The Physics of Trees

Theories of how plants grow upwards.

BY **JOHN BICKART** | September 24, 2024

Respect in Science Class

It would be great if science education increased in its respect for ancient ideas. Sometimes we (I am a science teacher, too) tell how modern discoveries replace older ones saying, "Now we know this or that, but previous scientists got that all wrong." We often describe the march of knowledge as a linear process, where we build upon previous ideas, always getting better and better.

The reality of scientific understanding is not a straight line, always going upward. Sometimes, we lose our way for a while. Let me give you some examples.

In the era of classical mechanics, during the 1700s and 1800s, science took a detour into the idea that the physical world is a big machine. We likened all of nature to mechanical devices that had separate pieces, separate functions, and individual effects. Then, in the 1900s came quantum mechanics. All of a sudden, some ancient ideas seemed to come back into view. Ideas like the *observer effect* and *entanglement*.

The Observer Effect

Many indigenous cultures believed in spiritual worlds and spiritual, unseen forces. Plato asserted that reality is subjective. This idea resonates with the observer effect in quantum mechanics, where the act of observation can influence the physical world. Both Hinduism and Buddhism assert that consciousness has relationship to the physical world.

Entanglement

Chinese Taoism underlines the interconnectedness of all things. This aligns with entanglement in quantum mechanics, where particles can be linked in ways that defy classical understanding. Many ancient mythologies describe the universe as a cosmic dance or play. This may have been a precursor to the interconnected nature of physical matter.

How to Bring Back the Respect

Show students of science how ideas from previous eras can come back. Be a model for your students of a person who learns. Show them how you respect both old and new ideas - how you listen with wonder and awe to both ancient and new theories. One way to do this is to describe the structure of scientific evolutions and revolutions.

Thomas Kuhn, in his seminal work "*The Structure of Scientific Revolutions*," (Kuhn, 2004) introduced the concept of paradigm shifts to explain how scientific progress occurs. He argued that

science doesn't evolve gradually but rather undergoes radical transformations. For example, take the way science thought about the effect we can have on nature by *observing* it.

> The *Ancients* had a form of learning new ideas from spirit guides, astral projection, or interconnectedness with nature. Thus, they thought that the observer has an effect on physical reality.
>
> Then in the *Newtonian Era*, scientists thought that you must physically have local interactions between objects that are not connected in order to affect the material world. Thus, they thought that the observer does NOT affect physical reality.
>
> Now, in *Quantum Physics* scientists are seeing non-local interactions, called entanglement, where affecting one particle instantaneously affects another - even over vast distances. Therefore, we now are back to the ancient idea that the observer does, in fact, affect physical reality.

So, respect old ideas. This has at least two benefits. On the one hand, it keeps the student alert for clues as to the next discovery. And, on the other hand, it promotes a state of *wonder*, where the student expects or hopes to receive that which may be wonderful. Contrast this to a state of simple *curiosity*, where the student may fall into the learning as an act of reaching out to grab something for some form of personal gain.

Theories of How Plants Grow Upwards

"The ancients used to think that trees held up their branches using an opposite to gravity, sometimes called levity", I have often said over the last half century of teaching. Then I go on to say, "Science now has a universal law of gravitation and no way of measuring any force of levitation." But then I always add, "However ... do not ever consider this case closed. Science is always alive. And ancients are to be respected. You must always keep an eye out for something that was believed long ago, for it may have a grain of truth to it. It may be a seed for a future discovery. The fun of science is that it is always finding something new."

Material-Based Modern Theories

Plants often grow upwards to most efficiently take in light. This often means going upwards as opposed to sidewards. Some ways plants do this are as follows.

> *Phototropism* is a theory where the instinct of green plants receive sunlight by turning toward the light, allowing for photosynthesis.
>
> *Auxin* is a plant hormone that stimulates growth and development.
>
> *Photoreceptors* in plants take in light.

Gravitropism is the tendency of the plant to sense gravity pulling down and to therefore grow up.

Thigmotropism is the plant's response to touch or physical contact. For example, if another plant presses against it, it may bend to continue toward light.

Growth Adjustment of plants occurs when they adjust growth rate or direction in response to mechanical stress. You see this when they climb over objects.

In order for plants to grow upwards, they need sap to flow upwards. Some theories of how this happens in trees are as follows.

Capillary Action, where tubes (the xylem vessels) transport sap, are increasingly narrow. The surface tension of the water in the sap causes it to rise in these narrow xylem tubes which are 20 to 200 micrometers wide. The tiny cell wall pores are 2 to 5 nanometers.

Root Pressure, where the roots act as pumps.

Water Movement from the surrounding soil pushes the sap upward.

Cohesion of water being attracted to itself causes it to seep upwards.

Now, step back and look at the modern theories above. Notice that they all have a mechanical, physical, material-based set of

causes to explain how plants grow upwards. In every case, there are responses, pushes, and pulls from separate physical parts of plants that trigger the action of the plant.

The ancient indigenous cultures spoke of spiritual causes. They are often seen as people who are simply making up their ideas - attributing science to the Gods. They are thought to be inventing tales because they could not really figure out the detailed explanations. While it is true that humankind has learned a great deal about the specific workings of plants, we sometimes throw away the entire gist of the ancients without listening carefully to their ideas. The ancients have seed-thoughts. Like the oak tree grows from a tiny acorn, our next discoveries in science can grow from listening in wonder to the spiritual teachings of ancient, indigenous peoples. Let's try this process of integrating ancient and modern science in a specific case. Let's look at how trees are pulled down by gravity yet grow to great heights.

How Does a Tree Hold Up its Branches

Science class can be a place where we walk the walk of the social emotional act of respecting others, by integrating ancient philosophical/scientific ideas with modern science. Since the frontier of science is always changing and is built upon former discoveries, we constantly have the chance to learn from earlier views, and trees are a fruitful place to begin. Trees are amazing. They grow upwards, they hold up branches to seemingly defy gravity, their sap rises hundreds of feet, the sturdy trunks can sway in the wind, their dense wood is made primarily of air and water, their bark seems to be a communication network within a

single tree, not to rival the incredible collaborative mycelium network of trees in a forest.

How does a tree hold up its branches?

To begin integrating ancient with modern consider this. Moderns often go right to the mechanical processes of the tree to ask, "How does it work?" This is much the same as one would study a car or a television. There is nothing wrong with this, if it is the first half of an inquiry. Let's integrate this approach with an ancient way of study.

Ancients often distinguished between curiosity and wonder. Curiosity of how something works could all too easily have a selfish aspect. If you are solely curious, you can find yourself looking at a tree like a person who is shopping for something in a store, asking questions like, "What can this do for me?", or "How much will it cost to gain all of the benefits of this?"

Wonder can be different. To approach the tree with wonder, one might, as my friend would say, go on "A quest, not a mere questioning." Aristotle held a teleological worldview - a quest to explain a phenomenon by asking, "what is its purpose?", rather than "what caused it". The appreciation and quest for a *purpose* has the possibility of encompassing a worldview that is beyond the student's self. Instead of selfishly getting benefits from the tree, the student is in community with the tree and the forest and the whole world asking how to fit in. This can suppose a spiritual world. It can postulate that there are higher plans for the tree ... and for oneself. Aristotle assumed a purposeful, moral, harmonious, ordered universe. He would say that the purpose of a seed is to become a plant. In some modern materialist science, we sometimes limit our questioning to the physical and material aspects, bereft of a possible role of moral principles or spiritual dimensions. So, using both the ancient and modern lenses to learn how trees hold their branches up, we might look at the physical facts, and also at possible plans nature has for the tree. Maybe you could tell your students that ancients believed that the tree holds up its branches because the spiritual beings that run nature gave it the power to oppose gravity. Now, that brings up the ancient notion of levity ...

How Can Trees Work with Gravity ... Is There a Force of Levity?

Lau Tzu alluded to an opposite to gravity in Verse 76: LET YIN PREDOMINATE OVER YANG in the *Tao Te Ching*,

> "Wherever you go,

the rigid lie low.
While the weightless in the sky,
and all that is gentle,
fly boundlessly high."

(Tzu, by Ralph Alan, & photographs by John,
2002/circa 500 BC, p. 153)

In ancient Greece, roughly around the same time as Lau Tzu, Aristotle, Plato, and the Stoics wrote of a quintessence - a fifth element - something that was ethereal, pure. The quintessence was believed to be something spiritual. It was lighter than the four classical elements: earth, air, fire, and water - not a substance. It was considered to be pure and perfect - a spiritual or higher power or principle. It is interesting to note, that in modern science, quintessence is still being discussed as a theoretical form of dark energy.

Elsewhere in the world, indigenous Native Americans shared views with Australian Aboriginals, and some African cultures in beliefs that plants were connected to spiritual forces or the Great Spirit or Creator who guided the upward growth of plants, symbolizing their connection to the heavens or a higher power. (Jacobs & Narváez, 2022)

Often, we modern science teachers feel that it is misleading to mention something like levity. It is seen as a useless concept that has been proven to be non-existent. But I disagree. I listen to ancient descriptions with respect. At the very least, the concept of levity may have a grain of truth in it. At best, it may be a concept that can move science forward as a forgotten

principle that we have lost the ability to see because we look at the tree as a machine. Who knows if future discoveries about the tree may show that it has a nature-given purpose to communicate across forests to other trees, the animals, and to humankind. It may be that trees will provide wise insights, not the least of which is the way it holds up its branches. When I teach about such beliefs, I cite historical cases where science discovered unseen phenomena that revolutionized our understanding of nature. One such case was when, in the late 1700s to the early 1900s, 13 different scientists in 7 countries discovered wonderful ways to work with electromagnetism. Prior to these advances, electromagnetism was an unseen novelty, a curiosity.

Volta 1745-1827 Italy Battery
Goethe 1749-1832 Germany Matter as Field
Ampere 1775-1836 France Current
Oersted 1777-1851 Denmark Electromagnetism
Ohm 1789-1854 Germany E = I * R
Faraday 1791-1867 England BIG 3, Field
Maxwell 1831-1879 England Field Equations
Edison 1847-1931 USA DC, Light Bulb
Tesla 1856-1943 Croatia/USA AC, Resonance
Hertz 1857-1894 Germany Frequency
Marconi 1874-1937 Italy/England Radio

One case in point was where Oersted 'saw' evidence of this unseen relationship between electricity and magnetism. Here are the exact notes of his observations, circulated privately to physicists and scientific societies in July of 1820 in a document entitled "Experimenta circa effectum conflictus electrici in

magneten" (Experiments on the Effects of the Electric Conflict on a Magnet).

> "When the wire of the galvanic apparatus is placed above the magnetic needle, the latter is deflected to the west; when it is placed below, the needle is deflected to the east."
>
> "If the wire is placed at right angles to the magnetic needle, the latter remains stationary."
>
> "The deflection of the magnetic needle is proportional to the strength of the electric current."
>
> "The direction of the deflection of the magnetic needle is reversed when the direction of the electric current is reversed."

Michael Faraday picked up on this unseen phenomenon, constructing what is arguably the basis for all modern electromagnetic invention by creating the GENERATOR, MOTOR, and TRANSFORMER. Faraday - Einstein's favorite scientist - not only observed the same relationship of electricity to magnetism as Oersted, he also seemed to inquire of the nature-given purpose.

To get back to the point of respecting the ancient force of levity - the possible opposite of gravity, consider this. One current theory of a use of a spinning electromagnetic field is that it may cause an ability to oppose gravity and levitate objects. My students always ask, "Are you guessing at flying saucers?" To

which I always answer, "Perhaps - but did you know that trees - which often rotate as they grow upwards, also emit an electromagnetic field? Maybe trees will spawn future scientific discoveries on levitation." My students always pay very close attention to science class, once I mention that one of them may hear a clue as to how to invent the hovercraft!

Whether levity exists or not, it exercises our social responsibility to listen to others when we give real respect to ancient concepts. Having done this, I integrate modern facts about trees that support the theories of how they grow upwards. Take note as you read the facts below, that my classes are constantly remembering the idea of levity as I describe the phenomenal things trees can do.

Modern Facts About Trees

I was teaching in China back in 2007. One of my students was the head architect of a 3,000 architectural firm. He led the team of the top 50 architects assigned to the sister cities of Shanghai and Pudong. You may have seen some of his work - incredibly creative and beautiful buildings that 'color outside the lines.' He wanted me to compare the English language to Chinese. He was constantly in meetings with Americans who were making baseball references in their metaphors - *that idea is a home run, that's a close call, that's a swing and a miss, you just hit that one out of the park*. He needed translations.

There are some 20,000 modern Chinese characters with over 100,000 from history, where each character is like a word. Arguably, another one of the largest languages may be English,

as spoken in the U.S. We Americans change our language and add so many words, that some count our vernacular and idiomatic expressions to include 650,000 words, whereas there are typically 200,000 words in other Romance languages.

One day, my architect/student suggested we have our 'class' at the top of one of his magnificent buildings. Sitting with drinks and snacks, he told me how that particular building was designed to be able to sway 18 inches. I have since learned that the Empire State Building in NYC sways 6 inches, and some buildings sway up to 3 feet. This got me thinking about trees. I live in the heart of the greatest diversity of hardwoods in America - the Smoky Mountains of North Carolina. The oaks in my back yard sway approximately 18 feet when a storm is coming. How do they do it? What does nature know about 'building' that we have not yet discovered? How do they grow so tall and stay so flexible, yet strong?

Are Trees Joking (levity)? I run to my treehouse when a storm is coming. It can sway 18 feet!

Branches

A tree's branches often have interlocking cells in the place where the branch meets the trunk. Modern explanations of tree branches claim that these cells are responsible for the way the tree holds up the branches? I wonder.

As I take hikes in the Smoky Mountains - about 3 per week, I marvel at the branches that stretch out. Some typical weights of hardwood trees (in pounds) that have branches that are 10-12 inches in diameter, over a 40 ft span in length are as follows.

TREE	10" diameter	12" diameter
white oak	1131 lbs	1703 lbs
red oak	708 lbs	1074 lbs
black oak	868 lbs	1285 lbs
hickory	1138 lbs	1598 lbs

How do they do it?

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Wonder versus Curiosity

Wouldn't it be great if we kept *wondering* and sought to have communication and coexistence with nature versus feeding our voracious appetite for *curiosity* of nature's benefits to humankind? Think critically about this one question … is the end goal of science to see how to *USE* nature, or is it how to be in *HARMONY* with nature? Sure, one might answer, "Both." But, which way we lean could shift our thinking to find a new

level of insight! Barbara McClintock's official Nobel Statement issued at Cold Spring Harbor Laboratory, October 10, 1983, revealed the scientist she was. It showed that she listened with respect. She sought relationship with the maize plant (corn). Yes, she sought after and successfully learned how to use corn. But she did so by following the plant's lead. She let the plant speak.

> "It might seem unfair to reward a person for having so much pleasure over the years, asking the maize plant to solve specific problems and then watching its responses." (Fine, 1998)

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I leave this essay with an exercise I use in class, where we envision the life of a tree.

Exercise of Envisioning Lightning: close your eyes and envision a place that is no place - outside of space and time. Now imagine a tree growing over and over as if it is a movie or a fantasized vision. Each time you grow the tree, run your fantasy vision at increasing speeds until the tree grows before your mind's eye in an instant. Do this for a minute or two. When you are done, read the poem below. It comes from a vision I had when I was younger.

Quickening

fire and lightning
may appear
separate from
plants growing here

but see the branch and flower spread
to full grown height from a single seed
then quicken the vision inside your head
till the scenery reaches terminal speed

trees and bush
grass and stem
are simply fire
slowed down, then

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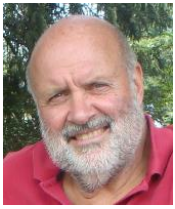
About the Author



John Bickart

John Bickart, Ph.D., likes to work in the background and let good ideas speak for themselves. He believes that children, and sometimes adults, know what they want and that they empower themselves when they listen to their hearts.

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