Tree Chemicals that Kill or Cure

A Continuing Plea for Chemistry in Arboriculture

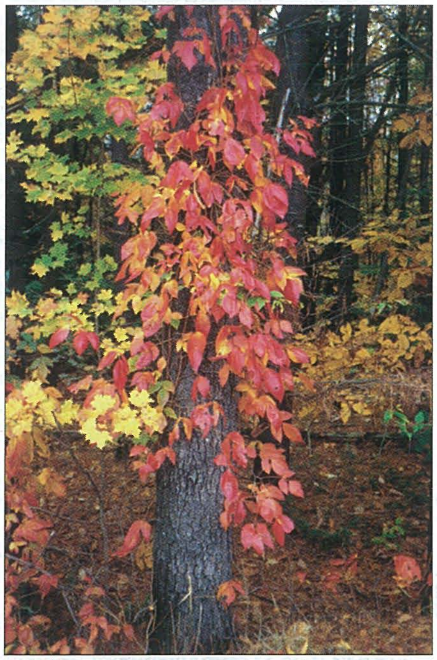
By Dr. Alex L. Shigo

Chemicals are atoms arranged in an almost infinite number of ways. As the kind of atoms, their arrangements, and their numbers change, so do their properties. The keywords to remember when the word chemical is used are atoms, numbers, arrangements and properties. The kill or cure part of chemicals comes to play when "amounts" or "dose" are used. The best example of dose is any fast-release fertilizer. A little promotes lush growth while a lot will kill the plant. Is the fertilizer good or bad? Is it a helper or a killer? A professional is a person who understands dose.

We are bags of chemicals, and so are trees. We and trees grow and mature as chemicals increase and change over time. In time, chemicals are recycled for new life. Time becomes a major variable. A major responsibility of arborists is to provide care for trees in ways that optimize time for high-quality growth.

Trees and aspirin

Trees through the ages have been the source for chemicals used by humans for killing and curing. Some tree species stand



Climber beware! Poison ivy can be beautiful in the fall, but chemical volatiles from the plant can cause serious skin problems for many people.

Photos courtesy Dr. Alex L. Shigo

The oldest name in rope is new again!

THE AMERICAN GROUP

The American Group announces name change:

SAMSON
ROPE TECHNOLOGIES
The Strongest Name In Rope

The American Group was created by the merger of Samson Ocean Systems, American Manufacturing and Herzog Rope in 1993 and the subsequent acquisition of First Washington Net Factory in 1999. From this merger was born one of the largest rope and cordage manufacturers in the Northern Hemisphere. In total, The American Group represents well over 300 years of rope making experience.

Each company can lay claim to innovations that set new industry standards. By joining the pacesetters of the last century and maximizing the strengths of each, one company was created with a common mission: leadership in rope technology into the next century.

To better reflect our common mission, and the strength of our combined histories, The American Group has been renamed.
The new corporate name, Samson Rope Technologies, draws upon our combined past while reflecting our mission for the future. The Samson name, along with the trademark of Samson and the Lion is the oldest continuously registered trademark in the United States. It is a great symbol to represent the combined strength and performance of our product line. It also symbolizes strength over time; longevity which can only be achieved through commitment to continuous development and the creation of new fiber combinations and constructions to provide greater strength, safety and security.

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1876-1884:
Samson trademark is registered to the J P Tolman Company.

1888:
Tolman incorporates Samson Cordage Works.

1889:
American Manufacturing Company Founded.

1948:
AMCO Introduces synthetic 3-strand nylon ropes.

1952:
Herzog Rope founded in Canada. Specialize in ropes for the Northwest fishery.

1955:
First Washington Net Factory established. First company to produce nylon knotted netting to fishing industry.

AMCO Introduces the first 3-strand polypropylene in the US.

1961:
Samson introduced the first all synthetic fiber double braided rope.

1972:
Samson Nystron is the first synthetic fiber rope used to moor an oil tanker to a loading buoy in the North Sea.

1989:
Herzog develops Permaflex leadline for the seine fishery.

1992:
AMCO perfects coextrusion and produces Ultra Blue fiber, 30% stronger and 3 times more abrasion resistant than polypropylene.

1993:
The American Group is formed by merging AMCO, Herzog and Samson Ocean Systems.

2001:
Samson Rope Technologies is the banner that unites four illustrious cordage industry innovators under one name and one mission: Leadership in rope technology.

Cherry blossoms are a sign of spring. When leaves that fall are injured, chemical reactions take place that form cyanide-based poisons. If animals eat many of the fallen injured leaves, death could follow.

Mango is in the same family as poison ivy. Some people are affected by chemicals in the skin of the fruits.

out in history. The most commonly used chemical or medicine today originally came from the bark of the white willow, *Salix alba*. The medicine, of course, is aspirin. It is not only a human painkiller - analgesic - but it is often recommended for lowering the risk of heart attack.

The bark was used by early humans for pain reduction, but it was not until 1899 that the chemical was discovered. Acetylsalicylic acid is aspirin but salicylic acid, the base molecule, is in a large family of analgesics. Exactly how aspirin works is still not well understood. It is known that the chemical blocks an enzyme that is necessary for nerve impulses.

Trees and malaria

Trees come to the aid of humans again with the bark of a tree native to South America. Ancient scholars believed that the cure for any human disease could be found in the plants growing where the disease was most severe. So it is with quinine, an alkaloid from the bark of the cinchona tree that grows where malaria is a severe disease.

Recycling? Maple syrup cures the "sweet tooth." Maple syrup is an ingredient in many spring tonics. Sassafras tea sweetened with maple syrup can be a cure for many ailments.

The mode of action of quinine is fascinating. The chemical binds with the DNA in infected cells. More interesting is that the greater the infection, the greater the binding. Once DNA is disrupted the cell cannot divide. Maybe the ancients knew more than we give them credit for.

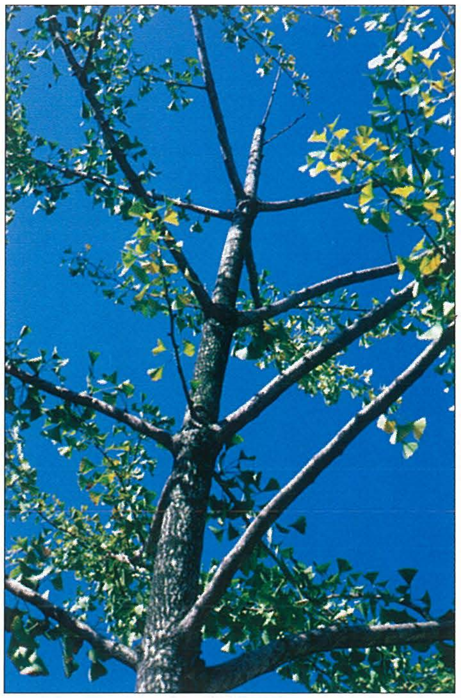
Quinine is well known also for its place in tonic to make a gin and tonic. In higher doses, quinine causes uterine contractions in animals, and this action could lead to abortion. Dose is the thing!

An alkaloid is a naturally occurring molecule that contains nitrogen. They are bases (alkaline) and many are poisonous as doses increase.

Trees and cancer

Taxol is a tree chemical that has become very well known for its ability to stall some human cancers. The chemical comes from the bark of the Yew, or *Taxus*, tree that grows in the forests along the Pacific Northwest and into Canada.

The mode of action is similar to quinine and many chemicals used to stall or cure cancers. The chemical taxol attacks the apparatus that is supposed to stretch as cells divide. Taxol prevents the stretching and thus inhibits cell division. Remember, humans are regenerating systems. Parts grow, break down, and are replaced in the same spatial position. Cancer cells don't like to break down. They only want to divide. So any chemical that prevents cell division gives the cancer cells some problems. Taxol does give cancer cells some problems for rapid division.



***Ginkgo biloba* has become a favorite for many people who believe in the medicinal powers of plant chemicals. The extract is supposed to benefit memory. Here is a ginkgo tree in its native land of Korea.**

Trees and other medicines

Aspirin, quinine, taxol – some big chemical actors – and all from trees originally. When the benefits of trees to humans are listed, the medicines are often left out. Most people are not aware that a tree in India, the Neem tree, has been at the center of international legal disputes. Why? Because the local people have used the chemical powers of the tree for medicines for centuries. Now some companies want to concentrate the chemicals and trademark them for sale. This situation is not unique to India. Many tropical trees are being tested for the powers of their chemicals. And, again, local governments are stepping in to regulate or stop possible exploitation.

Most chemicals found in trees are in a very dilute form. Usually the chemical must be increased in concentration before it can be used for some purpose. The ancients cooked or boiled the tree parts; usually the bark. Most of the chemicals function as enzyme blockers. This is how most medicines work. To explain this in an extremely crude way, the chemicals "fit" into places where their presence blocks the next "fit" of a pathway.

Enzymes: Biohelpers

Enzymes are chemicals that "help" natural essential processes to go on at highly efficient rates, while the enzyme itself is not "used up" in the process. Enzymes keep heat down while reactions speed up. If enzymes did not do their work, the processes themselves would "burn out" the cells.

Enzymes are big molecules with a protein core. Proteins are connected amino acids. Most enzymes have two other parts: one is a vitamin and the other is usually some element. Enzymes are often likened to keys. For a key to work, it must not only go into the slot, but the notches at the end must be arranged so that they fit exactly in the correct position to turn on a device or motor. If a key notch is altered, the key might slide into the slot, but it will not turn. Any chemical that connects onto an enzyme might so alter its shape that the function of the enzyme is blocked. Many enzymes are specific to different plant and animal species.

The way many pesticides and herbicides kill is that some introduced chemical alters some unique enzyme that fails to work, thus causing death.

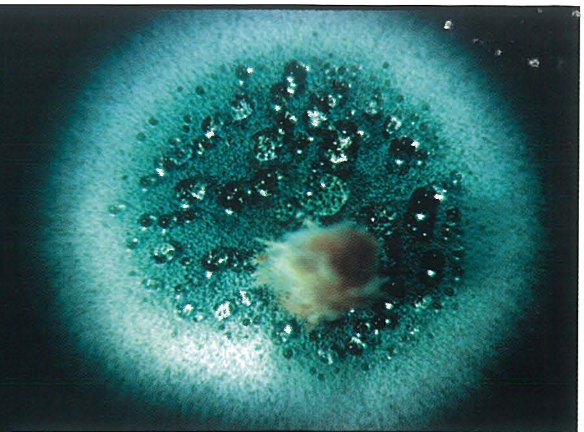
***Eucalyptus* species have chemicals in their leaves that are used in many medicines, especially cough drops. The leaves on this eucalyptus species is the favorite of koalas in Australia.**

Tree defense chemicals

Trees produce chemicals that can kill other plants, insects and even animals, including humans. Chemicals that leach from tree parts that kill other plants are called allelopathic substances. Juglone from black walnut roots is one well-known example. The list of allelopathic substances is long. As I will discuss later, most of these killer chemicals have a similar base or core structure that includes a phenol or terpene. But, before I go on with that, I would like to mention some other common killer chemicals against insects and animals.

About 25 years ago, the talk was all about trees sending signals to produce chemicals to kill attacking insects. The experiments worked well in the laboratory, as so many do, but they did not work outside, also, as so many do not. The story was that once a few insects began to attack one tree, that tree would "send out" chemicals that would alert nearby trees to start producing more chemicals that would stop the attack. In theory, and in the lab as stated, it all fit. In the field, no proof. Again, the killer chemicals were phenol based, which can kill insects.

Lichens are tree associates. Their growth indicates clean air. Many species of lichens will not grow in polluted air.



***Penicillium* species are common inhabitants of fresh tree wounds. *Penicillium* species and other non-decay-causing fungi, I think, are nature's real "wound dressings." *Penicillium* species produce antibiotics that have saved many lives.**

Trees and human toxins

Now, onto some "big ones" that can cause human problems, even death: Just as I gave some good news for aspirin, quinine, and taxol, the bad news keeps coming back to phenol-based chemicals. Many trees and other plants produce chemicals that irritate or sicken humans, but one tree native to south Florida and the tropics can do you in. It has the ominous common name of poisonwood, which tells you something. The tree is *Metopium toxiferum*. All parts except the pollen of this tree are deadly. The tree belongs to an infamous family that causes many animals and humans problems – Anacardiaceae. Other notable trees and vines in this family are poison ivy, poison oak and poison sumac. Mango belongs in this family and some people are highly sensitive to the skin of the fruit.

Another large family that has some notable species is the Roseaceae. The major genus that produces harmful chemicals is *Prunus*. And the species are *Prunus serotina*, black cherry, peach P. *persica*, and apricot, *P. armeniaca*. Cyanide is the basic culprit. In peach and apricot pits it is in a molecule called amydaline. It has the taste of bitter almonds. The pits of cherries are much smaller, but they also have similar molecules. In black cherry, cyanide-based chemicals are also in the leaves, and especially in injured leaves. Death of cattle is well known after chewing leaves, again especially fallen injured leaves, have been eaten. A note here is that healthy cherry leaves contain the nontoxic cyanide precursor prunasin. When the leaves are injured, the prunasin is split to release prussic acid or hydrocyanic acid. Cyanide blocks oxygen from bonding with hydrogen, thus blocking the release of the hydrogen in water. In cyanide poisoning, one could still breathe even though death is due to suffocation.

Pathway blockers

Blocking enzymes and pathways – and nasty phenols and terpenes – seem to repeat as the cause of problems. Some discussion on enzymes has been given. Here is a little more on the other subjects.

Cells are highly compartmented bodies. Or, you could say that many smaller bodies are highly compartmented in cells. The cell bodies are compartmented, yet they pass along their products to other bodies in the cells. Each body in a cell has a "job" to do. The job is to process chemicals in a highly ordered and efficient way, as in an assembly line. These processes are called biochemical pathways. The pathways differ from the conventional straightforward assembly line in that there are loops along the way. The loops are places where energy must come in to power the pathway along. The rules for the pathways are similar to your computer rules. Unless every dot, dash or comma is in absolutely the correct place, the system won't work. To make an extremely long story short, some of the nasty chemicals disrupt or block the pathways. It really does not matter where in the sequence of items the block comes; in a short time the entire pathway scrambles or shuts down. As more pathways shut down, it is not long before chain reactions go on as others shut down. In the end, the entire system shuts down. We call it death.

That is the worst-case scenario. There are ways out of this. Most pathways come with possibilities for shunts - detours. If you can get to the blocked area soon enough and encourage a shunt, the pathway could continue. Medicines do this by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blocking the blockers. The shunts work as a temporary fix while the blocker is being unblocked. (Not very scientific, but that's the way it is.)

Trees, energy and life

Life is a state where a system run by the power of the sun is so highly ordered that it repeats. We have seen that the system has many safeguards, redundancies, and protection and defense schemes. That is the good news. Disrupting agents (non-living) or pathogens (living) have ways of causing disorder in the system. That is the bad news.

Trees produce chemicals that defend and protect their system. The major killer chemicals are phenol- or terpene-based. The major targets for these killer chemicals are the pathogens that attack trees: insects, animals, bacteria and fungi. Sometimes humans get into the animal zone as shown here. But most of the time it is the others that are the targets.

An extremely quick summary must start with photosynthesis, where the energy of the sun is trapped in a molecule of ATP, adenosine triphosphate. Water and carbon dioxide are the main chemicals. Through many elaborate chemical processes, glucose is formed. In the process, oxygen is given off. In living cells, the process of respiration releases the energy stored in glucose and releases the carbon dioxide and water. Oxygen is required for this process. So, we start with carbon dioxide, water and oxygen, and we end with the same actors ready to act again as they trap, store, transport and use the energy of the sun. The end product we call life. Enough!

Glucose is the key

Glucose is the key molecule here. It is used to power living processes, but it is also used in other ways. It could be used to form cellulose, hemicellulose and lignins. Or it could be altered to a nonsoluble state for future use - starch or oils. Or, it could be used to form a long list of chemicals essential for life as defense or protection chemicals. Here I focus on defense chemicals - phenols, terpenes.

Phenols are found mostly in angiosperms and terpenes mostly in conifers. Phenols have the basic pattern of a six-carbon ring with an oxygen and hydrogen on the second carbon. There seems to be an almost endless number of ways to connect the rings. As the rings connect, they are called polyphenols. Their major actions seem to be blocking enzymes, especially in the fungi that cause wood decay. As always in nature, there are exceptions. Some of the first fungi that are able to invade tree wounds are those that are able to not only grow in the presence of polyphenols, but can actually break down the chemicals and use them as an energy source. The major group are *Phialophora* species and related fungi. Many are closely associated with bacteria. I believe this is an extremely important subject that is not being studied. I suppose that splitting wood and isolating microorganisms is just not "hot" now. Too much work.

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Terpenes are connections of isoprenes. Isoprene is the basic building block for many resinous chemicals and even latex and rubber.

Carbon and the chemistry of life

Organic chemistry is the chemistry of carbon. Exceptions are diamonds, graphite, coal, oil and a few other substances that are not considered organic. When you hear "organic," you know there is a carbon there someplace. Phenols and terpenes are organic molecules. They have carbon frameworks. When you connect carbon, hydrogen and oxygen, you can get thousands and thousands of chemicals for life. And when you add nitrogen, phosphorus and sulfur, you have molecules that make up about 98 percent by weight of all living matter.

Tree associates and more chemicals

Trees not only produce chemicals that kill or cure, they also support, through intimate associations, other organisms that also produce chemicals that kill or cure. Fungi that produce fruit bodies we call mushrooms head the list. Many mushrooms are edible, and others are not. Ancients used mushrooms in many of their ceremonies. Many of those mushrooms were the fruit bodies associated with mycorrhizae. The real killers are those in the genus *Amanita*.

Here is a fungus fact that relates directly to arboriculture but few people are aware of: One of the most well-known and famous fungi in the world grows on fresh tree wounds. This fungus produces a chemical so powerful that millions of people have been cured of many diseases that could have killed them. The fungus is *Penicillium notatum*. I isolated this fungus frequently from the surface of fresh wounds. When this fungus is around, few others will be. To this day I believe that species of *Penicillium*, *Mucor*, *Aspergillus*, *Alternaria*, and a long list of yeasts and bacteria, are a tree's first line of defense after wounding. In a sense, these wound surface organisms are nature's real "wound dressing." It is the only wound dressing that I know of that works. The problem is that it comes free. It is so sad when you consider how much time and money has been spent and money made disrupting a beneficial natural defense. But, you have heard it before. Some are still not listening!

Time to accept chemistry in arboriculture

It is time to accept chemistry in arboriculture. Arborists that touch trees every day need to know about tree chemicals. Every species has something, from the fragrance of a pine to the sweet smell of a birch. Every time you cut into a tree, you release some chemicals. These chemicals tell you much about the tree.

In the end, the more you learn about the way trees work, the better and faster you will be able to work on them.

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