

AUTUMN INVESTIGATION · GRADES 2–8 · ABOUT 30 MINUTES OF WORK, THEN AN HOUR OF WATCHING

The autumn time machine

Prove that the yellow was hiding inside the green leaf all summer long

Dear fellow scientist,

Every autumn the same thing happens, and almost nobody asks why. A tree that has been green since May turns yellow, orange, sometimes red, and then lets go of its leaves. Where did the yellow come from? Did the tree make it in October, the way you would mix a new paint? Or was it there all along, hidden under the green?

You can find out. The trick is to catch one tree in the middle of changing, take four of its leaves at four different stages, and pull the colours out of each one so they can be seen separately. Four leaves from one tree are like four photographs of the same leaf at four moments in time. That is your time machine. The tool that takes the colours apart is called chromatography, and chemists use it every day.

*Four leaves, one tree, four moments in time.*

What you need

- Four leaves from *one* tree: still green · half-turned · fully yellow or orange · red, if that tree makes red. (Many trees only go yellow — birch, poplar, aspen, elm. Then use three stages, and borrow a red leaf from a maple, a dogwood or a Virginia creeper as a guest. Label it as a guest.)
- Rubbing alcohol (isopropyl alcohol, 70 % or 99 %) — from the pharmacy shelf
- Four small glasses or jars, one per leaf, and something to cover them: plastic wrap, saucers, or lids
- A dish or a baking pan, and hot tap water
- White coffee filters, or a sturdy white paper towel, and scissors
- Four pencils, tape, a ruler, a spoon, and a sheet of white paper
- An adult, for the alcohol and the hot water

What to do

- 1. Collect and number.** Find your tree and pick four leaves at four stages. Lay them out on white paper in order, 1 (green) to 4 (most changed), and take a photo or draw them in the record on the last page. Fresh leaves work best — do this the same day.
- 2. Tear and crush.** Tear leaf 1 into pieces the size of your fingernail and drop them into glass 1. Do the same for the other leaves, each in its own glass. Label the glasses. Crush the pieces with the back of a spoon — bruise them well. The colour lives inside the cells, and the cells have to be broken open.
- 3. Add the alcohol.** An adult pours in just enough rubbing alcohol to cover the pieces: two or three spoonfuls, no more. Less alcohol means a stronger colour, and a strong colour means bright bands later. Crush and stir again for a minute. Watch the alcohol take on the colour of the leaf.



Crushing the pieces: the alcohol starts to turn green.

- 4. The warm bath.** Stand all four glasses in a dish of hot tap water — as hot as your tap gives, not from a kettle — and cover each glass. Leave them for 30 minutes; swirl each glass now and then. Warmth helps the alcohol pull the colour out. Add more hot water to the dish if it cools. While you wait, do step 5.



Four covered glasses in a hot-water bath, labelled 1 to 4.

- 5. Cut the strips.** Cut four strips of coffee filter, about 2 cm wide and a little longer than your glass is tall. With a **pencil** (never a pen — ink would join the race and confuse everything), draw a line across each strip 2 cm from the bottom. Write the leaf number at the top. Tape the top of each strip to the middle of a pencil.
- 6. Run the race.** Take the glasses out of the bath. Rest each pencil across its glass so that the very tip of the strip touches the liquid and the pencil line stays *above* it. Cover the glass again and put it somewhere it will not be bumped. Now watch. The liquid climbs the paper on its own, and as it climbs, the colours begin to separate — the fast ones pull ahead of the slow ones. Give it 30 to 90 minutes.



The race is on: colour creeping up the paper.

- 7. Stop and compare.** When the wet edge is about 2 cm from the top, lift the strips out and mark the wet edge with pencil right away — it disappears as the paper dries. Lay the dry strips side by side on white paper in order 1 to 4. Look at them for a good while before you say anything. Then fill in the record.



The verdict: four strips side by side. Where is the yellow?

If the bands are pale — the chemist's trick

Real laboratories do it this way, and it gives sharp, bright bands. Leave a glass uncovered in the hot bath until only a few drops of very dark liquid are left. Dip the tip of a toothpick in it and dab it along the pencil line of a fresh strip. Let it dry (blow on it), dab again on the same line, and repeat five to ten times until the line is dark. Then stand the strip in a clean glass with half a centimetre of *fresh* rubbing alcohol in the bottom — the line above the liquid — and let it run. The darker the starting line, the clearer the answer.

What you should see

Every leaf is different and every strip is a small surprise, but here is what usually happens:

- **Strip 1, the green leaf:** green — often two shades of green, one bluish and one yellowish — and, *above* the green, a band of yellow. Sometimes a faint orange line at the very top.
- **Strip 2, half-turned:** the same yellow band, and the greens getting weaker.
- **Strip 3, yellow or orange:** yellow and orange, and little or no green at all.
- **Strip 4, red:** a pink or red smear that stays low, close to the pencil line — it hardly climbs. Above it, the yellow is often still there. Green is faint or gone.

Now look at strip 1 again, the green leaf, the leaf from July. The yellow band is on it. The tree did not mix a new yellow in October. It was inside the green leaf all summer, hidden behind the green the way the stars are hidden behind daylight. You have just proved it — with a coffee filter.

Why does the paper pull the colours apart?

Lay a corner of a paper towel in a spill and the water climbs into it. The alcohol climbs your strip the same way, and it carries the dissolved colours with it. But not all of them equally.

Each colour is a different substance, and each one has two loyalties: to the alcohol that is moving, and to the paper fibres that are standing still. A substance that dissolves very well in the alcohol and hardly sticks to the paper rides almost to the top. A substance that clings to the paper keeps stopping and starting, and falls behind. Orange carotene is the best traveller; the yellow xanthophylls come next; the greens, the chlorophylls, are slower; and the red, called anthocyanin, loves water and paper more than it loves alcohol, so it barely leaves the starting line. Different speeds, different places — and a mixture becomes a row of bands. That is chromatography: “colour writing”.

And in the tree? All summer the leaf keeps its green chlorophyll in constant repair, because sunlight wears it out every day. In autumn the tree stops repairing it. The green breaks down within days and drains away — and the yellow, which was always there doing quieter work, is finally seen. The red is a different story: the tree makes it fresh, in autumn, out of sugar trapped in the leaf on bright cold days. So your strips tell two things at once. The yellow was hiding. The red is new.

A number older scientists use

Measure, from the pencil line, how far a band climbed, and how far the wet edge climbed. Divide the first by the second. That fraction is called the R_f value, and it is a fingerprint: the same substance in the same alcohol on the same paper always gives about the same R_f , whatever glass it ran in. So if the yellow band on strip 1 and the yellow band on strip 3 have the same R_f , they are the same substance — and the case is closed.

Think like a scientist

Choose the questions that fit you. There is no wrong place to start.

- **Grades 2–4:** Point to the yellow on strip 1. Was that colour inside the green leaf? How do you know? If the tree really did make its yellow new in autumn, what would strip 1 look like?
- **Grades 4–6:** Put the strips in order from most green to least green, without looking at the numbers. Does your order match the order of the leaves? Predict what a brown, dead leaf from the ground would give — then test it in a fifth glass.
- **Grades 7–8:** Measure the R_f of the yellow band on every strip and compare them. Then explain, using the word *solubility*, why the red stays low: rubbing alcohol is part water, paper is made of cellulose, and anthocyanin dissolves best in water. What would you change to make the red climb — and what do you predict would happen to the green if you did?

Did you know?

- Chromatography was invented in 1903 by the botanist Mikhail Tsvet, who used it on exactly this problem — the pigments of leaves. His name, in Russian, means “colour”.
- The two shades of green on your strip really are two different substances, chlorophyll a and chlorophyll b. Every green leaf on Earth carries both.
- The yellow pigments in leaves are cousins of the orange in carrots. Some of them end up in egg yolks and in the feathers of goldfinches — birds cannot make them and have to eat them.
- Evergreens keep their chlorophyll in repair all winter. They pay for it with tough, waxy needles that can stand the cold.



Take care

An adult handles the rubbing alcohol. Keep it away from flames and the stove, keep the lids on, and work in a room with a window open — the smell is a sign it is evaporating. Never drink it, and wash hands afterwards. Use hot tap water for the bath, not boiling water from a kettle. Do this on a counter that can take a spill, and keep everything away from small children and pets.

MY RECORD

Time machine record

Name: _____ Date: _____ Tree: _____

1 • My four leaves

Draw and colour each leaf as it looked when you picked it, or tape in a photo.

1 • green	2 • half-turned	3 • yellow / orange	4 • red

2 • What came out

Leaf	Colour of the alcohol after the bath	Bands I saw on the strip, from the bottom up
1		
2		
3		
4		

Draw and colour the four dry strips, side by side, as they really look. Mark the pencil line and the wet edge on each.

Strip 1	Strip 2	Strip 3	Strip 4

3 · The verdict

Was the yellow inside the green leaf? Say how the strips prove it, in your own words:

4 • For grades 7 and up — the fingerprint

Measure from the pencil line, in millimetres.

Strip	Wet edge climbed (mm)	Yellow band climbed (mm)	Rf of yellow	Rf of green
1				
2				
3				
4				

Rf = distance the band climbed ÷ distance the wet edge climbed (always between 0 and 1)

Are the yellow Rf values about the same on every strip? What does that tell you?

A note from Professor Alexey

Today you did something remarkable: you answered a question about the past — what was inside a leaf in July — using only what you could measure in the present. That is exactly how geologists read rocks and astronomers read starlight. You also used a real laboratory method, and you used it properly: pencil not pen, line above the liquid, wet edge marked at once. Keep your strips. Next autumn, run the same tree again and see whether it tells the same story.

More investigations like this one, all year round: learn.discoverymath.ca/science/