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HOW DO PLANTS PROTECT THEMSELVES AGAINST ANIMAL ATTACKS?

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Natural systems are made up of countless interactions between living beings. One of the most essential interactions is when a plant is eaten by an animal. Why is this so important? When plants are eaten, their growth and ability to reproduce decrease, and we all know that plants are critical because they provide us with food, medicine, and wood. They also provide homes for other living things, produce the oxygen we breathe, keep soils healthy, regulate humidity, and contribute to climate stability. Plants have also developed smart strategies to defend themselves from animal attacks. Some plants have evolved protective structures like thorns and thick leaves, while others have produced defensive chemicals. Together, plant protection mechanisms can reduce or prevent the damage that plant predators may cause. In this article, you will learn many strategies plants evolved to protect themselves from plant-eating animals.

DEFENSIVE PLANTS?

Stop for a second and imagine that a mosquito is trying to suck the blood out of your arm. Or that you are walking down the street and suddenly you see a ferocious dog. How would you react to both situations? You would surely swat the mosquito away, and maybe run from the scary dog. Humans can react immediately to avoid dangerous situations and plants can do the same. It may not seem as obvious, but plants have various defenses to protect themselves from attacks, too. And this is important because plants are a critical part of life on Earth. They provide us with food, medicine, and wood. They also provide homes for other living things, produce the oxygen we breathe, keep soils healthy, regulate humidity, and contribute to climate stability.

NATURAL ENEMIES

Living organisms that feed on other organisms. They can kill, weaken, or reduce the reproductive potential of the species they feed on.

HERBIVORY

Biological interaction between two living organisms in which animals eat living plant tissues, like leaves, stems, roots, flowers, or fruits.

HERBIVORE

Animal that feeds mainly on plants.

HERBIVORES: THE ENEMIES OF PLANTS

Plants have many **natural enemies**, from bacteria to insects, fungi to mammals. These enemies are attracted to plants because they may have bright colors, nice smells, good-tasting leaves, or fruits. **Herbivory** is an important interaction between plants and animals because it is the process by which some animals feed on living plants. So, animals that eat plants are known as **herbivores**. Herbivores damage plant organs, such as leaves, stems, roots, and flowers, when they feed on plants. If a plant loses part of its living tissue, it can have trouble taking in water and nutrients, leaving the plant weaker. In some cases, herbivory decreases photosynthesis, growth, reproduction, and survival. This means that herbivory can control how abundant plants are in nature, and it can even determine if forests grow back after they are cut down or destroyed by wildfires.

Insects are the main plant herbivores, and they make up more than 50% of the known species in terrestrial ecosystems. There are at least 450,000 species of plants distributed throughout the world [1], so there are a lot of options on the menu for plant-eating insects! Unlike humans, plants cannot run away from dangerous predators—so how have plants managed to avoid being eaten by herbivores? The answer lies in the fascinating mechanisms plants have developed to protect themselves. But first, we need to explain how the environment affects how plants respond to threats.

THE ENVIRONMENT AFFECTS PLANT DEFENSES

To survive and grow, humans need food and a healthy place to live in. Plants also need resources from the environment to grow and reproduce, including water, sunlight, good-quality soil, and access to nutrients. A scientific theory called Resource Availability Theory

helps us understand how the environment, particularly the availability of resources, affects plant responses [2]. The theory says that plants living in ecosystems with high availability of natural resources will use their energy for growth and development. On the contrary, plants that *do not* get enough resources will put their energy toward resistance or tolerance mechanisms, which help them survive in the face of limited resources.

ENVIRONMENTAL VARIABLES

Elements or aspects of the environment that can affect living organisms. Some of these include the amount and quality of water and soils, temperature, and the presence of other organisms.

The availability of resources in an ecosystem depends on many **environmental variables** (Figure 1). The amount of rainfall, soil type, temperature, and wind intensity are examples of environmental variables that affect how plants respond. Throughout time, plants have grown in diverse environments, each with its specific levels of resources which has been important for the evolution of plants and their ability to adapt to many different conditions.

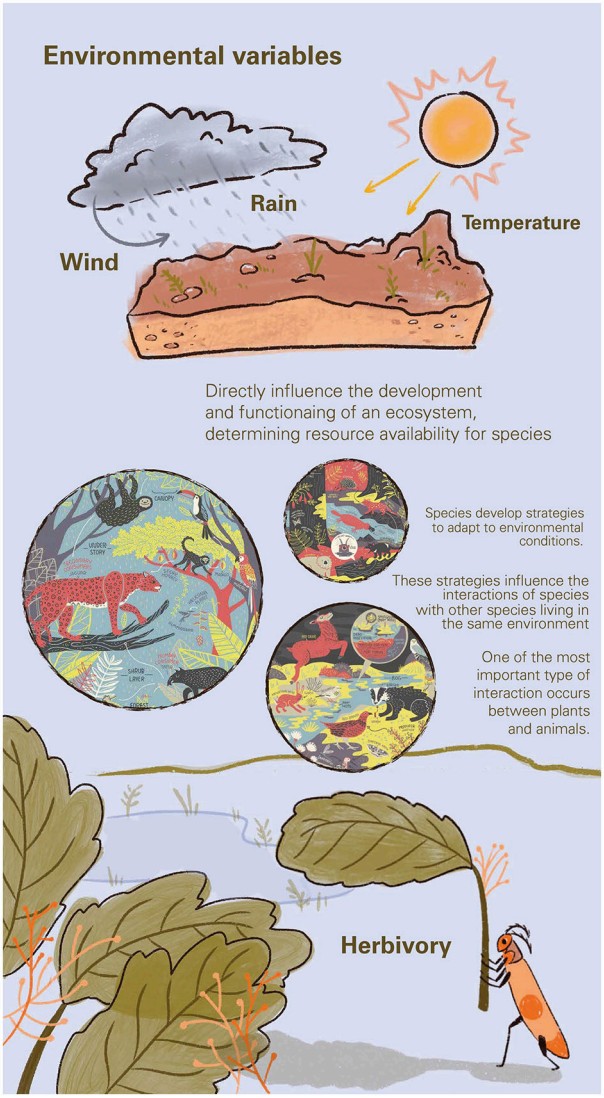

Figure 1

Environmental variables. The environment influences the amount of natural resources necessary for the survival of species. How species define their life strategies will affect how they relate to others. Herbivory is an important interaction between species within ecosystems.

ENVIRONMENTAL GRADIENT

Differences in the environmental characteristics from one area to another.

Differences in the natural abundance of a resource from area to area is called an **environmental gradient**. Environmental gradients can change the way plants and herbivores interact by affecting both herbivores and the physical and chemical traits of plants. For example, there are more plants in habitats with more resources so these patches are more attractive to herbivores increasing the chances of plants being eaten [3]. The traits of individual plants can also influence herbivory; for example, nutritious plants are more likely to be eaten if they don't have defense mechanisms to keep herbivores away. These traits vary from plant to plant depending on environmental variables such as soil quality, amount of rainfall, and exposure to sunlight. In general, the environment in which plants live will influence their ability to protect themselves from external damage.

THE DELICIOUS PLANT LEAVES

You do not have to be a botanist to know that leaves are the part of a plant most eaten by herbivores—just go to your garden and observe. But what do leaves have to attract herbivores? Leaves are rich in nutrients that insects need, including carbohydrates, nitrogen, phosphorus, protein, and water. However, plants can develop chemicals that make their leaves less digestible, making it more difficult for herbivores to get nutrients from them, decreasing herbivory [4].

Similarly, the physical characteristics of leaves, such as their weight, thickness, and size, influence how attractive they are to herbivores (Figure 2). For example, larger leaves attract more attention from

Figure 2

Leaves are the most commonly eaten parts of plants. Three main characteristics of leaves affect whether they attract or repel herbivores: the physical characteristics of the leaves (size, thickness, and hardness), the amount of nutrients in the leaves, and the amount of defense chemicals in the leaves.

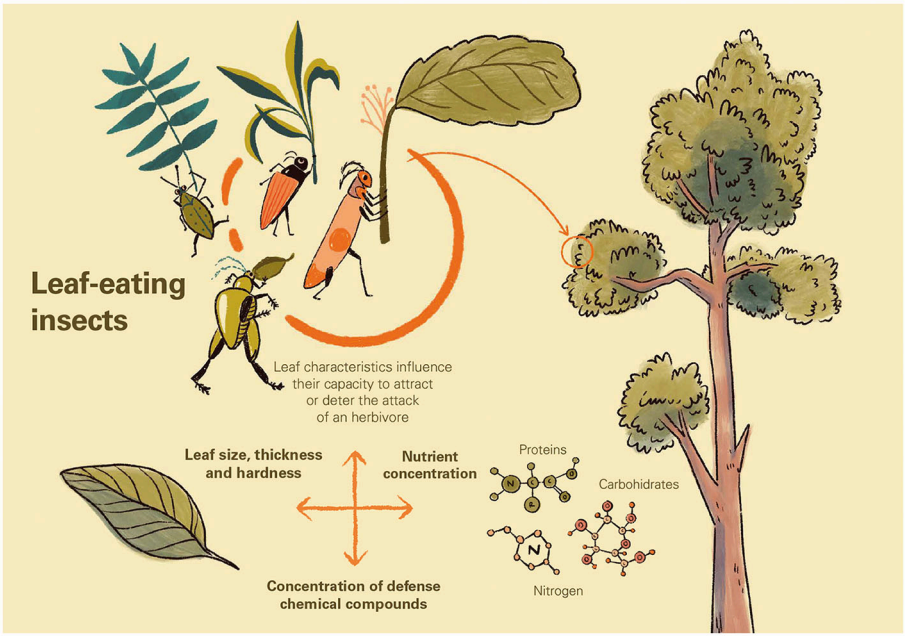

Figure 2

herbivores because bigger means more food. Likewise, thick, tough leaves attract less attention because they are more difficult to chew and digest.

Herbivores have managed to overcome some of these plant defenses thanks to their own **adaptations**. For example, some insects have developed mouth parts that penetrate thick, tough plant tissues. Others have developed the ability to break down toxic compounds using strong digestive proteins, making the leaves edible.

ADAPTATIONS

Changes that organisms underwent over time according to what they need to survive in their natural environment.

WHAT ABOUT ROOTS, STEMS, AND FLOWERS?

Most herbivores eat leaves; however, some eat roots and stems and, therefore, also decrease the plant's growth. The absorption of water and nutrients through the roots decreases, as does the amount of nutrient reserves that are stored underground. Root-eating herbivores are among the most damaging and dangerous pests. They reduce the ability of plants to reproduce. Like leaves, roots produce a variety of toxic and repellent compounds that scare off subterranean attackers. In addition, plants react to root attacks by redirecting roots into enemy-free space or storing nutrient reserves in undamaged root tissues [5]. Thanks to these nutrient reserves, damaged roots can sometimes be regenerated.

Herbivore attacks on stems are more dangerous than attacks on leaves, because stems transport vital nutrients along the plant. Stem-eating herbivores can eat the outer bark of the stem or suck out the sap inside. When the stem is damaged, the passage of nutrients from the root to the leaves is blocked, which can stop plant growth and even kill the plant [6]. Stems defend themselves by producing lignin, which makes the stem rigid and challenging to eat.

Flowers are delicious treats for herbivores. Flowers are crucial for the reproduction of plants. When herbivores eat flowers, less pollen is available for pollinators like bees, butterflies, hummingbirds, and bats. Further, if many flowers are removed, the plant becomes less attractive to pollinators, and they may stop visiting and fertilizing the plant. That is why flowers have also developed strategies to protect themselves from herbivore attacks. Flowers produce chemicals and toxins to repel herbivores; some can close their petals to protect their reproductive organs, and others release airborne compounds that attract the natural enemies of their herbivores [7].

CONSTITUTIVE

Characteristic that is part of a whole.

INDUCED

Something that is produced thanks to an external stimulus.

TYPES OF RESISTANCE AND PROTECTION

Past studies have shown that plant defenses can be of two main types: **constitutive** or **induced**. Constitutive defenses are those that are *always* in the plant and constantly protect it. These include thorns and

plant hairs called trichomes, as well as various chemical compounds. However, having these defenses around all the time, regardless of whether they are needed, can use a lot of energy. In contrast, induced defenses only develop or activate *after* an attack. Many plants only invest resources in these defenses once they know an attack is happening. This saves the plant energy.

Whether they are constitutive or induced, plant protection mechanisms can be classified into two main methods: mechanical and chemical [4]. Plants use mechanical protection, such as thorns, hairs or trichomes, as well as the firmness of their leaves, to resist wind, rain, and hail, for example. Mechanical protection is also used to protect against the attacks of some herbivores. Chemical protection involves the production of compounds that kill microbes and fungi, or that can poison an herbivore's heart or cause it to hallucinate (Figure 3). These chemical defenses include terpenes, tannins, phenols, and oils [4]. The concentrations of these chemicals can vary according to things like the age of the leaves, soil quality, nutrient availability, sunlight, and water.

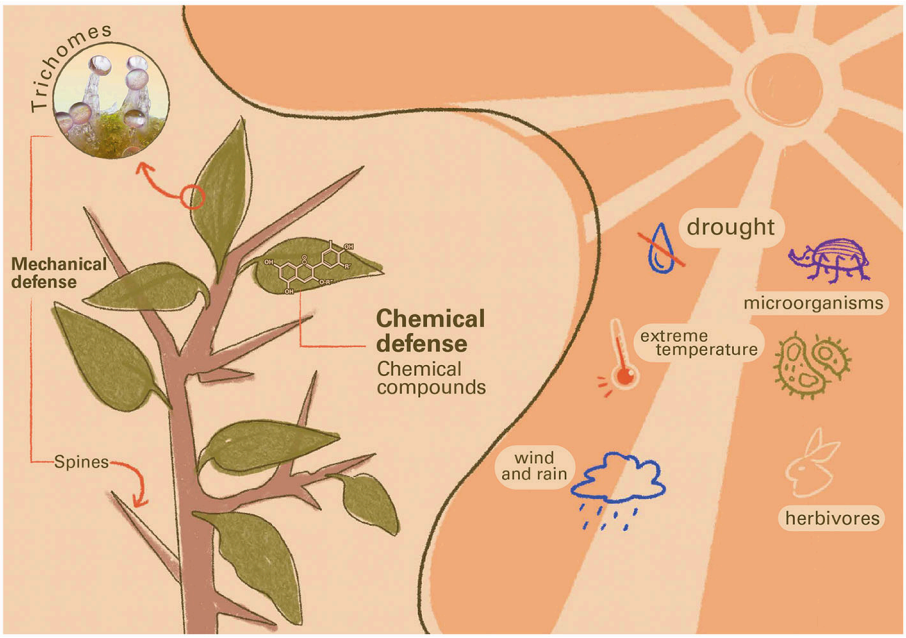

Figure 3

Plant protection mechanisms can be mechanical or chemical. Mechanical defense mechanisms include thorns and trichomes (plant hairs). Chemical defense mechanisms are found within the leaves. All these mechanisms help plants to protect and defend themselves from environmental factors such as drought, wind, rain, temperature extremes, microorganisms, and herbivores.

IN CONCLUSION

This article has shown that plants are like a fortress, fighting to protect themselves and stay alive when they are under attack by herbivores. Now, it will be easier for you to understand how plants have dominated the world for millions of years and, despite adversity, are still a major component of our planet. In the end, plants may lose some battles, but they will rarely lose a war.

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REFERENCES

1. Raven, P. H. 2021. Plants make our existence possible. *Plants People Planet*. 3:2–6. doi: 10.1002/ppp3.10173
2. Coley, P. D., Bryant, J. P., and Chapin III, F. S. 1985. Resource availability and plant antiherbivore defense. *Science* 230:895–899. doi: 10.1126/science.230.4728.895
3. Castagneyrol, B., Giffard, B., Valdés-Correcher, E., and Hampe, A. 2019. Tree diversity effects on leaf insect damage on pedunculate oak: the role of landscape context and forest stratum. *For. Ecol. Manage*. 433:287–294. doi: 10.1016/j.foreco.2018.11.014
4. Mostafa, S., Wang, Y., Zeng, W., and Jin, B. (2022). Plant responses to herbivory, wounding, and infection. *Int. J. Molec. Sci.* 23:7031. doi: 10.3390/ijms23137031
5. Johnson, S. N., Erb, M., and Hartley, S. E. 2016. Roots under attack: contrasting plant responses to below-and aboveground insect herbivory. *New Phytol.* 210:413–418. doi: 10.1111/nph.13807
6. Stephens, A. E., and Westoby, M. 2015. Effects of insect attack to stems on plant survival, growth, reproduction and photosynthesis. *Oikos* 124:266–273. doi: 10.1111/oik.01809
7. Haas, S. M., and Lortie, C. J. (2020). A systematic review of the direct and indirect effects of herbivory on plant reproduction mediated by pollination. *PeerJ* 8:e9049. doi: 10.7717/peerj.9049

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CONFLICT OF INTEREST: 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.

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Atharv is a High School student at Amity International School Mayur Vihar, New Delhi, India. He is curious to learn new areas of science. He is always happy to read and interested in commenting on scientific articles and magazines.

OLIVE, AGE: 12

My name is Olive and I am a sixth grader. I love reading, science, biology, medicine, and taking care of animals, and I hope to study veterinary medicine when I get into university. Our family has one dog, one blue tongue skink, and one busy fish tank. I do Aikido and Outschool online classes. My hobbies are: crocheting, reading books, cooking, reading things on the computer, watching cartoons, and walking our dog.

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I am a biologist from the Universidad Michoacana de San Nicolás de Hidalgo, in Mexico. I earned my Master of Science degree in integrative ecology. My project evaluated the chemical and nutritional content of the leaves of the oak *Quercus glaucoides*, and its relationship with herbivory and environmental variables. I am currently studying for my Ph.D. in biological sciences at the same University. My doctoral research focuses on the response of the oak *Quercus castanea* to drought, and I am analyzing the phenological and chemical variation of oak trees as well as their interactions with herbivores. My academic interests are biotic interactions and chemical ecology specially in trees of temperate ecosystems and for conservation objectives.

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