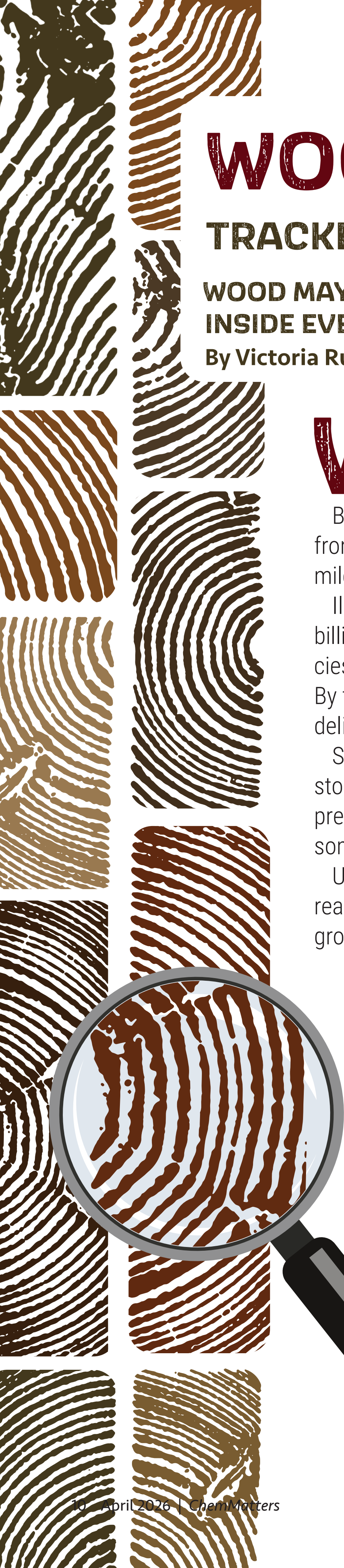

WOOD CHEMISTRY

TRACKING ILLEGAL LOGGING USING FORENSICS

WOOD MAY SEEM SIMPLE—JUST TREES TURNED INTO BOARDS—BUT INSIDE EVERY PIECE OF WOOD IS A CHEMICAL RECORD OF ITS LIFE.

By Victoria Russell

When you walk through a furniture store, the wood around you seems ordinary. Floorboards gleam under bright lights. Tables and cabinets are labeled with familiar names of wood, such as oak, rosewood or mahogany.

But to forensic chemists, that wood can raise troubling questions: Where did it come from? Was it harvested legally? Or was it stolen from a protected forest thousands of miles away?

Illegal logging is one of the world's most profitable environmental crimes, generating billions of dollars each year. Trees are cut down in protected forests, endangered species are harvested and wood is smuggled across borders disguised as legal products. By the time that wood has been sanded, stained, shaped into something familiar and delivered to a store, it may look completely harmless.

So how can scientists tell whether a piece of wood was legally harvested or illegally stolen from a protected forest? The answer lies in the unique chemical fingerprints, preserved deep inside every tree, that can reveal what species a tree belonged to and sometimes even where it grew.

Using tools such as mass spectrometry and metabolomics, forensic chemists can read those chemical fingerprints. This science, known as wood forensics, plays a growing role in protecting forests, wildlife and communities around the world.

METABOLOMICS: READING A TREE'S CHEMICAL HISTORY

When scientists talk about metabolites, they mean small molecules made by living organisms as part of everyday life. The study of all these small molecules is called metabolomics.

Trees excel at preserving metabolite patterns because many of these compounds become locked into the wood, where they can remain stable for decades or longer. For wood forensics, metabolomics allows scientists to compare complex chemical fingerprints and distinguish between species that look identical to the eye.

Agarwood, for example, is one of the most valuable woods on Earth. Native to South and Southeast Asia, its high price has driven widespread illegal harvesting. High-quality agarwood can sell for thousands of dollars per pound.

Agarwood forms when Aquilaria trees become infected by certain fungi. In response, the tree produces a dark, fragrant resin as a defense mechanism. Only a small fraction of trees ever form this resin naturally, which makes agarwood extremely rare. Because of its scent, agarwood is used in incense, traditional medicines and luxury perfumes.

To confirm that a sample is agarwood, chemists look for certain patterns of metabolites:

- **Syringylpropene** is more abundant in flowering trees than in conifers, helping distinguish between them. Agarwood comes from a flowering tree.
- **Phenylethylchromones**, a family of aromatic molecules found in agarwood, produce a distinctive pattern in a mass spectrum that can reveal whether a sample is agarwood. Aromatic molecules are cyclic organic compounds with alternating single and double bonds. Many aromatic molecules have characteristic odors, which is how this class of molecules got its name.

By comparing these chemical patterns, forensic chemists can identify rare and protected woods, even after they have been cut and processed.

A Global Problem Hidden in Plain Sight

Illegal logging is a massive global problem. Interpol, the international police organization, estimates that the illegal timber trade is worth up to $152 billion each year, making it one of the world's most profitable environmental crimes.

Wood often passes through multiple countries before reaching its final destination. Logs may be cut in one country, processed in another and sold somewhere else entirely. Along the way, paperwork can be falsified, and wood from protected species can be mislabeled as something legal.

Once trees are cut and processed, many of the features used to identify them—leaves, bark and growth patterns—are gone. Even experts can struggle to tell different species apart by sight alone.

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BY THE NUMBERS

UP TO
$152 BILLION
VALUE OF THE ILLEGALLY LOGGED TIMBER INDUSTRY

GLOBALLY
15% to 30%
OF ALL TIMBER TRADED IS THOUGHT TO BE ILLEGAL

EVERY YEAR
25 MILLION
ACRES—AN AREA THE SIZE OF INDIANA—OF TREES ARE CUT DOWN ACROSS THE WORLD

SOURCES: INTERPOL; WORLD WILDLIFE FUND; ENVIRONMENT AMERICA

WHAT IS WOOD FORENSICS?

Wood forensics is the science of identifying wood, not just by species, but often by where it came from and whether it was legally harvested.

A piece of wood might be illegal for several reasons. It may come from a protected tree species, be harvested from a restricted area, exceed legal harvesting limits or be mislabeled to avoid tariffs or regulations.

To investigate these cases, forensic chemists usually focus on two key questions:

» What species is this wood?
» Where did it grow?

Answering those questions isn't simple. There are more than 70,000 tree species worldwide, and many of them look nearly identical once they've been cut, dried, sanded and treated.

FROM TREES TO CRIME SCENES

When most people think of forensic science, they imagine fingerprints, DNA or crime labs solving human-centered mysteries. But forensic chemistry can also be used to protect forests, wildlife and ecosystems.

Forensic chemist Cady Lancaster of Oregon State University, who is a founder of the U.S. Forest Service's Wood Identification Screening Center (WISC) in Corvallis, Oregon, didn't set out to study trees. Her path into wood forensics began with an early interest in forensic science and an unexpected opportunity.

As a high school student, she attended a forensic science day hosted by the chemistry department at Southern Oregon University in Ashland, Oregon, where a former FBI forensic scientist had just joined the faculty. The experience convinced Lancaster to pursue chemistry.

While in college, Lancaster volunteered at the National Fish and Wildlife Forensics Laboratory in Oregon, the world's only full-service lab dedicated entirely to crimes against wildlife. There, she worked on a wide range of projects, from identifying polymer-tipped bullets used in wildlife poaching to analyzing timber evidence.

One project changed the direction of her career. Using advanced mass spectrometry techniques, Lancaster and her colleagues analyzed wood samples to see whether tree species could be identified based on their chemical makeup. The work, which was published in several scientific journals, revealed how powerful chemistry could be in environmental crime investigations.

"Working at the National Fish and Wildlife Forensics Laboratory opened my eyes to the vast range of applications for forensic chemistry, far beyond traditional human-centered cases," Lancaster said.

Forensic chemistry doesn't solve crimes on its own, but it provides critical evidence.

In one case Lancaster worked on, chemical analysis revealed that a company claiming its wood products came from Europe was actually

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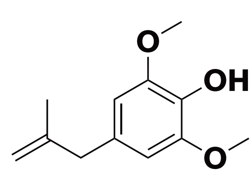
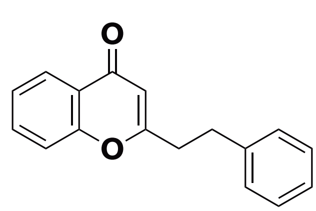
Oud oil is a perfumy metabolite produced by fungi-infected Aquilaria trees.



Syringylpropene



2-(2-Phenylethyl)chromone

KELLEY J. DONAGHY

selling items made from protected African tree species. Faced with the evidence, the company changed its supply chain.

"Now, when I look at their website," she said, "I only see domestic species."

Cases like this show how chemistry can influence real-world decisions and help protect forests before irreversible damage occurs.

A TREE'S CHEMICAL FINGERPRINTS

One of the most powerful tools in wood forensics is metabolomics, which is the study of small molecules produced by an organism during cellular metabolism. Similar to how people have unique fingerprints, trees have unique chemical fingerprints. These fingerprints are made up of thousands of small molecules produced as a tree grows.

All wood contains large structural molecules such as cellulose and lignin, which give trees strength. Cellulose is long-chain polysaccharide made of repeating glucose units that form fibers and provide rigidity to plant structures. Lignin is a polymer made from alcohols that acts as a binding agent holding the cellulose fibers together. But these molecules are similar across most tree species and don't reveal much about identity.

Instead, scientists focus on smaller molecules called metabolites. These molecules include natural oils, resins, phenolic compounds (a large group of ring-shaped molecules mainly found in plants) and molecules involved in growth and defense.

Different species produce different mixtures of metabolites, creating that unique chemical fingerprint that can identify what type of tree their sample came from—and sometimes even where it grew—long after it has been cut down.

> *That is the really wonderful thing about multidisciplinary research. You become the jack of all trades you need to be to solve the problem.*
>
> CADY LANCASTER

"Trees are particularly good at preserving these chemical signatures in their heartwood," the dense, inner core of a tree trunk, Lancaster explained. "A tree felled today can have a very similar metabolomic profile to one cut thousands of years ago."

That durability makes wood an ideal material for chemical analysis.

USING MASS SPECTROMETRY TO READ THE CLUES

To analyze these chemical fingerprints, forensic scientists use mass spectrometry, a technique that measures the masses of molecules.

In mass spectrometry, molecules are bombarded with a stream of electrons that break them into charged particles known as ions. Those ions are then separated based on their mass-to-charge ratio using electric and magnetic fields. The separated stream of ions then moves through the mass spectrometer to the detector, which records how many ions of each mass are detected.

The result is a graph called a mass spectrum. It looks like a barcode made of peaks, where each peak represents molecules with a specific mass. The peak pattern helps chemists identify what substances are present.

For wood forensics, one technique has proven especially useful: Direct Analysis in Real Time Mass Spectrometry (DART-MS).

Unlike many instrument-based laboratory methods, DART-MS can be used in the field (like in the forest or at a lumber yard) and requires little sample preparation. A stream of heated gas flows over a wood sample, lifting molecules from its surface and ionizing them. The ions are then pulled directly into the mass spectrometer.

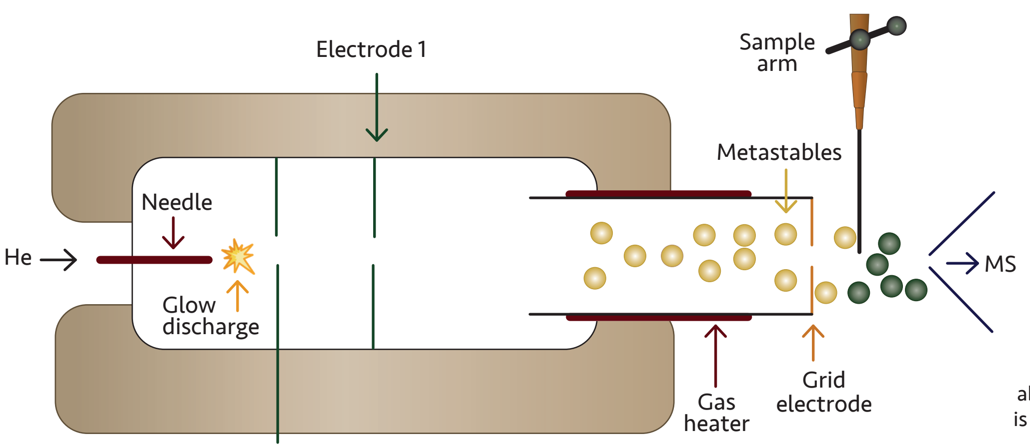
Within seconds, scientists can collect a spectrum containing hundreds, or even thousands, of molecular signals.

DART-MS has become popular in forensic science because it is fast, relatively inexpensive and easy to use. It is already widely used to identify illegal drugs and explosives.

Traditional mass spectrometry often includes a separation step, such as chromatography, which spreads molecules out before they reach the detector. DART-MS skips that step, meaning many molecules enter the instrument at once. The resulting spectra can be messy and difficult to interpret, because wood can contain thousands of compounds.

Instead of searching for one specific molecule, scientists compare patterns in the overall arrangement of peaks in a spectrum.

To make that comparison easier, researchers have developed software tools that help analyze complex DART-MS data. These tools allow scientists to compare unknown samples against large databases of reference wood spectra.



DART-MS

Helium gas enters and is superheated into a plasma. Then the sample is bombarded with the metastable He, which ionizes the sample molecules that are then pulled into the MS for analysis.

Watch » See the details about how DART-MS is actually performed on drug samples

KELSEY CASSELBURY

WHEN LOOKS ARE DECEIVING

Some tree species are easy to identify under a microscope. Others are nearly impossible.

Take rosewoods, for example. These dense, dark hardwoods are prized for furniture and musical instruments. High demand has led to widespread illegal logging, and once processed, many rosewood species are nearly indistinguishable.

Two South American rosewoods, *Dalbergia nigra* (Brazilian rosewood) and *Dalbergia spruceana* (Amazon rosewood), are highly sought after in the illegal timber trade. Brazilian rosewood has been overharvested to the point of endangerment and is protected under international treaties such as the Convention on International Trade in Endangered Species (CITES), which strictly regulate its international trade. Amazon rosewood is less restricted.

Even under a microscope, the two woods are nearly indistinguishable visually. Chemically, however, they are different.

By analyzing dozens of reference samples from each species, scientists build statistical models of each species' chemical fingerprint. When an unknown sample is tested, the model determines which species it most closely matches. This combination of chemistry and statistics is critical for enforcing timber laws.

BEYOND SPECIES: WHERE DID THE TREE GROW?

Sometimes identifying the species isn't enough. Investigators may need to know where a tree grew to determine whether it was legally harvested. For example, oak harvested legally in one country may be illegal in another.

"For the same species from different regions, sometimes there isn't enough difference in the metabolomic fingerprint to tell them apart," Lancaster said.

In those cases, forensic chemists turn to other tools, such as stable isotope analysis. Stable isotopes are atoms of the same element that share the same number of protons but differ in their number of neutrons. Because they are non-radioactive, they remain stable and do not decay over time. The ratios of certain isotopes (such as carbon or oxygen) vary depending on climate, altitude and geography. For example, trees growing in drier regions incorporate different oxygen ratios of oxygen-16 and oxygen-18 than trees growing in wetter climates. By measuring these ratios, scientists can sometimes narrow down a tree's region of origin.

No single method works for every case. Instead, wood forensics relies on a toolbox of complementary techniques and collaboration among chemists, biologists, statisticians, and taxonomists (scientists who classify species).

WHY ILLEGAL LOGGING MATTERS

Illegal logging affects far more than trees. Forests support entire ecosystems and communities, and when illegal logging operations move in, the damage can spread quickly.

Consider Mongolian oak (*Quercus mongolica*), a protected species heavily logged in parts of Northeast Asia. Its acorns are a major food source for Siberian boars, which are prey for the endangered Amur tiger. Remove the trees, and the entire food web begins to collapse.

"A single act of illegal logging cascades through the entire ecosystem," Lancaster said. "A whole food web can collapse just to make hardwood flooring."

Illegal logging also contributes to climate change by releasing stored carbon into the atmosphere. Profits from illegal timber can fund organized crime and corruption, and consumers may unknowingly support these activities when illegal wood is disguised as legal products.

A CAREER BUILT ON PUZZLES

Wood forensics is deeply interdisciplinary. It brings together chemistry, biology, genetics, statistics and public policy.

Along the way, Lancaster's career expanded beyond chemistry, as she learned about botany, microscopy, data science and even a bit of history to track changing species classifications.

"That is the really wonderful thing about multidisciplinary research," she said. "You become the jack of all trades you need to be in order to solve the problem."

If the job had a tagline, she joked, it would be "Must love puzzles."

By learning to put together these chemical puzzles, forensic scientists are helping protect forests, wildlife and communities around the world.

Victoria Russell is a freelance science writer from Utah.

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THE RIPPLE EFFECT OF ILLEGAL LOGGING

Illegal logging of the Mongolian oak tree in Northeast Asia sharply reduces the supply of acorns that Siberian boars depend on for food.

As a result, Siberian boar populations shrink, leaving the endangered Amur tiger with fewer prey to hunt.

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