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BRANCHFLOWS: UPSIDE-DOWN RIVERS CLINGING TO THE BARK ABOVE OUR HEADS

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AGES: 15–17

If you look up during a storm or when it is foggy, you may see little rivers flowing down the tree branches above your head. These are called branchflows, and they play an important part in moving water along trees and through forests. For scientists who study water, branchflows are really weird! They do not flow on top of something, like rivers that flow over the ground. Instead, they flow *underneath* branches, clinging to the bark, the same way you might cling to monkey bars at the park. Branchflows can also disappear before making it to the ground, because the water gets stuck inside of tree holes. Branchflows transport important stuff through the forest and to the forest floor, from life-saving meals to life-ending predators! Please join us as we explore what branchflows are, where they flow, what they carry, and why we need to know more about them.

WHY SHOULD WE LOOK UP DURING STORMS?

Looking up during a storm can be just as unpleasant as looking up on a clear, sunny day: instead of receiving an eyeful of sunlight, you might get a face full of water! If you are in a forest during a storm and you look down, you may notice dry spots here and there. What keeps these spots dry? The leaves and branches above your head, which are called the forest **canopy**, do this. When it starts to rain, a dry canopy keeps the surface below dry, simply by catching raindrops and snowflakes before they can reach the ground. Like a drinking glass, leaves and bark can only hold so much water, and eventually they will overflow. When leaves overflow, they begin to drip (Figure 1a) and the area below them gets wet. On the other hand, when bark on the top (upper) side of a branch is soaked, water drains down the bark to the bottom (underside) of the branch (Figure 1b), but it may not drip to the ground. Instead, this water flows along the branch bottom, hanging from the bark, defying gravity all the while (Figure 1c, Video 1).

The flow of water along branches is called **branchflow**, and it can transport liters (bucketsful!) of water from one area to another in a storm [1]. In this way, branchflows can keep some areas of the forest floor dry while making the area where the branchflow ends wet. We humans may prefer to wait out the storm in one of the drier spots. However, there are many thirsty ground-dwelling plants and microbes that may not have had a drink of water since the last storm. These organisms might prefer to make their homes in the wetter places at the ends of these upside-down rivers. In other words, understanding branchflows in the canopy can help us understand what is happening on the forest floor, particularly what grows and thrives where, and why.

CANOPY

The above-ground leaves, branches, and plants growing on them, in any ecosystem, like a forest.

VIDEO 1

After enough water drains to the branch bottom, branchflow paths can be seen.

BRANCHFLOW

Rain, fog, dew, or melting snow water that drains down the bottom of a branch of a tree or shrub.

Figure 1

Wet leaves and wet branches. **(a)** When leaves are soaked, they will usually begin to drip. **(b)** When the tops of branches get soaked, water drains to the bottom of the branches. **(c)** After enough water drains to the branch bottom, branchflow paths can be seen [Photograph credits: **(a)** John Van Stan; **(b)**, **(c)** David Dunkerley].

So, where can branchflows end up? And importantly, what can these branchflows carry and deliver to the places they travel?

WHERE DO BRANCHFLOWS GO?

Branches come in many shapes and sizes and can be covered in many different types of bark. As a result, branchflows can run into, or over, many obstacles as they drain to a bigger branch or to a tree trunk. These obstacles can force water off of its path. For example, if a branchflow hits a sharp bend in the branch, or a bark ridge that is too tall, water can lose its grip on the bark surface and drain to the ground below. This can create a **drip point** that can deliver 10 times more rainwater to a small spot on the forest floor [2]! Just as smaller rivers flow into larger ones, branchflows come together at bigger and bigger branches, gathering larger and larger amounts of rainwater. Scientists have observed some of the largest canopy water flows at the trunk, where branchflows from all over the tree unite and become what is called **stemflow**.

DRIP POINT

An area, usually at the bend of a branch, where lots of branchflow falls off the branch.

STEMFLOW

Branchflows that come together at the trunk and drain to the forest floor.

Given the right conditions, stemflow can drain hundreds of liters of rainwater to a small area around a tree! One of the conditions that affects stemflow is the type of bark. Smooth bark (like that in Figure 1) and bark with channels in it tend to drain the most stemflow, while flaky or spongey bark drains less due to the water getting sucked up, or splashed off. In some forests, stemflow can be so large and powerful that it rips away soil particles at the base of the tree trunk. At one site, stemflow carried away several centimeters of the soil surface (about the thickness of a juice box) in a single year [3]! In other forests, stemflow enters the soil easily by traveling along the roots. So, the story for stemflow does not end at the forest floor. In fact, scientists are still puzzling over why stemflow goes in different directions (into the soil or over it) at different sites.

In fact, some stemflow may not reach the forest floor at all. After all, tree trunks can have just as many obstacles as branches do. In addition to the extreme bends and rough bark, trunks often have holes in them. These tree holes can capture stemflow water, becoming what are called **dendrotelma**. Dendrotelma can store many liters of water before they overflow and let the stemflow continue down the trunk (Video 2). There are also many tree-dwelling animals that have been seen to give the bark quite a licking. For example, wild koalas have recently been caught drinking stemflow [4].

DENDROTELMA

A hole in a tree that fills up with water during a storm.

VIDEO 2

Here we see a small tree hole filled with stemflow water (called a "dendrotelma") and overflowing, permitting the stemflow to pass further down the trunk.

WHAT IS IN THESE UPSIDE-DOWN RIVERS?

Branchflows, like rivers, can carry a lot of stuff—from life-saving meals to life-ending predators [5]. Scientists call all these very tiny things particles. Many of these particles are made of elements (like carbon,

Figure 2

Creatures found in branchflows can include nightmarish nematodes, cute tardigrades, orchid seeds, lots of bacteria, and many fungal spores. Illustration by Tyasseta.

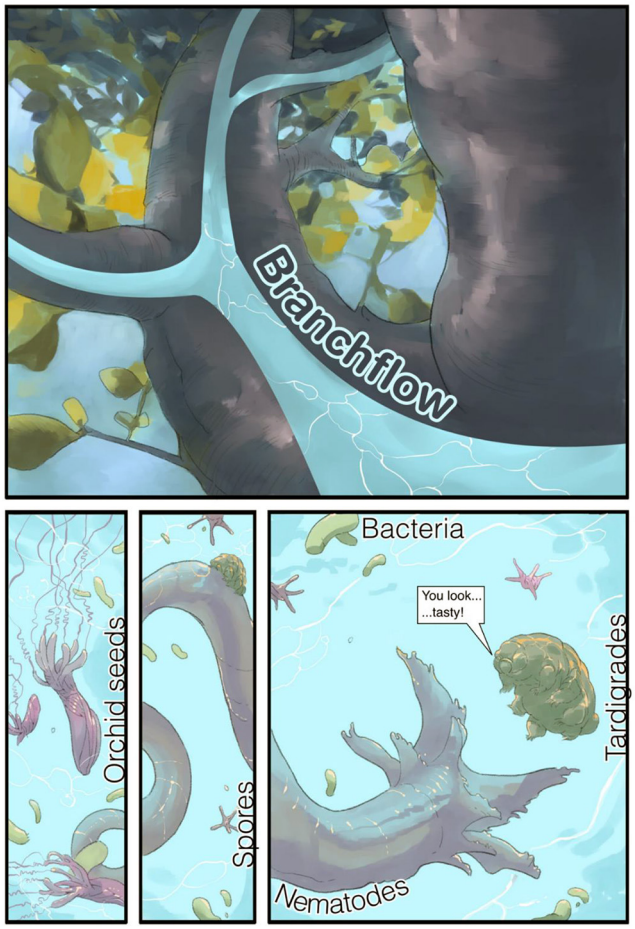

Figure 2

nitrogen, and phosphorus) or compounds (like sugars, proteins, and fats). Tiny creatures in the soil eat these nutritious particles to survive. Soil creatures like some of the particles delivered by branchflows more than others. You see, before these particles were picked up by branchflows, they were baked in various types of ovens...sort of. One type of oven might be a car engine, for example, while another could be the belly of a bug. Both ovens bake carbon-rich particles that can end up on bark and in branchflows. But it is much harder for creatures in the soil to digest the meal baked in a car engine (basically soot) than the meal baked in the belly of a bug (basically sugar). Which would you prefer?

Some of the particles in branchflows are alive (Figure 2). The tiny creatures that hitch a ride on branchflows may look like they came from a horror movie. For example, wormlike creatures called **nematodes** not only look scary, but also can be a real horror to the bacteria they eat. Luckily for nematodes, branchflow waters can carry hundreds of thousands of bacteria in a single drop of water. Other tiny beasts in branchflows are considered by many to be Disney-level cute—cute enough to earn "meme" status—like the **tardigrade**. Some of the larger tardigrades do not see nematodes as nightmarish at all,

NEMATODES

A small worm, often called "roundworms."

TARDIGRADE

A small animal with eight legs that is commonly called a "waterbear."

but as lunch. Branchflows can also be a major way for certain plants and fungi to disperse their seeds and spores (Figure 2). For example, one type of orchid seed can put out octopus-like tentacles when it gets into branchflows. These tentacles help the seed to stick to a nice spot on the branch and grow. Many fungal spores do not want to stick to the branch at all—instead, they have multiple "fins" that help them ride branchflows out of the canopy. Loaded with snacks, microbes, animals, and plants, branchflows have the same types of particles that bigger water flows, like rivers, have. They are just a lot smaller.

SO WHAT? WHY "BARK UP" THIS BRANCH?

What brought attention to branchflows in the first place? The same thing that, according to the story popularized by Voltaire, led Isaac Newton to investigate why apples fall from a tree straight into the ground—but, in reverse! Scientists did *not* see falling droplets hit their rainfall collectors under a tree on rainy days. Of course, they wondered where the droplets went. This is when, according to known records, a young poet, forester, and scientist named Carl Eduard Ney saw stemflow and branchflow, when wandering the Bavarian forests in search of the "missing" rain [6].

We need to study branchflows because they contain important information about how forests work. Because branchflows are formed by rainwater draining from all over the tree canopy, they can represent a meaningful amount of the total rainwater that reaches forest soils. Branchflows can also result in intense rainwater supplies to small areas, in the case of drip points and stemflow, which can increase how deeply the water penetrates into soils and can also reduce the amount of soil around trees. Thus, branchflows may be important for "recharging" a forest's soil and ground waters and for transporting soil to other spots. It is just as important to take note of the elements, compounds, and creatures delivered by branchflows to dendrotelma, animal bellies, and the soils. In fact, the materials that branchflows deliver to a dendrotelma are more important than they appear at first glance. For example, if you investigate a dendrotelma, you will notice that it provides a comfy nursery for mosquitos—and for the diseases they can spread. In summary, from the health of plant roots to human diseases, there are many reasons why scientists in forests should continue gazing upward during storms.

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We are the best school in the world, because we are the tallest and the cleverest, and we have the best teachers. But specifically we are the best class of the school because we have a lot of different type of people and we are very funny. We love science because we have a very good teacher.

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