Plant roots mysteriously pulsate and we don't know why—but finding out could change the way we grow things

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You probably don't think about plant roots all that much—they're hidden underground after all. Yet they're continually changing the shape of the world. This process happens in your garden, where plants use invisible mechanisms for their never-ending growth.

Scientists discovered about 15 years ago that genes at the root tip (or more precisely, the level of proteins produced from some genes) seem to pulsate. It's still a bit of a mystery, but recent research is giving us new insights.

What we do know is this oscillation is a basic mechanism underlying the growth of roots. If we better understood this process, it would help farmers and scientists design or choose the best plants to grow in different types of soil and climate. With increasingly extreme weather such as droughts and floods, damaging crops around the world, it is more important to understand how plants grow than ever before.

To really understand how plants grow, you need to look at processes that happen inside cells. There are numerous chemical reactions and changes in the activity of genes happening all the time inside cells.

Some of these reactions happen in response to external signals, such as changes in light, temperature, or nutrient availability. But many are part of each plant's developmental program, encoded in its genes.

Some of these cell processes have regular oscillations—some families of molecules rhythmically appear and disappear every few hours. The most well known example is circadian rhythms, the internal clock in plants and animals (including humans).

Natural cycles

There are many other examples of spontaneous oscillations in nature. Some are fast, such as heartbeats and the mitotic cell cycle, which is the cycle of cell divisions. Others, like the menstrual cycle and hibernation, are slow.

Most often, they can be explained by an underlying negative feedback loop. This is where a process triggers a series of events, which then represses the very activity it triggered. This seems to be the case for the root growth pulsation.

Shortly after the root tip gene oscillation was discovered, scientists noticed this pulsation leaves an invisible mark. They found this out by using fluorescent markers visible under a microscope. These marks are left at places where the root can grow sideways. This means they provide regular cues that lead to the root system taking its shape.

Its cause is unknown today, although scientists have ruled out theories that it may be driven by circadian oscillations.

We do know there are many feedback loops involved. A plant hormone called auxin seems to be crucial to the process. It wakes up some genes coding for proteins, such as those needed for growth. Charles Darwin hypothesized the existence of auxin, and its chemical structure was confirmed around 100 years ago.

The genes which oscillate are the auxin "targets". When auxin enters a cell, these target genes tend to become more active. Some of these genes are related to growth but not all. Auxin triggers the removal of "repressors", proteins which can block the activity in genes. Animals have repressors in their cells, too.

However, these repressors are activated by the genes they block. It could be that this feedback loop triggers the oscillations we see, but we don't know for sure.

We know auxin moves from cell to cell via an intricate network of transporter proteins. The way proteins directly travel to parts of cells depends on the surrounding levels of auxin itself. This is another feedback loop. The pulsation happens in growing roots, where cells at the tip are continually dividing as a result of the cell cycle (which involves separate feedback loops).

What a conundrum

Scientists often turn to mathematics to help explain things. Researchers have used geometry since ancient history to study the visible part of plants. A branch of mathematics developed in the 19th century called Dynamical Systems Theory (DST) has given scientists some clarity about why plant roots oscillate. Scientists have been using tools from DST to try and show how auxin patterns are affected by rounds of cell divisions.

If these rounds of cell division were well synchronized, we could show that, in theory, this would produce a regular pulse of auxin.

But this doesn't solve the mystery because cells do not typically divide all at the same time, and so any pulsation of auxin would be fairly irregular.

When my team looked under the microscope for fluorescent auxin markers, we found a lack of regularity in auxin in the parts of the root where its target genes oscillate regularly.

This suggests that the root tip gene oscillation may be linked to root growth but doesn't happen at the same time as root stem cells are dividing.

Though still mysterious, we are now better equipped to decipher this enigma. The answer is probably not with one single process, but a result of an interplay between various processes. We know the key players, but the rules of the game they play are yet to be discovered.

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