The Upside-Down Intelligence of Plants.

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Red text cues to power point slides

In the Sixteenth century, everyone believed that the earth was the center of the Universe. Then in 1543, Copernicus published a model with the sun at the center of our planetary system. Galileo with his telescopes confirmed that the earth moves around the sun. Putting Galileo to death could not stop the reality of his vision. People had to continue to struggle with a new vision of how the universe was put together.

Fast forward two centuries. Most people accepted the words of Archbishop Ussher that the world was created on October 23, 4004 BC and was therefore 6,000 years old. Then Christopher Lyell used geological evidence to proclaim that the earth was billions of years old. Again people struggled to accept a radical change in their understanding of the world.

Then along came Darwin stating that humans had descended from monkeys. As you well know, a hundred years later, some people are still struggling to accept that idea.

I bring up these examples because, we, in our own time are faced with another radical restructuring of our understanding of the world. We have thought that plants are just there - they grow, but otherwise they are not much different than a stone. However, scientists are conducting experiments that show that plants do indeed behave as if they had a brain. For us, accepting the evidence and figuring out what it means for the interdependent web will be a real challenge.

So what is the evidence that plants can hear, see, learn and remember, that they have language, and that even some can count?

Let's start with learning and remembering, since the effectiveness of many of the other "senses" depends on the plant remembering prior stimuli.

Sensitive plant

Many of you have seen and touched a sensitive plant. Normally its leaves are spread wide. But the minute one of the leaves is touched, the leaves all fold up, presumably to get away from danger. Dr. Monica Gagliano put sensitive plants on a suspended platform. When the platform was dropped six inches, the leaves all folded up…for the first through fourth drops. In subsequent drops, the leaves folded up less and less. By sixty drops, the plants ignored the experience. It appears that they learned there was no danger. The amazing thing is that even a month later these plants ignored being dropped. They appeared to remember that there was no danger. But if they were shaken, they'd fold up right away. This shows that it wasn't just fatigue. By contrast, studies with honeybees show that these bees don't remember things any longer than 48 hours.

Seedlings

Dr. Gagliano did another study with pea seedlings. She put their pots beneath a Y maze with a fan and blue light (sky) on one branch of the maze. Other peas were in a maze that had a fan on one side and the light on the other. After being trained, the seedlings that had been growing toward the light and the fan would grow toward the fan as if the breeze made them expect the light to be there.

Dr. Gagliano's experiments show that plants have the ability to predict future events based on their association with past occurrences.

What is the evidence that plants can hear? It has long been known that sage plants produce noxious chemicals in their leaves when they are nibbled by caterpillars. These chemicals are volatile. When they move through the air, nearby plants are warned that an attack is beginning. Recipient plants then produce toxic chemicals in preparation for an oncoming attack. When scientists merely played a sound recording of nibbling caterpillars, the plants that heard it geared up by producing toxic chemicals.

In another experiment. Dr. Gagliano put her pea seedlings in their y maze pots. This time one arm of the pot was placed in either a tray of water or in a coiled plastic tube through which water flowed; the other arm had dry soil. The seedlings grew toward the fluid side, even when the moisture was hidden inside the tubing. She says, "They just knew the water was there, even if the only thing to detect it was the sound of flowing water."

Next let's consider language. Let's go back to the sage plants that produce airborne chemicals to warn their neighbors. This could be considered a language. People use sound waves to convey information, plants release various volatile chemicals into the air. Different individual plants release different compounds – words - which combine in different ways, the equivalent of a sentence. When you sniff sage, you are smelling various camphor compounds. The more related the plants are, the more similar their language, and thus the more easily they communicate. Sage seedlings inherit this individual 'language' of scent from their parents.

Trees

The next time you are in a deep forest, sniff deeply. What you are smelling is the language of the trees. Trees also use volatile chemicals to communicate. Within a large tree, most processes are very slow. The speed with which chemicals can move through the air makes them a very useful communication tool, warning of attack. In a 1980s study, it was found that when leaves are damaged, their healthy neighbors emit natural insect repelling tannins as if they themselves were under attack. When trees are weakened, they are more attractive to predators, so it is in the best interest of the whole community to stay strong - thus the warnings.

Another kind of airborne communication is used to call in predators. It has been shown that some trees can actually taste the difference between different kinds of insect saliva. The trees calibrate their response by which insect is bothering them. They can emit specific chemicals to call in predatory insects. For example, (in pines) a small predatory wasp will come and lay its eggs in the larvae of the chomping caterpillar. These eggs hatch and destroy the caterpillar.

We all know that plants use the fragrance of flowers to call in insects and birds for pollination. I just read another interesting example. It seems that the function of caffeine in plants is to entice bees to come back to the same plant. Once bees are hooked, they are likely to return.

The language of trees is also conducted underground through root tips. In a forest, roots are all connected to one another through a microrhizal network. This interwoven system of fungus and root tips acts to carry messages throughout the forest. Dr. Susan Simard, one of the scientists who studies this network calls it the 'wood-wide-web.' In fact these networks act much as our Internet, sending messages about insect attack and drought from one tree to another. There appears to be a language of underground transmission. Dr. Simard says

"Information is being sent from one plant to another directly and it changes their behavior".

Hold up book

Much of this information about trees comes from a book by Peter Wohlleben, The Hidden Life of Trees. Many of you may have already read it. It is full of good scientific information. Even so, it gives my scientist and botanist friends conniption fits. This book is exceedingly anthropomorphic. "Mother plants don't want their children to grow up too fast." "Lazy plants who live where there is plenty of water are spendthrifts who can't survive drought. These trees don't know the meaning of restraint. " Really now…. I'll come back to questions of anthropomorphism later.

Venus fly trap 1 & 2

Now for the most amazing discovery – that at least one plant can count. The Venus Fly Trap is known for its ability to catch and digest insects. The trap is a modified leaf that has sensory hairs. One hair being triggered and the plant does nothing – it could be a raindrop, a gust of wind. No point in wasting energy on a false alarm. But if it is a fly, who bumps a second hair it sets off an electrical impulse – an action potential. This raises the plant's calcium levels. The plant responds by sending water into its leaves which rapidly change shape and entrap the insect. Hairs three, four, and five trigger the emission of digestive enzymes.

Once the insect has been caught, the trap turns into a 'green stomach' filled with meat disintegrating enzymes. It takes several days to digest the dead fly. It has been shown that there are chemical sensors lining the trap. It can detect insect chitin and substances in the fly's blood. So long as it tastes something, it keeps on digesting. Then the trap turns into 'intestines'. The same five electrical impulses that closed the trap now trigger enzymes to absorb the nutrients from its prey.

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I have shown you that there is a good basis in the data indicating that plants seem to have intelligence. Now we come to the hard question. What is intelligence? Is it necessary to have a brain? Can we use words like learn, remember, forget, hear, or see when we talk about plants? Should we blur the line between plants and animals that has, until now, seemed so clear? Or should scientists and the rest us just say "this is a bunch of poppycock"?

Part of the reason that humans have so much trouble imagining that plants have intelligence is that much that happens in plants either happens out of sight, or in an incredibly slow time frame. Plants are sessile – they must spend their whole lives in the place where they are rooted. This means they must have a nuanced understanding of their immediate vicinity. We humans have 5 senses; plants have more than twenty. They can sense temperature, humidity, light, gravity, nutrients, toxins, microbes, electrical signals and many different chemicals, as well as signals from other plants. Until the advent of computer probes and time-lapse photography, all of this was invisible.

We think of behavior as action. Running, jumping, eating: in these terms, plants have no behavior. But if you define behavior as active response to cues, then, as I have already shown you, plants do have behavior. Decision making is certainly behavior. Roots or branches that grow in the optimal direction are therefore behaving, even if it happens so slowly that it is hard to see.

But how can this all happen without a brain? Or any other organs, for that matter. Yet, if you stop to think about it, organs contain essential life activities in specified locations. This won't do. If you are grass, a moose could come along and eat your brain or your heart. There is a survival advantage to dispersing bodily functions. By dispersing the essential functions of life throughout the plant, 80% of a plant can be destroyed and it can still continue to thrive. Ask a gardener who pulls weeds and they will say with a wry smile, "Yup, that's true."

The best way to think about the intelligence of plants is that it is like a hive of bees. Intelligence is the cumulative effect of interactions of the whole. A better metaphor for our time would be that plant intelligence is like the Internet or artificial intelligence. A plant's dispersed sensory system depends on electrical signals, just as we depend on neurons. It also depends on chemicals like serotonin and dopamine, just as our bodies do.

Darwin started thinking about these questions more than a hundred years ago. He theorized that plants have special cells devoted to processing information and making decisions about root growth. Darwin had a mental image of plants as being like a person, only upside down. A plant's head is in the soil, and its reproductive organs (flowers) are sticking in the air. A plant has upside down intelligence.

What are we to make of this new information in our time? How will these new scientific studies change our perception of the world we live in? Will we embrace them? Resist and fight their implications? Time will tell, but we can start now to discuss these fascinating ideas.

I mentioned earlier that scientists are intensely opposed to anthropomorphism, the attribution of human characteristics to things which are not human. On the whole, this attitude has served science well. But it also blinded scientists to much that is true. It took the daring of Jane Goodall to convince the world that chimpanzees have social and family life. Goodall said, "Only if we understand, will we care. Only if we care, will we help. Only if we help shall all be saved."

Conservationists have long known that it is much easier to raise funds and political will to protect dramatic large animals like the panda. It is very difficult to get people to care about

protecting plants. There are endangered plants growing right here in NY State, yet I'm willing to wager that you know more about the spotted owl in the Pacific Northwest. Possibly a bit of anthropomorphism will help. If people know that trees and other plants have behavior and intelligence, they might be more willing to protect them.

Another way this new information could be helpful is in farming. Perhaps a mechanical 'nose' could be invented to put on a tractor. This nose would sample insect warning chemicals being put out by plants. For example, this nose could be mounted on a tractor out at Indian Ladder Farms. They could drive the tractor through the apple orchards to be alerted to the exact time and location of a new insect attack in order to pinpoint the danger and nip the problem in the bud.

We know that the monocultures of corn, soybeans, and other plants take massive infusions of pesticides and herbicides to do well. You might say that we have bred the intelligence out of them; these crops are no longer able to protect themselves. Once scientists really understand the mechanisms of plant intelligence, they might be able to breed some protective wildness back into our food crops.

In the end, perhaps above all this is a spiritual task. Like the people of Galileo's time, and Darwin's, we must be open to change. It is exciting to try to envision a world that we never knew was out there. We must be humble. The earth is not the center of the universe. Evolution is real. Human beings are not the only organisms who are intelligent.

I close with a quote from Ferris Jabr. "To recognize that we are not alone, that we share our world with other conscious, thinking, speaking beings, requires us to sacrifice a great deal of ego. At the same time, it folds us, palpably, inextricably, into the fabric of a much grander universe."

From "Can We Talk? "Ferris Jabr NYT magazine 5/14/17