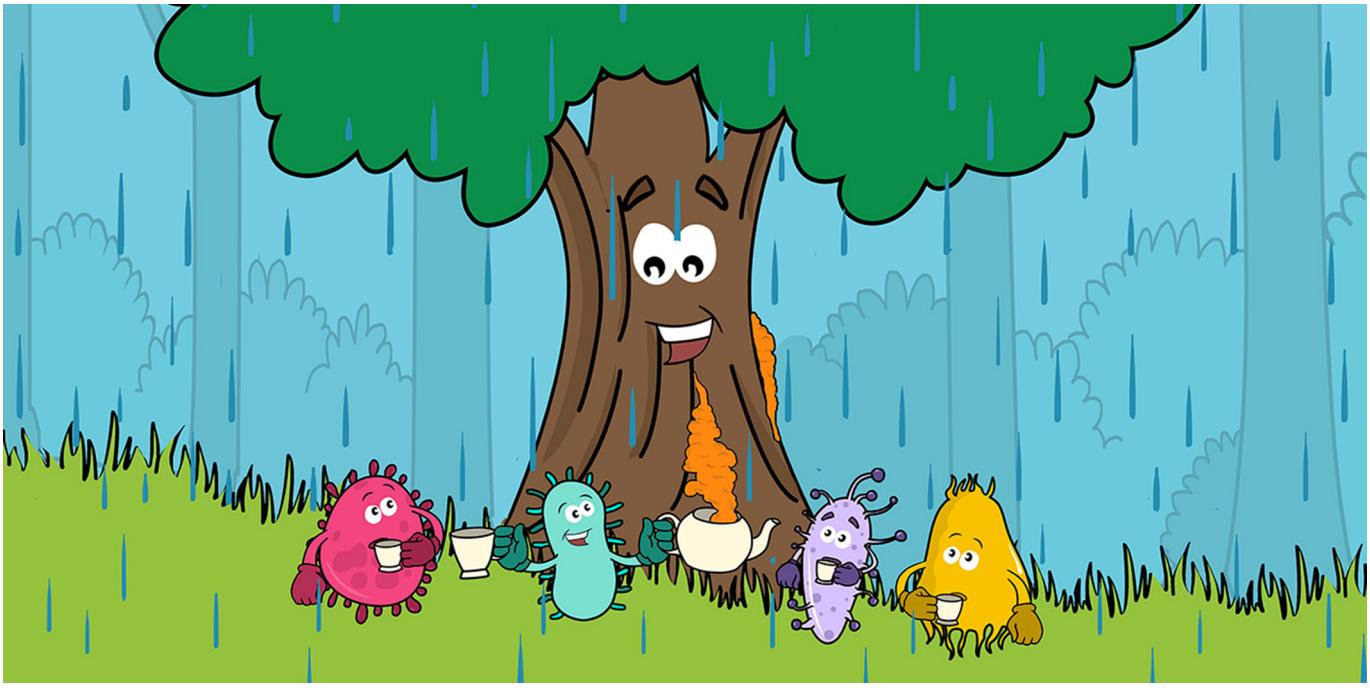
frontiers FOR YOUNG MINDS

EARTH AND ITS RESOURCES
Published: 14 April 2022
doi: 10.3389/frym.2022.703704



HOW TREES MAKE TEA

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YOUNG REVIEWER:

LAUREL

AGE: 10

Tea is a mix of natural plant chemicals dissolved in water. You should not drink it, but a weak tea drips through a tree's branches and runs down its trunk when it is raining. The main ingredients in both tea and tree tea are organic molecules. Some, like tannins, are colorful and give tea and tree tea their brownish colors. Others, including sugars, are clear and loaded with energy. Some molecules build up on the tree's surface as it sweats. Other molecules are deposited on the tree by the wind, building up like grime on a car. When it rains, the built up sweat and dirt are washed away as tree tea. Tree tea is an energy drink that bacteria on the forest floor crave! Tree tea is also a flow of carbon from trees to soils that researchers are just beginning to understand.

THE ROLE OF TREES IN THE CARBON CYCLE AND CLIMATE

CARBON CYCLE

The study of how carbon moves around the world and is transformed from one form of molecule to another. Understanding the carbon cycle is critical to predicting our future climate.

PHOTOSYNTHESIS

The process by which green plants and some other organisms use sunlight to synthesize organic molecules from carbon dioxide and water.

ORGANIC

Containing hydrogen and carbon. This is different from "organic" produce in the supermarket. Examples of organic molecules include sugars, oils, proteins, and wood.

RESPIRATION

The use of organic molecules by organisms for energy. When we, trees and most bacteria respire, we use up organic carbon and oxygen, producing carbon dioxide, water and energy.

TREE TEA

The solution made when it rains on trees. Tree tea contains a mix of organic molecules that bacteria consume, but you should not drink.

Humans are changing the Earth [1]. Our use of fossil fuels has increased the concentration of the greenhouse gas carbon dioxide in the atmosphere, which is warming the planet. Scientists recognized over 100 years ago that global warming would be a side effect of fossil fuel use. This led researchers to study the natural **carbon cycle**, to see how human use of fossil fuel carbon and the natural carbon cycle interact to shape our climate. Today we have a good understanding of how carbon cycles around the world. Trees on land take carbon dioxide out of the atmosphere, using a process called **photosynthesis**. Photosynthesis uses the sun's energy to make sugars and other **organic** carbon molecules from carbon dioxide. Humans, other animals, and bacteria use the organic carbon molecules created by trees for energy. When we eat a sandwich or add sugar to our tea, the energy we gain was originally from the sun. When we and other organisms use the organic carbon and energy in foods, we convert the organic carbon back to carbon dioxide, which is released when we breathe out. Scientists call this process of using organic carbon for energy and releasing carbon dioxide **respiration**. The carbon dioxide produced by respiration goes back into the atmosphere. When scientists study the carbon cycle, they are interested in how much of the carbon taken from the atmosphere by photosynthesis is converted back to carbon dioxide by respiration. To understand this on land, they need to follow organic carbon from where it is created in trees out into the wider world.

Often, when trees and forests are in the news, they are mentioned as important carbon stores. To store carbon, trees take carbon dioxide from the air and use it to build their leaves, branches, trunks, and roots. As trees can live a long time and grow to be big, they can store lots of carbon. When forests are burnt by people or wildfires, the carbon the trees worked so long to store is sent back into the atmosphere as carbon dioxide. Adding this carbon dioxide back into the atmosphere adds to climate warming. Although the best way to reduce climate change is to reduce the use of fossil fuels, protecting and regrowing Earth's forests is also important.

Trees are the architects and the architecture of forests. As well as building the forests, trees and other plants provide most of the organic carbon and energy for all the other creatures on the land and in freshwater like rivers, and even for some of the creatures in the ocean. To feed the organisms in these different environments, organic carbon from trees must be transported from the trees to these other places. There is a general flow of organic carbon from trees to the soil, into rivers, and eventually out into the oceans. Most of the organic carbon from trees makes its way to the soil when leaves fall from trees or when trees die. However, there is another way for organic carbon to reach the forest floor: as **tree tea** [2].

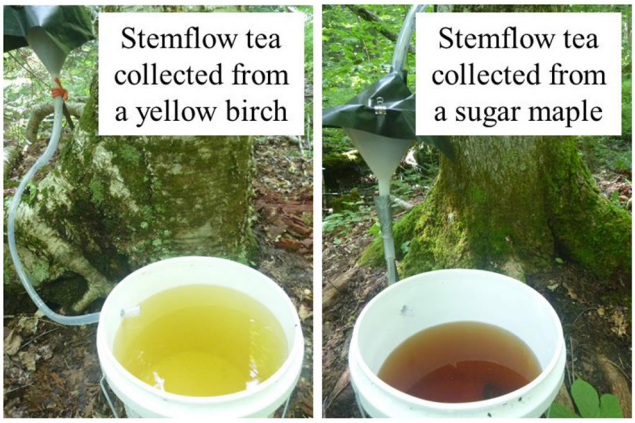

Figure 1

Different trees make different teas. When rainwater runs off a yellow birch tree (left), a yellow tea is formed; while rainwater running off a sugar maple (right) results in a golden, syrup-colored brew. Maple syrup is different from the tree tea in the photo! Syrup comes from inside the tree, while the organics in tree tea are washed from the tree surface.

PREPARING TO MAKE TREE TEA

When it is dry, trees sweat. The name for this sweat is **evapo-transpiration**. As trees sweat, they get dirty, just like us. Some of this dirt is organic carbon. When it is dry, trees also pick up organic carbon, and other dirt from the air. This is like the grime we might find on our skin after we exercise somewhere dusty or that we find building up on cars and windows. The organisms that live in trees can also add organic substances to the mix. Then, when it rains, all these different types of organic carbon are washed off trees and fall to the forest floor as tree tea: a wonderful molecular mix that fuels forest floor microbial tea parties [3].

EVAPO-TRANSPIRATION

The combined loss of water to the air from plants and is the sum of evaporation from and transpiration (sweating) by plants.

HOW TREES BREW WEAKER AND STRONGER TEAS

There are two main flow paths rain can take to the forest floor, and each creates a different strength of tea. The largest flow is as **throughfall**. Throughfall is the rain that drips through leaves and branches, bouncing from leaf to branch and then falling on your head if you walk under a tree. Throughfall tea is a lightly colored brew. The other, much smaller flow path is called **stemflow**. Stemflow is the rainwater that flows along the tree's branches and then down the trunk of the tree to the forest floor. This water spends more time in contact with the tree's surface. Just like letting a tea bag soak, the long, close contact between stemflow and the tree makes for a rich, dark brown tea (Figure 1). So throughfall makes a light tea and stemflow a dark tea [3]. Although throughfall is a lighter tea, much more rain reaches the forest floor as throughfall compared to stemflow. Thus, throughfall supplies 5–400 times more carbon to the forest floor than stemflow does [2].

THROUGHFALL

The portion of rain that makes it to the forest floor by dripping through leaves and branches.

STEMFLOW

The portion of rain that makes it to the forest floor by flowing down tree trunks.

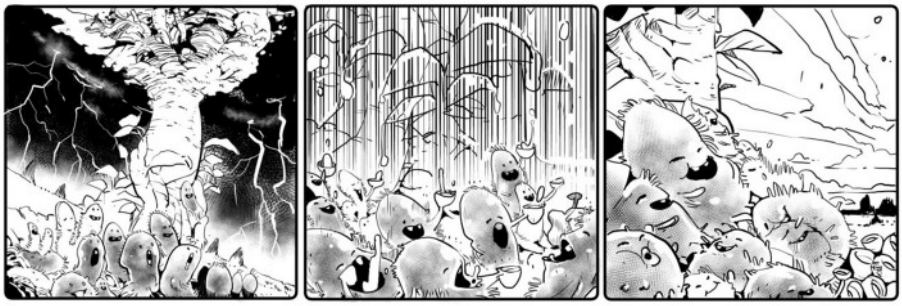

Figure 2

Figure 2

A storm brings a hot moment at a tree tea hotspot. As a storm brews, (left) the tree tea shop prepares to open for its bacterial consumers under the forest canopy, who have been without rain for days, weeks, or even months! During the storm, (center) bacteria "fuel up" with tree tea that drains from the leaves and bark overheard. Once the storm has passed, (right) the bacteria have had a filling meal and the tree has had a cleansing shower.

HOW TREES MAKE DIFFERENT TEAS

If we make tea from black tea leaves, we get a brown, caffeinated brew. If we make tea from mint leaves, we get a light green, minty tea. It is the same for tree tea—different trees make different teas. Live oak trees in Savannah, Georgia, USA, are covered in other small plants and mosses called epiphytes. The sweaty limbs of these oak trees result in rich, brown teas when washed clean by rainwater. In Vermont, USA, rain falling on sugar maple trees makes a golden, syrup-colored tea, while a yellower brew washes off yellow birch trees (Figure 1). Although the sugar maple stemflow may look sweet, the molecules that give tree tea its color may not be sweet at all, and you should not drink them. The same way tea, coffee, and orange juice have different colors and chemistries, different tree tea colors are also due to chemical differences in the molecules made and released by different trees [3].

WHO DRINKS TREE TEA?

You should not drink tree tea because it may contain potentially unhealthy ingredients [4]. So, who *does* drink it? Although other organisms on the forest floor, like fungi and animals, may use the organic carbon in tree tea, bacteria are its most important and voracious consumers. Although we cannot see them, these tiny microbes are critical for the health of forest soils and for carbon cycling. Just like us, bacteria need food and water. Laboratory experiments have shown that bacteria can use the organic carbon in tree tea [2]. When it is dry under the trees, they can survive. But when it rains, they really come alive. Stemflow runs down the tree trunk and throughfall drips from drip points in the branches, piping tree tea energy drinks to fuel hotspots of bacterial activity. While we may like to sip tea in the sunshine, the tea shops of the forest floor open in a downpour (Figure 2).

BACTERIA, THE TINY CONSUMERS THAT DRIVE THE CARBON CYCLE

As well as being lovers of tree tea, bacteria are one of the most important groups of organisms on Earth. There are about 8 billion people on the Earth today and collectively we add up to about 0.06 billion tons of carbon. Trees are the largest living store of carbon on Earth, totaling 450 billion tons of carbon. Although they are so tiny we cannot see them, bacteria are so numerous that they add up to an estimated 70 billion tons of carbon [5]. So, bacteria are not just numerous, they are a major store of carbon globally and they are one of the main users of organic carbon on Earth. Bacteria have a mixed diet. They can consume almost all forms of organic carbon, including the organics in soils, in sea and fresh water, and in decaying plants and animals. Bacteria in your stomach also help digest what you eat, so both you and they can access the organic carbon in your food.

HOW WILL TREE TEA SHOPS CHANGE AS THE WORLD WARMS?

Tree tea is important to forest soils, forest bacteria, and to ecosystems downstream of forests, such as rivers and the ocean. Natural patterns drive the delivery of tree tea to the forest floor. Where trees grow and when they lose their leaves influence when and where organic carbon is available to make tree tea. Patterns in rainfall influence when and where rain washes trees clean and carries tree tea to the forest floor. People are changing when and where tree tea is made. Deforestation, agriculture, and urbanization have altered the distribution of trees across the planet. Climate change is altering where certain trees can live, as well as when trees grow their leaves in spring, when they flower, and when they lose their leaves in fall. Climate change is also altering when, where, and how strongly it rains. All these factors need to be understood to predict how the delivery of tree tea will change in the future and whether changes in the amount and flavors of tree tea available will affect how downstream ecosystems function. There is plenty still to discover about tree tea. Grab a coat and a cup, and help make the next breakthrough in understanding forest brewing.

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SUBMITTED: 30 April 2021; **ACCEPTED:** 22 March 2022;
PUBLISHED ONLINE: 14 April 2022.

EDITOR: Leonardo Fernandes Fraceto, São Paulo State University, Brazil

SCIENCE MENTOR: Lynette Cheah

CITATION: Stubbins A, Ryan KA and Van Stan J (2022) How Trees Make Tea. Front. Young Minds 10:703704. doi: 10.3389/frym.2022.703704

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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LAUREL, AGE: 10
Hello, I like mechanical engineering and Lego. I like making things and tinkering. I like learning English and science.

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