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AN ELECTRIFYING VIEW INTO THE LIFE OF PLANTS: THE PLANT ELECTROME

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YOUNG REVIEWERS:

JOCELYN
AGE: 15

MAYTE
AGE: 9

TANISHKA
AGE: 15

Do living beings need brains to do extraordinary things? The human brain manages many tasks at the same time, from keeping the body working to thinking and dreaming, thanks to the electrical signals it produces. But what about organisms that survive pretty well without brains, like plants? You might be surprised to learn that plants can produce electricity as well, and they use electrical signals for communication, learning, self-preservation, and as a rapid alarm system against potential threats. All this without any brain cells! With scientific equipment, it is possible to study the hidden electrical activity of plants and discover the secrets of their lives in a challenging world. Plant scientists have developed gadgets like those used to study the brain to explore plant electricity. They have made

astonishing discoveries about hidden aspects of plant life. Join us in exploring the electrifying world of plants and uncovering their remarkable powers.

ELECTRICAL SIGNAL

When ions move in and out of a cell, they change the electrical charge on the cell's surface. This creates electrical signals that carry messages from one cell to another.

ACTION POTENTIAL

A quick electrical signal that travels through cells in plants and animals. It always has the same strength and helps cells communicate, allowing things like movement or reactions to happen.

IONS

Tiny particles with an electric charge, either positive or negative. They move in and out of cells and help plants and animals do important things like send signals or grow.

PLASMA MEMBRANE

A thin layer that surrounds and holds everything inside a cell. It controls what goes in and out of the cell, like ions and water.

VACUOLE

A storage space inside cells. In plants, it stores water, ions, and waste. It helps the cell stay healthy and keep its shape.

PLANTS AND ELECTRICITY

Have you ever wondered about living beings with electric powers? Maybe you have heard of electric eels—fish that can zap other animals with electric shocks to defend themselves or catch prey. Other organisms have this superpower, but not in such an obvious way. This includes humans! We have electricity inside us, powering our brains so that we can think, talk, and remember. Even walking needs electricity!

Speaking of moving, there are some plants that also use bioelectricity to move. Do you remember the Venus flytrap that features in Mario Bros? It snaps shut when an insect lands on it, thanks to a type of **electrical signal** called an **action potential**—similar to what happens in our brains. What about most plants, which do not move? They also use electrical signals for communication between their parts. And they do all this without a brain! But how?

Scientists have found that plants produce electricity all the time, and this electrical activity changes when plants notice what is happening around them, from shifts in lighting to the presence of another plant [1]. Imagine if a plant gets too hot or too cold, or if pesky bugs start chewing on it, or even if it gets too much salt in its roots. All these things can cause problems inside the plant (Figure 1A). Just like us, plants have special parts in their cells that make this electricity happen. When some of the electrical activity moves, carrying information, it is called electrical signaling.

HOW ARE ELECTRICAL SIGNALS MADE?

Electrical signals are created by tiny, tiny particles called **ions** and their strong pull toward each other. Have you heard the phrase "opposites attract"? Well, some ions have positive charges, and some have negative charges, and oppositely charged ions really want to be together. Normally, ions are separated by the **plasma membrane**, which keeps many ions either inside or outside the cell, preventing them from getting in or out. When the cell allows these ions to move in or out of the cell across the plasma membrane, this creates an electrical signal. You have probably heard of some of these ions: calcium (found in milk), potassium (found in bananas), sodium and chloride (found in kitchen salt), for example (Figure 1B). In addition to the plasma membrane, the membrane of the **vacuole**—which is like the cell's storage unit—also plays a big role in the plant cell's electrical activity, because the vacuole manages many ions. Membranes contain

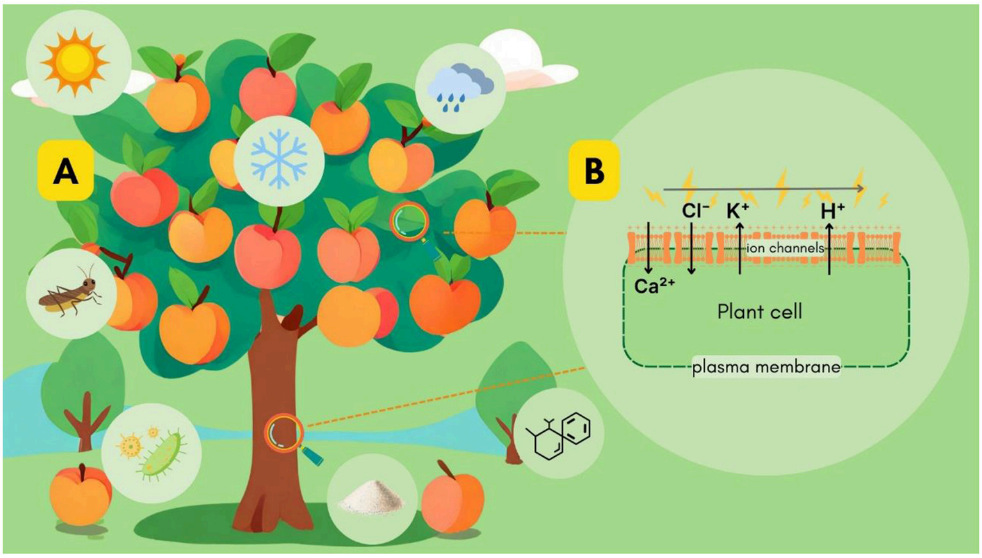

Figure 1

Figure 1

The influence of the environment on the generation of a plant's electrical signals. **(A)** Plants, like trees, receive and perceive different types of stimuli, from sunlight to insects taking small bites. **(B)** Focusing on a single cell, you can see the components involved in generating an electrical signal that makes part of the plant's electrome. The ions involved include calcium (Ca^{2+}), potassium (K^{+}), chloride (Cl^{-}), and protons (H^{+}).

lots of different proteins that help ions move around. Some act like channels, opening and closing to let ions through, while others work like pumps, pushing ions against the flow [2].

ELECTRICAL SIGNALS TOGETHER: THE PLANT'S ELECTROME

Many scientists study specific types of electrical signals in plants. These signals can give valuable information about what the plant is perceiving or doing. However, inside plants, everything happens at the same time. Studying signals individually might not give scientists the whole picture, and they could miss important details about what is happening in the plant. This is where **electrome** analysis comes in! A scientist named Arnold De Loof defined the electrome as "all the electrical currents in different parts of any living thing" [3]. Other scientists, including some authors of this article, applied the electrome concept to plants [2].

ELECTROME

The collection of all the electrical signals and activities that happen in plants and animals over time.

Inside plants, many processes create electrical activity. This electrical activity is used to send messages between parts of the plant (like roots and leaves), to activate photosynthesis (which is how plants make their own food), to regulate transpiration (basically plant perspiration—sweating), and to control the uptake of nutrients from the soil by the roots. In all these processes, ions are moving around. This movement changes throughout the day and during specific stages of the plant's growth and development, and it also varies between species, making the electrome of each plant unique [2].

WHAT CAN A PLANT'S "ELECTRICAL SIGNATURE" TELL US?

Things happening around the plant, like animals trying to eat it or sudden changes in temperature, can affect how the plant works, creating specific "electrical signatures" that can be grouped into specific characteristics. How do scientists record and analyze plants' electrical signatures? To collect electrical data from plants, we use a technique very similar to the one used to measure the electrical activity of brains. After getting the data, we need to interpret it using mathematical calculations and statistics, along with **artificial intelligence**, which helps us to understand large amounts of data. As a result, we can gather a lot of information about the electricity of plants. And what can we do with all this information?

ARTIFICIAL INTELLIGENCE

A computer process designed to act like humans to solve problems. It learns from lots of information to do things like answering questions, playing games, or sorting information.

The analysis of the plant electrome can help scientists to understand plants better. Scientists have learned how electrical activity influences plants' ability to memorize, learn, and communicate. They have also found practical uses for the plant electrome in agriculture, such as identifying diseases caused by fungi before symptoms even appear and detecting if pests are attacking plants [4, 5]. In the future, scientists might be able to attach gadgets to plants to understand what is happening inside them (Figure 2). This could help us to conserve natural resources, like water, and to use less chemicals, like insecticides and fungicides, to control pests. So, understanding the plant electrome can help produce more **sustainable** food and decrease the damage we cause to our planet!

SUSTAINABLE

Something created without harming the environment or using up resources, ensuring they last a long time. It is about protecting the planet so we can keep living here.

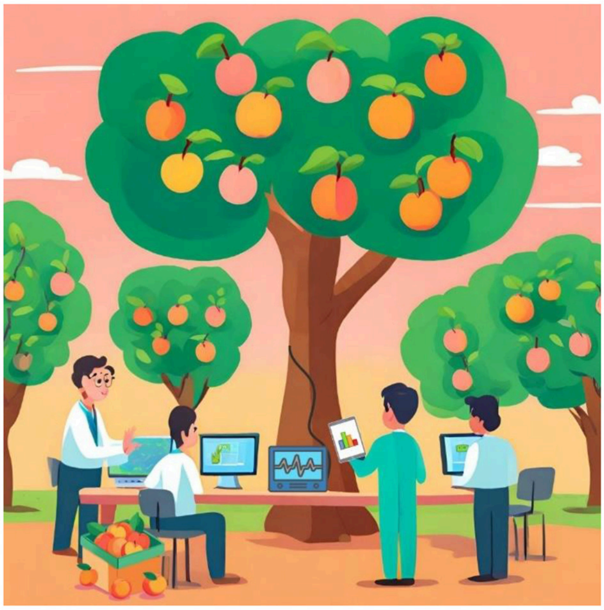

Figure 2

Figure 2

Scientists and researchers of the future, recording the electrome of peach trees and analyzing the data to detect diseases early and check if the plant has enough water and nutrients.

ORIGINAL SOURCE ARTICLE

de Toledo, G. R. A., Parise, A. G., Simmi, F. Z., Costa, A. V. L., Senko, L. G. S., Debono, M.-W., et al. 2019. Plant electrome: the electrical dimension of plant life. *Theor. Exp. Plant Physiol*. 31:21–46. doi: 10.1007/s40626-019-00145-x

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GR and TO dedicate this work to their beloved daughter Éris, with the sincere hope that she, along with many other young individuals, may have access to a science that is inclusive, igniting their curiosity, and empowering them to explore its wonders.

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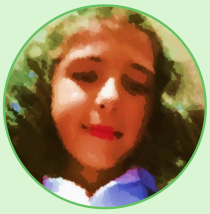
YOUNG REVIEWERS

JOCELYN, AGE: 15

I am from Mexico and I like animals and plants and go out to discover new traditions and cultures. My favorite subjects at school are chemistry and mathematics.



MAYTE, AGE: 9

I like cooking and playing with bugs in the garden and my favorite subject is math. I also like shopping and hanging out with my friends.

TANISHKA, AGE: 15

Tanishka is a young researcher, advocate, and writer passionate about environmental and agricultural sciences. She has conducted extensive research on plant disease management and has received 1st Place at the International Science and Engineering Fair and the H. Robert Horvitz Prize for Fundamental Research. She is also a published author in numerous scientific journals. Tanishka has been awarded at numerous international competitions such as Invention Convention, Broadcom Masters, UNESCO Goi Peace Foundation Contest, HOSA Internationals and has received the USF Hall of Fame Top Innovator award. She is an environmental activist and STEM advocate, consistently aiming to make STEM education accessible to youth worldwide.

AUTHORS

GABRIELA NIEMEYER REISSIG

I am a food chemist with a passion for biology. I love delving into how things work, from plant growth and its interactions with other organisms, to what happens in our bodies when we eat plants. Currently, I am conducting postdoctoral research at the LACEV laboratory within the Postgraduate Program in Plant Physiology at the Federal University of Pelotas in Brazil. My research primarily focuses on the electrome/electrical signals in fruits during ripening and when they are under attack by insects. Outside of work, I enjoy spending time with my family, which includes five dogs, and discussing a wide range of scientific discoveries with my friends. I am also a keen language learner! *gabriela.niemeyer.reissig@gmail.com

THIAGO FRANCISCO DE CARVALHO OLIVEIRA
I am a physicist who lives by the motto of never going a day without learning something new. I am fascinated by the physics behind biological processes, especially in plants, living beings with lifestyles so different from ours yet endowed with intelligence and cognitive abilities. I study how plants use electricity, how complex systems work, and how to analyze signals using math. I also develop tools that use artificial intelligence to help us understand how plants behave. Currently, I am pursuing a Ph.D. at the LACEV laboratory within the Postgraduate Program in Plant Physiology at the Federal University of Pelotas in Brazil. My research primarily focuses on the electrome/electrical signals underlying the attention process in plants. I love spending time at home with my family, playing video games, and watching interesting things on the internet.

ANDRÉ GEREMIA PARISE
I am a biologist and Ph.D. candidate at the University of Reading, in the United Kingdom. I love studying the natural world, and in particular, I enjoy trying to understand the intelligence of plants, fungi, and organisms with no brains. It is so fascinating to observe these organisms, so different from us, and yet capable of solving their problems, communicating with each other, and being just successful in surviving! My research is currently trying to understand how plants and their fungal partners communicate with each other.

DOUGLAS ANTÔNIO POSSO
I am an agricultural engineer with a deep passion for plant biology. I am naturally curious and enjoy engaging with my colleagues in conversations that range from light-hearted topics like cartoons to deep scientific reflections. Learning is something I cherish, especially when it comes to exploring new languages and delving into the fascinating world of plant biology. I particularly enjoy teaching, especially children and teenagers, as I strive to ignite their interest in the incredible realm of plants. Green happens to be my favorite color, which perfectly aligns with my love for all things botanical. Currently, I am a postdoctoral researcher at the LACEV laboratory within the Postgraduate Program in Plant Physiology at the Federal University of Pelotas in Brazil. My research focuses on unraveling the mysteries of plant communication, electrical signals, intelligence, and biochemistry. Outside of work, I find joy in activities like going for walks, hiking, playing games with my little brother, watching TV shows, movies, and, of course, cartoons.

GUSTAVO MAIA SOUZA
I am a biologist who fell in love with plants from a very young age. Even though they do not speak directly to us, plants can teach us important lessons about how to live better in our beautiful world. So, I have spent the last 30 years of my career as a plant ecophysiologist trying to listen to them and understand them. It is not easy, because they just "whisper" but it is definitely worth it!