** Rafflesia, one of the largest flowers in nature. This particular one, from Borneo, is 80 cm wide [Photo **(a)**: Jim Lounsbury, Wikipedia (https://commons.wikimedia.org/w/index.php?curid=9403460; Photo **(b)**: Marcus Holland-Moritz, Wikipedia (https://commons.wikimedia.org/w/index.php?curid=40728121); Photo **(c)**: C. Michael Hogan, Wikipedia (https://commons.wikimedia.org/wiki/File:Diademed_ready_to_push_off.jpg); Photo **(d)**: Aguara, Wikipedia (https://pt.wikipedia.org/wiki/Lobo-guar%C3%A1#/media/File:Aguara1.jpg); Photo **(e)**: Heris Luiz Cordeiro Rocha, Wikipedia (https://commons.wikimedia.org/wiki/File:Capara%C3%B3_e_a_Mata_Atl%C3%A2ntica.jpg); Photo **(f)**: Steve Cornish, Wikipedia (https://en.wikipedia.org/wiki/Rafflesia#/media/File:Rafflesia_80_cm.jpg)].

CLIMATE CHANGE

The change of weather and temperature patterns around the world.

the New Guinea/Melanesian Islands have the highest number of endemic terrestrial (land-living) species on Earth [6]. Figure 2 shows some examples of biodiversity hotspots and some of their endemic animals and plants.

In addition to land, the waters surrounding these tropical regions are just as important, and equally in danger [4]. Tropical coral reefs are currently being threatened by **climate change** and habitat destruction. These areas are some of the most biodiverse ecosystems on our planet! Scientific studies of 3,235 marine species in these areas, including fishes, corals, snails, and lobsters, show that high percentages of these species are at serious risk of becoming extinct [7]. Conservation of species living in fresh or seawater is especially difficult, because many bodies of water are interconnected. For example, all the oceans are connected through sea currents that allow the movement of species, minerals, and pollution across the entire globe [8].

EXTINCTIONS AND A LOOK INTO THE FUTURE

Interestingly, the organisms that we know today represent only a very small portion of all the living creatures that have inhabited the planet since life began. All the species living today represent only 5% of all the species that have roamed the Earth during its history! This is a reminder that extinction is a constant force shaping Earth's biodiversity.

However, many scientists would agree that, today, we are facing a rate of species extinction that is faster than has ever been seen before. Plant and animal species in biodiversity hotspots are currently suffering devastating losses. In fact, by definition, a biodiversity hotspot must have lost at least 70% of its habitat [9]. Biodiversity hotspots now cover only 1.4% of the land on Earth, when they originally covered 12% of the land [10]. Factors, such as pollution, exploitation of land, invasive

DEFORESTATION

The destruction of forests or the removal of great number of trees.

species, **deforestation**, and climate change are the leading causes of habitat loss and destruction [11]. The fact that these factors are widespread creates challenges for the species that manage to survive; and with an ever-changing climate and unpredictable circumstances, species that cannot resist the changing environment or move to a more suitable habitat will likely become extinct [4].

When we think about the future of biodiversity on Earth, we need to consider the role we play in climate change. Some scientists predict that up to 54% of species are at risk of extinction due to climate change. The consequences of climate change are extremely widespread, threatening even places untouched by humans [12]. In order to protect our planet, we can start by making small changes in our daily lives. Taking action by recycling, picking up trash, being conservative with our water consumption, and limiting pollution by walking, biking, or taking public transportation are ways that we can help the environment. We can also come up with our own ideas, as we educate ourselves on biodiversity by reading about different places and living things.

SUMMARY

As we have learned, a region with a large number of species is considered to be biodiverse. There are 36 biodiversity hotspots on our planet, and these areas are dazzling, unique, and full of life. Plants, animals, and other living organisms that populate these places are rare and many of them are only found in these specific geographic areas. These biodiversity hotspots are currently at risk of being destroyed [13]. Habitat destruction directly caused by humans, as well as destruction due to climate change, are the leading causes of the increasing extinction of Earth's species.

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We are the kids of a vibrant township community in South Africa. Where we live, education is difficult for many people, and we strive to improve our lives through sports and learning. We are all different ages, and after school we enjoy practicing our cycling skills. We also compete in cycling events locally and nationally. We believe that education is important, and will help us grow in the future.

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I am a senior at CSU East Bay, hopefully earning my Bachelor of Science in Biology this spring. My interests include plant biology, genetics, and the effects that climate change has on different organisms. I hope to begin a Ph.D. program in Plant Biology in the fall and I am excited to continue doing research.

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THE CERRADO BIOME: A FORGOTTEN BIODIVERSITY HOTSPOT

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AGE: 9–11

Have you heard of the Cerrado biome? Do you know what a biodiversity hotspot is? In this article, you will learn why we should care about the biodiversity in the Cerrado biome. A biome is a community of plants and animals in a large area that shares the same climate and habitat features. Tropical biomes have the greatest diversity of plants and animals on the planet. However, when it comes to tropical biodiversity, people are quick to think of the Amazon. The Cerrado has a great biodiversity that is just as important to conserve as the Amazon Biome. However, the Cerrado continues to be forgotten and neglected, leading to the devastation of its natural areas. Let us learn more about this fantastic biome and help us spread the word about the urgency of preserving the Cerrado!

BIOME

A large ecological area on the earth's surface, with fauna and flora (animals and plants) adapting to their environment.
A biome also defined by its non-living factors, such as climate, geology, soil, and vegetation.

INTRODUCTION

What is the Cerrado? The Cerrado is a vast tropical **biome** composed of savannas and grasslands amid humid and dry forests. In Spanish, the word cerrado means closed, shut, thick or dense, but in Brazil, the word has been used

to describe an arid ecosystem and all the native species that are adapted to live in its seasonally variable climate. Where is the Cerrado? The Cerrado is located in the highlands of Central Brazil and covers about 2 million km^2 or 21% of the Brazilian territory. It represents the second largest biome in South America, after the Amazon. The total area is equivalent to the size of Germany, France, England, Italy, and Spain all combined. Why is the Cerrado a hotspot of biodiversity? To be classified as a biodiversity hotspot, a region must have a high number of organisms that are not found anywhere else on earth. Also, the region must be in danger of being destroyed and have less than 30% of its natural vegetation. A hotspot, in other words, has an irreplaceable biodiversity. The Cerrado has over 4,800 species of plants and vertebrates (animals with backbones) found nowhere else on the planet. However, this extraordinary biodiversity is in danger because of the misconduct of political leaders and the lack of knowledge of our society.

THE RICHEST SAVANNA IN THE WORLD

The Brazilian Cerrado encompasses the most extensive woodland-savanna in South America (Figure 1). Woodland savannas are landscapes with scattered trees and shrubs forming a sparse canopy. The Cerrado region also has a great variety of habitats, from vast grasslands to dry-canopy forests [1]. Humid forests are also found along streams and rivers as green corridors (or gallery forests) throughout the landscape. Each of these unique habitats has different groups of plants, vertebrates, insects, and microorganisms that are adapted to live there. This variability of the environment makes the Cerrado one of the richest of all tropical savannas [2].

The Cerrado has more than 12,000 plant species, about 4,000 of which only exist in the Cerrado, including almost all of the herbs and short plants. When a plant exists only in a given location and nowhere else in the world, we say it is "**endemic**" to that location. Some of the most unique plants in the Cerrado include a giant palm tree called "buriti" (Figure 2A) that grows only in swampy grasslands and forests. This tree is important to many birds for nesting and food and one of the most emblematic birds that nests on this palm is the blue-throated macaw (Figure 2B). This species forms permanent lifelong couples as they travel across the palm swamp after the buriti fruits. Also, tapirs, peccaries, fish, and monkeys depend on buriti fruits as their main food source. It is astonishing, how many animals are connected with the existence of a single plant. In terms of beauty, there are magnificent trees and shrubs coloring the landscape of Cerrado, such as the roble or trumpet trees (Figure 2C), which have a beautiful bloom of brilliant pink-, yellow-, white-, and purple-colored flowers. The "cigana-do-Cerrado" is a popular shrub because it stands out in the savannas with its strong reddish color (Figure 2D).

ENDEMIC

The situation in which a species is restricted to a particular region and found nowhere else on the planet.

FIGURE 1

An image of the Cerrado region showing the amount of natural vegetation that remains intact (green), the location and size of the national protected areas (yellow and red), and the total deforested area (pink). You can see that the Cerrado region covers a big area of the Brazilian territory. Unfortunately, only a tiny amount (less than 3% of the area) is currently protected by law. Source: Françoso et al. [3].

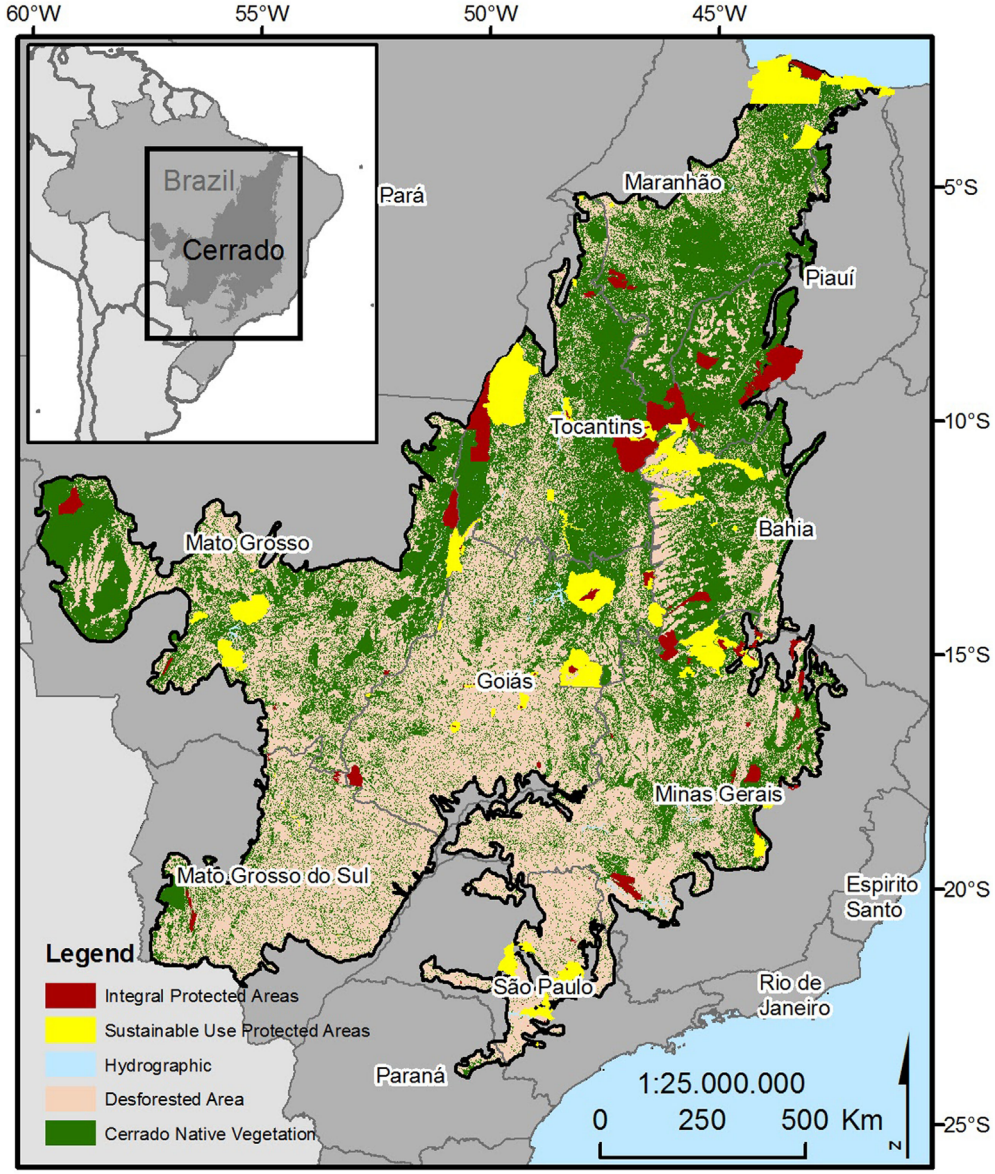

FIGURE 1

Around 20,000 years ago, large mammals, also known as megafauna, lived together with primitive humans in the Cerrado region. Many fossils of giant armadillos and giant sloths have been found here. A fossil is a remain or impression of a prehistoric organism preserved in petrified form or cast in rock. Nowadays, the Cerrado is still the main habitat of many rare large living mammals. One of the rarest mammal species is the maned wolf (Figure 2E), a golden-red, large-eared, and long-legged fox-like animal that can grow to 2.7 ft in height and weigh about 50 pounds. Two of the most remarkable mammals in the region are the giant armadillo (Figure 2F) and the giant anteater (Figure 2G), the largest anteater in the world. When the armadillo feels the danger, its defense is to fold its body by tucking their head and legs into a shell and wait until the threat leaves. The giant anteater grows up to 7 ft in length from the nose to the base of its tail, which is enormous and flag-like. Anteaters

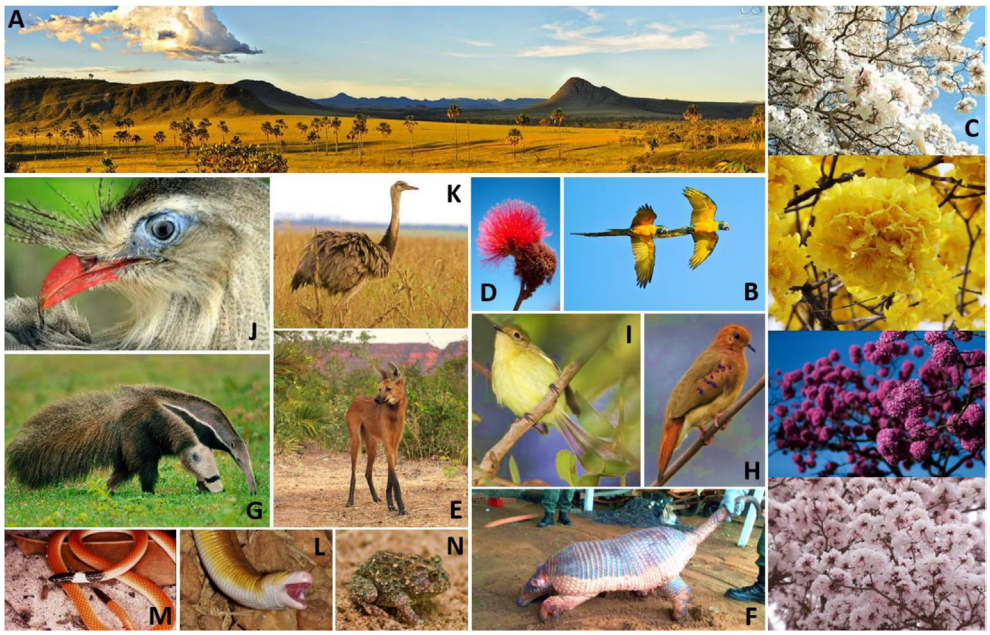

FIGURE 2

FIGURE 2

Examples of the extraordinary diversity of species and habitats found in the Cerrado. **A.** A natural habitat of the "buriti" palm (scientific name: Mauritia flexuosa) growing in swampy grasslands; **B.** The blue-throated macaw (scientific name: Ara glaucogularis), one of the most emblematic birds in the Cerrado; **C.** The magnificent roble or trumpet trees in the genus Tabebuia, which have a beautiful bloom of brilliant pink-, yellow-, white-, and purple-colored flowers; **D.** The "cigana-do-Cerrado" (Caliandra dysantha) is a well-known shrub because it stands out in the savannas with its strong reddish color, which stands out in the savannas with its strong reddish color; **E.** The maned wolf (Chrysocyon brachyurus), a golden-red, large-eared, and long-legged fox-like mammal; **F.** The giant armadillo (Priodontes maximus) that folds its body into a shell when it feels threatened; **G.** The giant anteater (Myrmecophaga tridactyla) that grows up to 7 ft in length from the nose to the base of its tail; **H.** The blue-eyed ground dove (Columbina cyanopis) and the **I.** "minas-gerais" tyrannulet (Phylloscartes roquettei) listed as highly threatened on the IUCN Red List; **J.** Some of the largest birds in South America include the red-legged "seriema" (Cariama cristata); **K.** The rhea (Rhea americana); **L.** One of the strangest reptiles is the giant worm lizard (Amphisbaena alba); **M.** The coral snake group (Apostolepis sp.), that

(CONTINUED)

have a feeding strategy of licking up tons of ants and termites as quickly as possible. The anteater's tongue is covered with thousands of tiny hooks which are used to hold the insects together with large amounts of saliva. The giant anteater has to visit up to 200 nests per hour to consume the thousands of insects it needs to satisfy its hunger.

Regarding bird diversity, the Cerrado has more than 800 bird species, of which nearly 20 are endemic. Some birds species are listed as highly threatened on the **IUCN Red List**, like the blue-eyed ground dove (Figure 2H) and the "minas-gerais" tyrannulet (Figure 2I). Many bird watchers visit the Brazilian Cerrado because of the extraordinary bird diversity. Some of the larger birds in South America include the red-legged "seriema" (Figure 2J) and the greater rhea (Figure 2K), which are the largest birds on the continent. The rhea males are the ones who take care of the babies. They eat mostly fruits, invertebrates, and small vertebrates, like lizards, snakes, and rodents. The insect diversity of the Cerrado is far from being completely discovered. Scientists suggest that there are more than 50,000 species including butterflies, moths, termites, wasps, and bees waiting to be discovered in the region.

One of the strangest reptiles is the giant worm lizard (Figure 2L). It can grow up to 3 ft in length and feeds on ants, beetles, and spiders. Of the other reptile species, 30 of 220 are considered endemic in the Cerrado, including 6 species of coral snakes (Figure 2M). The amphibians are extremely threatened because of the water pollution. An example of such a threatened species is the rocket frog (Figure 2N), that is found in only a few places in the biome. A recent threat to the amphibians in the Cerrado is a very powerful fungus (*Batrachochytrium dendrobatidis*, known as "Bd") that is responsible for the global decline and

FIGURE 2 CONTINUED

includes six endemic species in the Cerrado; **N.** An example of threatened frog species in the Cerrado (Odontophrynus moratoi).

IUCN RED LIST

The world's most complete list of the conservation status of plants and animals. It evaluates the extinction risk of thousands of populations and species. This list is maintained by the International Union for Conservation of Nature.

EXTINCTION

The disappearance of a species of living organisms. Extinction usually occurs because of changed conditions to which the species is not suited. If no member of the affected species survives and reproduces, the entire species dies out.

extinction of frog populations. The Bd was first reported in the Cerrado region in 2013 attacking two species of frogs. Amphibians breathe and take up water through their skin, and since the Bd fungus infects the frog skin, the infected frog can no longer breathe normally. In a period of a few months, the frog population can go from abundant to nearly non-existent.

The great biodiversity is not the only highlight of the Cerrado. This biome is the most humid savanna in the world. Water that evaporates in the Amazon is brought to the Cerrado by the wind. Moisture is very important, because it determines the wet season in the area. The rainfall during the wet season is the water supply of many rivers that harbor a total of 800 species of fish, nearly 200 of which are found only in the Cerrado. The rainfall is also a vital source of water for food crops and millions of people in South America.

A WATER FOUNTAIN IN SOUTH AMERICA

In the heart of Brazil, the Cerrado is the water fountain of the most important rivers in South America: the Tocantins, Paraná-Paraguay, and São Francisco rivers. Scientists also consider the Cerrado to be "the cradle of waters" since it hosts three large aquifers, which are underground water reservoirs. The aquifers are similar to large pools or tanks that store the water at very deep underground layers. The roots of plants in the Cerrado are deep and larger than their canopies, so the root systems are responsible for absorbing rain-water and transporting it to the aquifers. Due to deforestation (cutting down the forests), the plants have stopped bringing water to the deeper soil regions, and the aquifers have stopped supplying many of the water springs in the area. Scientists believe that the amount of water in these aquifers has already reached its minimum level. Therefore, the protection of the Cerrado is urgent to ensure the maintenance of the water resources during climate change.

HOW DO PLANTS IN THE CERRADO DEAL WITH DROUGHT AND FIRE?

Did you know that the roots of trees native to the Cerrado can grow up to three times the size of their trunks? Dry and seasonal climate have influenced the Cerrado for thousands of years. From October to April, the region can receive 1,100 and 1,600 mm of rainwater, but the rest of the time it is as arid as a desert, and the plants and animals must be able to survive in these extremely dry conditions. In rain-poor environments, the most interesting survival strategy developed by trees is called water redistribution. During the driest period, the tree's main root dives deeper into the ground in search of water that is left from the rainy season. The main root brings the water to the surface roots, which in turn redistribute the water to the top layers of the soil. As a natural water pump that redistributes the water between the deep

FIGURE 3

Some examples of fire adaptations acquired by native plants in the Cerrado. **A.**,**B.** Thick and corky bark, **C.** Re-sprouting capacity after fire; **D.** Example of a fire event in the Brazilian Cerrado savannas; **E.** Leathery and rough leaves; **F.** Super bloom events after fire.

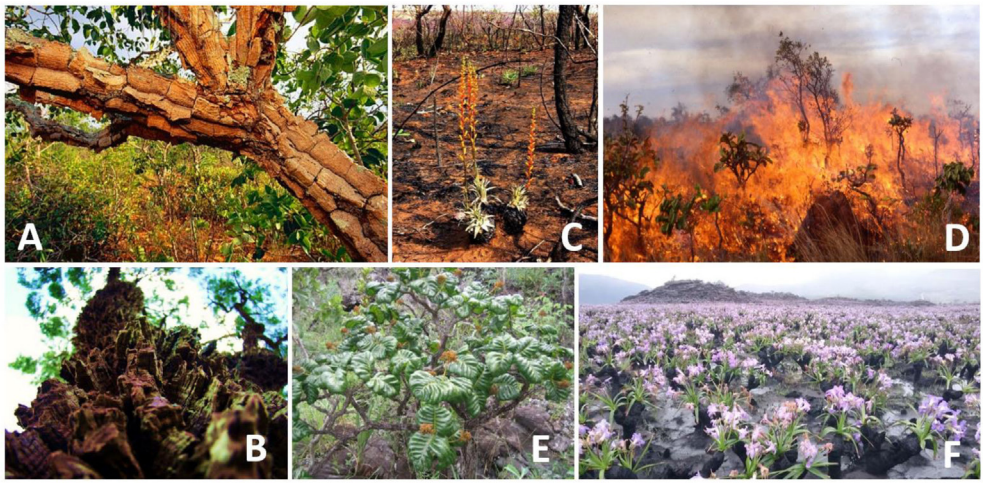

FIGURE 3

ADAPTATION

Change or the process of change by which an organism or species becomes better suited to its environment.

soils and the shallow roots, this mechanism is a necessary **adaptation** used by many trees in the Cerrado. With the arrival of the rainy season, the situation reverses: the surface roots absorb rainwater and transfer the water to the main root, which stores it several meters below the surface.

Fire is also part of the ecology in the Cerrado, and the plants there have numerous adaptations to fire, including corky bark to protect them from the heat, leathery and waxy leaves that resist wilting and water loss, and the ability to resprout very quickly after a fire, due to their deep root systems (Figure 3). Regular fires in this area help the nutrients to be recycled into the soil, benefit dormant seeds to sprout and stimulate certain flowers to bloom.

THE NATIVE PEOPLE OF THE CERRADO

Not only plants have adapted to live in the Cerrado but also humans have occupied the Cerrado over 12,000 years; and there is a rich mosaic of cultural heritage. The historical knowledge of these people represents an important layer of the biodiversity in the Cerrado. The Cerrado is home to 216 Indigenous (native people of South America) territories and 83 different ethnic groups. However, many of these communities cannot defend their ownership of the land, which has been one of the factors threatening the extinction of many tribes. The right to live and work on the land of the Cerrado is very important for these groups since it allows them to access essential resources necessary for their survival and their traditional ways of life.

Selling products manufactured by local communities in the Cerrado is a good way for the people living there to support themselves. Some of these products have been gaining popularity in the public markets. Fruit products

such as "baru" nuts (*Dipteryx alata*), "pequi" (*Caryocar brasiliensis*), "jatobá" (*Hymenaea stigonocarpa*) flour, "açaí" (*Euterpe edulis*) berry, and "buriti" (*Mauritia flexuosa*) jam, as well as cosmetics and medicinal products, help to support the economy of the Cerrado people and help conserve its biodiversity. Ancient methods of farming and making products from plants are important allies in the protection of the Cerrado, as they help to assure the continuity of the natural resources for the future generations.

THE FUTURE OF THE CERRADO

The Cerrado is not nearly as recognized as the Amazon, but it is equally or even more important in terms of biodiversity. In the Cerrado, the National Parks cover only 7.5% of the natural biome area (Figure 1), whereas in the Amazon they cover 46% of the area. A vast area of the Cerrado is used for agriculture [4]. Since the demand for food production is predicted to rise steeply over the coming decades, it is likely that the Cerrado's native vegetation will gradually be replaced by pasture and farmlands. That replacement is very worrisome, as many of the Cerrado's plants and animals are likely to die with this change in land use [5]. Another urgent threat is the global climate change. The temperature is rising, and the rainfall is decreasing in the Cerrado region. These ongoing changes have already affected several species that depend on the outside temperature to regulate their own body temperature, such as lizards and amphibians. Moreover, if there is no adjustment in the speed and magnitude of the deforestation caused by agriculture, scientists are expecting a catastrophic extinction event in the next few years [6].

More conservation of the Cerrado is urgently needed. It is vital for the Brazilian society to come together to try to protect the Cerrado. It is also essential that conservation strategies are focused on conserving the biodiversity, preventing deforestation, and safeguarding the areas rich in endemic plants and animals. Do not let the Cerrado be forgotten! Help us to spread the word about the beauty and importance of this biome, one of the most fascinating biodiversity hotspots in the world.

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REVIEWED BY

GUELPH MONTESSORI SCHOOL, AGE: 9–11

We are an upper elementary class of 9- to 11-year-old students. We live in a small city in Ontario, Canada. We are eco-friendly and enjoy learning about science, math, history, culture, and art. Our two favorite things about being young reviewers were learning how to edit a science story for kids and how scientists publish their findings. We also enjoyed learning that English is the international language of science.

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I am a Ph.D. Candidate at the Department of Integrative Biology, University of California Berkeley. I have studied plant diversity in the Cerrado and other tropical biomes for more than 15 years. My interests mainly lie in exploring tropical ecosystems, discover new species and catalog plants in poorly studied sites. During field expeditions, I love interacting with local people and getting to know their cultural history. Their historical knowledge represents an essential layer of biodiversity. *gdamasco@berkeley.edu

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I am ecologist teaching Plant Biology and Cerrado Ecology at the Federal Institute of Brasilia, Brazil. I am interested in understanding the drivers of species diversity and distribution at different spatial scales, as well as the effectiveness of conservation practices to maintain biodiversity in the Cerrado biome. Currently, I am studying how species and ecosystems are sensitive to climate change to guide environmental policies focused on landscape restoration.

RICARDO HAIDAR

I just finished my Ph.D. at the Department of Ecology, University of Brasilia. I have been studying plant diversity in the Cerrado for more than 20 years. In my doctoral dissertation, I investigated the ecological factors that drive the distribution of Seasonally Tropical Dry Forests in Brazil. I am currently working with reforestation projects that aim to recover the biodiversity and the natural ecosystems in the Brazilian Cerrado.

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WATER CONTROLS AMAZONIAN BIODIVERSITY

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REVIEWED BY:

NADYA
AGE: 13

CAROLYN
AGE: 13

Almost everything about the Amazon River is truly gigantic and amazing. It crosses more than 7,000 km. The area from which water and materials drain into the Amazon River from higher lands to the river's lowland plains covers about 7 million km2. This area connects aquatic and terrestrial ecosystems that contain 20% of the Earth's fresh water and most of the Earth's diversity of living organisms. Humid areas, where bodies of water directly affect biodiversity, cover 30% of Amazonia. Water in various forms, from flying rivers in the form of clouds, to rainfall, to flow of water from highlands to lowlands, is a major factor affecting biodiversity Amazonia. You can see this effect all over Amazonia, and water has controlled the ecosystem of this area for many years. The Amazon contains numerous species that together form a complex forest, both on land and underwater.

THE BIGGEST RIVER ON EARTH

Amazonia is the area drained by the Amazon River, and Amazonia covers about 7 million km^2. This massive area contains a large proportion of the world's microbial, animal, and plant species that together form a complex forest, both above ground and underwater. Almost everything about this mighty river is truly gigantic and amazing. The Amazon crosses more than 7,000 km

FIGURE 1

Northern South America, as mapped by Shuttle Radar Topographic Mission (http://dds.cr.usgs.gov/srtm/). The area from which the larger image is taken is indicated by the box over the picture of the earth in the upper right corner. The larger image shows differences in altitude above sea level represented by colors: green indicate lower lands, where big rivers are; yellow indicate the old exposed rocks and soils; and white indicate mountain ranges, the Andes.

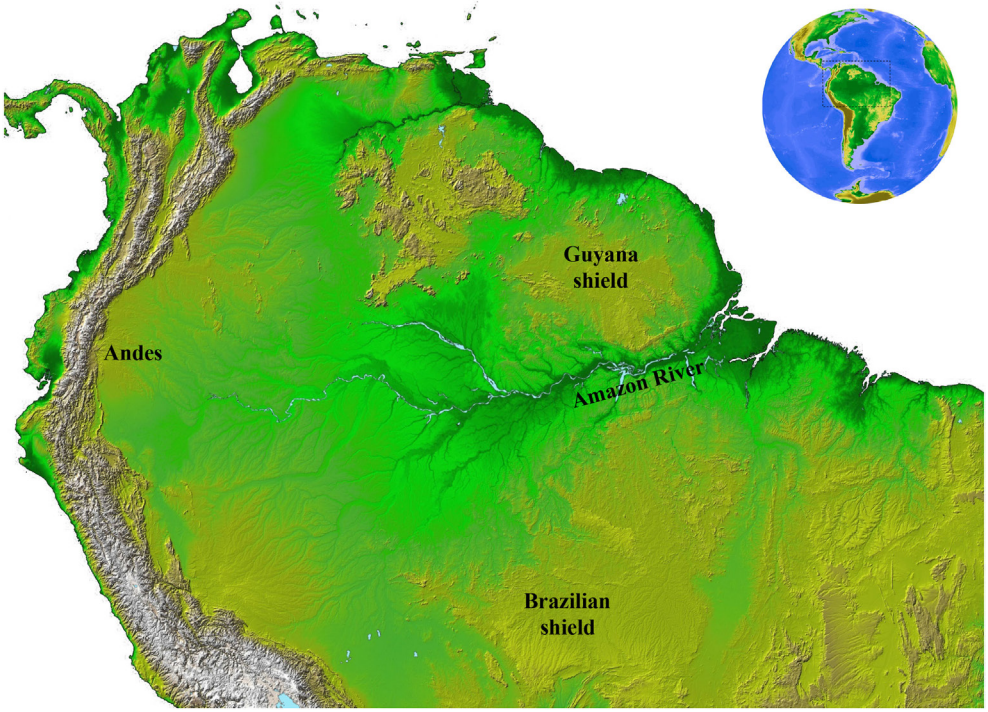

FIGURE 1

of northern South America, from the Apurímac River at the Andes Mountains of south Peru to the Atlantic Ocean in north Brazil (Figure 1).

Water is the main constituent of cells. It is essential for life because biological functions, such as respiration, photosynthesis, and digestion, happen in water. Rivers, streams, underground water, and clouds connect and sustain every living organism in the Amazonian forest. Therefore, water is the source of Amazonia's biodiversity.

The Amazon River is about 9 million years old. During the rainy season, the Amazon River can be up to 50 km wide at certain places. A water basin, or watershed, is the area where water and materials, such as sand, living organisms, trunks, and fragmented leaves, are drained through streams and rivers, moving from the watershed's higher lands to its lowland plains, because of gravity. This downhill flow of water connects aquatic and terrestrial ecosystems in the Amazon River's watershed, which covers a bigger area than the whole of Europe and contains 20% of all the freshwater in the world. Amazonia also houses most of the Earth's diversity of living organisms [1].

In Amazonia, we can find between 4,000 and 15,000 plant species (including Brazil nut and açaí), >400 mammal species (including jaguars, sloths, and bats), >1,300 bird species (including toucan and harpy eagle), >400 reptile species (including boa snakes and caimans), >400 amphibian species (including tree frogs), and around 3,000 freshwater fish species (including

piranhas and pirarucu). The diversity of smaller life forms is harder to estimate, and scientists have described more than 100,000 invertebrate species, like insects and spiders. The number of fungi and algae species are also difficult to estimate and many new species are being described every month. All this biodiversity is dependent on the unique water dynamic found in the region.

RIVERS THAT CAN FLY

Amazonia is a tropical landscape covered mainly by rainforests. The rain that falls on Amazonian rivers and forests comes from evaporation of the Atlantic Ocean and from the metabolism of the Amazonian ecosystem itself. Rainwater can reach rivers directly or can be captured by the forest, run throughout the canopy and trees trunks and finally reach the ground. Groundwater can then flow downhill to smaller rivers, carrying soil and other materials with it, and incorporate the runoff or infiltrate into soil into reservoirs. These processes are part of what we call the hydrological (water) cycle of a watershed. The hydrological cycle starts with precipitation (rainfall), which is followed by the runoff of that water into streams and rivers, infiltration of water into the ground, and a process called **evapotranspiration**, in which water is returned to the atmosphere through evaporation from soil and water surfaces or from the leaves, stems, or flowers of plants.

EVAPO-TRANSPIRATION

a phase of the hydrological (water) cycle that includes evaporation of water from soil and water surfaces, as well as from the stems, leaves, and flowers of plants.

Vegetation along the edges of streams and rivers helps to decrease and slow down water runoff into those bodies of water. These zones are called riparian zones and the plants there are called riparian vegetation. Riparian vegetation has two main roles: first, it feeds water back into the atmosphere, through evapotranspiration; and second, it softens the fall of water hitting the ground helping the infiltration processes, which gives back water to the soil. Big trees with large root systems can then access the underground water even during drier seasons. Some trees can release up to 1,000 l of water into the atmosphere each day!

As a result, Amazonia and its big rivers act like water vapor bombs, which put water into the atmosphere and form a dense layer of clouds that contain large amounts of water. These clouds flow with the winds, forming incredible flying rivers. Because of the high temperatures in Amazonia and the large amount of rain that falls around the equator, Amazonia has this massive power to exchange water between the forest and the atmosphere. The 4,000-m high Andean cordillera at the west of the South American continent acts as a barrier to winds and clouds coming across the continent and from the Atlantic Ocean. The result is a massive amount of rainfall on the areas of central, eastern, and southern Brazil and its neighboring countries. This river of clouds transports billions of liters of water in vapor form each year, which is almost

equal to the amount of water flowing from the Amazon River itself into the ocean each year. So, these rivers in the sky change the climate of the continent and, eventually, that of the whole world.

RIVERS THAT PULSE

The thick cloud layer pours its heavy rainfall down onto lowlands, forcing the big rivers to flood and water from the rivers to spread to higher lands, submerging many plants living in those higher areas [2]. These forests flood each year, so these forests have a terrestrial phase and an aquatic phase every year (Figure 2). The floodwaters in these forests can reach up to 8 m high for as long as 300 days! Most trees in these forests spend half of the year outside of water and the other half in different levels of submergence. These flooding forests contain more than 1,000 tree species. This pulsing water system controls many of the plants' biological processes, like flowering growth, which in turn influence terrestrial animal communities, which feed on or live in these forests. Aquatic animals, like fish and freshwater dolphins, also feed on and live in these flooded forests when the water level is high.

Species change from highland streams down to bigger rivers and their flooded forests, lower along the watershed [3]. Such succession in environmental structure determined by water is seen both in species composition as in forest structure, likely a result of adaptation to different levels

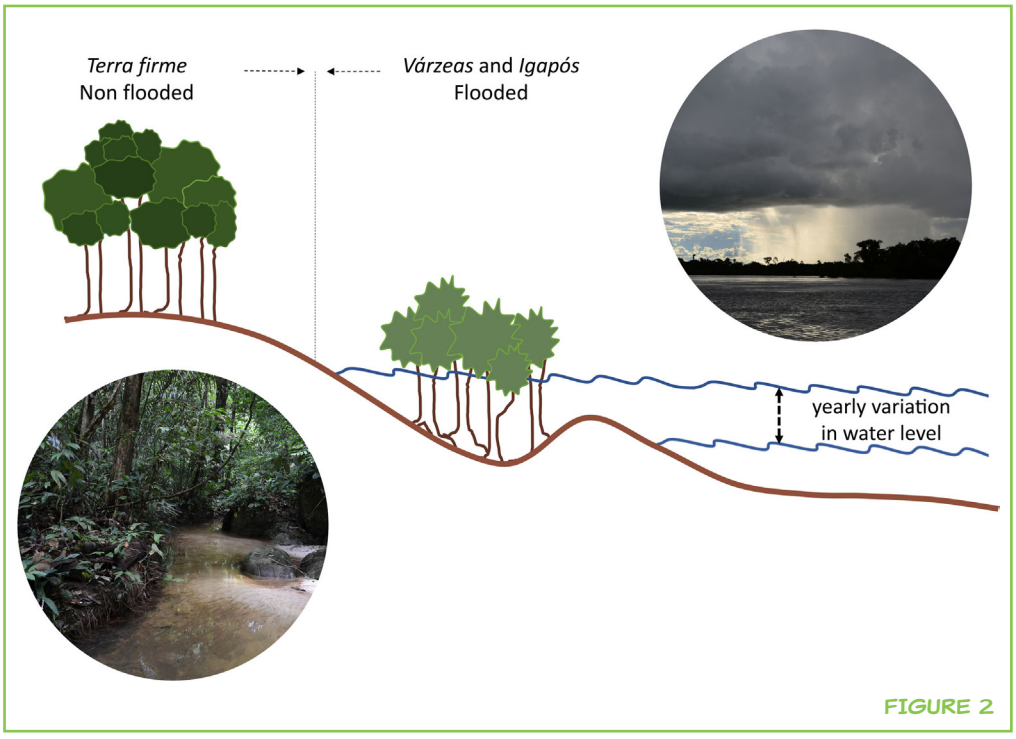

FIGURE 2

Flood pulse of Amazonian rivers, showing the terrestrial and aquatic phases of riparian vegetation.
The upper inset image shows rainfall over a stream that flows into the Tapajós River, with a wide flooded forest on its edges; the lower inset image shows a typical terra firme stream and its riparian vegetation.

of water in the soil [4]. In other words, each stream seems to be unique in the matter of which species arises in such environments.

VÁRZEA

areas flooded by rivers that are rich in suspended material eroded from the Andes Mountains, which makes the water whitish (for example, Solimões River and Madeira River).

IGAPÓ

areas flooded by rivers with acidic water, formed in the highlands of the Guyana and Brazilian old exposed rocks (for example, Negro River and Tapajós River).

Incredibly, flooded forests can be very different from each other. Depending on what the river floor is made of, the types of species present in the flooded forests can vary. The rivers in Amazonia have two main origins: the young soils of the Andes Mountains and the ancient soils of the Brazil and Guyana old exposed rocks. Rivers that flow over young soils create flooded forests called ***Várzea* forests**, and rivers that flow over ancient soils create flooded forests called ***Igapó* forests**. These two kinds of forests are very different in tree species and overall size. The geological origin of the river affects the water's chemical properties, which results in remarkable differences in water color: *Várzea* forests occur along white water rivers, and *Igapó* forests on black or clear water rivers.

RIVERS THAT FLOW UNDERGROUND

Plants and animals that live in riparian habitats on the edges of rivers and streams respond to the amount of water present in the soil. The pulse of water in riparian habitats is much more random and less predictable than it is in rivers since most of variation in water level in riparian habitats comes from rainfall directly over these habitats. Terrestrial and aquatic compartments in ***terra firme*** Amazonia are intimately related and changes in one can have huge consequences in the other. For instance, it has been shown that degradation of riparian forests can lead to reduction in aquatic species number [5].

TERRA FIRME

area above the floodplains of major rivers, where local vegetation is not seasonally flooded.

On higher lands in Amazonia that are not directly affected by the flooding of big rivers, water also rules biodiversity. These humid areas, covering about 1 million km^2, contain a dense and connected network of small streams, which are formed and maintained by underground water. These small streams are actually where most of the water in the big rivers originally comes from.

WATER CONTROLS AMAZONIAN BIODIVERSITY

From flying rivers in the form of clouds, through rainfall and the flow of water from highlands to lowlands, water is a major factor affecting biodiversity in Amazonia. Amazonian species have evolved many ways of living in or interacting with water, leading to high number of species in each area. Also, most Amazonian human populations live near its rivers and are also accustomed to the pulsing rhythms of those rivers. Amazonian forests are essential for Amazonia's contribution to the environment. Locally, these forests affect water quality and distribution, and more globally, they can affect the stability of

the climate. Water has controlled the ecosystem of this area for many years. So, you can clearly see that water in many ways creates different habitats that result in this biodiversity.

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REVIEWED BY

NADYA, AGE: 13

I love to paint and read and I want to become an art teacher when I grow up. My favorite books are the Harry Potter series. I am usually in my room painting or making jewelry. Art and science are my favorite subjects in school. It is interesting to learn about this planet and I want to make a difference in it someday.

CAROLYN , AGE: 13

As a child, I always dreamed of becoming a scientist. I was interested in all sorts of science. When I was seven years old, I became intrigued by zoology and enjoyed TV shows about wild animals and environment. My interest in animals grew after I encountered one bear, four deers, and an uncountable amount of seals last year. Although I do want to become an artist, becoming a scientist is still high in my priority.

AUTHORS

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THIAGO ANDRÉ

I am an evolutionary biologist interested in plant diversity. My research focuses on diversification of ginger plants, especially Amazonian Costaceae, Zingiberaceae, and Marantaceae. I teach plant evolution at the Federal University of West Pará, in Brazil. You can find me reading under a tree or nurturing my garden during weekends.

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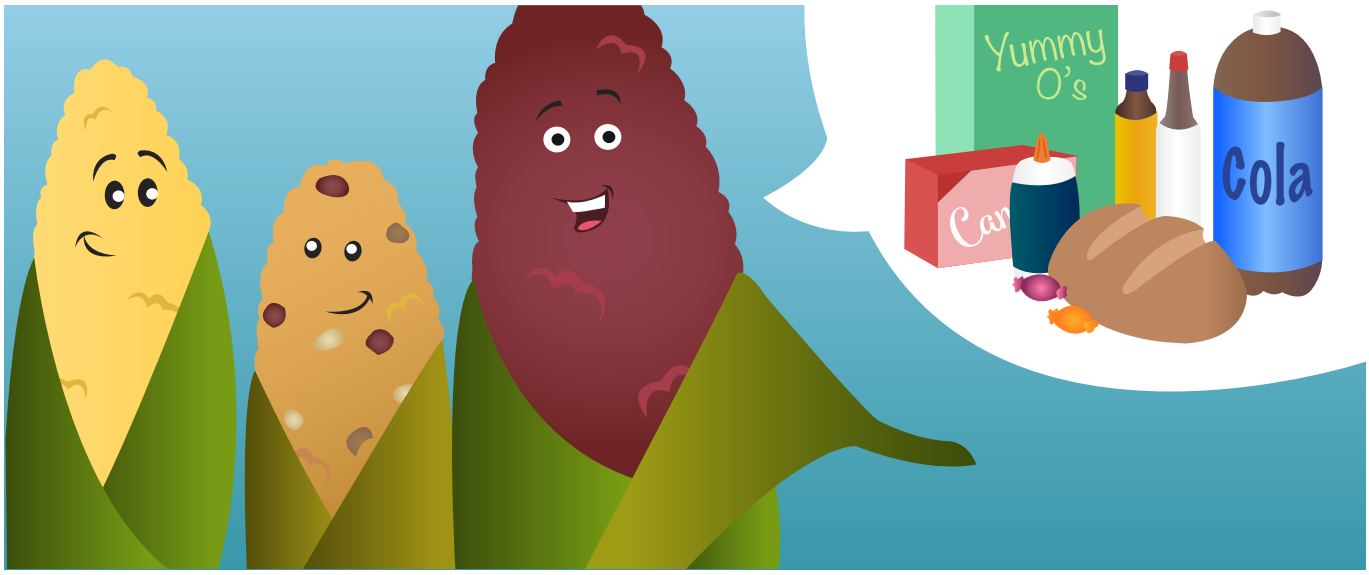

THERE IS MORE TO CORN THAN POPCORN AND CORN ON THE COB!

Alma Piñeyro-Nelson[1,2], Daniela Sosa-Peredo[1,2], Emmanuel González-Ortega[2,3] and Elena R. Álvarez-Buylla[2,4]*

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MARIA
AGE: 11

Corn (also called maize) is a useful plant that is part of the grass family (called Poaceae). Corn was first produced in what is now Mexico around 6,000 years ago, from a weed called teosinte. While corn and teosinte share many features, the "cob" present in corn, on which many grains or kernels are attached, is a unique feature of corn. Some of the biggest differences between teosinte and corn are due to human farming practices and selection of teosinte mutants. Corn is dependent on human assistance for its survival, while many pre-Columbian civilizations relied on it for their nutrition. Nowadays, corn continues to be one of the most important grain crops in the world, and corn is a central part of the diet of many people. In some cases, corn is eaten as a side dish, and in some places like Mexico, Central America, Colombia, and some African countries, corn makes up the main component of their cuisine. Such diverse cuisine relies, in turn, on the use of hundreds of different maize varieties, called landraces, which need different growth conditions and differ in color, size, and flavor. On the American continent, landraces are kept and actively modified by small

farmers. These local farming methods are very important for maintaining the genetic diversity of corn, which needs to be understood and protected to adapt to the changes in the environment that are likely to happen in the future, due to climate change.

CORN: A UNIQUE MEMBER OF A VERY POPULAR PLANT FAMILY

Corn—also known as maize, goes by the scientific name *Zea mays* subsp. *mays,* and is a part of the grass family or Poaceae. With approximately 12,000 species [1], the grass family has members almost all over the world. You can find grasses almost anywhere: your front lawn, the prairies, the African savannah, many forests and deserts, near the ocean and up high in the mountains.

While corn is quite special in its own way, it is not the only important crop that is part of the grass family. All edible species of rice, wheat, millet, rye, barley, sorghum, oats, even bamboo and last but not least, sugarcane, are members of the Poaceae.

Corn is a plant that humans have helped to create over thousands of years. It is very unlikely that corn would exist, as we know it today, without human help. While you may think that plants humans grow for food are always pretty dependent on human hands for their survival and reproduction, many of these plants could happily live back in the wild. But this is definitely not the case for corn, and there are good reasons why! Keep reading to find out.

DOMESTICATION

Is a multi-generational process in which a plant or animal population is taken from the wild and maintained by humans. One generation after another, a domesticated species is selectively bred to accumulate particular traits that are useful to us.

MUTANTS

A mutant is an individual that has suffered a change in its genes, such that it has different nucleotides in particular genes, when compared with other individuals of the same species. Mutations can potentially translate into differences in shape, growth patterns, susceptibility to disease, with respect to other individuals that do not have a particular mutation.

THE GENETIC ORIGINS OF CORN

Corn and its cob are quite unique within the grass family. Think about the spike of wheat or rice. They look very different from a corn's cob and even if we take a look at corn's closest relatives, tall, weedy grasses called teosintes, their "cobs" and kernels look nothing like corn's! Teosinte cobs have few seeds, and each seed is covered with a hard shell made of silica (the same material glass is made of), which is quite good for surviving fire, drought, and even being ingested by animals. By contrast, corn has "naked" seeds, and its cob is the product of the movement, during development, of the silica seed covers to the bottom of the kernel, forming a massive, tough structure (called a spike), from which kernels cannot get loose (see Figure 1 for a comparison). The cause of this huge change from the structure of teosinte to corn is actually simple: during the long process of creating corn for human use, called **domestication**, without knowing they were doing it, humans selected those teosinte plants that had a mutation in a gene called teosinte glume architecture 1 (tga1). This gene guides silica formation around the seed and humans selected atypical forms of teosinte plants (**mutants**) where this gene did not

FIGURE 1

In this figure you can see a comparison of rice, wheat, teosinte, and corn spikes. A seed for each grass is also drawn. Note how different corn's spike is from the other type of spikes. In the case of teosinte and corn, look at the differences in the number and shape of their seeds. Corn, in contrast with teosinte, has a "naked" seed, with only a little part of the silica shell present where it attaches to the cob (right). Rice and wheat appear larger than they really are. Figure by Luis Fernando Sobrado/ Zemperi.

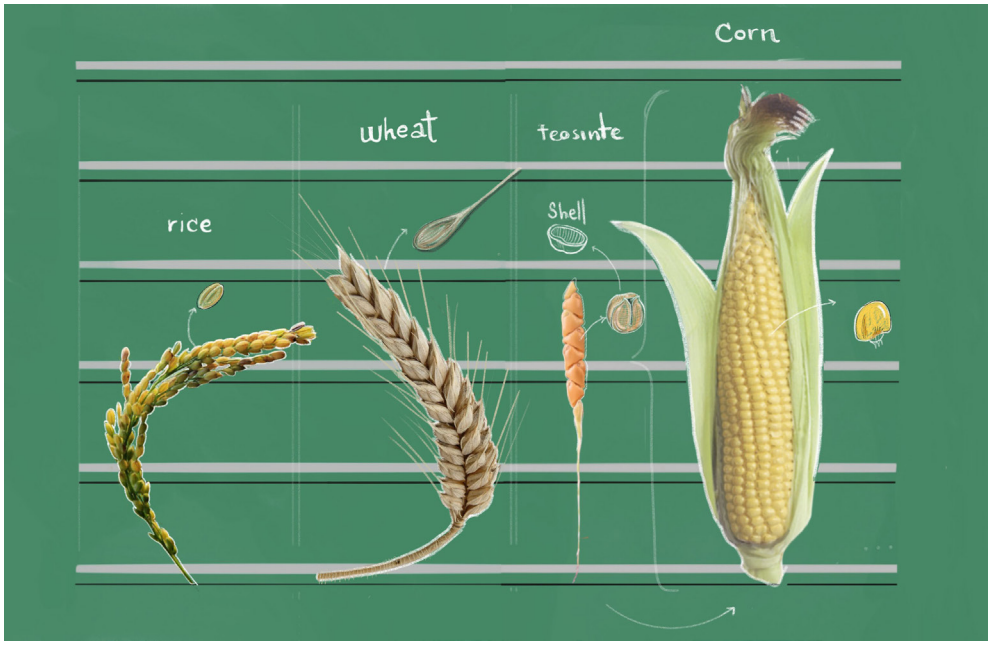

FIGURE 1

produce as much tga1 protein, which translated into loosing the silica cover but gaining a cob [2].

Another difference between corn and teosinte is that corn is covered by multiple layers of husk leaves, which prevents small animals and birds from eating and spreading the seeds. In teosinte, the husk will eventually open by itself, but the husks of corn never completely open by themselves. We, humans, have to open them. Corn has also evolved to differ in other ways from teosinte. For example, corn typically has a single stalk instead of many stalks. These two traits—a leafy husk and a single stalk, are related and came to exist together in the corn plant through human selection of teosinte plants that happened to have mutations in another gene called teosinte branched 1 (tb1). The mutant version of tb1 creates plants that have something called apical dominance, in which branches on the stalk are suppressed, and additional layers of leaves are added to the cob [2]. It has also been shown that corn and teosinte have different kinds of soil microorganisms associated with them. Read more about this in the Frontiers for Young Minds article by Jennifer Schmidt and Amélie Gaudin.

So, how long ago did corn, as we know it, come to exist? We can use a scientific approach called genetics to estimate when corn originated. In genetics, we study genes, which are the hereditary particles that are passed along one generation after another through sexual reproduction. These genes encode the instructions to produce all of the proteins that make us who we are. Comparing changes in genes from one organism against another, we can unravel part of the common history of their lineages. In fact, we can use genetics to study

the history of *any* organism that has DNA. Genetic studies of corn are easier than studies of wild plants because corn has been used, moved, and stored by humans throughout its evolutionary history. Because of its widespread use, corn remains have been found in many archeological sites. Thus, archeology is another source of historical information as to when and how this plant was "taken into a home"... or domesticated. In the case of corn, its oldest recorded remains—fossilized cobs—have been estimated to be around 6,000 years old [3]. These very old cobs were found in a cave in Guilá Naquitz, in the Mexican state of Oaxaca, Mexico [3]. This evidence and other scientific data have told us that Mexico is considered the center of origin and diversification of corn and harbors about half of all the **genetic diversity** (genetic variants) of this crop in the American continent [4]. We will later explain why this is so important to keep in mind in Section "Corn Landraces, Beautiful, Diverse, and Necessary for a Changing Climate!"

GENETIC DIVERSITY

Refers to the total number of genetic variants present in individuals from a particular species. Preserving genetic diversity is an important conservation target, as it can help individuals from a given species adapt to changing conditions or environments.

THE IMPORTANCE OF CORN IN THE HUMAN DIET: THEN AND NOW

The domestication of corn on the American continent was a huge deal for the people living in this part of the world, as this plant became a very important crop for most pre-Columbian civilizations until the Europeans came to the Americas (which happened in 1492 A.C.). In pre-Columbian times, only the potato had a similar role in the Inca Empire, located in what is now Peru and Bolivia. Corn's importance in the diet and in the farming practices of pre-Columbian civilizations on the American continent is similar to the role of wheat and rice as staple crops in ancient civilizations in the Middle East, Europe, and different parts of Asia. Nowadays, these three crops, corn, wheat, and rice, are still the main components of the human diet around the world, and they provide important sources of nutrients for the great majority of the world's population.

So, currently, which countries are the top corn producers in the world? According to recent data, China and the United States have the highest maize production worldwide, with 200 and 300 million tons per year, respectively, followed by some Latin American countries. Brazil, Argentina, and Mexico have a production of 79, 33, and 23 million tons per year, respectively.[1]

[1] http://www.fao.org/statistics/databases/.

Nowadays, many of us think about corn grains as food for chickens, pigs, and other farm animals, but corn has many other uses. In the food industry, corn starch, derived from ground corn kernels, is added into various foods such as pasta, candies, sauces, breads, soups, stews, and baby food. Some edible oils and syrups are also made from corn, such as fructose and other sweeteners, used in most sodas or even juices sold in supermarkets. Processed corn is also used in medicines, cosmetics, glues, paper, textiles,

paints, and solvents.[2] Corn residues or "scraps" have recently been used to create biodegradable materials similar to plastics. Another use for corn is to use its sugars to make biodiesel fuel for use in cars and other vehicles.

So, not only can we eat corn as an additive mixed into different foods, or as a side dish like delicious corn on the cob, or grits, or as a snack in the form of nachos and popcorn: around the world, there are many dishes—and cultures—that totally revolve around corn. In such cultures, corn is a central component of their cuisines. We will talk about this in the next section!

CORN-BASED CUISINE: DIVERSE AND YUMMY!

In countries such as Mexico, most of Central America, Colombia, and several countries in Africa, corn-based foods are eaten every day. In places like Mexico, you can even have a three-course meal with each plate having some (or a lot) of corn. All corn can be prepared as a form of bread (like a *tortilla*), as soups, or as all-in-one dishes. Examples include a soup called pozole and a steamed and stuffed tortilla dough, called a tamale. Corn is also used to make hot or cold beverages, and even desserts (see Figure 2). In Mexico alone, there are approximately 700 corn-based dishes! The corn-based cuisine from this country is considered an important part of world history and culture by the United Nations (UNESCO[3], 2010).

You may be wondering how so many different dishes can be prepared from a single type of corn. Well, it turns out that there are thousands of different varieties, or types of corn, grouped into hundreds of so-called **landraces** (varieties of corn that are kept by small-scale farmers, which share similar features and genes). Many of these landraces have existed since pre-Columbian times (before 1492 A.C. [4]). In the Americas alone, approximately 484 landraces have been recorded over the last 100 years [5]. These landraces have been adapted by humans to grow in environments with different soil

FIGURE 2

[2] http://www.worldofcorn.com/#/.

[3] https://ich.unesco.org/en/RL/traditional-mexican-cuisine-ancestral-ongoing-community-culture-the-michoacan-paradigm-00400.

LANDRACE

Is a plant (or animal) variety that has been bred and selected by humans over time to grow in a specific environment, after its isolation from other populations of the same species.

FIGURE 2

This figure shows to the left, some of the uses of corn as a food additive, where it is used as a sweetener in bread, soda, BBQ sauces, pasta sauce, or as corn oil. In comparison in the right side of the image, the use of corn as a main ingredient in foods is portrayed. In this case, corn is used not only for snacks like popcorn and nachos but also for many traditional dishes like tortillas, stuffed tortillas ("flautas"), and soups like "pozole." Figure by Luis Fernando Sobrado/Zemperi.

types, altitudes, water availability, and temperatures. In addition, the various landraces of corn have different kernel colors, cob size, and flavor! In the third figure of this article, you will see a map of the American continent with some examples of different landraces, as well as the regions where they were generated [3,6].

CORN LANDRACES, BEAUTIFUL, DIVERSE, AND NECESSARY FOR A CHANGING CLIMATE!

The fascinating "rainbow" of American corn landraces, shown in Figure 3, is the result of the interaction among three important factors: first, corn's biological qualities (its ability to grow fast and in very diverse weather conditions and types of soil, and its particular gene combinations), second, the environments where different corn varieties have been grown for over 6,000 years, and third, the diverse cultures across the Americas, whose people have been selecting maize varieties for different uses and flavors. Therefore, the huge variety of corn landraces will not always stay the same, because these three factors also change over time. This means that we cannot just go and collect lots of seeds from each variety of corn and store them in a fridge, expecting that the varieties we save will still be able to grow even when the conditions of the world change. This is the reason why we think it is crucial to preserve maize diversity *in situ* (in the sites where maize varieties are currently being grown), not only in seed banks (seed banks are called *ex situ* or "outside of their site").

We recently investigated what might happen to corn diversity in Mexico in the future, under different scenarios of climate change. We found that some landraces will thrive well if temperatures increase, but others may disappear [7]. Very importantly, we found that the more we preserve different types of corn landraces, we will be able to better adapt to climate change, reducing the negative impact on agricultural production (less yield per acre), as landraces will be more resistant to variable weather conditions than the commercial corn varieties that are currently being sown in many parts of the world.

Finally, it is also important to make sure that the traditional technologies with which corn has been cultivated for thousands of years are maintained. For example, in the Americas, since before 1492 A.C., maize has been cultivated using a system in which three different crops are grown together, usually beans, pumpkins, and corn are grown together on the same piece of land. This system is called *Milpa* in Latin America, or *the three sisters* in some parts of the USA. Different versions of the *Milpa* system are still used to grow these and other crops in Mexico and other countries in Central America. Even some of the so-called "weeds" that grow in the Milpa are

FIGURE 3

Here you can see a map of the American continent showing where corn was domesticated (the Balsas river basin in Mexico). This figure also shows some of the corn landraces that are currently being grown across the continent. Note how different they are in size, shape, and color! Figure by Lucia Campos Peredo and Luis Fernando Sobrado/Zemperi.

FIGURE 3

tolerated and used for various traditional dishes (turns out that these weeds are both nutritious and delicious!) or used in traditional medicine. The *Milpa* system makes a better use of critical resources for agriculture: soil,

physical space, sun, and water. This system is nowadays considered to be a very good method that has fewer negative impacts on the environment than other types of food production methods. By contrast, large-scale industrial farming relies heavily on the use of pesticides, synthetic fertilizers, irrigation, and heavy machinery, which all have huge impacts on the environment. Also, industrial corn agriculture is based on using maize varieties that are very similar genetically and as such, tend to perform poorly under difficult conditions (drought, extreme weather, and insect pests). These varieties tend to displace landraces, sometimes leading to local or complete extinction of local landraces. In addition, some industrial farms use corn varieties that have been genetically modified (GM) in a lab. Genetic modification involves adding genes from other organisms into the corn plant, to help it grow better under certain conditions. These GM varieties can cross with local landraces, potentially damaging them and the farmers who have them. Thus, corn plants that are very similar genetically can be useful in some contexts, but not in others, especially when it comes to diversifying what we eat.

CONCLUSION

Corn is part of an important plant family called Poaceae. It is the product of human selection over centuries, which made it have unique features such as a big, massive cob with hundreds of kernels. The differences between corn and its weedy relative, teosinte, are the product of humans selecting teosinte variants (mutants). Once corn came to exist, humans further adapted different varieties to different environments. These different varieties, which fed most of the human population before the arrival of the Europeans to the Americas in 1492 A.C., are known as landraces. Corn, together with wheat and rice, remains one of the central components of the human diet. Also, maize is highly versatile, as it has been used for fodder, food, and industrial purposes. When thinking about food, there are countries whose people rely heavily on corn-based dishes, which in turn are prepared using the many corn landraces that small-scale farmers have kept and bred for millennia.

The genetic diversity present in such corn landraces will be very useful to contend with the negative effects of climate change, thus, it is important that we preserve them, and the agricultural systems, such as the Milpa, where they are grown.

So, how many types of corn have you eaten lately? Try more! You will not regret it: corn landraces are pretty, tasty, and a good option for the environment.

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CONFLICT OF INTEREST STATEMENT: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

REVIEWED BY

MARIA, AGE: 11

My name is Maria, and I am 11 years old and live in the Bay Area. I really like hanging out with friends, animals, and playing soccer. I like to be with animals. When I grow up, I want to be the head of the Environmental Protection Agency because I really care about the Earth and want to protect it.

AUTHORS

ALMA PIÑEYRO-NELSON

I have been interested on all kinds of organisms since my early childhood, when I would spend many days in a country house observing and manipulating frogs, butterflies, birds, and plants. Lots of kinds of plants! I eventually became a biologist focused on studying them. I am particularly interested in understanding the effects of the interplay between plants and the environment where they grow and how this interaction can impact their development in the short run, but also across long periods of time, favoring diversification and speciation, as well as the emergence of unique shapes and structures. I especially like working with weird and unique plants, and corn is one of them! I have also worked in assessing plant genetic diversity and conservation, as well as the biosafety of crops domesticated in Mexico, which is one of the most biodiverse countries in the world.
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DANIELA SOSA-PEREDO

I studied biology because I was always interested in understanding how all the natural wonders that surrounded us had originated, from the universe to the tiniest living beings I could see. The origin and evolution of living beings were exciting topics in my career. Little by little I was acquiring knowledge that has helped me to understand a small part of all the questions that have arisen in the way of my academic life. My work has focused on the evolution at the molecular level of living beings and the use of mathematical and computational tools to manage all the information that exists of their genomes, to understand the processes or mechanisms that have led to living beings having their current form.

EMMANUEL GONZÁLEZ-ORTEGA

I am a plant and virus biotechnologist working on Biosafety Research. Through my research activity I have realized that maize (corn) is one of the magical ways in which Mother Nature dialogues with mankind, specifically with the indigenous peoples of the Americas. Currently, all the maize landraces are under risk of disappearing due to many reasons, one of these is the contamination with transgenes (GMOs). My job consists in keeping an eye on peoples' ancient maize for the presence of GMOs using laboratory tools and to explore, along with the communities, different means to preserve maize free of any kind of contamination and having it as good and healthy food for the present and future generations.

ELENA R. ÁLVAREZ-BUYLLA

Since I was a child I have been fascinated by life! My parents were both life scientists, and we all learned how fascinating it is to learn about plants and animals. My father wanted me to become a medical doctor, but I would rather spend my days watching the fruit trees in our garden, in the South end of Mexico City, observing how they grew flowers and fruits from apparently dry twigs. I have always been fascinated with development, and plants are wonderful to tell us their life histories as they cope with wind, dry soils, or too much or too little sunshine! Their architectures and growth habits make them fascinating creatures to ask questions about development. So, most of my efforts have been devoted to understanding how plants grow and develop. I also like to use mathematical and computer models to understand how multiple components are at play in development. More recently, I have realized that some of the discoveries that we have made in plants can also be useful to understand animal development and how it gets disrupted during illness. So we have lately started to apply our tools and approaches to biomedical issues, such as cancer, that we consider to be a developmental health problem. I am also fascinated by the rich variety of plant species that the people that originally lived in Mexico domesticated and diversified, many of which persist nowadays: over 15% of the food plants of the whole world come from our Country! We are therefore devoted to helping preserve such important diversity.

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ARE THERE WILD BAMBOOS IN MEXICO?

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LUANA
AGE: 14

Bamboos, unlike other grasses, mostly live in association with forests. Two different types of bamboos are recognized: the thick, hard "woody" bamboos, reaching up to 40 m tall, and the softer-stemmed "herbaceous" bamboos, rarely reaching more than 1 m tall. Worldwide, over 1,650 bamboo species are known, and although many people think of bamboos as Asian, 530 species (about one-third of total bamboo diversity) are native to the Western hemisphere. With the exception of Canada, every country in the Americas has a least one bamboo species—even the USA has three. In this article, we will focus on the Mexican bamboo species. Mexico has 56 of the 530 bamboo species, of which 52 are woody bamboos and 4 are herbaceous bamboos. A total of 24 Mexican bamboo species live in the cloud forest, so this type of vegetation is very important for the bamboos of Mexico. Among those 56 species, 36 are found only in Mexico, which means they are endemic. Native bamboos in Mexico were used long before Spanish conquerors arrived and are still used today.

BAMBOO, THE FOREST GRASS

When you hear the word bamboo, what comes to your mind? We know what you are probably thinking—panda bears in China, correct? But did

you know that in the Americas (the Western hemisphere) we have more than 530 native bamboo species? Counting all the bamboo species in the world, including those that the panda eats, there are more than 1,650 species [1]. Bamboos are native to every single continent in the world, except for Antarctica and Europe. When you think about bamboo, you probably think about those giant grasses reaching up to 40 m tall with hard, jointed stems, and graceful branches. However, in the tropical rain forests from Mexico down to South America, there are also bamboos with softer, smaller stems, usually less than 1 m tall. One of these, from French Guiana, only grows 2 cm tall (less than 1^2 high!) and is the world's smallest bamboo. The reason for this variability in bamboos is because there are two types of bamboos, the thick, hard "woody" bamboos that compete with trees for light, and the smaller "herbaceous" bamboos that live in the **forest understory** (the vegetation under the main canopy on the forest floor). And speaking of grasses, did you know that all the bamboos belong to the grass family (which has the scientific name **Poaceae**)? This means that the bamboos are cousins of lawn grass, corn, rice, wheat, sugar cane, and all the other grasses.

FOREST UNDERSTORY

The vegetation under the main canopy on the forest floor.

POACEAE

The grass family scientific name.

BAMBOO SCIENTIFIC NAMES ENGLISH PRONUNCIATION

Arundinaria: u-run-di-NÂ-ri-u; *Chusquea*: chus-KWÊ-u; *Guadua*: GWÄ-du-wu; *Olmeca*: OL-mâ-ku; *Otatea*: ô-tu-TÂ-u; *Rhipidocladum*: ri-pi-DOK-lu-dum.

NEOTROPICAL BAMBOOS

Herbaceous and woody bamboos living in the tropical areas of North, Central, and South America.

BAMBOO DIVERSITY IN THE AMERICAS

Every single country in the Americas has a least one species of native bamboo, with the exception of Canada. For example, the USA has three native species of the woody bamboo genus *Arundinaria* (see **Bamboo scientific names English pronunciation**). These three species are endemic to the USA, which means that they only live in the USA and not anywhere else in the entire world. However, the three North American bamboo species are not closely related to the Neotropical bamboo species that live from Mexico to Argentina and in the Caribbean Islands. The **Neotropical bamboos** include about 400 woody bamboo species and about 125 herbaceous bamboo species. The latest evolutionary tree of bamboos, which uses genetic similarities and differences to show how all of these bamboos are related to each other [2], confirms that the three North American bamboo species are more closely related to Asian bamboos rather than the Neotropical bamboos.

Of the 530 woody and herbaceous bamboo species living in the Americas [3], nearly 90% exist in three main regions. These regions have the highest bamboo diversity and the highest number of endemic species. Those regions are (1) Brazil, including the Atlantic forest and the Amazon basin; (2) the Central and Northern Andes mountains; and (3) Mexico and Central America. Brazil has the highest bamboo diversity by far, with 256 bamboo species, of which about 136 species are endemic to Brazil. The Andes has over 130 bamboo species, of which 110 species are endemic. Finally, Mexico and Central America have 87 bamboo species, of which about 52 species are endemic.

MEXICAN BAMBOO SPECIES

Mexico has 56 of the 530 American bamboo species growing within its borders. Fifty-two of them are woody bamboo species and only four are herbaceous bamboo species (Figure 1). Among those 52 woody bamboo species, 36 are endemic to Mexico, which means that 69% of Mexican bamboo diversity lives only in Mexico. Did you notice a distribution pattern of species diversity and **endemism** of the American bamboos? To the south, Brazil has the highest diversity of bamboo species; moving to the northwest in the Andes, the diversity is less than in Brazil but with more endemic species; and moving north to Mexico, both diversity and endemism decrease. The same south–north pattern of diversity and endemism is repeated in Mexico. The southern state of Chiapas has the highest diversity, with 32 species (both woody and herbaceous), followed by Veracruz, with 25 species and Oaxaca, with 23 species. If we move to the northeast in Nuevo Leon, we can find only one bamboo species, and moving to the northwest in Sonora, where we also find only one species, the same pattern is observed.

ENDEMISM

A species (endemic species) is restricted to a particular geographic region.

Let's get to know some of the Mexican bamboo species. We will begin with the herbaceous bamboos. Did you remember that, in Mexico, there are only four herbaceous species? One of them is *Cryptochloa strictiflora* which is the smallest herbaceous bamboo species in Mexico and only reaches 20 cm in height (Figure 1A). This species lives exclusively in the tropical rainforest at elevations less than 900 m above sea level (asl).

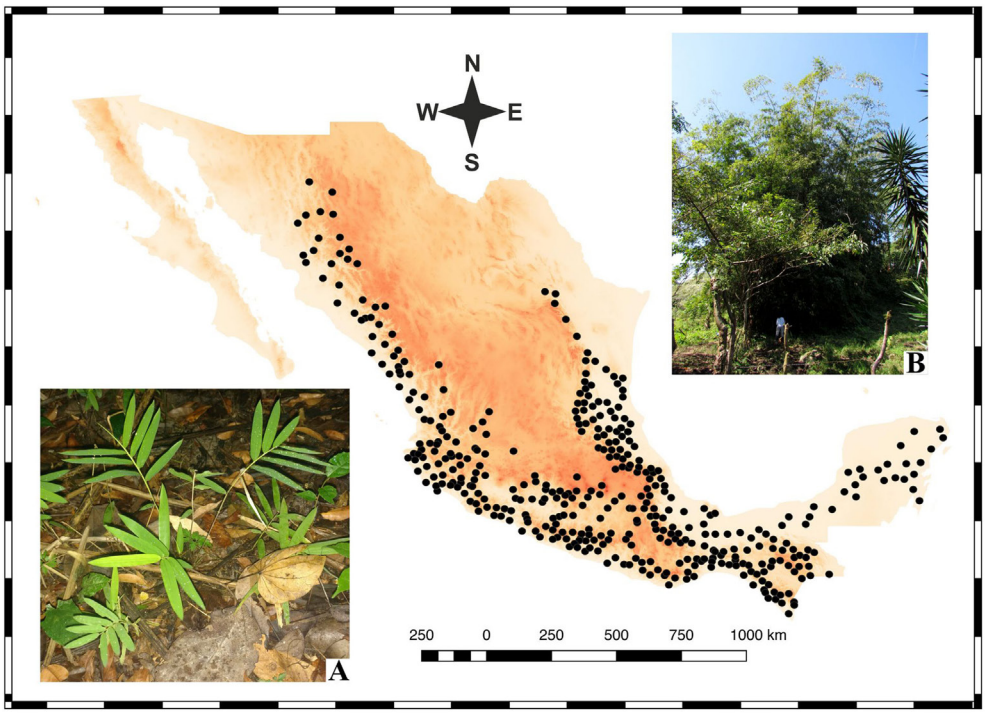

FIGURE 1

Map of Mexico, with black circles showing the sites where a least one species of native bamboo has been collected.
A. Cryptochloa strictiflora, herbaceous bamboo.
B. Guadua aculeata, the tallest woody bamboo species in México.

CLOUD FOREST

Mountain forests with persistent clouds or fog that provide much of the available moisture.

CONIFEROUS FORESTS

Forests dominated by pines and other cone-producing trees.

The woody bamboos in Mexico are represented by 8 genera and 52 species. *Chusquea enigmatica* is the smallest species of woody bamboo that grows in Mexico in the **cloud forest** (mountain forests with persistent clouds or fog that provide much of the available moisture), reaching a height of 40 cm to 100 m (Figure 2C). *Chusquea bilimekii* is the Mexican species that lives at the highest elevation, at around 3,150 m asl, in **coniferous forests** (forests dominated by pines and other cone-producing trees) on volcanoes. Two other species that live in the coniferous forest are *C. matlatzinca* and *C. septentrionalis*, the latter being the most recently discovered new bamboo species in Mexico. There are in total 22 *Chusquea* species, and 14 of them live in the cloud forest. The tallest woody bamboo species of Mexico is *Guadua aculeata* that grows more than 20 m in height (Figure 1B). This species is used to build houses in the region of the Gulf of Mexico, particularly in the Puebla and Veracruz states.

Olmeca, another woody bamboo genus, has five species, with four of them endemic to Mexico and three of them living in the cloud forest. Do you know that the *Olmeca*'s name is in honor to the Olmec ethnic group, who inhabited southern Veracruz and Tabasco between 400 and 700 B.C.? *Olmeca recta* and *O. reflexa* live in the **tropical rain forest** at low elevation (0–900 m asl) and both species produce unusual and fascinating fleshy fruits (Figure 2A). (The fruit of most bamboos looks like a grain of rice or wheat.) Another woody genus, *Otatea*, has 12 species, 10 of them endemic to Mexico. *Otatea victoriae* lives in seasonally dry scrubby vegetation. This last species is fascinating because it is

TROPICAL RAIN FOREST

Forests in which trees lose their leaves for only a short period.

FIGURE 2

FIGURE 2

Four native Mexican bamboo species. **A.** Fleshy fruits of Olmeca reflexa. **B.** *Otatea* acuminata in state of Oaxaca. **C.** Dr. Lynn Clark in front of *Chusquea* enigmatica, the smallest woody bamboo species in Mexico. **D.** Branches of Rhipidocladum racemiflorum from Veracruz.

one of the most drought-tolerant bamboos in the world. The *Rhipidocladum* genus has only four species in Mexico and only one of them is endemic that lives in the cloud forest. The species of this genus have branches in the form of a fan (Figure 2D) [4].

Did you notice that some of the Mexican bamboo species live in the cloud forest? Probably not, so we will tell you! A total of 24 Mexican bamboo species live in the cloud forest. Maybe are you thinking, "Why is this kind of forest important?" The cloud forest in Mexico, as well as in Central America and the northern Andes, is one of the more threatened types of environments. Less than 1% of the original total area remains and the rest has been replaced by other types of vegetation or croplands. However, cloud forests possess a great biodiversity, including **epiphytes** (plants such as mosses that grow on other plants, mainly trees) and many kinds of animals, and they capture and hold more water than other kinds of forests. The plant biodiversity that exists in the Mexican cloud forests reaches 2,500–3,000 species, which represents 10–12% of the total plant species diversity in Mexico.

EPIPHYTES

Plants such as mosses that grow on other plants, mainly trees.

BAMBOOS IN MEXICAN CULTURE

Native bamboos in Mexico were used long before the Spanish conquerors arrived in the early sixteenth century. There is archeological evidence that some ethnic groups, such as the Aztecs and Olmecs among others, used bamboos

FIGURE 3

Some uses of Mexican bamboo species. **A., B.** Various uses (baskets, walking sticks, and door) made with the culms of *Otatea* acuminata. **C.,D.** Two walls (bajereque) using *Otatea* fimbriata **C.** and Guadua paniculata **D.**

in their every-day lives. Of the 56 Mexican bamboo species, *Otatea acuminata* is by far the most abundant and widespread and is the most utilized species (Figures 2B and 3A,B). It is known as "otate," which means solid cane, a name derived from the Nahuatl "otatl," which means "cane." This species sometimes forms dense forests, known as "otatales." The name otate, however, is also given to some other bamboo species, or even to non-bamboo grasses. The most used part of *Otatea acuminata* and the other Mexican bamboo species is the culm (the name for the main cane). When used to build houses, the culms make up the framework and then are covered with mud to build walls, known as "bajereque" or "bahereque." Also, culms of this species are used to build roofs of rural houses, as well as doors, fences, baskets, walking sticks, and tool handles used in agriculture [5] (Figure 3). Just as some Mexican bamboo species are used to make houses, baskets, and handicrafts, other bamboo species are also used to do the same in South America, Asia, and Africa.

CONCLUSION

Now you know that the over 1,650 species of bamboos live not only in Asia; here in America we have at least 530 native species and in Mexico 56 species, including both bigger woody bamboos and smaller herbaceous bamboos. The Mexican bamboo species are widely distributed in Mexico and the cloud forest is one of the most important environments where most of the bamboo species live, but some Mexican bamboos also live in very dry places. Bamboos, especially otate, traditionally have been used for housing and various other purposes in Mexico and continue to be used in these ways. So, the next time that you see bamboo or hear the word bamboo, you will think of America and of Mexico, not just pandas and Asia.

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REVIEWED BY

LUANA, AGE: 14

I'm 14 years old, and dogs are my favorite things in the world. For my future career, I'd love to become a Vet, specifically creating smart prosthetics that can communicate with the animals' nervous system.

AUTHORS

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I did my Bachelor's in biology at the University of Guadalajara, Mexico with an emphasis on grasses. My Ph.D. was focused on the woody bamboo genus *Otatea* at the Institute of Ecology, Mexico. Since 2008, I have been studying Mexican bamboo species, and I have described 17 new species in collaboration with Dr. Lynn Clark and other bamboo specialists. Now I work as a professor at the University of Guadalajara, Mexico and I continue to study Mexican bamboo species. Every afternoon I like to walk with my dog

"Filogenio" and on weekends I like to watch series on Netflix and read non-science books. *ruizsanchez.eduardo@gmail.com

LYNN G. CLARK

I have been studying bamboo for over 40 years. I did my Bachelor's degree in botany at Michigan State University and then did my Ph.D. on the woody bamboo genus *Chusquea* at Iowa State University. In 1987, I became a professor at Iowa State University and have been studying the diversity and evolution of bamboos and other grasses ever since. I also teach classes in plant systematics and plant anatomy. As part of my research, I collaborate with bamboo specialists throughout Latin America, including Dr. Eduardo Ruiz-Sanchez, and travel frequently to countries such as Mexico, Costa Rica, Brazil, Colombia, and Ecuador for field work. I have described over 100 new species of Neotropical bamboos. I live with my husband and three cats on a farm that we converted to tallgrass prairie, and we also have a big vegetable garden and a small orchard.

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SHELLS IN TROUBLE—TURTLE ECOLOGY, CONSERVATION, AND THE ASIAN TURTLE CRISIS

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AGE: 13–14

Turtles are more than just animals with shells. They have important jobs in nature, eating and being eaten by other living things. Tropical Asia is a biodiversity hotspot for turtles—more than one quarter of all turtle species on Earth are found here. Some sad news is that turtles are going extinct because of humans hunting the turtles and destroying their habitats. This situation has been named the Asian Turtle Crisis. Many professionals are working hard to conserve turtles, but most importantly you can help also. In this article, we give you some background on the ecology and conservation of turtles, and we hope to inspire you to help with turtle conservation.

THE SCOOP ABOUT TURTLES

What are the first three words you think of to describe a turtle? Most people think of "shell, slow, and green." Shell is a great word to describe a turtle, because all turtles have shells. Even a cartoon turtle like Squirtle from

Pokemon has a shell. No other animal on Earth has a shell like a turtle. To transform your body into a turtle shell, you would have to put your shoulders and hips inside your ribcage! Slow and green are not such good words to describe turtles, because not all turtles are slow and green. If you saw a turtle swim, you would know that they can move quite fast. And only a handful of the turtle species in the world are green. Most turtles have dull colors, like brown, gray, and black, but many have bright red, orange, and yellow patterns (Figure 1).

There are 356 living turtle species on Earth [1]. Turtles come in all shapes, sizes, and colors. You can see a few examples of interesting turtles in Figure 1. Some of the differences between turtles may help them to survive better in their particular habitats. For example, the common box turtle (scientific name *Terrapene carolina*, Figure 1A) can pull in its head, arms, and legs, and completely close its shell for protection. Completely opposite, the big-headed turtle (*Platysternon megacephalum*, Figure 1D) has such a big head that it cannot pull its head into its shell. Its large head gives this turtle a strong bite, which is helpful for feeding and protection. Turtles can have interesting colors and patterns, too. The Beal's-eyed turtle (*Sacalia bealei*) has spots on the back of its head that look like eyes. Scientists are not sure if the spots have a function. Many believe these spots may be used to trick a potential predator into thinking it is being watched, but this is just a hypothesis.

BIODIVERSITY HOTSPOT

A geographic region that has a high number of species, and is threatened by habitat destruction. These regions have been identified as priorities for conservation.

BIODIVERSITY HOTSPOTS FOR TURTLES

Species are not evenly spread across the Earth. There are some areas that have more species, and we call these areas **biodiversity hotspots**. A biodiversity

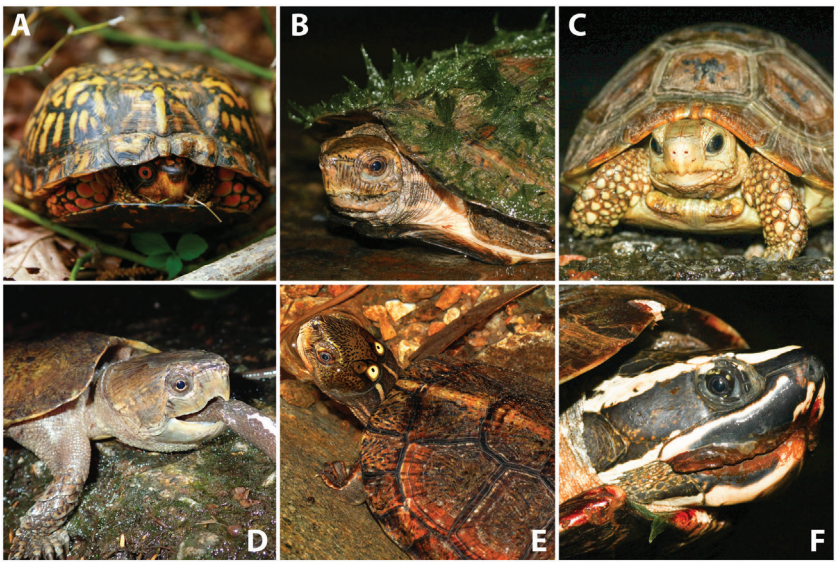

FIGURE 1

Turtle diversity. Although all turtles have shells, the various species can look very different. **A.** The common box turtle (*Terrapene carolina*) can completely close its shell for protection. **B.** Oldham's leaf turtle (*Cyclemys oldhamii*) spends so much time in the water that algae may grow on its shell. **C.** The elongated tortoise (*Indotestudo elongata*) lives in dry, hot areas and has short, stubby feet like an elephant. **D.** The big-headed turtle (*Platysternon megacephalum*) has a big head that can't be pulled into its shell. **E.** The Beal's-eyed turtle (*Sacalia bealei*) has spots on the back of its head that look like eyes. **F.** The Malayan snail-eating turtle (*Malayemys macrocephala*) has bright white stripes on its black head (All photos by Yik-Hei Sung).

ENDEMIC

Being native to a particular geographic area. Usually this is used to refer to a species that is only found in a small area.

hotspot can be even more special if it has a lot of **endemic** species. An endemic species is special because it is *only* found in that place. For example, the emperor penguin is endemic to Antarctica—it isn't found anywhere else on Earth. Three biodiversity hotspots for turtles are found in tropical and subtropical Asia: the Ganges–Brahmaputra floodplains, the Indo-Burma hotspot, and the Sundaland hotspot. The Ganges–Brahmaputra floodplains hotspot includes Bangladesh, Bhutan, China, India, and Nepal. The Indo-Burma hotspot includes Cambodia, China, Myanmar, Laos, Thailand, and Vietnam. The Sundaland hotspot includes Indonesia and Malaysia. More than one quarter of the world's turtles are found in these three hotspots [2].

THE ASIAN TURTLE CRISIS

Human actions are pushing turtles toward extinction. There are three main causes. First, the natural habitats that turtles live in are being destroyed. Many turtles move back and forth between dry land and water, so damaging either of these habitats can be bad for turtles. Second, turtles are being hunted to be used as food. In many countries in Asia, turtles are eaten as food because there is a cultural belief that eating turtle meat can heal and protect the body. There is no scientific evidence to suggest that turtle meat is any different from other meats and seafood [3], but people in Asia still prize turtles for food. The third thing pushing turtles toward extinction is that turtles are hunted to be sold as pets. Often, turtle species that are rare and exotic are the most popular. The situation for Asian turtles is especially serious. This serious situation has been given the name "The Asian Turtle Crisis" [4]. The destruction of habitats and the huge demand for turtles as food and pets are putting Asian turtles in danger of extinction.

The life cycle of a turtle also puts it at high risk of going extinct (Figure 2). There are four main stages in a turtle's life cycle—egg, hatchling, juvenile, and adult. Turtles lay eggs just like birds and many other reptiles. In fact, turtles and birds are closely related, but that is a story we will leave for another article. Just like the name sounds, a hatchling is the baby that hatches out of the egg. As the hatchling grows bigger, it becomes a juvenile. This is like a teenager for humans.

FIGURE 2

General life cycle of a turtle. There are four main stages in the life cycle of a turtle—egg, hatchling, juvenile, and adult. Many individuals die as eggs and hatchlings. Changing from a juvenile to an adult takes a long time. Once an adult, the turtle can reproduce many times in its lifetime. Hunting usually targets adults. It is hard for a turtle population to survive when adults are taken away, because there are no turtles left to reproduce.

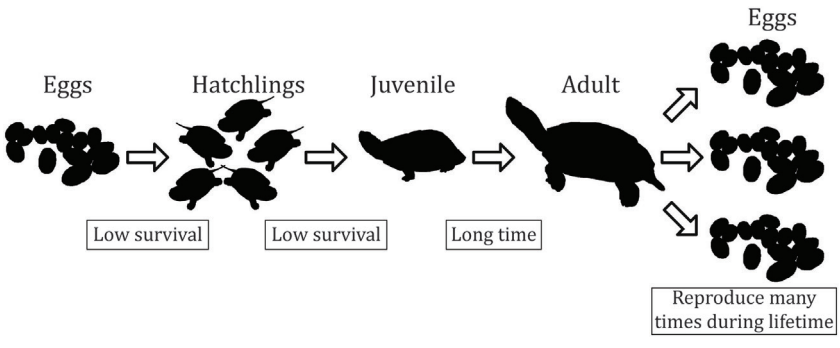

FIGURE 2

Lastly, the juvenile becomes an adult when it can reproduce. During the egg and hatchling stages, many turtles die (Figure 2) [5]. Juveniles and adults can survive well because their shells are so good for protection. Changing from a juvenile to an adult takes a long time—often more than 10 years. But once an adult, a turtle can live a long time and reproduce many times in its lifetime (Figure 2). Turtle populations survive because a few adults keep reproducing. Why does hunting put turtles at a high risk of extinction? It is because hunters usually take adults. Once the adults are taken, there are fewer turtles that can reproduce and the population starts to disappear.

WHY ARE TURTLES IMPORTANT?

TOTAL BIOMASS

The mass of a group of individuals from an area at one time. This measurement is often used to understand how important an organism is to the ecosystem.

Scientists are slowly gathering evidence of the important role turtles play in the ecosystem. One way to calculate the importance of an animal in an ecosystem is to measure the **total biomass**. If you could collect all the animals of one species and weigh them together, this would be the total biomass of that species. This kind of measurement is impossible, so scientists have found ways to estimate total biomass, such as multiplying the estimated population size with the average body weight. Studies have found that the total turtle biomass is one of the highest for vertebrates (which include mammals, amphibians, reptiles, fish) [6]. Based on this, if you think mammals are important in an ecosystem, turtles may be even more important.

An important function of turtles in an ecosystem is as both prey and predator [7]. Turtle eggs and hatchlings are prey for many animals. Fish, snakes, crocodiles, birds, mammals, and other turtles are known to eat eggs and hatchlings [7]. One reason for the low survival of turtle eggs and hatchlings (Figure 2) is because they are food for other animals. If turtles disappear, many animals will need to find new sources of food. As predators, many turtle species eat both plants and animals. Turtles that eat fruits can help the plant disperse its seeds [8]. If turtles disappeared, these plant species may have trouble reproducing and may also disappear. Turtles that eat meat often scavenge for dead animals. By eating dead animals, turtles keep an ecosystem clean and help the decomposition process [7].

TURTLE CONSERVATION AND YOU

Conservation is never easy, but we believe there are four main ways to protect and preserve turtles around the world and especially in Asia. The first is education. Before reading this paper, did you know that turtles around the world are going extinct? Most people in the world know that pandas and polar bears are going extinct, but few know about turtles. Public awareness of the possibility of turtle extinction could reduce the demand for turtles as food and pets.

The second way to preserve turtles is to protect the environment. To preserve turtles, we must preserve the habitat that they live in. Many turtle species live both on land and in water, so both land and water need to be protected. Important steps include keeping the water clean and not cutting down forests. Preserving the land and water in the turtle biodiversity hotspots [2] is a good first step.

NON-GOVERNMENTAL ORGANIZATION

Any non-profit, voluntary citizens' group. These groups are independent of the government and focus on specific issues, such as human rights, environment, or health.

The third way to protect turtles is legislation. In addition to the governments of countries, **non-governmental organizations** (NGOs) can help to make laws to protect turtles. NGOs are organizations that work independently of the governments, are non-profit, and usually work to address a social or political issue. Two important NGOs working on the conservation of biodiversity are the International Union for Conservation of Nature (IUCN) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Governments and NGOs can work together to pass new laws or strengthen old laws to protect turtles. For example, IUCN and CITES have lists that indicate how endangered a species is. Almost all countries around the world are members of IUCN and CITES and follow their rules. The turtle specialist group in IUCN has reevaluated how threatened turtle species are and has submitted a proposal to raise the protected status of many species [1].

The fourth action to preserve turtles is research. We need to understand the turtle species to protect them. A few basic things we need to know are where they live, what they eat, and how they reproduce. We can use this information to help with conservation. For example, the major threat to many endangered turtle species is hunting, so understanding where the turtles live can help us decide where to crack down on illegal hunting. Some turtle species have become too rare in the wild, so breeding and releasing turtles into the wild is needed to restore their populations. Breeding is usually done by zoos, but there are NGOs that anyone can join to help with breeding. Studying turtles to understand what they eat and how they reproduce is essential for successful breeding and conservation of turtles.

There are many things that you can do to help turtle conservation. First, you can teach others about turtles. If you have a project in your science class, you can choose to study and present information about the Asian Turtle Crisis. Second, if you want to keep a turtle as a pet, do some research beforehand so you don't choose a rare or endangered turtle species. An even better choice is to adopt a turtle. Many people buy turtles for pets when they are cute and small, then discard the turtle when it gets too big and takes too much work to care for. If you want to adopt a turtle, you can go to your local animal shelter or search online for local organizations that rescue abandoned turtles. But make sure you are ready for the big responsibility of caring for a turtle. The third thing you can do to help turtles is to keep studying hard in school. For your future job, maybe you will become a scientist that studies turtles. Maybe

you will be a politician and help pass laws to protect turtles. Maybe you will join an NGO that protects turtles. There are many jobs in which you can help protect turtles!

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REVIEWED BY

JACK G. DESMOND MIDDLE SCHOOL, AGE: 13–14

This article was reviewed by the students of Desmond Middle School in Madera, California. The school is located in a rural part of the San Joaquin Valley of California and strives to provide scholastic opportunities to lower income families that they would otherwise not have access to. The class that reviewed this article is an engineering elective offered at Desmond that brings students closer to possible future career paths in the sciences and engineering.

AUTHORS

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I am an assistant professor in the Science Unit at Lingnan University, Hong Kong. For research, I am interested in evolution and how it shapes the biodiversity on Earth. By using DNA data, we can understand how closely related populations/species are and connect it to geography. These results can be applied to protecting endangered species. I am particularly interested in amphibians and reptiles, but have also worked on bacteria, fungi, and invertebrates. *jonfong@ln.edu.hk

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DIVERSITY OF TROPICAL SPIDERS

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Spiders are among the most diverse groups of animals on the planet. There are over 45,000 known species of spiders. Most of this diversity is found in the tropics. However, scientists believe that there may actually be over 100,000 spider species, most of which we simply have not found yet. Exploration of the biodiversity of the tropics is still far from complete, and spiders are an important part of that biodiversity. In this article, we provide an overview of the world of spiders in the tropics.

YOUNG REVIEWER:

LUCAS
AGE: 12

TAXONOMY
A field of biology that discovers, describes, and names new species.

ARANEOLOGIST
A spider scientist.

DNA
A molecule present in every single cell, containing genetic information.

Taxonomy is the field of biology that describes and names new species. Spider taxonomy dates back to the eighteenth century, when you could count the number of **araneologists** (those who study spiders) on the fingers of one of your hands. Today, several hundred spider taxonomists work around the globe. Their job is to collect and discover new spider species. This is a very exciting time to be a spider taxonomist. New tools have recently been developed that use the information in spider **DNA** to understand how many species of spiders there are. Like the early taxonomists of the eighteenth century, we still carefully study

the spiders' shapes, but combining this with genetic tools has really modernized the process of discovering, describing, and naming new spider species.

SPIDER SHAPES

Spiders have two main body parts. The frontal part, known as the **carapace**, carries the spider's four pairs of legs, its head, and its eyes. Most spiders have eight eyes, but some have fewer—a few are even eyeless! The hard carapace also covers the spider's muscles, digestive system (like its mouth and stomach), and venom glands. The hind part of the spider's body, called its **abdomen**, is soft, round, and smooth. It contains

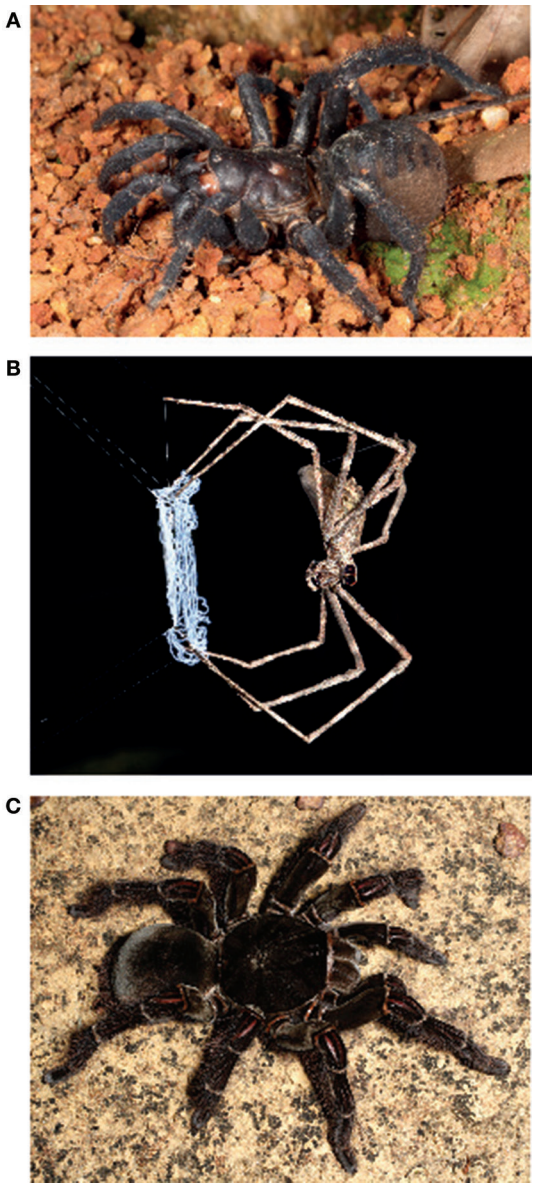

Figure 1

CARAPACE

The anterior part of a spider's body that carries its head and legs.

ABDOMEN

The posterior part of a spider's body that carries most internal organs, as well as spinnerets.

Figure 1

Three major groups of spiders. **(A)** Spiders with segmented abdomens belong to a group called **Mesothelae**. These are the most primitive, ancient spiders. **(B)** Most modern spiders belong to a group called **Araneomorphae**. Here, you can see an ogre-faced spider. Ogre-faced spiders are known for their enormous eyes and for holding their capture web with their feet. **(C)** Tarantulas, or bird-eating spiders represent the group **Mygalomorphae**.

MESOTHELAE

One of the three major groups of spiders, the most ancient one.

ARANEOMORPHAE

One of the three major groups of spiders, so called "modern spiders."

MYGALOMORPHAE

One of the three major groups of spiders, tarantulas and relatives.

SPINNERETS

Organs at the tip of the spider's abdomen that release silk.

the spider's glands that produce silk, **spinnerets**, as well as glands that help to digest food. The abdomen also contains the spider's breathing organs (spiders do not breath through their mouths), as well as its genital system. Only the most ancient, primitive spiders still have segmented abdomens, which means that they are divided into smaller parts (Figure 1A), like you would see on a shrimp, an insect, or a scorpion.

We classify spiders into over a hundred families, like jumping spiders, crab spiders, wolf spiders, ogre-faced spiders (Figure 1B), bird-eating spiders (which are also known as tarantulas) (Figure 1C), and the primitively segmented spiders. Some spiders are very good at camouflage—the art of disguise. Often, the colors of camouflaged spiders blend nicely into the environment, but spiders do a lot more than that to protect themselves. Some, for example, are difficult to tell apart from ants, and that disguise makes them safe from predators that dislike stinging ants. Tropical orb weavers have lots of different shapes. Some look like leaves, others like twigs, bark, or even bird droppings (Figure 2A) and all in order to fool

Figure 2

Diversity in shapes of orb-weaver spiders. **(A)** Some orb-weaver species mimic twigs, bark, or even bird droppings. **(B)** Others have thorny projections that predators avoid. **(C)** Others show flashy colors to warn their predators. **(D)** A species from tropical forests of China resembles a green leaf and a dried-up leaf at the same time.

their predators. Other spiders may protect themselves with armor. Spiny orb weavers, for example, have various thorny projections that predators will want to avoid (Figure 2B). Some other spiders show flashy colors intended to warn their predators that they are not the kind of prey that should be meddled with (Figure 2C). Recently, we discovered an orb-weaver spider in the tropical forests of China whose abdomen resembles both a green leaf and a dried-up leaf at the same time (Figure 2D).

SEXUAL SIZE DIMORPHISM

Great difference in size between males and females of the same species.

Male and female spiders of the same species are often different shapes and sizes, and this phenomenon, named **sexual size dimorphism**, is particularly widespread in the tropics. Most often, the males of a species are many times smaller than the mightier females (Figure 3A). Is this because the male spiders are dwarfs or because the females are giants? This question is often asked when visitors to the tropics encounter the golden orb weaver *Nephila*. The females have a leg span as large as a human face (Figure 3B), and the males are 10 times smaller. In this case, it is the females that have become giants. Still other species have giant males and females. Examples include the South American goliath spider, which is as large as a dinner plate (Figure 3C), and the giant crab spider, which often enters bedrooms in Southeast Asia. However, most spider species are small, only a few millimeters long.

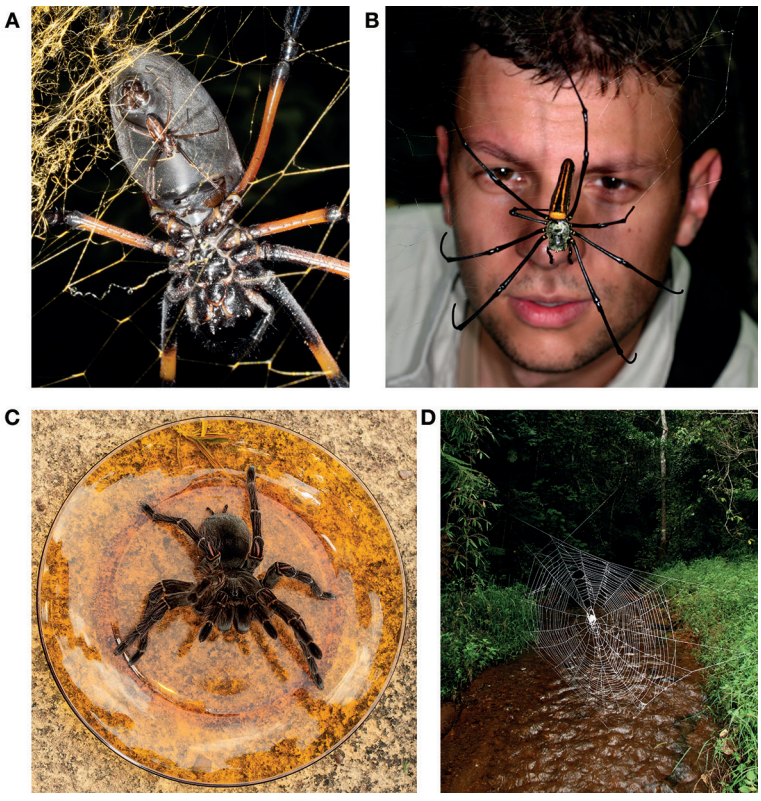

Figure 3

Spider giants. **(A)** Some female spiders are huge, but the males of the same species are small, and this is called sexual size dimorphism. Here, you can see a small golden orb-weaver male climbing on the body of the large female. **(B)** The female golden orb-weaver, genus Nephila, is a well-known giant spider. **(C)** The South American goliath spider is the largest of spiders, placed here on a dinner plate. **(D)** Darwin's bark spider from Madagascar makes the largest webs.

SPIDER WEBS

Spiders produce silk using silk glands and spigots located near the tip of the abdomen. They use the silk for many parts of their lives, with the most familiar use being the spider web, which functions to capture the spider's food. Spider webs range from very small (a few centimeters) to extremely large (a meter or wider). The largest webs are found in the rainforests of Madagascar, where majestic giant webs crisscross rivers and lakes and span up to 90 feet (Figure 3D). Those giant webs are made by Darwin's bark spider, a species we jointly discovered and named to honor Charles Darwin, the father of evolutionary biology. Darwin's bark spider uses silk of amazing strength to make its web. In fact, its silk is the toughest material in nature; as strong as steel and tougher than the materials we use to make bullet-proof vests. Tough silk means that it takes a lot of effort to break the spider's silken thread. Why then, you may ask, can I easily waive my hand through a spider web? The answer is that the spider's silk threads are extremely thin; you could also easily waive your hand through a web made of equally thin steel threads!

Spiders make diverse kinds of webs. We classify spider webs into types, such as orb webs, cob webs, sheet webs, funnel webs, ladder webs, and others. Among the best known and most diverse are orb webs (Figure 4). Spider specialists can "read" these webs much like reading a book, understanding not only which spider made a certain web, but also how the spider behaved when making it. Orb webs have glue drops on the threads, which make insects stick to the web.

Some spiders build very strange webs and use them in unusual ways. For example, ogre-faced spiders, also known as net-casting spiders, make small but intricate webs that they hold in their front pairs of legs. When a net-casting spider spots an insect walking on the ground that sets its strategy in action. The spider releases the web from its suspended position, stretches it like a bed sheet, and then literally casts it over the insect with its legs (Figure 1B). When it relaxes its grip on the web, the web then shrinks and totally engulfs the helpless prey.

Bolas spiders make very simple webs. They only spin a single thread, but at the end of that thread they make a large ball of very sticky glue. Inside the sticky ball they place **pheromones**—fragrant molecules that attract moths toward the trap. When the moth is within reach, the spider then expertly lassos the insect, which ends up glued to the silken ball: dinner is served! Some spiders make no webs at all. You may be surprised to hear that the majority of spider species are actually webless. Instead, they sit and wait, or wander around in search of prey, and use silk in other ways than to make webs.

PHEROMONES

Airborne molecules that attract males or females.

Figure 4

Spider webs come in numerous forms and shapes. Here are some examples of orb webs, which are among the best known and most beautiful types of webs.

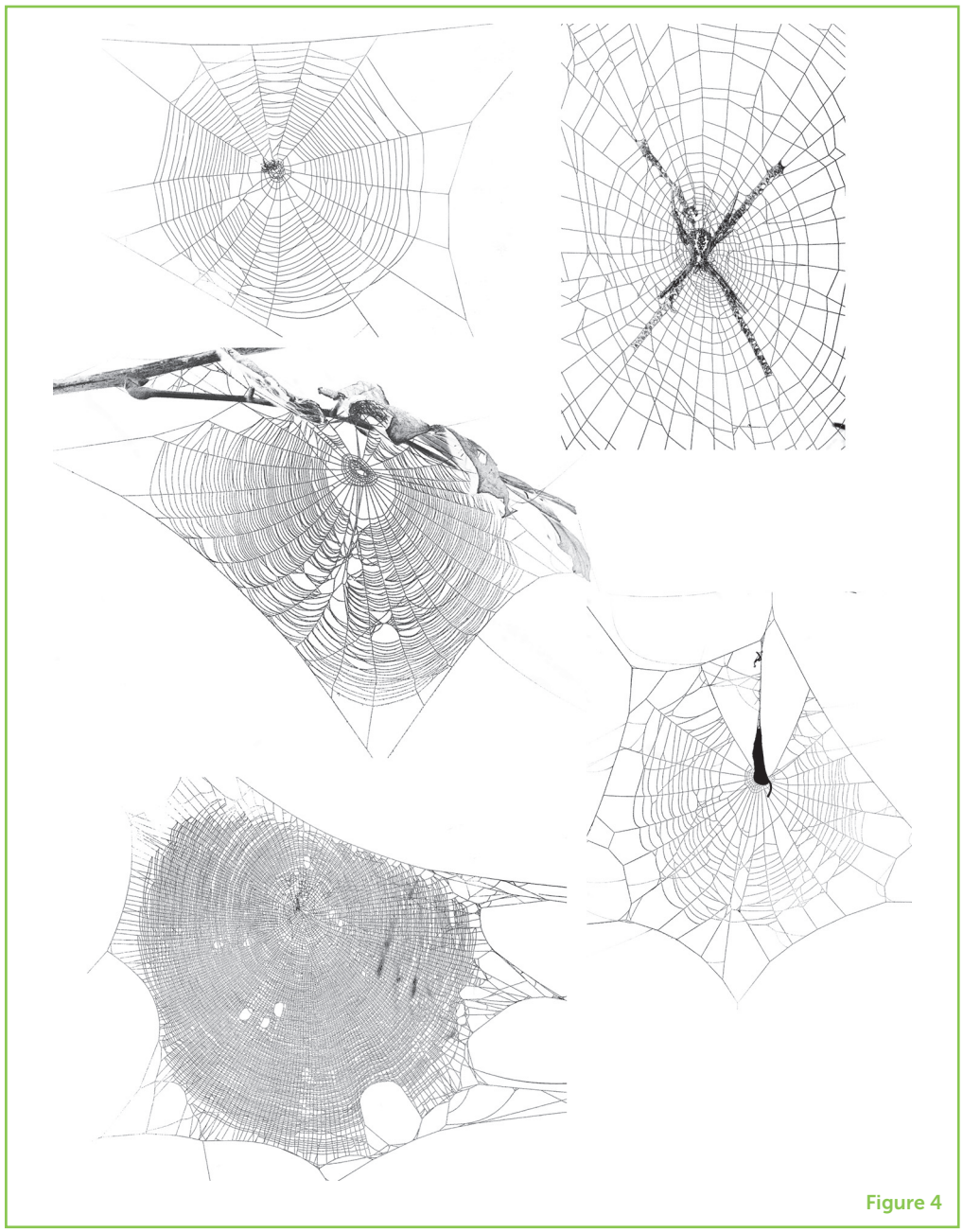

Figure 4

Most spiders live solitary lives, without interacting with other member of their species, except to mate. Only a few spiders are known to be social and form groups—many people's darkest nightmare! Some spiders make community webs but continue to mind their own business, while others, the true social spiders, make common nests that contain males, females, and baby spiders (called spiderlings) working together (Figure 5A). Social nests contain a few to over 10,000 individual spiders, and such spiders, only known in the tropics, attack their prey together, as a group. We have discovered numerous social species of spiders from tropical America, Africa, Madagascar, Asia, and Australia.

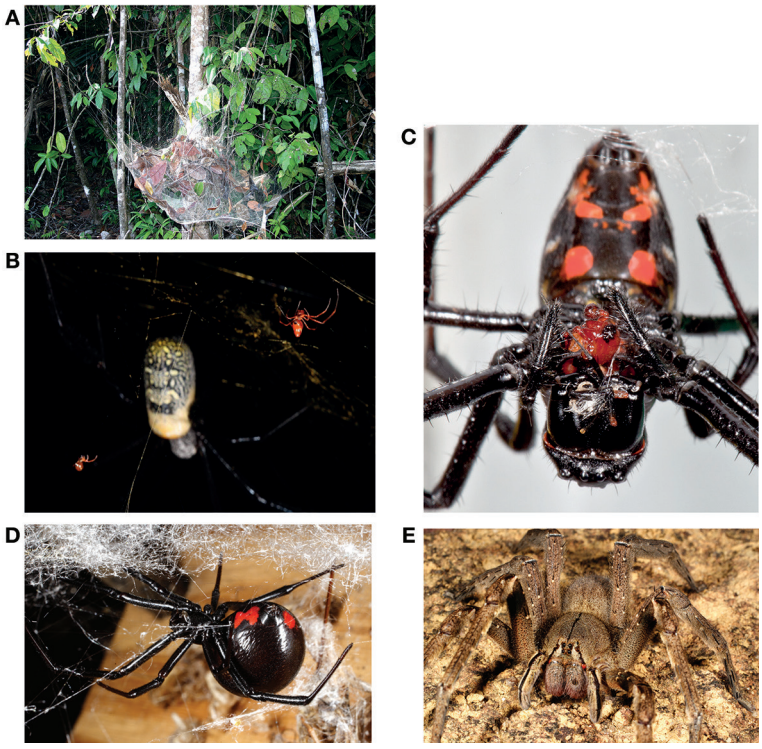

Figure 5

Tropical spider natural history. **(A)** Social spiders make communal nests, where many spiders live together. **(B)** Kleptoparasites are little spiders that live in bigger spiders' webs and steal their food. **(C)** Some spider females kill and eat the males when they are not in the mood for love. **(D)** Among the venomous spiders are black widows and **(E)** the aggressive South American wandering spider.

SPIDER BEHAVIORS

Behavioral science studies how animals interact with each other, with their prey and predators, and with their partners. Spiders may have many eyes, but most spider species have poor vision. They rely on other senses instead, such as smell, taste, and touch. It is fascinating to study how orb weavers build their webs, attack prey, avoid predators, and meet their mates, all in near blindness.

Some tropical spiders make meals out of small lizards, snakes, birds, or bats. Most spiders, however, eat insects. A lot of insects! If spiders were eliminated from the planet, their prey—the insects—would take over in huge numbers.

Instead of making their own webs, some spiders prefer a more cunning lifestyle. They sneakily live in webs of bigger spiders, where they steal their hosts' prey, eat their silk, prey on their offspring, and sometimes even kill the bigger spider (Figure 5B). Scientifically, we call these spiders' **kleptoparasites**, a name literally meaning "parasites that steal."

KLEPTOPARASITES

Small spiders (or other organisms) that steal prey form other species.

When large female spiders are not in the mood for a relationship, they can attack an approaching male, and even make a meal out of him (Figure 5C). Small male golden orb weavers approach these females cautiously.

They jerk their bodies, pluck the female's web, and gently lay fine silken threads onto her, all in the hopes of calming her down, and not starting a fight in which they might end up on the dinner table.

How do spiders travel to remote places, such as islands in the middle of the ocean? Do they fly without wings? Actually, they do! They travel by **ballooning**, meaning they fly in the wind currents with the help of silken threads—like those they use to build their webs. They travel away from their birthplace often when still small, and then they settle down in a new place. This behavior explains why spiders are among the first animals to occupy volcanic islands that have recently emerged out of the ocean.

BALLOONING

Airborne travel by small spiders using silk to disperse via air currents.

SPIDER VENOMS

What probably pops up in most people's minds when they think about spiders is their venom, the reason that spider bites hurt. Almost all spiders have venom glands, organs in their bodies that make a poisonous cocktail, which is used to kill prey. Spiders inject this venom into the body of an insect or other prey through pincers-like weapons called **chelicerae**. Spiders also use venom for defense.

CHELICERAE

Pincers-like weapons a spider uses to inject venom into its prey.

Most venoms are fairly harmless to humans, but in some cases, the venom is powerful enough to paralyze—even occasionally kill—a human being. Have you heard of the black widow? That is one such spider (Figure 5D). The most venomous of all spiders are a few tropical species, like the much-feared banana spider, genus *Phoneutria*, a large and aggressive South American wandering spider (Figure 5E). Another dangerous spider is the violin spider, also found in tropical America. The Sydney funnel-web spider of Australia is probably the deadliest of all.

Luckily, spider bites are not really that common, and serious injuries or deaths from spider bites are very rare. In fact, most of the time, conditions that doctors diagnose as a "spider bite" are probably something else. Rashes from plants, insect stings, bacterial infections, and a variety of other options should be among a doctor's first guesses, long before the doctor considers an injury to be the result of a spider bite.

HOW MANY SPIDERS ARE OUT THERE?

There is an enormous number of spider species in the wet tropics. Studies have counted several hundred species of spiders in a single small forest patch (a hectare, 100 m long and wide), and have further estimated that up to a thousand species may exist in a single forest. If many of these species live only in that particular environment, then

imagine the numbers of spider species around the equator, and around the world. As we mentioned above, there might easily be well over 100,000 species of spiders. But how about the number of individual spiders? In the South American country of Guyana, a hectare of tropical moist forest was estimated to harbor over one million individual spiders at a given moment in time. These were mostly quite small, averaging only 2.8 mm.

Two major problems limit our knowledge of tropical spiders. One is the destruction of habitats, which is leading to species extinctions. Through habitat destruction, we lose many more species than experts manage to discover and describe which brings us to the second major problem. There are too few spider specialists to do the job of discovery and description of spider diversity. We hope that this article will inspire a new generation of young and budding scientists to perform this important research.

We hope you enjoyed our brief foray into spider diversity in the tropics. Thousands and thousands of spiders of unknown species, shapes, and behaviors have yet to be discovered: why do you not join us?

ACKNOWLEDGMENTS

We dedicate this paper to our kids Eva, Amélie, Maj, and Francis. And to all other kids around the world: Stay curious and explore nature.

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CONFLICT OF INTEREST STATEMENT: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWER

LUCAS, AGE: 12
I live in Western Australia. I like music and going for walks in the bush.

AUTHORS

MATJAŽ KUNTNER
I am a biologist from Slovenia, and although Slovenia has almost a thousand species of spiders, I prefer to wander into the tropics, where spiders are even more diverse, and interesting. I have discovered dozens of species of spiders, among them the largest golden orb weaving spider, as well as Darwin's bark spider that makes by far the largest capture web. Together with Ingi, we not only discover new spider species, but also new types of webs and behaviors. *kuntner@gmail.com

INGI AGNARSSON
I am from Iceland, another spider guy who travels the world looking for these creatures. Often, this involves wandering around in the forest in the middle of the night wearing a headlamp, looking around, and sometimes hitting a tree with a stick to see what falls down. In this way, I discover new species, particularly those of social spiders. Then, I take these specimens to the lab to study them, and then work at the office writing papers about discoveries, like this little article.

frontiers FOR YOUNG MINDS

BIODIVERSITY
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IS ARTHROPOD BIODIVERSITY ON THE RAINFOREST FLOOR THREATENED BY RUBBER AND PALM-OIL PLANTATIONS?

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YOUNG REVIEWER:

LUANA

AGE: 15

Tropical rainforests are a particularly threatened type of ecosystem because humans are converting rainforests into farmland. On Sumatra, the world's sixth largest island, most of the tropical rainforest that once covered the island has been turned into plantations for rubber trees and oil palms. Rubber and palm oil, the agricultural products produced from such plantations, are an important source of income for the local farmers. Unfortunately, replacing rainforests with plantations reduces the number of arthropods, like insects and spiders that would normally live in the rainforests. This can have negative effects on ecosystem functions that are normally carried out by these arthropods, such as the decomposition of dead organic matter or the control of crop pests. We went to Sumatra to find out what happens to communities of ground-living arthropods, a diverse and ubiquitous group of animals important for the functioning of ecosystems, when rainforest is turned into plantations.

INTRODUCTION

Tropical Rainforests Are Being Converted to Agricultural Plantations

Tropical rainforests are among the most biodiverse ecosystems on earth. This means that they are home to more species of plants, animals, fungi, bacteria, and other forms of life than most other ecosystems on our planet. At the same time, tropical rainforests are threatened by humans, as we continuously turn large areas of forest into agricultural plantations. On such plantations, people can grow food and other natural products for themselves or to sell to global markets in order to earn money to feed their families. Humans have been turning forests into fields for their crops and pastures for their livestock since about 10,000 years ago, but the number of humans on earth keeps increasing, while the amount of forest land worldwide grows smaller every day. We need to understand the consequences that the conversion of forests to farmland has on the communities of organisms living in the forests, because these organisms keep ecosystems working in a healthy way. With this knowledge, we can conserve the most important natural forest areas, design farmland that has less negative impact, and, at the very least, be prepared for the negative impacts of rainforest conversion that might be unavoidable in the future.

Threatened Indonesian Rainforests Are a Biodiversity Hotspot

BIODIVERSITY

The variability of life, typically measured at the ecosystem level, the species level or the genetic level. Biodiversity loss is a major threat to natural ecosystems and mankind.

Southeast Asia is a hotspot of **biodiversity**, which means there are large numbers of rare species. Southeast Asia is also an area in which these species are threatened by loss of their natural habitat. Indonesia lies at the heart of this biodiversity hotspot, which makes it an important area for the conservation of natural habitats and the species that live there (Figure 1A). Unfortunately, Indonesia's rainforests are threatened by high rates of deforestation [1], in which forests are removed and replaced by other types of ecosystems. Moreover, Indonesia is the world's biggest producer of palm oil, a vegetable oil that is commonly used to produce food (everything from bread to ice cream), soaps, and even fuel. Also, rubber-tree plantations producing natural latex are common in Indonesia. Both oil palms and rubber trees are typically planted in **monoculture** (single-species) plantations by farmers or large companies. Just like most other monocultures, rubber and oil-palm plantations differ a lot from the ecosystems that they have replaced.

MONOCULTURE

An agricultural practice of growing only one crop species in a given field at a time.

Biodiversity Loss Has Consequences for the Way Ecosystems Function

When rainforests are destroyed, many species cannot survive in these areas and can vanish completely. Every species plays its own specific

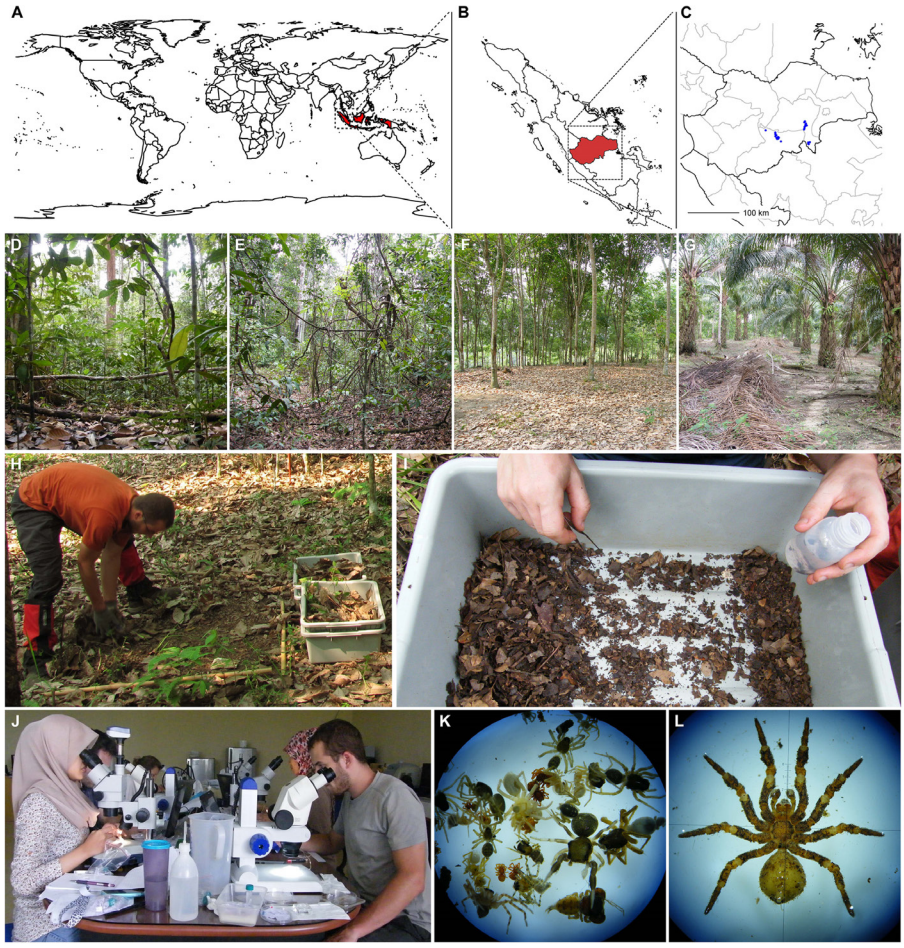

Figure 1

Figure 1

What did we do and how did we do it? Our study was conducted in Indonesia, in red **(A)**, on the island of Sumatra **(B)**, in the Jambi Province, in red. Blue dots in **(C)** show the distribution of research sites within two regions in the Jambi Province. Sampling took place across a total of 32 sites: 8 sites in each of 4 land-use systems: forest **(D)**, jungle rubber **(E)**, rubber plantations **(F)**, and oil-palm plantations **(G)**. On each research site, we collected the leaf litter on three square-meters of ground and dumped it onto a sieve **(H)**. Animal individuals were collected from the siftings by hand **(I)** and taken to the lab **(J)** where they were sorted into major groups, such as spiders **(K)**. They were then identified, counted and measured for their body length **(L)** to calculate individual body masses.

role within the ecosystem that it lives in. Every species consumes certain resources and is in turn eaten by other organisms higher up in the food chain. All of the organisms in an ecosystem carry out some work that keep ecosystems functioning–for example, by pollinating plants, helping dead organic matter (dead plants and animals) to decay, or by feeding on other animals. Scientists call these processes "ecosystem functions." We do not know all of the species on earth and we certainly do not know what all of them do. But we do know that if we lose species, we are in danger of losing the functions that they carry out. We, as ecologists, are interested in how different organisms interact and how these interactions affect the way that ecosystems function.

Can Arthropods Tell Us How Rainforest Loss Will Affect Tropical Ecosystems?

If you are interested in species loss in tropical forests, you will often hear about charismatic and well-known species, such as tigers and great apes, being endangered. While these beautiful and interesting species are important for their ecosystems, there are other organisms that often

escape the eye and that we know very little about. However, this does not mean that these less well-known species are less fascinating or important for the ecosystems they live in. **Arthropods** are one of the most diverse groups of organisms on our planet. Insects, spiders, centipedes, millipedes, and isopods are major groups of arthropods that you almost certainly see every day. You have probably noticed that there are many arthropods around of many different kinds. There are far more arthropods on our planet than primates and tigers combined. In fact, there is more total **biomass** (or weight) of arthropods than of mammals on earth [2]. Their wide distribution, diversity, and high biomass make arthropods important for the functioning of ecosystems, and thus we decided to focus on them for our study. Because we wanted to know what happens to arthropod communities when their natural habitat is turned into agricultural plantations, we went to Indonesia to study tropical arthropods in a rainforest that was being converted to rubber and oil-palm monocultures [3].

ARTHROPODS

A taxonomic group of animals defined by having an external skeleton, body segments and pairs of jointed appendages. Examples include spiders, insects (like beetles), and woodlice.

BIOMASS

Here, the total weight of all animals present in a given area, for example the total weight of all arthropods found on one square meter of rainforest ground.

WHAT DID WE DO AND HOW DID WE DO IT?

Studying the Effects of Changing Land Use for Ecosystems and Humans in Indonesia

In 2012, a large group of German and Indonesian researchers set out to study the consequences of changing **land use** on Sumatra, Indonesia. Within the project, small teams worked on different topics related to the overall question, "What happens to ecosystems and to the local people after tropical rainforests are turned into rubber and oil-palm plantations?" The first researchers that got to Sumatra (Figure 1B) chose and marked field sites where the teams could measure different organisms, soil characteristics, and local climate conditions. Across two different regions (Figure 1C), they selected 32 sites in rainforest, jungle rubber, rubber, and oil-palm plantations (Figures 1D–G). Jungle rubber is a special type of rubber plantation where rubber trees are planted inside the rainforest between the other trees. Rubber and oil-palm plantations are like cornfields, because they have only one species of plant that is maintained as a monoculture crop. In each of the two different regions, the researchers made sure that there were four repeated sites in each of the four types of land use. This replication (repeated measures of each system) assured that we could assess the average conditions for each system.

LAND USE

The management and modification of natural environments to provide certain goods or services. For example, oil-palm plantations are a managed agricultural environment providing palm oil.

Collecting Ground-Dwelling Arthropods on the Research Sites

Between October and November 2012, we sampled arthropods that live on the ground at the various sites, by collecting the decaying leaf litter from the forest floor and searching through it to find all the arthropods.

To do this, we built self-made sieves with a mesh size of about 2 cm. On every research site, we randomly selected three square-meter plots where we collected the leaf litter by scratching it off the ground with leather gloves (because you never know what potentially venomous animals you might find in tropical forests) and dumped it into the sieves (Figure 1H). As we shook the sieves, the smaller animals would then fall into the boxes below, where we could then hand-collect all the arthropods that we found (Figure 1I) and take them back to the laboratory.

Arthropod Samples Were Further Processed in the Laboratory

In the laboratory (Figure 1J), we first sorted the arthropods into major **taxonomic groups**, such as beetles, millipedes, or spiders (Figure 1K). We measured the body length of each individual and identified which species they were (Figure 1L). Many of these tropical arthropod species have never been found or described by scientists and have no name. Because of this, we had to try to distinguish different species by what they looked like, even though we did not know their official name. Then, we counted the number of individuals of each species on each of the sites and determined what **feeding guild** they belonged to: predators (feeding on other animals), herbivores (feeding on plant material), detritivores (feeding on dead animal or plant material) or omnivores (feeding on more than just one of these food resources). To determine arthropod biomass, we first estimated body masses based on the individual body lengths of all animals. Then, we added up these individual body masses to obtain total arthropod biomass, which is the total weight of living arthropods, for each of the different feeding guilds at each site.

TAXONOMIC GROUP

Taxonomy defines and names groups of organisms based on shared characteristics. Taxonomic groups can be defined at any level of taxonomic organization, for example the insect order Coleoptera—beetles.

FEEDING GUILD

A group of animals defined by what they eat, for example detritivores feeding on dead animal or plant material.

We Used Statistical Tests to Understand Changes in Arthropod Communities

After collecting 7,472 arthropod individuals, measuring lengths, calculating biomasses, counting numbers, and assessing species diversity, we used statistical tests to find out if there were overall differences in the arthropod communities in the leaf litter of the four different land-use systems. Additionally, we tested if the changes in diversity, individual density and biomass from forests to plantation ecosystems differed between the four feeding guilds.

WHAT HAPPENS TO ARTHROPODS ON THE FOREST FLOOR?

Oil-Palm Plantations Had Fewer Arthropods Than Did Forests

We found that oil-palm plantations contained fewer species, fewer individuals, and lower biomass of arthropods than the forest sites

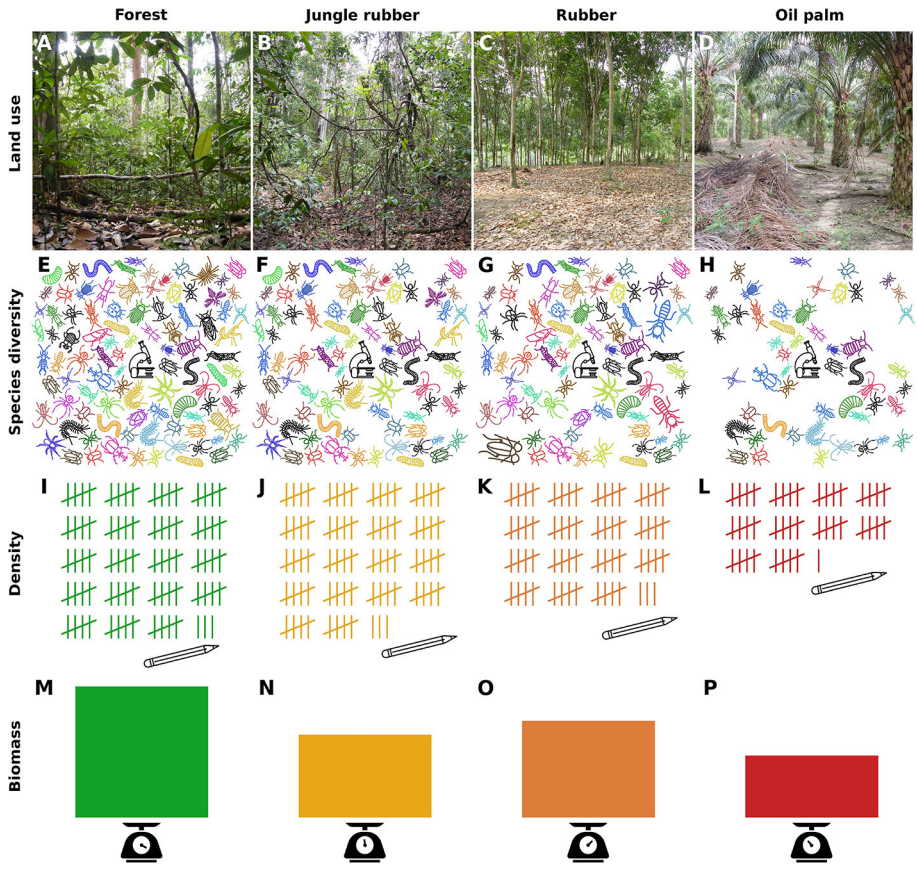

Figure 2

Figure 2

What did we find? Across the four land-use systems, forest **(A)**, jungle rubber **(B)**, rubber plantations **(C)**, and oil-palm plantations **(D)**, we analyzed litter arthropod species diversity on three square meters per site **(E–H)**, counted the number of arthropods per square-meter (density, **I–L**) and calculated arthropod biomass **(M–P)**. Results for the four land-use systems are presented in the columns below the pictures of those systems. We calculated the average values across the eight replicate sites per land-use system, which are shown by the number of species icons and tally marks. The biomass bars show average arthropod biomass per square meter and vary between 342 mg/m^2 in the forest and only 161 mg/m^2 in oil-palm plantations. In comparison with the forest sites, species diversity was reduced by 45%, individual density by 48%, and biomass by 52% in oil-palm plantations, respectively (Animal drawings by Yu luck, weighing scale altered after anbileru adaleru, pencil and tally marks altered after Juan Pablo Bravo, and microscope by Gregory Sujkowski from the Noun Project).

did (Figures 2A–D). In comparison with the forest sites, species diversity was reduced by 45% (Figures 2E–H), individual density by 48% (Figures 2I–L), and biomass by 52% (Figures 2M–P), respectively. This means that arthropod communities in the leaf litter were roughly halved in oil-palm plantations compared with rainforests. Now, what does this mean and why does it matter? Biodiversity loss has various consequences. In some cases, these consequences are more obvious, such as when a top predator—a species high up in the food chain that consumes other animals but is rarely ever consumed by others is lost. In this case, there can be cascading effects along the food chain because losing the top predator can result in an increase in its prey but a decrease in that prey's food, and so on. For example, losing wolves could lead to large herbivores, such as elk, growing in number because they are not being hunted, and feeding far more on the plants they like to eat, which are then heavily reduced. This changes the look of the ecosystem but also the functions that are carried out by the community. In most cases, the changes that happen following the loss of a few species might not be as dramatic. Still, other species that would normally feed on the lost ones will either need to switch food resources or leave their homes to find food elsewhere, so they do not starve. In our study, we found that the effects of land-use change from forest to oil palm differed between the four feeding guilds.

For species diversity and individual density, land-use change had the strongest negative effects on predators. As we explained in the example above, these changes in predator populations are concerning, because they can have cascading effects on other animal and plant species and disrupt the way that the whole ecosystem functions.

Biodiversity Loss Has Negative Consequences for the Way Ecosystems Function

Besides consequences for the animal and plant communities, there are other issues with biodiversity loss. For example, we know that in many cases higher biodiversity allows ecosystems to healthily perform several functions. Losing biodiversity might therefore lead to a loss in some of the services that people receive from ecosystems like clean air, clean water, and healthy soils. This is true for ecosystem functions, such as the growth of plants in grasslands, which humans rely on for producing food. Moreover, where there is higher biodiversity, ecosystems are able to perform more functions at the same time. This means that higher numbers of species in ecosystems can often provide more natural benefits to humans, which is one of the important reasons for protecting global biodiversity.

WHAT CAN WE DO TO PREVENT MORE SPECIES LOSS IN TROPICAL RAINFORESTS?

Our study has shown that arthropod species diversity, density, and biomass are strongly reduced in agricultural systems like oil-palm plantations. However, palm oil is a very important agricultural product in global food and fuel markets. Furthermore, oil palms produce more oil per unit area than other plants. This means that in order to switch from using palm oil to other vegetable oils, we would need to turn even larger areas of land into plantations. One way that we can prevent tropical species loss is to reduce our overall consumption of palm oil, by avoiding products that are made using it. This will help to convince larger companies that they should use less environmentally harmful products. Additionally, we can try to make palm-oil production more sustainable by reducing its negative impacts on nature. This can be done by using already cleared sites for new plantations, rather than cutting down existing forests. As another alternative, colleagues in our research project have established enrichment plantings in an oil-palm plantation [4]. They removed a few oil palms and planted small patches of local trees in the resulting gaps. The different tree species are used for timber production or to produce fruits and thus result in additional income for the plantation owner. At the same time, the tree patches attract and provide habitat for native bird and arthropod species within

the plantations and even lead to an increase in productivity of the oil-palm plantation. Such experiments and their results could be used to convince plantation owners to enrich their monocultures with additional plant species in order to make palm-oil production more sustainable and maintain higher levels of tropical biodiversity.

AUTHOR CONTRIBUTIONS

MJ wrote the first draft and created the figures and AB contributed to revising the manuscript to make it accessible for young minds.

ACKNOWLEDGMENTS

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ORIGINAL SOURCE ARTICLE

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YOUNG REVIEWER

LUANA, AGE: 15
I am a 15 years-old girl, who is passionate about animals, in particular, dogs. I want to become a Veterinarian Neurosurgeon, and help design prosthetic capable of interacting with the animals' nervous system. I love singing, being artistically creative, and biology.

AUTHORS

MALTE JOCHUM
I studied Biology because, as a teenager, I built a small pond in my parents' garden and realized that this subject would never cease to amaze me. As a community ecologist, I am very interested in how human activities affect the structure and functioning of plant and animal communities. My work has focused on aquatic and terrestrial ecosystems across temperate and tropical areas and mainly involves arthropods. When not at work, I like to explore nature with my daughter, do rock climbing, cycling, or canoeing and, more recently, I discovered an interest in beginner-level triathlon. *malte.jochum@idiv.de

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ANDREW D. BARNES

Since a very young age, I have been fascinated by the diversity and complexity of our natural world, especially that found in tropical rainforests. I work as a community ecologist, investigating how species interact with each other and how their interactions affect the way that ecosystems function. I am particularly interested in forest ecosystems and how humans impact the organisms that inhabit them, including everything from microbes to insects to birds. In my free time, I love doing outdoor activities like hiking and rock climbing, as well as traveling to other countries to explore new ecosystems and cultures.

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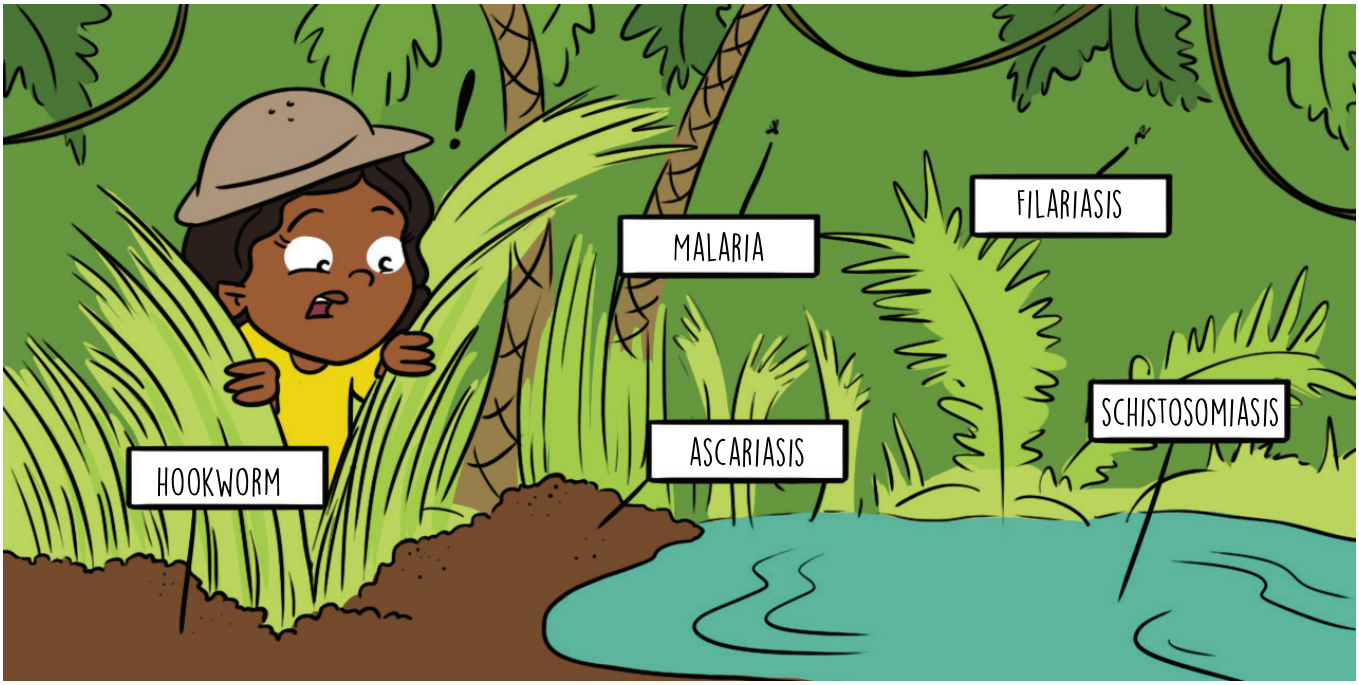

IMPORTANT HUMAN PARASITES OF THE TROPICS

*Binh Cao and Pascale S. Guiton**

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YOUNG REVIEWER:

ANNA-MARIE
AGE: 13

All living things on this planet interact in one way or another with other living things. We use different terms to describe the interactions between two different species. If both species benefit from interacting with each other, that is, if each species relies on the other one for its well-being, then the relationship is called mutualism. In contrast, antagonism is the term used to describe a relationship that benefits only one of the species, while causing harm to the other one. In this article, we discuss a specific type of antagonism called parasitism. We will provide an overview of the diversity of parasitic species, discuss their role in major tropical diseases, and highlight the importance of the study of parasites to the medical field.

WHAT IS A PARASITE?

PARASITE

A microorganism that lives in or on another organism from which it obtains nutrients and harms in the process.

The word "**parasite**" will make most people cringe, probably because they associate it with little worms living inside them. This is not completely wrong, as we will see later. In the ancient Greek, however, the term "*parasitos*" was initially used to describe community officials who went

Figure 1

Different groups of parasitic organisms. The asterisk (*) shows the groups of organisms that are considered parasites in the field of parasitology, which is the scientific study of parasites (These organisms are not drawn to scale).

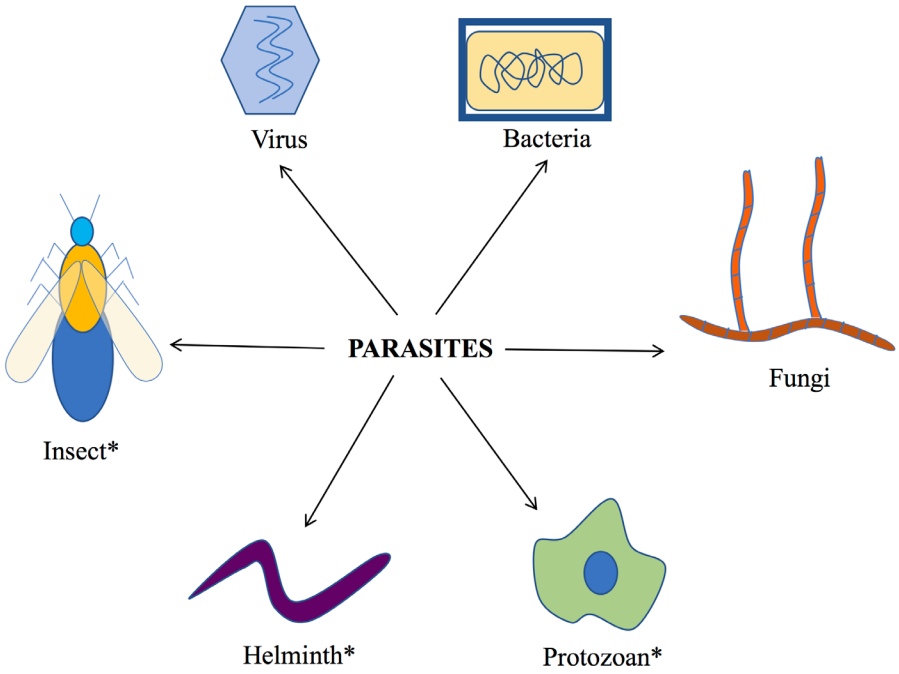

Figure 1

to public events and spent the community's money for their meals and entertainment [1]. Over time, "parasite" evolved to describe any person who lives off of other people's riches. It was not until the seventeenth century that the biologist Carolus Linnaeus used the term parasite to describe tapeworms. Nowadays, a parasite refers to any **microorganism** that is adapted to life in or on another organism, from which the parasite obtains nutrients while causing the other organism harm. This broad definition includes viruses and members of the six Kingdoms of life, namely Archaea, Bacteria, Fungi, Protozoa, Plantae, and Animalia (Figure 1). Yet, in parasitology, the field of biology that studies parasitic organisms, the term "parasite" applies only to protozoans (animals made up of a single cell), helminths (parasitic worms), and insects.

MICROORGANISM

An organism that is too small to be seen with the naked eyes.

PARASITES ARE VERY DIFFERENT FROM EACH OTHER

Parasitologists (scientists who study parasites) study a very diverse group of organisms. In fact, the number of different species of parasites is so large that it is impossible to count all of them. Parasites can be divided into groups using many features, including their shapes and sizes, their geographical locations, the ways they move around, and the organisms they live in. Some parasites are made of only one cell (unicellular) and are as small as a few micrometers (one-thousandth of a meter). For instance, the banana-shaped *Toxoplasma gondii* is about 6 micrometers long. In contrast, other parasites consist of multiple cells (multicellular)

and can reach up to 80 feet (25 m) in length. An example of such parasite is the adult tapeworm.

Parasitic organisms are found almost everywhere, from tropical and sub-tropical regions to freezing places like Antarctica. Yet, what every parasite needs is an organism that provides food, shelter, and a place to reproduce. This organism is called a **host**. The host is eventually harmed by its interaction with the parasite. Parasites can be classified into two groups, depending on where they live in their hosts. Parasites that live *outside* the host are called ectoparasites (Figure 2A). For example, a flea is a parasite that lives on cats. In contrast, parasites that live *inside* their hosts are known as endoparasites (Figure 2B). For instance, *Wuchereria bancrofti* is a worm that lives in the human **lymphatic system** and causes a disease known as elephantiasis. Among the endoparasites, some can live inside the host cells and are called intracellular parasites. *Plasmodium falciparum* is one such parasite, because it lives and grows inside the red blood cells of people who have malaria.

HOST

An organism that provides food and shelter for parasites.

LYMPHATIC SYSTEM

A system of vessels that drains lymph (fluid accumulated in tissues) into the circulatory system.

Parasites also vary in the number of hosts they need to survive. While certain parasites need only one host, other parasites use multiple hosts to complete their life cycles. The host in which the parasite completes its sexual reproduction is called the **definitive host**.

DEFINITIVE HOST

The host in which a parasite completes its sexual reproduction.

HOW DO PARASITES SURVIVE IN THEIR HOSTS?

Parasitism is a constant battle for survival between the parasite and its host. Because parasites depend on their host for food and shelter, they must not destroy the host until they are ready to move on to the next host. Meanwhile, the hosts must protect themselves from harm. To protect themselves, the hosts constantly challenge parasitic organisms by creating unfavorable conditions. The host will try to deprive the parasites of nutrients, effectively starving them, or will attack the parasites with its strong immune defenses. To live in such a difficult environment, each parasite has evolved different survival strategies. Over millions of years of evolution, parasites have acquired lots of

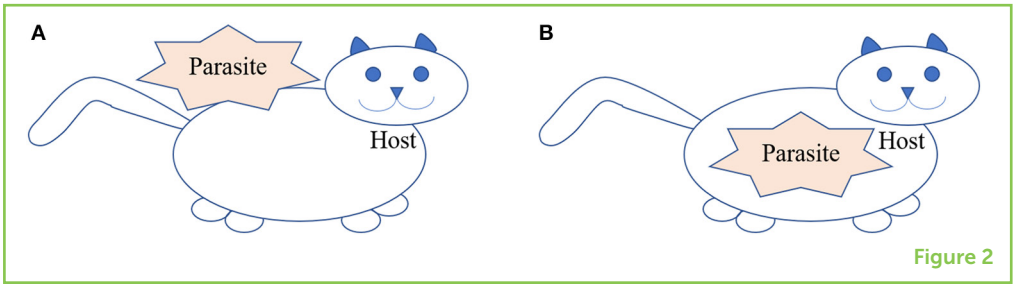

Figure 2

Ectoparasites vs. endoparasites. **(A)** Ectoparasites live outside and on the host. Examples include the cat flea *Ctenocephalides felis*,

(Continued)

Figure 2 Continued

crab louse that lives on Human skin. **(B)** Endoparasites live inside the host. Examples include *Dirofilaria immitis,* a roundworm that lives inside cats and causes heartworm disease, hookworms inside human guts, and *Plasmodium falciparum,* a parasite that lives inside human red blood cells.

interesting features to help them adapt to specific environments [1]. Here are some of them.

1. Evading the host's attacks

   Each parasite is constantly challenged by the host's defenses and other unfavorable conditions, such as nutrient deprivation. Parasites have developed unique ways to respond to attacks by their hosts. For example, *Trypanosoma brucei* and *P. falciparum*, which cause diseases in humans, can change their appearances by switching the proteins on their surfaces and thereby avoiding recognition by the host's immune system. Other parasites have acquired the ability to directly kill human immune cells.

2. Acquiring new reproductive strategies

   Parasites have evolved to live and reproduce within the environment of one particular host. This is called host specialization. While this strategy allows the parasite to be more successful inside that particular host, the host specialization also has its limitations, including reducing the parasite's chances of finding a mate. Parasitic organisms have evolved different ways to solve this problem. For *Schistosoma* species, once the female and male worms find each other in the host, they stick with each other forever, unless another male is present nearby. As for the tapeworms, they use a reproduction strategy called **hermaphroditism**. In hermaphroditism, both male and female reproductive organs are located on the same worm, which removes the need of finding a mate.

HERMAPHRODITISM

A reproductive strategy wherein female and male sexual organs are located on the same individual.

3. Limiting damage to the host

   Another problem with host specialization is directly linked to the very nature of parasites. They damage their host. If the parasite is too destructive to its host, then the host may die before the parasite completes its life cycle. This can lead to the parasite's own death, or force the parasite to search for a new host. So, from the point of view of the parasites, it is important to limit the harm they cause, so that the host stays alive for a long period of time. Parasites have developed strategies to solve this problem. For instance, when there are lots of tapeworms present in a host, those worms will only grow to a small size, to avoid overwhelming and destroying the host. But each worm will grow larger when there are only a few worms present, because there is less competition for the host's resources and the host will not be so easily depleted.

HARMFUL EFFECTS OF TROPICAL PARASITES ON HUMAN HEALTH

There are a number of parasites that cause diseases in humans. Parasitic diseases are most common in developing countries in tropical and sub-tropical regions of the world (Figure 3). These places are often hot and humid, conditions which are suitable for the growth of many parasites. In addition, tropical countries are often affected by poverty, poor sanitation, inadequate healthcare facilities, and low educational level. These factors often increase the transmission of parasitic diseases through insects, contaminated water, or contaminated soil, and make it difficult to control or eliminate them. Below, we describe some important parasitic diseases in tropical regions (Table 1).

Malaria

Malaria is one of the most common diseases in Africa and other tropical places, where it causes millions of deaths every year. *P. falciparum* is the protozoan responsible for this disease. The female *Anopheles* mosquito transmits the parasite when it draws blood from a human. *P. falciparum* infects red blood cells, which are then destroyed or changed in such a way that they clump together. These effects on the

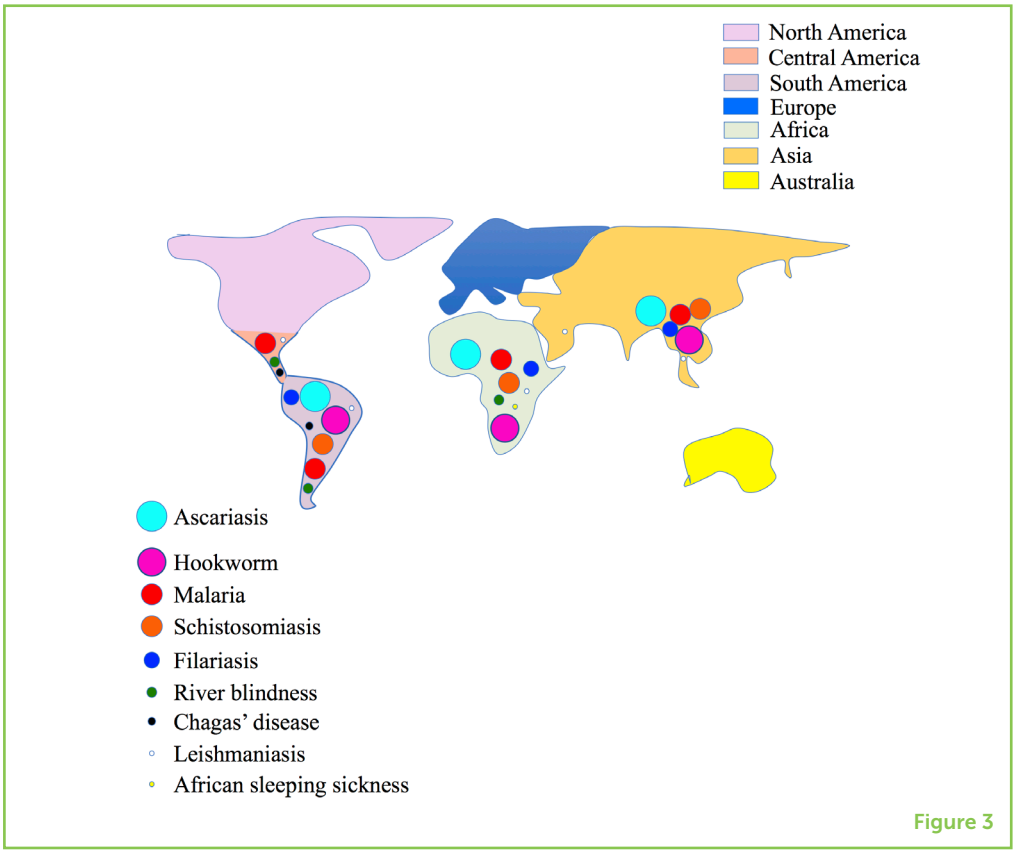

Figure 3

Distribution of important parasitic diseases. The continents are shown in different colors. You can see the key in the upper right corner. The dots represent parasitic diseases. The key for the diseases is in the lower left corner. The size of the dots shows how common the disease is in the region/continent–the larger the dot, the more people who are infected with the disease. You can easily see from this drawing that many parasitic diseases occur in tropical regions of the world (Not drawn to scale).

Table 1

Summary of common tropical parasitic diseases.

*From the Center for Disease Control and Prevention at https://www.cdc.gov/parasites.

**Number of new cases every year because of the acute nature of the disease.

Disease name	Frequency* (total number of cases)	Parasitic organism	Transmission
PROTOZOAL DISEASES			
Malaria	216,000,000	*Plasmodium*	Mosquito bites
Leishmaniasis	1,200,000	*Leishmania*	Sandfly bites
African sleeping sickness	10,000**	*Trypanosoma brucei*	Tsetse fly bites
Chagas' disease	8,000,000	*Trypanosoma cruzi*	Kissing bug feces
PARASITIC WORM DISEASES			
Schistosomiasis	200,000,000	*Schistosoma*	Water
Filariasis	120,000,000	*Wuchereria bancrofti*	Mosquito bites
River blindness	25,000,000	*Onchocerca volvulus*	Blackflies bites
Hookworm infection	740,000,000	*Necator americanus*	Soil
Ascariasis	1,200,000,000	*Ascaris lumbricoides*	Soil

Table 1

red blood cells result in poor blood supply to several organs and tissues, which can eventually lead to the death of the infected person.

Leishmaniasis

Leishmaniasis is transmitted to humans by female sandflies, which bite and release *Leishmania* organisms into the blood. Unlike *P. falciparum*, *Leishmania* prefers white blood cells, especially the ones called **macrophages**. Usually, the parasite causes a mild skin disease. However, it can sometimes invade and damage internal organs and cause more severe disease or even death.

MACROPHAGE

A type of white blood cell that kills pathogen by engulfing them, a process called phagocytosis.

African Sleeping Sickness

As its name suggests, African sleeping sickness is prevalent in Africa, where it affects around 10,000 people every year. It is caused by *Trypanosoma brucei*, a protozoan transmitted by the bite of tsetse flies. Infection with this parasite often leads to inflammation of blood vessels in multiple organs. Heart inflammation may ultimately lead to death from heart failure, or inflammation of the brain may cause seizures and excessive sleepiness. The sleepiness is why the disease is called "sleeping sickness".

Chagas' Disease

Chagas' disease is caused by another member of the trypanosomes, *Trypanosoma cruzi*. Unlike African sleeping sickness, Chagas' disease is

more often seen in Latin America, where it currently affects eight million people. *T. cruzi* is released from the feces of the kissing bug, whose bite on the skin creates an entrance for the parasite into the bloodstream. The parasites spread throughout the body, damage different organs and cause inflammation of the heart and brain.

Schistosomiasis

Also called bilharziasis, schistosomiasis currently affects more than 200 million people in Africa, East Asia, and South America. Schistosomiasis is caused by flatworms called *Schistosoma* and is transmitted through water. The worm larvae in water penetrate the skin, enter the bloodstream, and finally take up residence in the intestines or the bladder. There, the worm larvae mature into adults and lay eggs, which activate the human immune system and cause persistent inflammation. Over time, the persistent immune activation may lead to cancer.

Filariasis

Usually called elephantiasis, filariasis is a disease that causes major body disfigurement. It is transmitted by mosquitoes and currently affects approximately 120 million people. The larvae of *Wuchereria bancrofti*, the roundworm responsible for this disease, are released into the bloodstream from a mosquito's bite. The larvae quickly migrate to the lymphatic system where they grow and mature into adults. When the roundworms get large, they prevent the flow of fluids through the tissues, so fluids accumulate in the tissue and cause grotesque swelling of the limbs and scrotum.

River Blindness

Caused by another roundworm, *Onchocerca volvulus*, river blindness currently affects 25 million people, mostly in Africa and South America. *O. volvulus* is transmitted by blackflies, which are insects that mainly live near and reproduce in rivers and streams. When introduced into the skin of a human, *O. volvulus* can stay there and mature. The presence of these worms in the skin triggers an immune response and causes skin inflammation. In other cases, the parasites migrate to the eyes, where they cause serious damage that leads to blindness. River blindness is a very common cause of blindness in tropical countries.

Intestinal Infections With Roundworms

Hookworms, such as *Necator americanus*, and ascarids, like *Ascaris lumbricoides*, are common roundworms in regions with poor sanitation. *A. lumbricoides* eggs are infective and can be ingested with foods

containing contaminated soil, whereas hookworm eggs must hatch into larvae in the soil before they burrow through human skin. Both types of worms cause malnutrition, because they often live inside the gut where they compete with the host for nutrients. In severe cases, hookworms cause anemia, because they suck the blood of their hosts. Malnutrition and anemia in children can lead to problems with physical and mental development. Additionally, *A. lumbricoides* can also cause intestinal blockage, which results in intense abdominal pains in the infected person.

ARE THERE HIDDEN BENEFITS OF PARASITIC INFECTIONS?

By definition, parasites are harmful to their hosts. However, some parasitic infections may have protective effects against other diseases, such as allergies and chronic inflammatory bowel disease (IBD) [1]. Specifically, long-term infections with parasitic worms were shown to decrease allergies and symptoms of IBD. This is because parasitic worms have evolved strategies to block parts of the human immune system. These parts of the immune system, namely the **eosinophils** and IgE antibodies, are also the main players in allergies, IBD, and many other inflammatory diseases. So, maybe it is not surprising that people infected with parasitic worms have fewer allergies and inflammatory diseases! In fact, a study conducted in Africa and South America revealed that dewormed children (without parasitic infections) were more susceptible to allergies.

EOSINOPHIL

A type of white blood cell that are recruited to fight helminths and play a role in allergies.

These recent findings inspired many scientists and doctors around the world to explore ways that parasitic infections may actually be helpful for some human conditions. The goal is to use these benefits to design new treatments for inflammatory diseases.

CONCLUSION

Parasites are a diverse and complex group of organisms that include the protozoans, helminths, and insects. Parasites have a complicated and constantly evolving relationship with their hosts, and that relationship is ultimately harmful to the host. Some parasitic organisms cause major diseases in humans, especially in tropical regions with conditions favorable to parasites' growth and transmission to hosts. Thanks to scientific advances, our understanding of parasitic organisms has expanded in recent years. Yet, the field of parasitology remains open and appealing to many. We have only scratched the tip of the iceberg.

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YOUNG REVIEWER

ANNA-MARIE, AGE: 13

I am very interested in finding new materials, because with more knowledge about it, the future could be changed. I also like the universe, because there is so much more than we know and think about in there to be found out. But the key to find out how the world works lays in the biology, because all starts with us humans and the evolution.

AUTHORS

BINH CAO

I am a senior undergraduate student majoring in Microbiology at California State University East Bay in Hayward, CA. I interned at the National Institute of Allergy and Infectious Diseases in Bethesda, MD. My current research in Dr. Guiton's laboratory centers on understanding how proteins are trafficked to specialized secretory organelles in *Toxoplasma gondii*. I aspire to become a physician-scientist specializing in infectious diseases.

PASCALE S. GUITON

I am very intrigued by the hidden world of microbes. I was trained as a molecular microbiologist at Washington University in St. Louis and Stanford University. The work in my laboratory seeks to understand the biology of the amazing parasite, *Toxoplasma gondii*. As a scientist-educator, I strive to teach my mentees the love of a work well done and instill in them the skills required for rigorous scientific experimentation. Besides playing with microbes, I love to hike with my family, play with my dog, and travel the world. *pascale.guiton@csueastbay.edu

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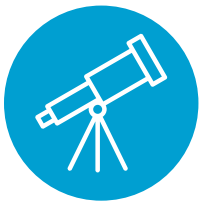

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