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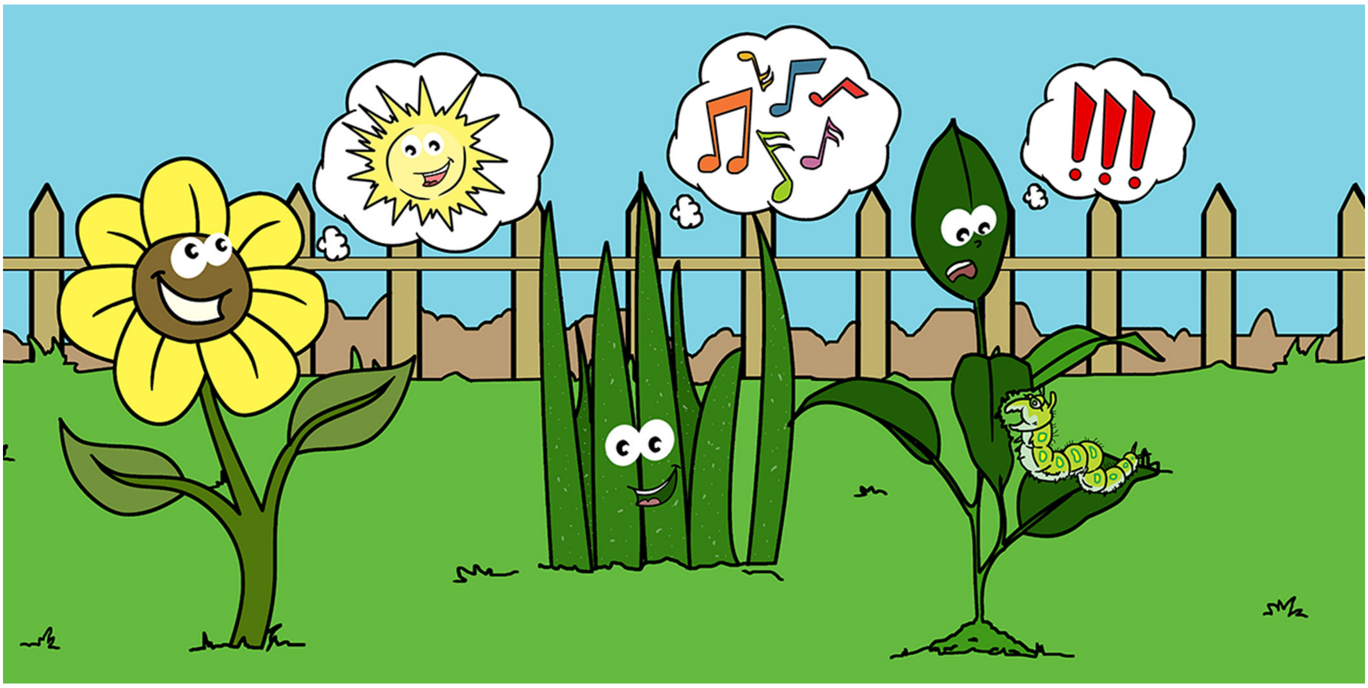

PLANTS CAN "SPEAK" TO EACH OTHER

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YOUNG REVIEWERS:

DARIO
AGE: 14

MARLENE
AGE: 16

VICI
AGE: 15

When we think about plants, we do not normally imagine them "speaking" to each other. But they do communicate—in many different ways. More than a century ago, the eminent biologist Charles Darwin suggested that plants have a brain-like structure at their root tips! In this case, Darwin's root-brain hypothesis was wrong, but more modern research shows that plants *can* communicate. They speak with other plants as well as with animals and even people. They do this primarily using chemicals and sound.

INTRODUCTION

All communication between living things requires the exchange of information (signals) between partners. We know that animals constantly communicate with each other as they move around their habitats. Think of birds singing or lions roaring. In contrast, plants are often regarded as unmoving organisms that are incapable of such communication. One of the first scientists to challenge this notion was none other than Charles Darwin.

DARWIN'S EARLY RESEARCH ON PLANT BEHAVIOR

ROOT TIP

The growing tip or "apex" of a root, known also as "a root cap."

In the 1880's, Charles Darwin and his son Francis conducted a series of experiments on roots, which showed that the tip of the root is the most important part of the plant. **Root tips** sense and respond to stimuli such as light, gravity, chemicals, and sound. The root tip transmits messages that function as signals to activate processes such as growth, directional movement, and the production and release of special gases. Animal and human brains do similar things, so the two Darwins suggested that the root tip could function as the plant's "brain" (Figure 1). Here are some of their own words:

> *It is hardly an exaggeration to say that the tip of the radicle* [a young root]*... having the power of directing the movements of the adjoining parts,* **acts like the brain***...; receiving impressions from the sense organs, and directing the several movements* [1].

AUXIN

A plant hormone that stimulates stems to get longer and/or to curve.

Charles Darwin also showed the importance of chemicals as communication signals in plants. Some of the earliest reports of plant chemical signaling came from his experiments in the 1870's. Darwin showed that soluble substances produced at the tip of the growing shoot of barley seedlings were transported down through the stems, where they caused cell division and curvature of the stem. We now know that these chemical signals are hormones called **auxins**, which move throughout the plant bodies and play many important roles in their growth pattern and overall shape.

PLANTS COMMUNICATE USING CHEMICALS AND SOUND

One of Darwin's key insights was that plants are highly active organisms. We now know that, although they are normally anchored in one place by their root systems, plants are still capable of movement. For example, by using sophisticated measuring devices, we can see that plant leaves, roots, and tendrils are in constant rhythmic motion as they respond to external factors such as daylight, gravity, temperature, water, nutrients, and threats. Plants do not just move randomly; they move in a purposeful manner. Plants move to detect key information about their environments, to respond appropriately, and to communicate this information to other plants, using easily understood signals.

Unlike animals, plants normally stay in one place during their lifetimes (except for the roots, which can move through the soil), but sometimes that location can turn out to be far from ideal. For example, there might be too little light or water, or too few nutrients for efficient growth. Other competing plants may already be present to crowd out the new

Figure 1

Figure 1

Darwin suggested that plant intelligence is kept in the "brain" of plants, found in the root tips, like upside-down people, or other animals. He thought that maybe a plant's "brain" was kept underground to protect it. While this hypothesis was incorrect, other research has shown that plants *can* communicate.

PATHOGENS

Organisms that causes diseases.

VOLATILE ORGANIC COMPOUNDS (VOCS)

Gaseous compounds that act as chemical messengers between organisms.

PHEROMONES

Chemicals secreted by some animals that help them communicate with others of their species.

plant, or pests and **pathogens** might attack it, not to mention grazing animals. In evolutionary terms, it makes sense that a plant facing these threats could signal its distress to other plants, so that they could avoid the dangers or better defend themselves against threats. Recent research shows that the two most important plant communication methods are chemicals and sound.

CHEMICAL SIGNALS—THE IMPORTANCE OF VOCS

Volatile organic compounds (**VOCs**) are the most common type of chemical signals released by plants. VOCs are small molecules released as gases that readily diffuse through the air, away from the plant that produces them. Some of these plant VOCs are chemically similar to the **pheromones** that are used by many animals. For example, the world of ants is largely controlled by pheromones that allow them to find food and identify their nestmates. One of the most common plant VOCs is called methyl jasmonate (MeJA), which is produced and released by plants that are under attack (Figure 2). MeJA is formed inside a wounded plant, for example when an animal tries to eat it. Once released by the attacked plant, MeJA moves through the air to the non-damaged parts of the same plant and to the neighboring plants, where it activates defense mechanisms in non-attacked neighbors. Another defense-related VOC made by plants is methyl salicylate, which is chemically similar to the human painkiller, aspirin.

Plants release VOCs into the air to alert their neighbors to threats, and the neighboring plants respond to these signals by preparing to defend themselves even before they are attacked. For example,


Figure 2

Figure 2

Plants can protect their neighbors by communicating with them. For example, when an individual plant is attacked by a caterpillar, the plant sends warning messages to its plant neighbors, telling them to reinforce their defense systems. The warning messages could be in the form of odors or sounds.

within seconds, plants that detect VOCs will start making anti-fungal compounds or anti-insect toxins to protect themselves. In some cases, VOCs can also travel long distances underground, *via* the root system. This means that plants can stimulate root cells to mount defense responses against invading fungi or bacteria in the soil. Other VOCs are released from root cells to *attract* beneficial fungi or bacteria. Examples include fungi that help plant roots to absorb soil nutrients more efficiently, or bacteria that convert nitrogen gas from the atmosphere into nutrients that help the plants to grow faster. So, plants use certain VOCs to warn their neighbors about threats, while other VOCs allow them to attract more useful organisms.

FREQUENCY

The number of occurrences of a repeating event per unit of time. Frequency is measured in hertz (Hz) which is equal to one event per second.

SUBSONIC

Sound waves with frequency <20 Hz. Humans cannot hear these frequencies.

ULTRASONIC

Sound waves with frequency more than 20,000 Hz. Humans cannot hear these frequencies.

SOUND SIGNALS

We humans use sound waves to communicate with each other, but not all sound waves are detectable by human ears. One of the main properties of sound waves is their **frequency**, which is measured in Hertz (Hz). Humans can hear only sound frequencies ranging from 20 to 20,000 Hz. Sounds with frequencies below 20 Hz are commonly called **subsonic**, while those with frequencies more than 20,000 Hz are called **ultrasonic**.

The sound signals used by plants tend to be at a frequency that cannot be heard by the human ear, but they can be picked up by other plants and animals [2]. In the wild, plants might grow well with some neighbors but not with others [3]. For example, a 2013 study in Australia clearly showed the beneficial effects of basil plants on the growth of chili plants, which confirms what many gardeners had previously observed in their gardens. Chili seedlings grow less well in the presence of fennel plants, however. These authors speculate that tiny vibrations in the cells of each plant might produce "sounds" of frequencies that can be detected by other plants, telling them whether they are growing near a "bad" or a "good" neighbor [4].

XYLEM

Network of tiny "pipes" in plants that transports water and minerals from the roots to the rest of the plant.

In other experiments, young maize roots were found to make tiny clicking sounds that are at the lower end of the human hearing range (about 220 Hz). When the roots were suspended in water so that they could move more easily, they leaned toward these sounds. Other sounds include what sounds like fizzy bubble bursts in the **xylem** tissue of plants, but these are ultrasonic and are only detectable by insects and some other animals, so perhaps these plants are communicating with animals [5]. The technology to hear plant bubbles explode is actually quite simple. Acoustic sensors designed to detect cracks in bridges and buildings can catch the ultrasonic pops.

Researchers in China have shown they can increase plant yields by broadcasting sound waves of certain frequencies. So, maybe there *is* some truth in the old gardener's advice to talk to your plants! Other researchers have investigated how different frequencies and intensities of sounds change plant gene expression. Their results show that acoustic vibrations really *do* affect the basic chemical reactions happening within plant cells.

THE IMPORTANCE OF PLANT COMMUNICATION

The bottom line is that plants are really great communicators. They are constantly releasing lots of useful information into the environment, especially using chemicals and sounds. We are only just beginning to understand how this information is produced and how it is then picked up by other plants and animals who can use it for their own benefit. So, the next time you tread on some grass or pick a flower, remember that the poor injured plant might be screaming out to its neighbors—but we humans just cannot hear it!

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YOUNG REVIEWERS

DARIO, AGE: 14

My name is Dario. I live in a small village in Austria. It is full of nature so in my freetime I like to go out with my dogs or climb trees. My parents are both biologist so I got into biology pretty early.

MARLENE, AGE: 16

My name is Marlene and my interest are science (especially physics) and art. I also love cycling and hiking with friends. Through Frontiers for Young Minds I hope to discover new interesting fields of research.

VICI, AGE: 15

Hi, my name is Vici and I am very interested in science more specific in microbiology, the anatomy of the human body and astronomics. In my freetime I am reading a lot about space or try to think about new theories. I also love to cook food and of course eat it because food is good.

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