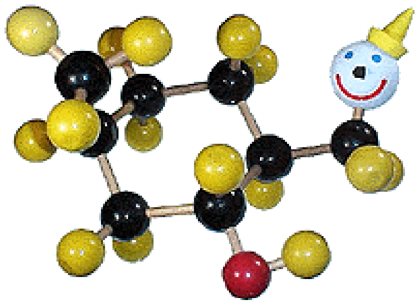

Major Types Of Chemical Compounds In Plants & Animals

Part II. Phenolic Compounds, Glycosides & Alkaloids

Note: When the methyl group containing Jack's head is replaced by an isopropyl group, the model depicts a molecule of menthol.

Back To Part I

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Types Of Phenolic Compounds: Make A Selection

VI. Phenolic Compounds: Composed of one or more aromatic benzene rings with one or more hydroxyl groups (C-OH). This enormous class includes numerous plant compounds that are chemically distinct from terpenes. Although the essential oils are often classified as terpenes, many of these volatile chemicals are actually phenolic compounds, such as eucalyptol from (**Eucalytus globulus**), citronellal from (**E. citriodora**) and clove oil from **Syzygium aromaticum**.

Like the terpenes, many phenolic compounds are attached to sugar molecules and are called glucosides or glycosides, depending on the type of sugar. Most vanilla flavorings sold in markets are synthetic vanillin containing artificial food coloring and preservatives. Vanillin is a single-ring phenolic compound derived from the breakdown of lignin, a complex phenolic polymer that gives seasoned wood its color, hardness and mass.

Natural vanilla flavoring also comes from vanillin plus several other aromatic compounds in the seed capsules of the vanilla orchid (**Vanilla fragrans**).

The double-ring phenolic compound called coumarin imparts the distinctive sweet smell to newly-mown hay. Coumarin is also an anticoagulant that represses the synthesis of prothrombin, a plasma protein produced in the liver in the presence of vitamin K. Prothrombin is the precursor of the enzyme thrombin which catalyzes the conversion of fibrinogen to fibrin in the clotting process. Threads of fibrin wind around blood platelets in the damaged area of a blood vessel and provide the framework of a blood clot. Coumarin is converted into the anticoagulant dicoumarin during the improper curing of sweet clover hay from species of **Melilotus**. Hemorrhaging and death may occur in cattle that eat spoiled sweet clover hay, depending on the amount consumed. Dicoumarin and related drugs are used in human medicines as blood thinners and are commonly used in rodent poisons such as Decon®, which literally cause rats to bleed to death.

See Tonka Beans: A Source Of Coumarin

The oxidation of natural phenolic compounds in apples and potatoes causes them to turn brown or black. Chemically, the phenolic compounds are oxidized into quinones which rapidly combine into a dark polymer residue. The brown pigments in "pigment cells" of certain duckweeds (**Spirodela** and **Wolffia**) are polymerized quinones within the cells. Urushiol, the insidious allergen of poison oak, is a phenolic compound that is oxidized into a quinone after it has penetrated the epidermis of skin. The more reactive, oxidized quinone attaches to the membranes of white blood cells, initiating a complex cell-mediated immune response leading to a blistering rash (see poison oak reference below). A special quinone called ubiquinone (the oxidized form of coenzyme Q) is found in the membranes of bacteria and cellular organelles (mitochondria and chloroplasts) where electron transport and ATP production occurs. The name "ubiquinone" reflects the ubiquity of this compound since it occurs in virtually all cells. When ubiquinone is reduced (after it picks up protons and electrons), it becomes the alcohol ubiquinol. Unlike iron-containing cytochromes, ubiquinone carries both an electron and a proton. This is crucial for chemiosmosis (chemiosmotic coupling) where the electron flow generates a higher concentration (charge) of positively-charged hydrogen ($H+$) ions (or protons) on one side of the membrane. When one side of the membrane is sufficiently "charged," these protons recross the membrane through special channels (pores) to generate molecules of ATP from ADP and phosphates.

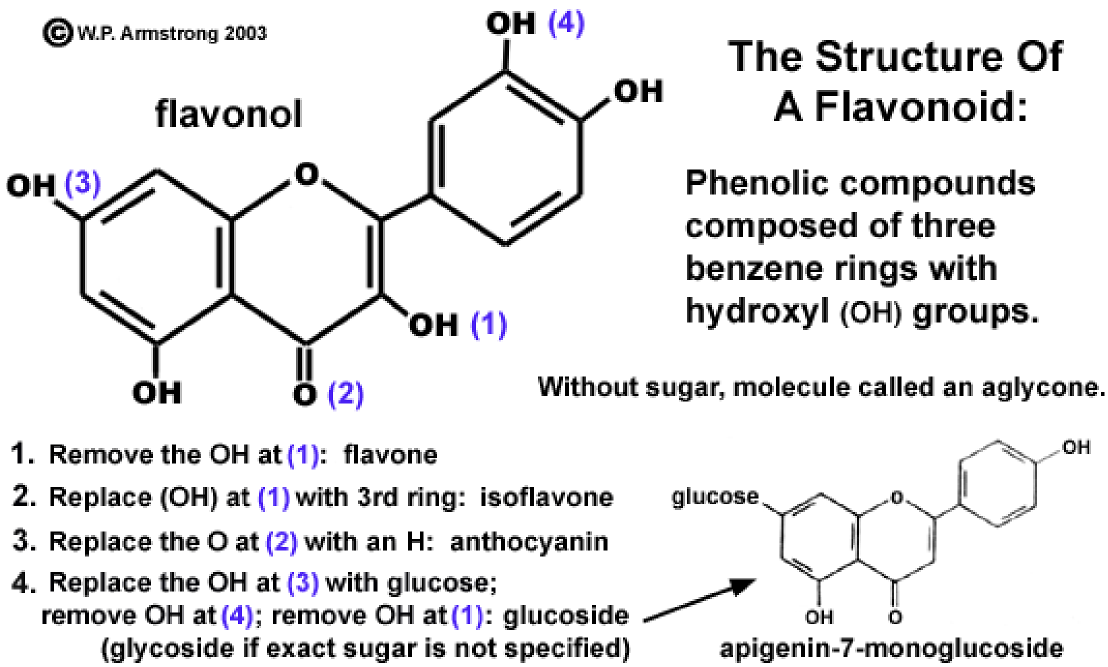
Some phenolic compounds occur as polymers (often combined with glucose). Tannins are phenolic polymers that combine with the protein of animal skins (collagen) forming leather. Historically, tannins played a major role in the development of human civilizations. Natural tannins are obtained from the bark of European hemlocks (**Tsuga**) and from the tanbark oak (**Lithocarpus**) in America. In some countries, tannins have been replaced by sodium dichromate which has a similar action on animal hides.

Lignin is a valuable phenolic polymer that gives wood its characteristic brown color, density and mass. It has been estimated that 40 percent of the weight of the world's forests is lignin! Lumber is essentially composed of dead xylem cells that have dried out. The dead tissue is hard and dense because of lignin in the thickened secondary cell walls. In order to make paper, logs and wood chips must be converted into pulp. Several methods are used to convert wood into pulp, including the ground wood process, sulfite process and the sulfate process. In addition to chemically digesting the wood until it is reduced to its component fibers, the lignin must also be removed in fine quality papers. Cardboard containers and supermarket shopping bags (kraft paper) are stiff and brown because they still contain lignin.

Hardwood And Ironwood Trees
The Anatomy Of Stems And Roots

[Paper & Textiles From Plant Fibers](#)
[The Structure And Anatomy Of Wood](#)

Flavonoids are 3-ring phenolic compounds consisting of a double ring attached by a single bond to a third ring. In leaves they block far ultraviolet (UV) light (which is highly destructive to nucleic acids and proteins), while selectively admitting light of blue and red wavelengths which is crucial for photosynthesis. Flavonoids include water soluble pigments (such as anthocyanins) that are found in cell vacuoles. [Note: Carotenoids are fat soluble pigments found in plastids.] You have probably observed water soluble anthocyanins if you have cut open a fresh head of red cabbage. [Note: The nitrogen-containing, water soluble pigment in beets is not a flavonoid, but a different type of chemical called a betacyanin or betalain, with a complex chemical structure similar to an alkaloid. Betacyanins also produce the reddish color of flowers such as **Bougainvillea**.] Water soluble flavonoids (mostly anthocyanins) are responsible for the colors of many flowers and can range from red to blue, depending on the pH of the watery sap in the vacuoles. The common garden shrub called hydrangea (**Hydrangea macrophylla**) produces showy clusters of white, pink, red or blue flowers depending on the pH of the soil.



Duckweeds of the family Lemnaceae contain many kinds of flavonoids, including red anthocyanins in some species. They are often difficult to identify because they are such reduced flowering plants with relatively few characteristics. Using two-dimensional paper chromatography, duckweed species have been separated and identified by their unique flavonoid content. When viewed under UV light, each species has a distinct spot pattern or "fingerprint."

[See Anthocyanin In A Duckweed](#)

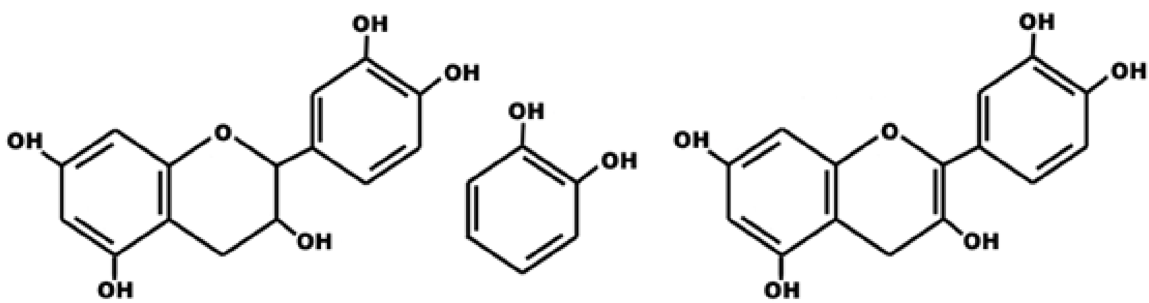
Flavonols are colorless or yellow flavonoids found in leaves and many flowers. Quercetin is the yellow flavonol pigment of oak pollen. The fall coloring of deciduous trees may involve carotenoid pigments (terpenes) as well as flavonoids. In some trees, such as red maple (**Acer rubrum**) and scarlet oak (**Quercus coccinea**), colorless flavonols are converted into red anthocyanin as the chlorophyll breaks down. Flavonoids with glucose side chains are called glucoflavonoids or glucosides (glycoside if the sugar is not specified), while the flavonoid component without sugar is called an aglycone. Some nutritionists recommend flavonoids (bioflavonoids and isoflavones) in order to maintain healthy tissues and promote the proper balance of hormones and antioxidants in the body. They may be obtained as supplements and from a good diet of fruits, vegetables and soy protein.

The leaves of many angiosperm trees fall from the branches during the autumn months, thus preparing the trees for their winter dormancy period. A special layer of cells at the base of the petiole, called the abscission layer, is controlled by growth hormones, such as auxin and ethylene. The abscission layer neatly separates the leaf from its stem, thus causing it to fall with the slightest breeze. In cold climates of northern latitudes it is vital to have all the branches devoid of leaves, so that snow falls through the branches. Without an abscission layer, persistent dead leaves attached at their petioles could collect snow, thus causing the limbs to break under the heavy weight. Contrary to some references, bright red autumn leaves can develop without a frost. The following leaves of two eastern U.S. trees, including sweet gum (**Liquidambar styraciflua**) and Texas red oak (**Quercus buckleyi**), turned red in coastal San Diego County without any frost. The trees are genetically programmed to drop their leaves in the fall, and red anthocyanins replace chlorophylls in the leaves.

For years it has been known that people in France who consume red wines on a regular basis have a reduced risk of coronary heart disease compared with the United States. This data is paradoxical considering that the French also consume a lot of fatty foods, such as pastries. A phenolic compound in the grape skins called resveratrol was discovered that seems to inhibit the plaque build-up or clogging of arteries (atherosclerosis) by increasing the level of high density lipoproteins (HDLs) in the blood. Beneficial HDLs carry cholesterol away from the arteries so that it doesn't form plaque deposits in the arterial walls. Resveratrol also reduces blood platelet aggregation or clotting (thromboses) within blood vessels. Resveratrol belongs to a class of plant chemicals called phytoalexins. They are used by plants as a defense mechanism in response to attacks by fungi and insects. One interesting phytoalexin called psoralen comes from the leguminous herb **Psoralea**. It has a chemical structure similar to coumarin. Psoralen has been used in the treatment of certain cancers, including T-cell lymphomas in AIDS patients. Another potentially valuable herbal medicine from grapes **Vitis vinifera** is grape seed extract, a mixture rich in bioflavonoids, specifically proanthocyanidins. The proanthocyanidins appear to enhance the activity of vitamin C through some unknown synergistic mechanism. Vitamin C protects cells from the damaging oxidation of free radicals, thus preventing mutations and tumor formation. The bioflavonoids in grape seed extract may also reduce the painful inflammation of swollen joints and prevent the oxidation of cholesterol in arteries which leads to fatty deposition (plaque) in the arterial walls.

Grapes: A Good Source Of Bioflavonoids

Some plants secrete bioflavonoids that inhibit the growth and seed germination of nearby plants of a different species. This phenomenon, called allelopathy, has been well-documented in chaparral shrubs that secrete terpenes which inhibit the germination of wildflower seeds. One potent allelopathic flavonoid called catechin is produced by the roots of spotted knapweed (**Centaurea biebersteinii** syn. **C. maculosa**). Catechin has two mirror image forms, a positive (+) form and a negative (-) form. The +catechin is an antibiotic and antioxidant that prevents the formation of free radicals. It is present in a number of plants, including green tea (**Camellia sinensis**). The -catechin induces oxidation and cellular death in root cells of neighboring plants. Although the mechanism is complex, -catechin is a potent phytotoxin that causes plants to self destruct by producing free radicals as well as triggering genes that kill the cells. Cellular death may occur within an hour of exposure to catechin. See the following reference for more details: H.P. Bais, R. Vepachedu, S. Gilroy, R.M. Callaway and J.M. Vivanco. 2003. "Allelopathy and Exotic Plant Invasion: From Molecules and Genes to Species Interactions." **Science** 301: 1377-1380 (September 5, 2003).



catechin ($C_{15}H_{14}O_6$) catechol ($C_6H_6O_2$) anthocyanin ($C_{15}H_{12}O_6$)

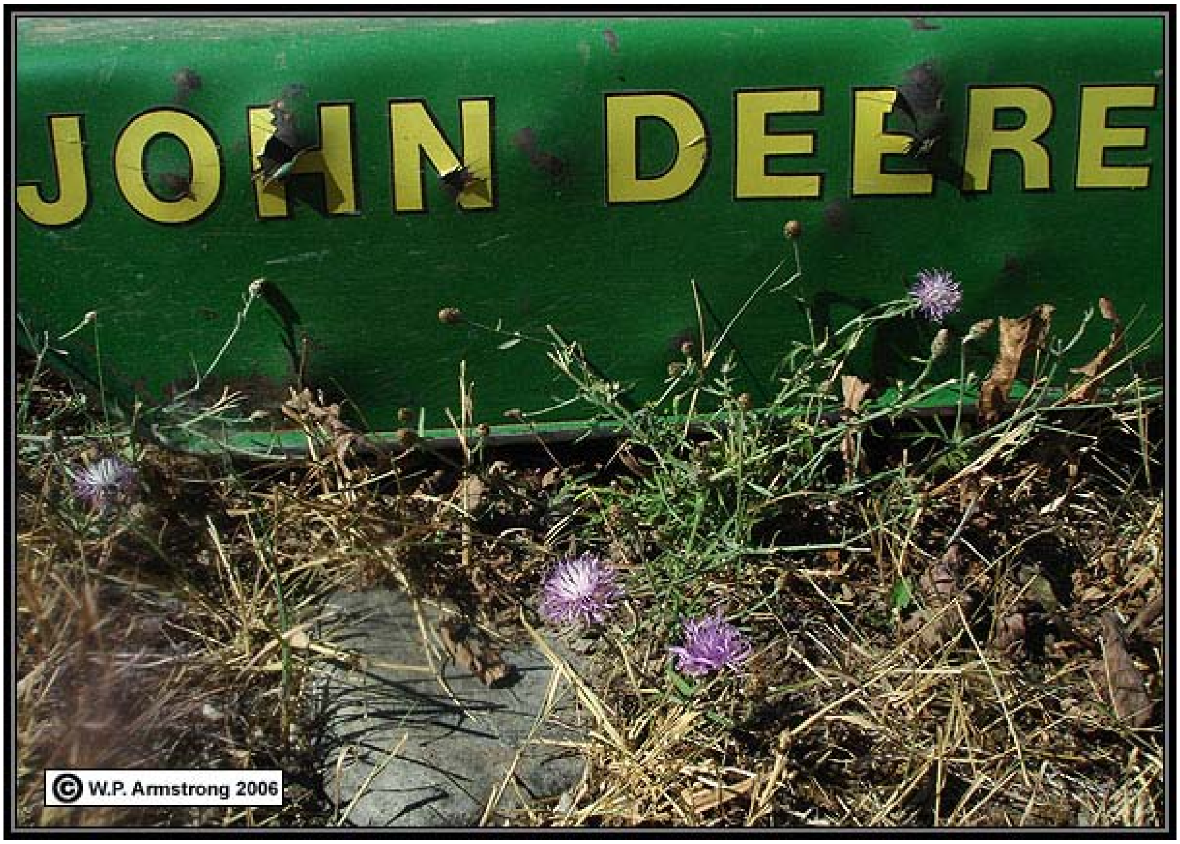
The chemical structure of catechin is very similar to the floral pigment anthocyanin. The second (middle) ring of catechin has no double bond, consequently the molecule has two additional atoms of hydrogen. Catechin has two mirror image forms, a positive (+) form and a negative (-) form. The +catechin is an antioxidant found in green tea. The -catechin induces oxidation and cellular death in root cells of neighboring plants. Catechol (pyrocatechol) is a very caustic compound found in the poison oak allegen called urushiol (pentadecyl- and heptadecyl-catechol). This may be the cause of rashes on people who attempt to pull out the spotted knapweed with their bare hands.

See The Potent Catechols Of Poison Oak & Poison Ivy
See Wayne's Word Article About Ashes To Wildflowers

Spotted knapweed was introduced into North America from Europe. It is estimated that it has infested more than a million acres of land and is listed as a noxious weed in 35 states. Other species of **Centaurea** have also invaded thousands of acres of cultivated land, including the star thistle (**C. solstitialis**) of California's Central Valley. Spotted knapweed is a very aggressive naturalized weed that actually destroys its competition by releasing -catechin into the soil. The chemical arsenal of spotted knapweed is just as effective as the potent chemical herbicide 2,4 D. Although -catechin is also toxic to the cells of spotted knapweed, the plant is apparantly able to maintain low levels of this chemical in its cells by quickly pumping it out. Researchers are currently studying the possiblities of catechin as a natural weed killer for agricultural areas. By transferring knapweed genes into other species, crop plants could eliminate competitive weeds and also be resistant to catechin herbicide. The ramifications of transgenic crops must be carefully scrutinized because genes of fertile plants can be carried in the pollen. Some crop plants can still cross pollinate with their weedy ancestors.

Spotted knapweed (**Centaurea biebersteinii**) in northern Montana. The flower head is subtended by black-tipped phyllaries, each tipped with a fringe of hairs. In the star thistles, each phyllary is tipped with a slender spine.

See The Star Thistle of California's Central Valley



When spotted knapweed (**Centaurea biebersteinii**) is mowed, it simply resprouts and produces seed-bearing flower heads below the cutting blades of the mower.

Eucalyptus "gums" are rich in tannins (kinotannic acid) and are similar to another phenolic compound called catechu. They are known in the trade as gum kinos and are used as tannins to convert animal hide into leather. One of the main Australian sources of gum kino is the red gum (**Eucalyptus camaldulensis**), a large tree that is naturalized throughout San Diego County. Kino gums are also used medicinally as astringents to relieve throat irritation, dysentary and diarrhea.

The name "gum" can be traced back to the voyage of Captain James Cook to the South Pacific in 1770. Captain Cook discovered the east coast of Australia, called New Holland at that time. In one harbor, the ship's naturalists found so many unusual and beautiful plants that they named it Botany Bay. Eight years later, a fleet of eleven English ships reached Botany Bay with 1,530 people, 736 of them convicts. This marked the establishment of England's most important prison camp of the nineteenth century, and the European settlement of a vast land called Australia. The actual discovery of the genus **Eucalyptus** is credited to the ship's botanist, Joseph Banks (later Sir Joseph Banks). One of the newly discovered species "red bloodwood" (**E. gummifera**) had a reddish gum exuding from its trunk, and the naturalists called it a "gum tree."

Eucalyptus Photos In Hardwood Article

Several important dyes are obtained from natural phenolic compounds in plants. Brazilin ($C_{16}H_{14}O_5$) and hematoxylin ($C_{16}H_{14}O_6$) are pigments from the heartwood of two tropical American trees. During the Middle Ages, colorful red and purple dyes were difficult to obtain and very expensive. Tyrian purple (royal purple), the dye used by seafaring Phoenicians, and for robes of ancient Greek and Roman aristocrats, was obtained from Mediterranean snails of the genus **Murex**. During the 1400s, one of the finest red dyes for cotton and wool came from the heartwood of an Asian tree called sappanwood (**Caesalpinia sappan**). Then in 1500, Portuguese ships discovered and claimed the Atlantic side of South America that straddled the equator and the tropic of Capricorn. This land mass was called terra de Brasil and later Brazil, because of the dyewood trees (**Caesalpinia echinata**) that grew there in abundance. The valuable dye from brazilwood (called brazilin) became a popular coloring agent for cotton, woolen cloth and red ink. As with precious cargoes of gold and silver, Portuguese ships loaded with brazilwood were favorite targets for marauding buccaneers on the high seas. Meanwhile, the Spanish had discovered another tree in Yucatan with a deep red heartwood similar to brazilwood. The tree became known as logwood (**Haematoxylum campechianum**). Another species from mainland Mexico and Baja California (**H. brasiletto**) produces a red dye called "brasil" or "palo de tinto." The dye from logwood is called hematoxylin, with a chemical structure practically identical to brazilin. Through oxidation the hematoxylin is converted into yet another dye called hematein. During the 1600s, the British established logging camps in mosquito-infested swamplands of a land called British Honduras, which later became the independent country of Belize. The birth of two nations, Brazil and Belize, is largely due to colonization by European explorers in search of two valuable dye trees, brazilwood and logwood. Although these dyes have been replaced by synthetic aniline dyes, they are still used extensively in acid-base titrations and nuclear stains for histology and microbiology.

Chemical Structure Of Brazilin & Hematoxylin

Known to both Aztec and Spanish conquerers, another bright red dye was obtained from tiny scale insects living on the flattened stem segments of prickly-pear cacti, including **Opuntia ficus-indica** and other species. The actual source of this brilliant red cochineal dye is from the body fluids of the cochineal insect (**Dactylopius coccus**), a homopteran related to aphids, scale insects and mealy bugs. Female cochineal insects are brushed from the cactus pads and the red pigment is extracted from the dried bodies. One pound of dye represents about 70,000 insects. Cochineal is the source of carmine red stain that is used to this day in microbiology classes. Incidentally, prickly-pear cacti were introduced into Australia as a source for this valuable dye, but without any natural predators, the introductions had disastrous consequences. By 1925, 60 million acres of valuable range land were covered with thickets of prickly-pear cactus.

According to Thomas Eisner et al. (Science 30 May 1980: Vol. 208 no. 4447, pp. 1039-1042), carminic acid, the dye from cochineal insects, is a potent feeding deterrent to ants. This may have evolved as a chemical weapon against predation. The carnivorous caterpillar of a pyralid moth (**Laetilia coccidivora**) is undeterred by the dye and feeds on cochineal insects. In fact, the moth has the remarkable habit of utilizing the ingested carminic acid for its own defensive purposes.

Logwood And Brazilwood Dyes
Cochineal Dye From A Tiny Insect

A remarkable biochemical phenomenon resulting from the alga-fungus union in lichens is the production of lichen acids, unique phenolic compounds produced by no other organisms. In fact, they are not even produced by the separate fungal or algal symbionts, only by the combined lichen. Lichen acids have the unusual property of changing colors under different pH conditions. In fact, the litmus dye that turns red in acid solutions and blue in alkaline solutions was originally derived from the fruticose lichen **Roccella**. The color change under different pH conditions is caused by changes in the electron configuration (resonance) of the molecule. This affects absorption and reflection of light; hence, the vivid color changes. The presence of certain lichen acids is used to identify some species. A drop of sodium hydroxide (lye) or sodium hypochlorite (bleach) is added to the exposed lichen tissue to see if it turns yellow, purple or red.

Lichen acids were the source of important dyes for cotton and wool in medieval Europe. Two purple and red dyes, orchil (sometimes spelled archil) and cudbear, were obtained from the lichens **Roccella** and **Ochrolechia**. Lichen dyes were dissolved in human urine, and the yarns were immersed in this mixture. Ammonia salts in the urine functioned as mordants to make the dyes permanent. Although most of the lichen dye industry was replaced by cheaper aniline dyes from coal tar, some lichen dyes are still used today. A brownish dye from the foliose lichen **Parmelia omphalodes** is used on hand-woven Harris tweeds from the Outer Hebrides. Orcein, a purple-red chromosomal stain found in every microbiology laboratory is derived from **Roccella tinctoria**. Pine lichen (**Letharia vulpina**), a beautiful chartreuse fruticose lichen that grows on the bark of pines and fir throughout the mountains of the Pacific United States, contains a mildly toxic yellow dye called vulpinic acid. The striking canary-yellow porcupine quills woven into the baskets of Klamoth and Yurok Indians were dyed with this lichen.

Lichen Dyes And Perfumes Dyes
Lichen Crust On Rocks & Boulders

It is beyond the scope of this outline to include all of the amazing phenolic compounds found in plants. Two additional compounds are taxol and urushiol. Taxol is a very complex phenolic compound found in the bark and leaves of the Pacific yew (**Taxus brevifolia**). Since this species is native to regions of the Pacific northwestern United States containing the timber tree Douglas fir (**Pseudotsuga menziesii**), it was once considered a weedy species when areas of the forest were logged. Luckily, the Pacific yew still survives because it is now considered to be an exceedingly valuable species. An extract from the bark (and needles) called taxol has been found to be a very effective treatment for ovarian and breast cancers. It is very important to preserve natural, old growth forests with a diversity of species, some of which may prove to be valuable medicines for the treatment of diseases.

In addition to terpene resins, the resin canals in species of **Toxicodendron**, including the Japanese lacquer tree **Toxicodendron vernicifluum**, poison oak (**T. diversilobum**), poison ivy (**T. radicans**) and poison sumac (**T. vernix**) contain a phenolic compound called urushiol, the insidious allergen that gives these species their bad reputation. The name is derived from "urushi", Japanese name for lacquer made from the sap of the Japanese lacquer tree ("kiurushi" or "urushi ki"). Urushiol causes a severe cell-mediated immune response in hypersensitive people. Depending on the species, urushiol is a mixture of at least 8 potent catechols, benzene ring compounds with hydroxyl (C-OH) groups at carbons #1 and #2. Carbon #3 has a long 15 or 17 carbon side which may saturated or with one, two or three double bonds. Urushiol and the mechanism of poison oak dermatitis is discussed in the Wayne's Word poison oak article (see link at end of this paragraph).

Pacific Yew: Source Of Taxol
Poison Oak: An Immune Reaction

Note: There are many other allergens that cause allergic reactions in people, such as antigen molecules from pollen and dust. The mechanism for allergic reactions is complicated and involves special IgE antibodies that bind to the surface of special white blood cells called mast cells (basophils) that are found throughout connective tissues of the body. When an antigen that provokes an allergic reaction attaches to the IgE antibodies on mast cells, these cells release histamine and other substances which cause mucus secretion and airway constriction. Histamine is derived from the amino acid histidine and is responsible for the misery of hay fever sufferers.

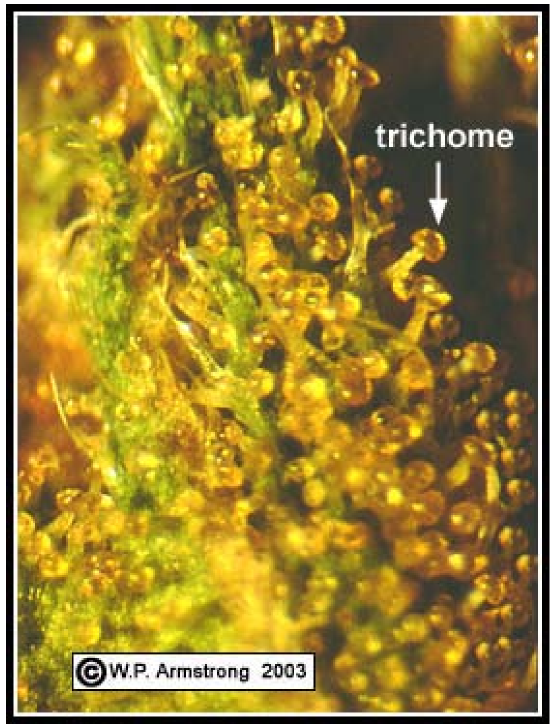
Histamine causes redness, swelling, and itching of surrounding tissues, especially respiratory passages and around the eyes. Antihistamines are effective in treating allergic reactions because they block the effect of histamine.

Cannabis Resin Containing THC

THC (delta-tetrahydrocannabinol) is the active ingredient in the marijuana plant (**Cannabis sativa**). It is a phenolic component of the resinous, glandular hairs (trichomes) on the inflorescences and floral bracts of female plants. The male plants generally lack the dense glandular hairs and are used for their strong and very durable stem fibers called Indian hemp. Pure marijuana resin is called hashish. It contains a mixture of volatile mono and sesquiterpenes, along with about 30 phenolic cannabinoids. The most potent cannabinoid is THC. Because of its hydroxyl (OH) groups, THC is technically an alcohol. It lacks nitrogen and is not an alkaloid. It is now known that THC binds to specific receptors in the brain where a natural compound called anandamide normally attaches. This brain interaction is undoubtedly responsible for marijuana's intoxicating properties. Statistics have shown that marijuana is less harmful than its legal, more widespread counterparts, ethyl alcohol and tobacco. Whether habitual use of marijuana dulls the brain or leads to more dangerous drugs is a controversial subject debated by authorities.

Marijuana is native to central Asia, and the Chinese appear to have been the first to harvest the plant for its hemp fibers and medicinal uses. The psychoactive properties of marijuana were first exploited in India. The Indians classified **Cannabis** products into ganja, consisting of the potent female flowers and upper leaves, and hashish, the golden resin containing THC. The largest quantity of resin is produced by **C. sativa** ssp. **indica**, also known as **C. indica**. High quality hashish may contain up to 50% pure THC. The most potent and resinous plants are bushy, well-spaced female plants grown in warm, sunny climates without male plants. The term "sinsemilla" (sin: without) and (semilla: seed) refers to unpollinated, unfertilized female plants without seeds. Through the travels of Marco Polo, Napolean and British colonists, the virtues of marijuana as a fiber plant and psychoactive drug spread to Africa, Europe and the New World.

Marijuana has a number of therapeutic uses. For casual smoking and medical purposes, the gland-covered female flowers and floral bracts are commonly used, rather than the potent hashish. Marijuana reduces the nausea experienced by cancer patients undergoing radiation and chemotherapy. Since THC dilates bronchial vessels, it provides relief for asthma sufferers. It also relieves hypertension, and is effective in reducing pressure in the eyes of glaucoma patients. Although it is illegal to grow without special medical permits, it is the number one cash crop in some remote areas of the United States.



Left: Close-up view of the inflorescence of a female marijuana plant (**Cannabis sativa**). The threadlike structures are styles of pistillate (female) flowers. The granular appearance is due to numerous glandular hairs (trichomes), each with a blob of resin. Male plants generally lack the dense, glandular hairs. Right: Microscopic view of the inflorescence showing numerous gland-tipped hairs called trichomes, each with a tiny blob of resin at the tip. The resin contains a mixture of volatile mono and sesquiterpenes, along with several phenolic cannabinoids. The most potent psychoactive cannabinoid is delta-tetrahydrocannabinol (THC).

An Excellent Reference About Plant Resins

- Langenheim, J.H. 2003. ***Plant Resins*** (Chemistry, Evolution, Ecology and Ethnobotany). Timber Press, Portland Oregon.

See Stem Fibers Including Marijuana
See Marijuana & Closely Related Hops

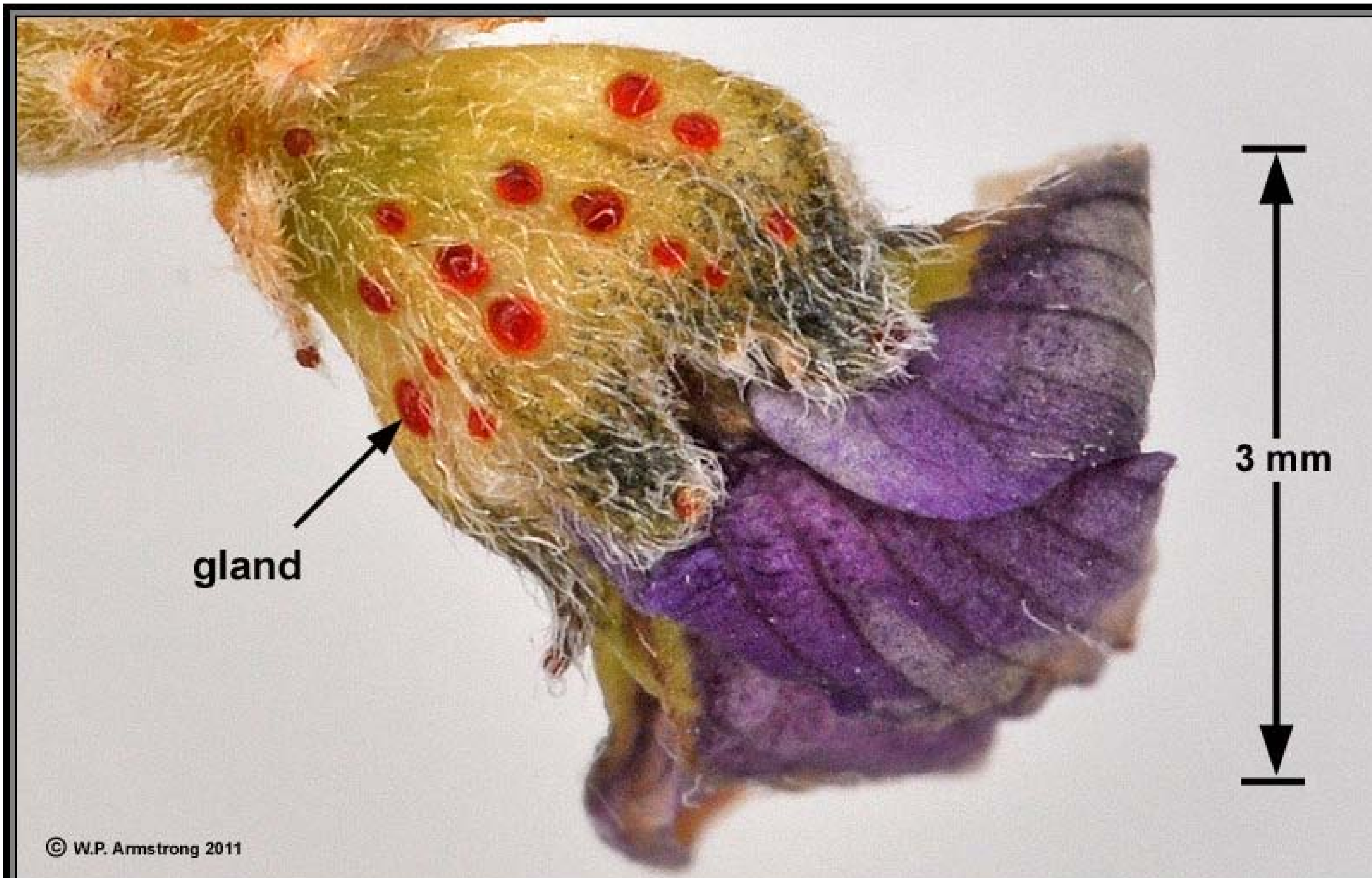
Chalcones & Related Chalconoids

Chalcones are aromatic ketones that form the central core for a variety of important biological compounds. They have antibacterial, antifungal, antitumor, antioxidant and anti-inflammatory properties. They are also intermediates in the synthesis of bioflavonoids. Chalcones are present in apples, tomatoes, strawberries and bearberries. At least 64 volatile compounds have been identified from the bright orange glands of **Psorothamnus** species. Some of these are known deterrents to herbivore browsing in other plant genera and may serve the same purpose in **Psorothamnus** species. A new chalcone with antiprotozoal properties was isolated from the widespread desert leguminous shrub **Psorothamnus polydenius**. In vitro tests have shown it to be effective against certain parasitic protozoans such as **Leishmania** and **Trypanosomas**.

"Bioactivity-guided fractionation of the methanolic extract of **Psorothamnus polydenius** yielded the new chalcone, 2,2',4'-trihydroxy-6'-methoxy-3',5'-dimethylchalcone, together with six other known compounds, 2',4'-dihydroxy-6'-methoxy-3',5'-dimethylchalcone, dalrubone, demethoxymatteucinol, eriodictyol, oleanolic acid and photodalrubone. This was the first report of chalcones in **P. polydenius."**.

1. Salem, M.M. and K.A. Werbovetz. 2005. "Antiprotozoal Compounds From *Psorothamnus polydenius*." *Journal of Natural Products* 68 (1): 108-11.
2. Hijova, E. 2006. "Bioavailability of Chalcones." *Bratislava Medical Journal* 107 (3): 80-84.

- Salem, M.M. and K.A. Werbovetz. 2005. "Antiprotozoal Compounds From *Psorothamnus polydenius*." ***Journal of Natural Products*** 68 (1): 108-11.



Close-up view of the flower of **Psorothamnus polydenius** showing orange glands on the calyx.

Psorothamnus polydenius in the Domelands of Imperial County, California

Types Of Glycosides: Make A Selection

VII. Glycosides: Plant compounds containing glucose (or a different sugar) combined with other non-sugar molecules, such as glucose + terpene or glucose + phenolic compound. The terms glycoside and glucoside are used interchangeably; however, glucoside is generally used if the sugar component is glucose. [Note: These compounds could also be listed under some of the above categories, such as terpenes or phenolics.] Several types of glycosides yielding toxic products upon hydrolysis occur in widely unrelated families. The most important glycosides involved in plant poisonings are cyanogenetic glycosides, saponin glycosides, solanines, and mustard oil glycosides.

Saponins are a group of glycosides (glucosides) found in several plant species, and are characterized by their soap-like property of foaming in a water solution. Upon hydrolysis saponin glycosides yield a triterpene or steroid sapogenin and one or more sugars, such as glucose, galactose, or xylose. Saponins lower the surface tension of aqueous solutions and form colloidal dispersions in water. When shaken they produce a soap-like froth. Saponins in powder form have been used chiefly as a foaming and emulsifying agent. Saponins have also been used in the manufacture of foam fire extinguishers, toothpaste, foam in beverages (including soft drinks and beer), shampoos, liquid soaps, and cosmetic preparations. Some saponin glycosides can irritate mucous membranes and destroy red blood cells. Saponin-rich plants, such as soap lilies of the genus **Chlorogalum**, have been used by native Americans for soap. Fishermen have thrown pieces of the bulbs into ponds and streams in order to stupefy the fish.

Soap Lilies & Other Saponaceous Plants

Steroidal glycosides (molecules containing a steroid plus sugar) are toxic to some vertebrates, including people. They are synthesized by many flowering plants, including milkweeds of the genus **Asclepias**. They are taken up by the larvae of monarch butterflies who feed extensively on milkweeds. When the caterpillars metamorphose into butterflies, the stored glycosides make them toxic to birds who learn to avoid these brightly colored insects. Steroid sapogenens from the hydrolysis of saponin glycosides are of interest because of the possibility of using them as a starting material (precursor) for the synthesis of certain steroidal hormones. Unlike the cardiac glycosides, saponins do not affect the heart.

Adult Monarch Butterfly
Danaus plexippus
Family: Nymphalidae

Mustard oil glycosides are found in species of **Brassica** in the mustard family (Brassicaceae), and can seriously affect the thyroid gland. They prevent the thyroid from accumulating iodine and inhibit the formation of thyroid hormones.

A cyanogenetic glycoside called amygdalin occurs in the pits and leaves of stone fruits of the genus **Prunus** (Rosaceae). Crushed leaves of cherries and apricots release hydrocyanic acid (HCN) which has a faint almond odor. Cyanogenetic glycosides are quite poisonous because they inhibit a key respiratory enzyme that can result in death if ingested in sufficient quantities. The anti-cancer drug Laetrile is essentially a cyanogenetic glucoside obtained from amygdalin in apricot pits. Salicin is a glucoside (sugar + phenolic) found in the bark of willow species (**Salix**). Willow bark contains salicylic acid (the key ingredient of aspirin) and was chewed by native Americans for headaches.

Species of nightshades (**Solanum**) in the tomato family (Solanaceae) contain a complex of toxic alkaloidal glycosides (sugar + steroidal alkaloid). One of these is called solanine, which is now known to consist of six different glycosides, each composed of a particular sugar and the steroidal alkaloid solanidine. [The steroidal alkaloid without its sugar component is called an aglycone.] Similar steroidal alkaloids are found in certain members of the lily family (Liliaceae) including the corn lily or false helibore (**Veratrum**) and death camas (**Zigadenus**). Some steroidal alkaloids are very toxic, causing severe gastroenteritis that may be fatal. Because many species of nightshades contain solanine, the closely-related tomato was once thought to be poisonous. Potatoes also belong to the genus **Solanum** (**S. tuberosum**). The leaves, stems, sprouts on tubers, and green skin on old potatoes contains the toxic solanine. In fact, this toxic alkaloidal glycoside is not destroyed when green potatoes are cooked. The potatoes must be carefully peeled first.

Potato: Tuber From South America
Tomato, Tomatillo And Eggplant

If ingested in sufficient quantities, cardiac glycosides can be fatal by literally stopping the heart muscle. They are found in a number of poisonous plants, including the leaves of the African shrub called oleander (**Nerium oleander**) and the common garden plant called foxglove or digitalis (**Digitalis purpurea**). In fact, there are reports of people being poisoned after eating hotdogs and other meats roasted on oleander stems used as skewers. However, when taken in smaller doses, cardiac glycosides of digitalis may actually improve the heart beat. Foxglove is the source of two potent glycosides used as a heart stimulant, digoxin and digitoxin. They are administered for congestive heart failure, weakened heart and irregular heart beat (arrhythmia). These glycosides prolong the relaxation phase of the heart (ventricular diastole), thus allowing the left ventricle to fill with more blood.

In accordance with Starling's Law of Contraction, the increased blood volume in the left ventricle results in a more forceful contraction (ventricular systole), thereby pumping more blood out into the aorta artery. After the contraction, as backflow pushes against the aorta semilunar valve, coronary arteries that feed the heart muscle fill with blood. They are able to fill with blood during diastole because the heart relaxes and the coronary vessels are not constricted. Of course, an overdose of cardiac glycosides can prolong diastole too much, causing a "flat-liner" by relaxing the heart permanently.

At the 52nd annual meeting of the American Association for Clinical Chemistry in San Francisco, California, Dr. Paul Wolf of the University of California at San Diego presented some fascinating information about the glycoside digoxin and how it may have affected the creativity of Vicent van Gogh (1853-1890). Van Gogh's epilepsy was treated with digoxin from the foxglove plant (**Digitalis purpurea**). His famous work, "The Starry Night" contains yellow circles around the stars, which are similar to visual problems described by patients with digoxin toxicity even today. Van Gogh also drank the liqueur absinthe on a regular basis. Absinthe is a green, bitter liqueur primarily flavored with wormwood (**Artemisia absinthium**), a European herbaceous perennial related to the native sagebrush species (**Artemisia**) of the western United States. According to Dr. Wolf, absinthe also contains thujone, a terpenoid component of many essential oils, including those found in **Artemisia** and the coniferous genus **Thuja**. Research has shown that thujone not only fuels creativity, but also that an overdose of the compound causes yellow-tinged vision. Either absinthe or digoxin toxicity may have contributed to van Gogh's increasing use of the color yellow in the last years of his life; or perhaps van Gogh may simply have loved the color yellow.

See Photo Of The Herb Called Absinthe

Strophanthus, an interesting genus of South African shrubs, has seeds containing several potent cardiac glycosides, including K-strophanthin and ouabain (G-strophanthin). The seeds of these shrubs have been commonly used by native people to make arrow poisons. Like digitalis, strophanthins are also used in modern medicine to treat congestive heart failure. In fact, the chemical structure of ouabain (G-strophanthin) is remarkably similar to that of digitoxin except that it has the sugar rhamnose intead of digitoxose.

Plants Producing Medical Glycosides

Types Of Alkaloids: Make A Selection

VIII. Alkaloids: Bitter, alkaline, nitrogenous compounds that may have pronounced effects on the nervous systems of animals. They may contain phenolic rings or terpenes (steroids), and include one of the largest groups of chemicals produced by plants. [Some alkaloids are also produced by animals, such as toxins in the skin of poison-dart frogs.] Many alkaloids are plant metabolic by-products derived from amino acids. According to R.F. Raffauf (**Plant Alkaloids: A Guide To Their Discovery and Distribution**, 1996), more than 10,000 different alkaloids have been discovered in species from over 300 plant families. For thousands of plant species, a vast arsenal of bitter alkaloids undoubtedly provides a competitive advantage by repelling hungry herbivorous mammals.

Tropical Pods Protected By Stinging Hairs
Acacias Protected By Ants Instead Of Alkaloids
Photos Of Acacias Protected By Ants & Alkaloids

Alkaloids often contain one or more phenolic or indole rings, usually with a nitrogen atom in the ring. The position of the nitrogen atom in the carbon ring varies with different alkaloids and with different plant families. In some alkaloids, such as mescaline and ephedrine, the nitrogen atom is not within a carbon ring. In fact, it is the precise position of the nitrogen atom that effects the properties of these alkaloids. Although they undoubtedly existed long before humans, some alkaloids have remarkable structural similarities with neurotransmitters in the central nervous system of humans, including dopamine, serotonin and acetylcholine. The amazing effect of these alkaloids on humans has led to the development of powerful pain-killer medications and spiritual drugs.

Alkaloids: Plants That Make You Loco
Photos Of Alkaloid-Producing Plants

Animated Structure Of Alkaloids

A. Alkaloids With Hetercyclic Nitrogen Atoms: Nitrogen atoms located within carbon rings. See psilocybin.

1. Pyridine-Piperidine Alkaloids: Single carbon ring containing one nitrogen atom (N). This class of alkaloids includes a number of poisonous plant species, including poison hemlock (**Conium maculatum**) and tobacco (**Nicotiana tabacum**). Poison hemlock belongs to the carrot family (Apiaceae) while tobacco belongs to the nightshade family (Solanaceae). The toxic alkaloid in poison hemlock causing paralysis, asphyxia and death is coniine, a single ring compound synthesized in the plant from octanoic acid. An extract of hemlock root was given to the famous philosopher Socrates. He was judged to be an enemy of the people in 399 B.C. and condemned to die. The closely-related water hemlock (**Cicuta douglasii**) contains cicutoxin, a terpenoid resin. Water hemlock is one of the most violently (convulsive) poisonous native plants in North America. If mistaken for a parsnip root, it acts directly on the central nervous system and is often fatal.

Dark Reactions Of Photosynthesis

The alkaloid in tobacco responsible for its highly addictive properties is nicotine, a mild stimulant of the central nervous system. In its pure form, nicotine is highly poisonous and is used as an insecticide. Nicotine is derived from nicotinic acid, a B-vitamin also known as niacin. Niacin prevents pellagra, a disease characterized by severe damage to the tongue, skin and digestive tract. Nicotinic acid is also converted into nicotinamide, a precursor of nicotinamide adenine dinucleotide phosphate (NADP), a vital coenzyme required for photosynthesis. [NAD is another vital coenzyme that carries electrons to the electron transport system in mitochondria.] During the light reactions of photosynthesis, NADP picks up two hydrogen atoms from water molecules forming $NADPH_2$, a powerful reducing agent that is used to convert carbon dioxide into glucose during the dark reactions of photosynthesis (also called the Calvin Cycle). When the two atoms of hydrogen join with NADP, oxygen is liberated, and this is the source of oxygen gas in our atmosphere. The following equation shows the overall reactants and products of photosynthesis:

$$6\ CO_2 + 6\ H_2O\ \text{(ATP \& } NADPH_2 \text{ from Light Reactions)} = C_6H_{12}O_6 + 6\ O_2$$

Note: The oxygen liberated during the light reactions comes from water.

CAM Photosynthesis

Some plants adapted to hot, arid regions have a different photosynthetic mechanism called CAM photosynthesis. CAM (Crassulacean Acid Metabolism) photosynthesis is also found in cacti and succulents, including the crassula family (Crassulaceae). During the hot daylight hours their stomata are tightly closed; however they still carry on vital photosynthesis as carbon dioxide gas is converted into simple sugars. During the cooler hours of darkness their stomata are open and CO_2 enters the leaf cells where it combines with PEP (phosphoenolpyruvate) to form 4-carbon organic acids (malic and isocitric acids). The 4-carbon acids are stored in the vacuoles of photosynthetic cells in the leaf. During the daylight hours the 4-carbon acids break down releasing CO_2 for the dark reactions (Calvin cycle) of photosynthesis inside the stroma of chloroplasts. The CO_2 is converted into glucose through a series of complicated reactions involving ATP (adenosine triphosphate) and $NADPH_2$ (nicotinamide adenine dinucleotide phosphate), the latter two compounds which were synthesized during the light reactions of daylight in the grana of chloroplasts. The adaptive advantage of CAM photosynthesis is that plants in arid regions can keep their stomata closed during the daytime, thereby reducing water loss from the leaves through transpiration; however, they can still carry on photosynthesis with a reserve supply of CO_2 that was trapped during the hours of darkness when the stomata were open.

Another interesting modification of the photosynthetic pathway is called C-4 Photosynthesis. During C-4 photosynthesis, CO_2 combines with phosphoenolpyruvate (PEP) to form a 4-carbon organic acid (oxaloacetic acid) which migrates (diffuses) to the photosynthetic bundle sheath cells surrounding the vascular bundles (veins) of the leaf. PEP essentially shuttles the CO_2 to the bundle sheath cells where it is released for the dark reactions (Calvin cycle) of photosynthesis. During hot weather the CO_2 level inside leaves is greatly reduced because the leaf stomata are closed. In ordinary C-3 plants which form a 3-carbon compound (PGA) during the initial steps of the dark reactions, photosynthesis in the leaf shuts down without a sufficient supply of CO_2. C-4 plants have a competitive advantage during hot summer days because they are able to carry on photosynthesis in the bundle sheaths where CO_2 levels are concentrated. C-4 plants such as Bermuda grass and purslane grow rapidly during hot summer days, while photosynthesis and growth in C-3 plants shuts down.

See Purslane: A Plant With C-4 Photosynthesis

Early explorers in the New World encountered native people in the Caribbean region smoking tobacco. Tobacco seeds were brought back to Europe by 1558. Sir Walter Raleigh planted tobacco plants and potatoes on his estate in Ireland in 1586. The famous taxonomist Carolus Linnaeus named the tobacco plant **Nicotiana**, in honor of the French ambassador Jean Nicot who distributed the seeds. The most carcinogenic (cancer causing) effect of habitual tobacco smoking is from the inhalation of tars produced from the burning leaves. This applies to the tobacco smoker and the other unfortunate souls breathing second hand smoke. Curing of tobacco leaves involves a series of complex biochemical events, including fermentation, browning, and the conversion of starches into sugars. During the curing process the water content is reduced from 80 percent to 20 percent. Dried tobacco leaves are used for cigarettes and cigars, and for pipe and chewing tobaccos. Tobaccos often contain other ingredients which enhance the flavor and aroma, including sugars, licorice, rum and menthol. Some of these compounds, such as coumarin, have been shown to be carcinogenic when burned. Most cultivated tobacco plants are tetraploids with four haploid sets of chromosomes. Polyploid plants (with extra sets of chromosomes) often have larger leaves, flowers and fruits, so the advantage of polyploid tobacco plants is obvious.

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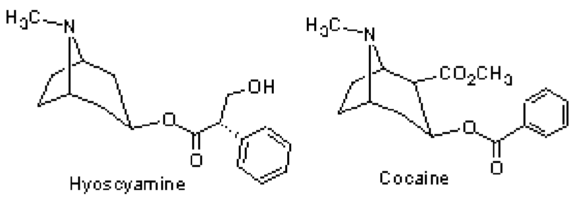
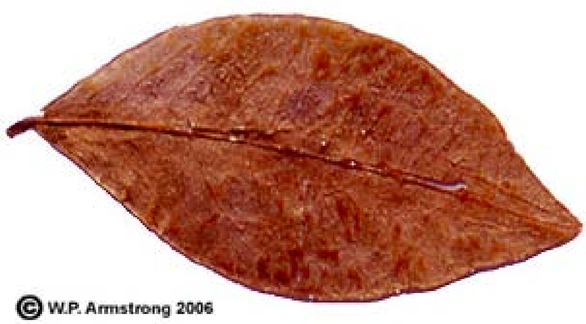
2. Tropane Alkaloids: Contain a methylated nitrogen atom ($N-CH_3$). See tropane alkaloid structure. Some of the most potent tropane alkaloids are atropine, hyoscyamine and scopolamine. These alkaloids affect the central nervous system, including nerve cells of the brain and spinal cord which control many direct body functions and the behavior of men and women. They may also affect the autonomic nervous system, which includes the regulation of internal organs, heartbeat, circulation and breathing. One autonomic response of atropine is the dilation of pupils, once considered to be a beautiful and mysterious look in Italian women. In fact, belladonna means "beautiful lady," so named because sap from the

closely related belladonna plant (**Atropa belladonna**) was used as eye drops to dilate the pupils. Tropane alkaloids are found in many other poisonous plants of the nightshade family (Solanaceae), including henbane (**Hyoscyamus niger**), pituri (**Duboisia hopwoodii**), deadly datura (**Datura** & **Brugmansia** spp.) and mandrake (**Mandragora officinarum**), all of which were used extensively in witches' brews and folk medicines.



A comparison of two tropane alkaloids: Hyoscyamine from henbane (**Hyoscyamus niger**) and cocaine from **Erythroxylum coca**. Note the methylated nitrogen atom at the top left of each molecule.

The action of tropane alkaloids at the cellular level is complex and is related to their molecular structure, particularly the methylated nitrogen at one end of the molecule (see tropane). This chemical structure is also found in the neurotransmitter acetylcholine, which transmits impulses between nerves in the brain and neuromuscular junctions. The anesthetic properties of tropane alkaloids may relate to their interference with acetylcholine, perhaps by competing with it at the synaptic junctions, thus blocking or inhibiting nerve impulses. It is interesting to note that the infamous tropane alkaloid cocaine, from the leaves of the coca shrub (**Erythroxylum coca**--Erythroxylaceae), is also a local anesthetic when injected into skin or muscle tissue. This property led to the discovery and synthesis of the more potent compound, novocain, widely used in dentistry.



The alkaloid cocaine is a white powder extracted from the dried leaves of the South American shrub **Erythroxylon coca**. It induces a sense of exhilaration in the user primarily by blocking the reuptake of the neurotransmitter dopamine in the midbrain.

Incas of the South American Andes have used coca leaves since pre-Columbian times for religious and medicinal purposes. They chew coca leaves for its stimulant properties to ward off fatique and hunger, to enhance endurance in the high altitude Andes, and to promote a sense of well-being. Cocaine acts primarily by interfering with the reuptake of dopamine. Dopamine produces feelings of well-being when it is released from one transmitting brain neuron to another. After release, dopamine is normally pumped back into the original neuron. Cocaine prevents the reuptake of dopamine and therefore prolongs the feeling of well-being.

Spanish conquistadores tried to prohibit coca use until they realized that the Indians they enslaved would work harder if allowed to chew the leaves. Coca leaves were taken back to Europe by the Spanish and in 1860 cocaine was extracted and became a popular drug in Europe. It was a popular ingredient in some beverages and medicines in the United States, including Coca Cola; however, since 1904 federal law has prohibited the inclusion of cocaine in any beverage. The Coca Cola Company complied with this law, but was sued for misleading advertising because the name implied that the beverage contained coca products. As a result, coca leaves, with the cocaine removed, were used to flavor the syrup from which the soda is made. In 1914 cocaine was formally declared illegal by the Harrison Narcotics Act.

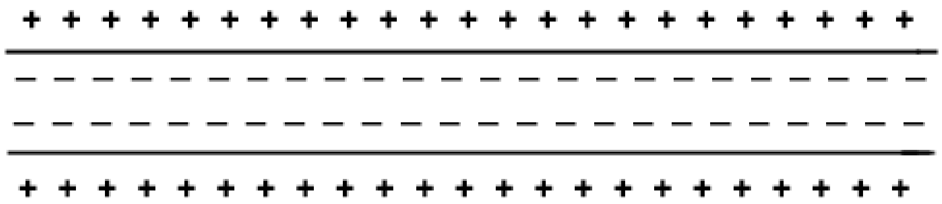
Cocaine is a 3-ring alkaloid that is most commonly taken as a hydrochloride salt known as "coke." Crystals of cocaine hydrochloride are ground into a fine powder. One method of taking this drug is to sniff (snort) a fine line of the powder. Since the hydrochloride salt decomposes at the temperature required to vaporize it, a method was developed to convert cocaine into the liberated "base" form. "Free-base" cocaine was typically produced by heating the hydrochloride in the volatile solvent ether; however, since ether is very flammable, this method is hazardous. Crack cocaine is produced by heating the hydrochoride in a solution of baking soda until the water evaporates. This type of base-cocaine makes a cracking sound when heated; hence the name crack cocaine. Both freebase and crack cocaine can be injected and, since they are unaffected by heat, can be smoked.

During the past century, many famous people in Europe and the United States took cocaine regularly. The fictional Sherlock Holmes character quite openly took cocaine in several of the stories in order to stimulate and clarify the mind. Cocaine addiction is associated with a number of health risks. If inhaled for long periods of time, it can cause damage to the inner surface of the nose. Cocaine users tend to increase the dosage to maintain the original highs, and continual use may eventually cause damage to neuroreceptors.

Depending on the dosages, several tropane alkaloids of **Datura** and **Brugmansia** (when absorbed together) may have synergistic properties resulting in extreme hallucinations, delirium and death. Since the alkaloids are fat soluble they are readily absorbed through the skin and mucous membranes. Volumes have been written about the uses and properties of **Datura** in the Middle Ages. Most of the uses involved the consumption of potions or concoctions made from various parts of the plant. The famous seventeenth century Dutch artist, David Teniers the Younger, made several paintings of witches preparing for their demonic orgy or sabbat. The scenes frequently depicted a witch being anointed while she straddled a broom for her flight into the sky. Clay tablets from Babylonian and Assyrian ruins indicate that **Datura** was used medically in ancient civilizations several thousand years ago. Greek and Roman physicians used **Datura** mixed with opium as a sedative and general anesthetic during surgery. In fact, the use of scopolamine (one of the alkaloids in **Datura**) plus morphine as an effective pain reliever and sleep inducer was common practice until the nineteenth century.

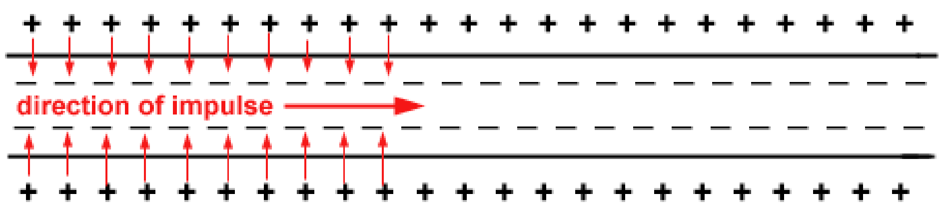
Action Potential (Wave of Depolarization) & Active Transport

The movement of ions through a cell membrane against a diffusion gradient (i.e. from a low to a higher concentration) is called active transport. This movement involves carrier proteins (channels) in the cell membrane and requires energy in the form of ATP (adenosine triphosphate). Active transport occurs during a nerve impulse or action potential (wave of depolarization) when a nerve cell membrane suddenly becomes permeable to sodium ions. The inflow of sodium ions moves quickly along the nerve cell axon, activating an adjacent nerve cell or muscle. As sodium ions rapidly move across the membrane to the inside of the axon, the polarity of the membrane changes. This reversal in polarity causes the sodium channels to close and the potassium channels to open. Now potassium ions move from inside the axon to the outside of the axon in a wave of repolarization. Some neurotoxins block the sodium and potassium channels, thus interfering with the polarity of nerve cell membranes and the wave of depolarization. Other nondepolarizing neurotoxins affect acetylcholine and acetylcholinesterase in the synaptic junctions between adjacent neurons and muscles.



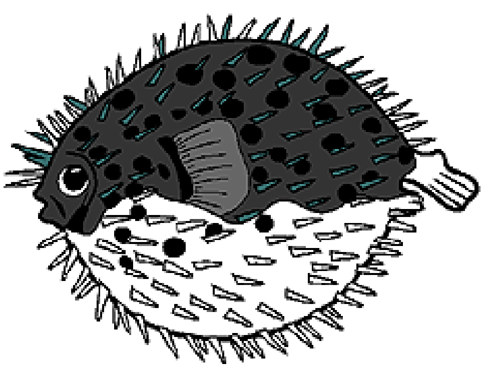
Section of an axon during the resting potential.

During the resting potential, the outside of the axonal membrane has a net positive charge due to an excess of sodium (Na+) ions. The inner side of the membrane has a negative charge. During this stage, the sodium and potassium channels in the axonal membrane are gated (closed). On an oscilloscope screen, the resting potential is displayed as a flat line.



Section of an axon during the action potential.

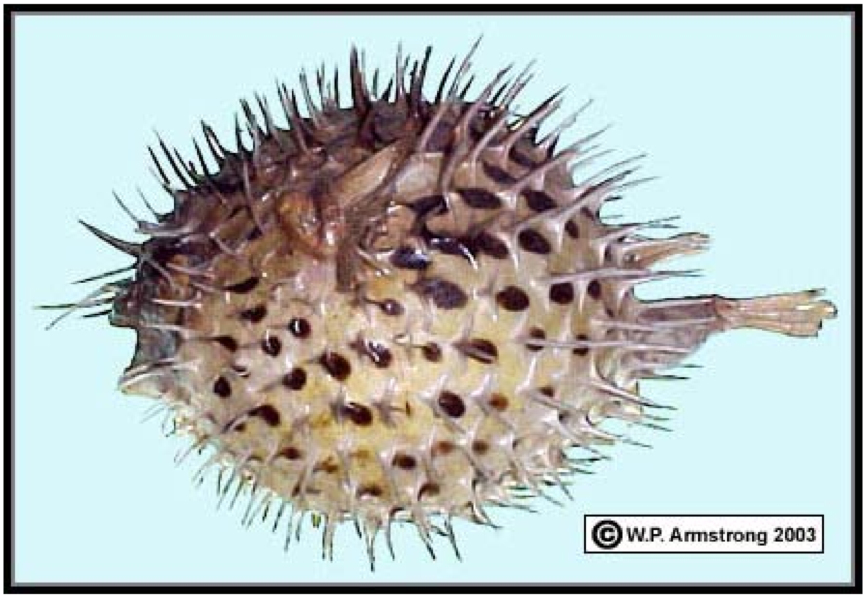
During the action potential or wave of depolarization, there is a rapid influx of Na+ ions through the membrane. Sodium channels in the membrane are suddenly opened and the membrane becomes permeable to Na+ ions. On an oscilliscope screen, the action potential is displayed by a characteristic peak. Depolarization is displayed by the steep upward slope of the peak. Repolarization of the membrane occurs as potassium channels open and potassium (K+) ions move to the outside of the axonal membrane. On an oscilliscope screen, repolarization is displayed by the steep downward slope of the peak. It is easy to see how a massive influx of potassium ions during a lethal injection of potassium chloride can disrupt the ratio of sodium and potassium ions and the polarity of nerve cell membranes.



The Japanese fugu (**Fugu rubripes**) is a puffer fish that is an expensive gourmet delicacy in Japanese cuisine. Also known as "torafugu," this species contains a potent sodium channel blocker called tetrodoxin. Ingestion of the toxin causes muscle paralysis and death due to respiratory failure. If not prepared correctly, eating fugu can result in fatal poisoning.

Tetrodoxin is found in the ovaries, skin, muscles and liver. These tissues must be carefully removed by the chef before eating the fish. The amount of tetrodoxin in one fugu is sufficient to kill more than 30 people. The lethal dosage for one adult is only about one or two milligrams, an amount small enough to fit on the head of an ordinary straight pin. Although it is 1200 times deadlier than cyanide, in a diluted form tetrodoxin is an effective painkiller for victims suffering from neuralgia, arthritis and rheumatism. Eating fugu has been compared with Russian roulette; however, licensed fugu cooks must take intensive courses and an apprenticeship. One who dines on fugu literally puts his life in the hands of the chef. Apparently the taste of this fish is incomparable, and fugu connoisseurs feel the risk (and expense) is worth it.

See Straight Pin & Sewing Needle Used In Wayne's Word Articles

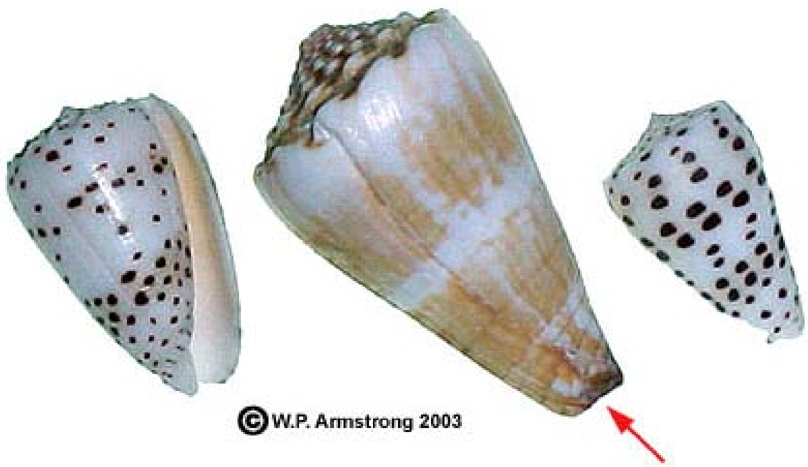


Without getting into complicated anatomy and physiology, one nerve cell (neuron) connects to an adjacent neuron by a long extension called an axon. The axon branches into axonal endings, each of which attaches to the adjacent neuron at a synaptic knob filled with acetylcholine. The minute gap or synaptic cleft within this knob is only about 0.02 micrometers. As a nerve impulse (wave of depolarization or action potential) reaches this gap, acetylcholine diffuses across the synaptic cleft and activates the adjacent neuron. Acetylcholine in the synaptic cleft is deactivated or broken down by the enzyme acetylcholinesterase, thus shutting off the action potential. Organophosphate insecticides, such as malathion and parathion, bind to active sites on this enzyme, thus preventing the normal shut down of nerve impulses and destroying the nervous control of insects. Nerve gasses developed during World War II have a similar effect on the nervous system. Gulf War soldiers carried atropine syrettes to counter the possible effects of nerve gas inhalation.

During a lethal injection, a fatal dose of potassium chloride is administered intravenously. The large influx of potassium ions interrupts the wave of depolarization (action potential) to the heart muscle resulting in cardiac arrest. A nondepolarizing paralyzing agent, such as pancuronium bromide or tubocurarine chloride, plus a lethal dosage of a general anesthetic, such as sodium thiopental (sodium pentothal) are usually given before the potassium chloride is administered. Tubocurarine is the active ingredient of curare, an extract from the bark and stems of the South American vine (**Chondodendron tomentosum**). Amazonian Indians use the gummy extract to coat the poison darts of their blowguns. The isoquinoline alkaloid D-tubocurarine blocks acetylcholine receptor sites at neuromuscular junctions, causing relaxation and paralysis of muscles, including respiratory organs and the heart.

Cone snails of the genus **Conus**, including the South Pacific **C. geographus**, can inject a potent neurotoxin (called conotoxin) that belongs to a class of poisons called calcium channel blockers. According to Dr. Bruce G. Livett, Department of Biochemistry & Molecular Biology, The University of Melbourne (personal communication, 2007), cone snails such as **Conus geographicus** contain omegaconotoxins that block calcium channels; however, it is generally accepted that the cause of death is due to the actions of alpha-conotoxins that block acetylcholine on nicotinic receptors at the neuromuscular junction, therby inhibiting depolarization and contraction of the diaphragm muscle and causing breathing to stop. In this case death is caused by asphyxiation rather than cardiac arrest.

Calcium channel blockers inhibit the flow of calcium ions into cardiac (heart) and smooth muscle cells. A sufficient inflow of calcium ions is necessary for contraction of the heart muscle. Muscle contraction involves the reaction of actin and myosin microfilaments which slide over each other. Calcium is essential for the phosphorylation of myosin; an insufficient uptake of calcium ions can result in cardiac arrest. As a medical treatment, calcium channel blockers are used to lower blood pressure, relieve painful angina, and to stabilize abnormal (irregular) heart rhythms. A calcium channel blocker based on the venom peptide omega-conotoxin MVIIA (Ziconotide) from **Cornus magus** has been developed commecially by Elan as an analgesic for the prevention of severe chronic pain that is resistent to morphine and derivatives. This compound is marketed under the name Prialt.



The shells of cone snails (**Conus**) are highly prized by beachcombers; however, when these snails are alive they are capable of injecting a painful, toxic venom. When the proboscis is extended from the anterior (aperture) end of the snail (red arrow), a barbed, spinelike, radula tooth is thrust into the prey or potential predator like a miniature harpoon. If handling one of these live snails, never allow the aperture end to touch your skin.

The terms poison and venom have entirely different meanings. Poisons are generally absorbed or ingested. For example, poison dart frogs contain a poisonous alkaloid in their skin that may be absorbed or ingested by a potential predator. Venoms, on the other hand, are always injected. The deadly Australian jellyfish called a sea wasp (**Chironex fleckeri**) has tentacles bearing thousands of stinging cells (cnidoblasts), each containing a "stinging organelle" known as a nematocyst. Like a miniature harpoon, each nematocyst delivers a microscopic injection into the prey. If deadliest venom is measured by how long it takes a person to die, then this species is certainly one of the world's deadliest. Depending on the extent of envenomation, the sea wasp can inflict excruciating stings that may cause death within five minutes. Ingenious Australian swimmers and snorkelers have devised a complete nylon body suit made from two pairs of panty hose, one put on the usual way; and the other put on over the hands, arms, and torso, with a slit for the head. Curiously, the deadly nematocysts of **Chironex** do not sting through panty hose, but watch out for runs!

The toxin of jellyfish nematocysts is a complex mixture of proteins, enzymes, polypeptides and tetramine. Pain and local histamine release of some jellyfish stings are attributed to 5-hydroxytryptamine, one of the ingredients in the stinging trichomes of nettles. The mechanism causing cardiac and respiratory failure of sea wasp venom is unclear. It may be due to blockage of nerve impulses at the synaptic junctions, similar to the action of curare.

Beautiful But Deadly Poison Dart Frogs
See Painful Botanical Encounters Of Nettles
Curare: Deadly Neurotoxin From A Tropical Vine

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3. Isoquinoline Alkaloids: Double carbon ring containing one nitrogen atom (N). This includes the narcotic alkaloids commonly found in certain members of the poppy family (Papaveraceae), such as the opium poppy (**Papaver somniferum**). Narcotic refers to the pain-relieving and sleep-inducing properties of these highly-addictive alkaloids, including morphine, codeine and thebaine. Morphine is named after Morpheus the god of sleep, while the specific epithet of the opium poppy (**somniferum**) means "to sleep" in Latin. These potent alkaloids are obtained from the milky latex sap of the mature seed capsule of the opium poppy. The raw opium sap drips from fresh cuts into the pericarp of the capsules, and upon oxidation and solidification in the air it turns black. Morphine is acetylated to produce diacetylmorphine--better known as heroin. The poppy seeds used on bagels and rolls also come from opium poppies, and although they don't cause any narcotic effects on hungry people after their coffee breaks, they can trigger a positive reaction in very sensitive urine tests for drugs. In addition to **Papaver**, naturally-occurring opiate alkaloids also occur in the related genera **Argemone** and **Dicentra**. The opium poppy has undoubtedly caused untold suffering by people addicted to its alkaloids, but has also brought immeasurable relief from pain for countless people throughout the ages. Although there are some potent synthetic opiates such as Demerol®, natural morphine is still one of the world's best pain relievers.

An extract from the bark and stems of the South American vine (**Chondodendron tomentosum**), a member of the Menispermaceae, is the source of a potent isoquinoline alkaloid used in the deadly poison curare. Amazonian Indians use the gummy extract to coat the poison darts of their blowguns. The alkaloid D-tubocurarine blocks acetylcholine receptor sites at neuromuscular junctions, causing relaxation and paralysis of muscles, including respiratory organs and the heart. In fact, D-tubocurarine has been used to relax the heart muscle during open heart surgery. It has also been used to treat the spastic paralysis of tetanus toxin which is caused by uncontrollable muscle contraction throughout the body.

See Milky Latex Dripping From Opium Poppy
See Photograph Of A South American Curare Vine

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4. Quinolizidine Alkaloids: Double carbon ring containing one nitrogen atom (N). These poisonous alkaloids are most commonly present in members of the pea family (Fabaceae), including lupinine from lupines (**Lupinus** spp.), sparteine from Spanish broom (**Spartium junceum**), and cytisine from Scotch broom (**Cytisus scoparius**). The bright red seeds of the beautiful, desert shrub called mescal bean (**Sophora secundiflora**) also contain cytisine. Although the shrub is called mescal bean, it does not contain the alkaloid mescaline, nor is it related to the highly intoxicating beverage called "mescal" or "mezcal," made from the fermented and distilled juices of several North American species of **Agave**, including **A. americana** and **A. atrovirens**. [Incidentally, the fermented juice is called pulque, and the

highly-alcoholic distilled products include mezcal and tequila.] Mescal beans were ingested by some North American Indian tribes in a vision-seeking "Red Bean Dance" prior to the widespread use of peyote. Although cytisine is not a hallucinogen, it does cause a delirium comparable to a visionary trance. According to R.E. Schultes (**Plants of the Gods**, 1976), mescal beans have been discovered in Indian sites dating before A.D. 1000, and from one site dating back to 1500 B.C. In fact, to this day the leader of the peyote ceremony in some of these tribes (called the "roadman") wears a necklace made from bright red mescal beans. [For biology students, cytisine is not to be confused with the pyrimidine base cytosine found in DNA and RNA.]

The bright red seeds of **Erythrina** species (called coral beans) contain a different type of alkaloid having a curare-like action. Many species of **Erythrina** contain erythroidine and related alkaloids which cause paralysis and death by blocking acetylcholine receptor sites at neuromuscular synaptic junctions. This is essentially how curare works, a gummy extract from the bark and stems of a South American vine **Chondodendron tomentosum,** highly prized by Amazonian Indians for blowgun darts. Coral trees are commonly grown as shade trees on coffee and cacao plantations of Central and South America, and are often called "madre arbol" and "madre de cacao" by local natives. Although coral beans are used in seed necklaces throughout tropical countries of the world, they are quite poisonous if eaten.

See Photo Of Colorful Mescal Beans
See Coral Beans In Botanical Jewelry
See Mescal Beans In Botanical Jewelry

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5. Indolizidine Alkaloids: Double ring compounds containing an indole ring. In contrast with some of the previous classes of alkaloids, the indolizidine alkaloids do not appear widespread in nature. Two of the most notable examples, swainsonine and swainsonine-N-oxide were originally discovered in the leguminous herb called darling pea (**Swainsona**), native to Australia. They also occur in the genera **Oxytropis** and **Astragalus**, often called locoweeds because of their effect on grazing animals, such as cattle and horses. The consumption of locoweeds over time can lead to a serious (often fatal) disease called locoism. The cause of locoism at the cellular level is very complex. The swainsonine alkaloids inhibit or tie up the key enzyme mannosidase resulting in the accumulation of mannose sugar in nerve cells and irreparable damage to brain tissue. This condition is remarkably similar to a genetic deficiency of the same vital enzyme in humans called mannosidosis. Mannosidosis is a genetic disorder called a lysosomal storage disease, in which cells of the central nervous system become filled with cytoplasmic vacuoles of mannose due to the lack of the vital enzyme mannosidase that is essential in breaking down mannose. The actual vacuoles are swollen organelles called lysosomes where the enzymatic breakdown process normally occurs. Lysosomal storage diseases, such as mannosidosis, are often caused by recessive genes and result in paralysis and death within a few years following birth. Perhaps one of the better known storage diseases is Tay Sachs Disease, in which nerve cells fill up with a lipid called ganglioside or GM2 because they lack the vital enzyme HEX A needed to break down GM2. Studies of the biochemical effects of locoweed poisoning on the central nervous system of cattle may lead to a better understanding of these tragic human neurological disorders.

Read About Locoweed Poisoning
See A Locoweed And Dead Steer
See Rare Death Valley Locoweed
See Spectacular Scarlet Locoweed
Enzyme Block By Poison Molecule

6. Quinoline Alkaloids: Double carbon ring containing one nitrogen atom (N). Quinoline alkaloids include quinine from the bark of **Cinchona ledgeriana**, a South American tree in the coffee family (Rubiaceae). The alkaloid quinine is toxic to **Plasmodium vivax** and three additional species, the one-celled organisms (protozoans) that cause malaria. The microorganisms invade red blood cells where they multiply, eventually escaping from the ruptured cells. The disease is characterized by spells of fever and chills, associated with the simultaneous rupture of red blood cells. Malaria is certainly one of the most widespread diseases throughout tropical regions of the world, and it is transmitted through the bite (blood meal) of the female **Anopheles** mosquito. During the 1600s, Spanish Jesuits in Lima, Peru learned that bark extracts from a local tree called "quina" (**C. officinalis**) could cure malaria. They successfully used this extract on Countess Chinchon. According to O. Tippo and W.L. Stern (**Humanistic Botany**, 1977), the genus was named by Linnaeus in honor of the countess, but spelled it **Cinchona** rather than **"Chinchona."**. Today, quinine trees are grown in plantations, although many synthetic antimalarial drugs have been developed, such as atabrine, chloroquine and primaquine. Some strains of **Plasmodium** are resistant to many of the synthetic quinine analogues, so natural quinine is still used to this day. In fact, some people take prophylactic doses of bitter quinine water (tonic) in the evenings, usually mixed with gin or vodka.

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7. Indole Alkaloids: Double ring compounds containing an indole ring. See structure of an indole alkaloid. Indole alkaloids contain the indole carbon-nitrogen ring which is also found in the fungal alkaloids ergine and psilocybin, the neurotransmitter serotonin, and the mind-altering drug LSD. These alkaloids may interfere or compete with the action of serotonin in the brain. One of the most amazing stories about naturally-occurring alkaloids in fungi concerns ergot (**Claviceps purpurea**), a rust fungus that infects grains. The alkaloid of ergot is called ergine (d-lysergic acid amide), better known as natural LSD. [The more potent synthetic LSD is d-lysergic acid diethylamide.] Natural LSD is also found in the seeds of two species of Mexican morning glory vines which are still ingested by native Indians in an important medicinal and religious ritual. During the Middle Ages, thousands of people in Europe were afflicted with ergotism, a malady characterized by gangrenous extremities, convulsions and madness. They ate rye bread infested with ergot fungus containing ergine and several potent vasoconstrictor alkaloids that affected blood vessels. Known as "St. Anthony's Fire," it was a dreaded disease. [Another strong hallucinogenic alkaloid, mescaline, comes from the Mexican peyote cactus (**Lophophora williamsii**) and the South American San Pedro cactus (**Trichocereus pachanoi**), and has a chemical structure remarkably similar to the brain neurotransmitter dopamine. Mescaline and the sacred peyote cactus are discussed under ephedrine alkaloids below.]

Another fascinating indole alkaloid called bufotenine occurs in the seeds of Yopo or Paricá (**Anadenanthera peregrina**), a South American leguminous tree of the Orinoco River basin (not to be confused with the leguminous genus **Adenanthera**). Indians of this region prepare a powder from the ground seeds which they use as a hallucinogenic snuff. Bufotenine (5-hydroxydimethyltryptamine) is a derivative of the indole alkaloid tryptamine, which is derived from the essential amino acid tryptophan. Tryptophan is one of the 8 (9) essential dietary amino acids in humans (which we cannot synthesize), and is widely distributed in the animal kingdom. Interestingly enough, bufotenine is also present in the skin secretion of certain toads of the genus **Bufo**, and explains the practice of licking toads by some people.

The indole alkaloid reserpine is derived from the roots of a shrub called snakeroot (**Rauvolfia**

serpentina), a member of the dogbane family (Apocynaceae). This genus is sometimes spelled **Rauwolfia**. Reserpine is chemically similar to serotonin, and has been used to terminate the schizophrenia-like symptoms from LSD and as a brain depressant for schizophrenic patients. Although snakeroot is native to India, other species of **Rauvolfia** from tropical regions of the world may be potential sources of reserpine. The very poisonous alkaloid called strychnine is another indole alkaloid. It is derived from the seeds of **Strychnos nux-vomica**, a small Asian tree in the logania family (Loganiaceae). Amazonian Indians coat their bow guns darts with curare, a poisonous extract from the bark and stems of a **Strychnos** species. The curare mixture also contains isoquinoline alkaloids from an extract of the poisonous vine **Chondodendron tomentosum** (Menispermaceae).

Two additional indole alkaloids, vinblastine and vincristine, come from the Madagascar periwinkle (**Catharanthus roseus**), a commonly cultivated bedding plant in the dogbane family (Apocynaceae). These alkaloids are called spindle poisons, and they have proven to very effective in chemotherapy treatments for leukemia and Hodgkin's disease (lymph node and spleen cancer). They cause the dissolution (depolymerization) of protein microtubules which make up the mitotic spindle in dividing cells. This effectively stops the tumor cells from dividing, thus causing remission of the cancer. Before periwinkle alkaloids were used as a treatment, there was virtually no hope for patients with Hodgkin's disease. Now there is a 90 percent chance of survival. This is a compelling reason for preserving the diverse flora and fauna in natural ecosystems. Who knows what cures for dreaded diseases are waiting to be discovered in tropical rain forests or other natural habitats. Other spindle poisons used in cancer chemotherapy include podophyllotoxin, an antineoplastic glucoside from the rhizomes of may apple (**Podophyllum peltatum**), a member of the barberry family (Berberidaceae); and colchicine, an amine alkaloid from the corms of autumn crocus (**Colchicum autumnale**), a member of the lily family (Liliaceae).

Illustration Of Indole Alkaloids
Mushrooms Containing Natural LSD
Morning Glories With Indole Alkaloids
Photographs Of Psychoactive Mushrooms
Photos Of Hallucinogenic Morning Glories
Photos Of Plants Producing Medical Alkaloids

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8. Steroidal Alkaloids: Double carbon ring containing one nitrogen atom (N), plus a steroid backbone composed of four carbon rings. See chemical structure of a steroid backbone. Steroidal alkaloids contain a tetracyclic (4-ring) triterpene compound called the steroid nucleus or steroid backbone. Because some steroidal alkaloids contain a sugar molecule, they are also referred to as alkaloidal glycosides (sugar + steroidal alkaloid). Species of nightshades (**Solanum**) in the tomato family (Solanaceae) contain a complex of toxic alkaloidal glycosides. One of these is called solanine, which is now known to consist of six different glycosides, each composed of a particular sugar and the steroidal alkaloid solanidine. Similar steroidal alkaloids are found in certain members of the lily family (Liliaceae) including the corn lily or false helibore (**Veratrum**) and death camas (**Zigadenus**). Some steroidal alkaloids are very toxic, causing severe gastroenteritis that may be fatal. Because many species of nightshades contain solanine, the closely-related tomato was once thought to be poisonous. Potatoes also belong to the genus **Solanum** (**S. tuberosum**). The leaves, stems, sprouts on tubers, and green skin on old potatoes contains the toxic solanine. In fact, this toxic alkaloidal glycoside is not destroyed when green potatoes are cooked. The potatoes must be carefully peeled first.

The bulbs of death camas (**Zigadenus venenosus**) are quite poisonous to cattle, sheep, and humans if ingested. The bulbs contain zygadenine, a very toxic steroidal alkaloid. In fact, **Zigadenus** was one of the few genera in the lily family (Liliaceae) in which the bulbs were not eaten by native Americans. There are a number of documented cases of deaths and poisonings of livestock in California due to the consumption of death camas. According to Fuller and McClintock (**Poisonous Plants of California**, 1986), one or two pounds of death camas may be sufficient to kill a 100 pound sheep. In addition, bulbs of death camas made into flour reportedly caused serious illness to members of the Lewis and Clark expedition. Several other species of **Zigadenus** called star lilies are native to the coastal mountains and grasslands of California.

See A Star Lily In Full Bloom
Toxic Green & Sprouting Potatoes
The Tomato, Tomatillo And Eggplant

One of the most interesting and poisonous steroidal alkaloids is produced by Central and South American poison dart frogs of the genera **Dendrobates** and **Phyllobates**. Some of these species exhibit bright warning colorations (aposematic coloration), an adaptation for diurnal foraging in which predators can easily recognize and avoid these very poisonous frogs. [In some species of these remarkable frogs, the female carries her tadpoles to water-filled bromeliads in the rain forest canopy and feeds them with unfertilized, nutritive eggs; an example of parental care in amphibians!] The alkaloid toxins are secreted from skin glands and are deadly to other small animals. [After handling a **Dendrobates** frog, another frog species died from the residue on the biologist's hand.] Amazonian Indians roast the toxic frogs like marshmallows on the tips of their blowgun darts, thus coating them with poison. One of the most potent steroidal alkaloids produced by **Phyllobates** frogs is batrachotoxin. **Dendrobates** frogs produce another poison called pumiliotoxin. Batrachotoxin blocks neuromuscular transmission, resulting in muscle and respiratory paralysis and death. Extrapolating from the lethal dosage (LD) in rats, approximately 136 micrograms of this alkaloid is the lethal dosage for a 150 pound (68 kilogram) person. This minute amount is roughly equivalent to the weight of two or three grains of ordinary table salt (NaCl).

One of the choice palms for making blowguns is the stilt palm (**Iriartella setigera**), a small, slender, tropical American palm with numerous straight stilts or prop stems branching off the main trunk. When the pith is removed and the bore highly polished, the stilts make a very accurate blowgun. Generally, the stem is sectioned longitudinally for pith removal, and then bound together again. Other slender palms and bamboos are also used for blowguns.

See Photos Of Poison Dart Frogs

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9. Purine Alkaloids: Double carbon ring containing four nitrogen atoms (N). Purine alkaloids have a molecular structure remarkably similar to the nitrogenous purine base adenine which is found in DNA, RNA and ATP. Most notable of the purine alkaloids are the mild stimulants caffeine and the very similar theobromine. Caffeine occurs naturally in many beverage plants, including coffee (**Coffea arabica**) in the coffee family (Rubiaceae); tea (**Camellia sinensis**) in the tea family (Theaceae); yerba mate (**Ilex paraguariensis**) in the holly family (Aquifoliaceae); guaraná (**Paullinia cupana**) in the soapberry family (Sapindaceae); and cola (**Cola nitida**) in the chocolate family (Sterculiaceae). The primary source of theobromine is from the seeds (beans) of cacao (**Theobroma cacao**), another member of the chocolate family (Sterculiaceae).

Coffee is a shrub or small tree native to the mountains of Ethiopia, although it is now grown throughout tropical regions of the world. Coffee was originally roasted and used as a beverage in Arabia. Mocha, a city in Yemen, was an ancient center of coffee trade. During the 1600s, coffee houses sprang up in England, where they became popular centers for political discussions and meeting places. Sri Lanka (Ceylon) was the main source of coffee imported by England, but a serious fungal disease (**Hemileia vastatrix)** destroyed the coffee plantations in 1869. Consequently, England switched to Ceylon teas which are the most commonly brewed beverage in Britain to this day. About half of the total world's coffee production comes from large plantations in Brazil and Colombia. Coffee fruits are fleshy berries, each containing two seeds which are pressed together so that the inner (adjacent) side of each one is flattened. The coffee beverage is made from the ground, roasted seeds (called coffee beans) that are removed from the coffee berries (called coffee cherries). Expresso coffee is typically made by forcing steam through ground, dark-roast (deeply roasted) beans. Decaffeinated coffees are made from beans in which the caffeine has been removed, either through solvent extraction or water extraction. Some coffees contain adulterants, such as ground chicory roots (**Cichorium intybus**), which reduce the bitterness and enhance the flavor. Chicory is a member of the enormous sunflower family (Asteraceae), and is a common roadside weed in the United States. Coffee substitutes, such as Postum®, are made from molasses and roasted cereal grains, such as wheat, rye and barley.

Green and black teas are caffeine beverages from **Camellia sinensi**, an Asian shrub closely related to ornamental species of **Camellia**. The grade of tea depends on the age of the leaves. In "golden tips" the youngest bud only is used; in "orange pekoe" the smallest leaf; in "pekoe" the second leaf; in "pekoe souchong" the third leaf; in "souchong" the fourth leaf; and in "congou" the fifth and largest leaf to be gathered. In green tea the leaves are dried and appear dull green. In black tea the leaves are fermented and then dried. "Oolong tea" is only partially fermented and is intermediate between black and green. The various pekoes, souchongs, and congous are black teas, while gunpowder and hyson are the most important grades of green tea.

Yerba mate is a popular caffeine beverage in South America. In Argentina a small gourd is made into a special cup for drinking "yerba mate," a popular tea brewed from the leaves of a native holly (**Ilex paraguariensis**). Mate is sipped through a perforated metal straw called a "bombilla." Mate gourds are often fashioned with silver rims or collars and support bases. Old mate gourds improve the flavor of this caffeine-rich tea and mate connoisseurs would never think of using glass, pottery mugs or styrafoam cups. Guaraná (the cola of Brazil) is a high-caffeine beverage made from the seeds of a trailing shrub or vine native to central Brazil. The drink contains more caffeine than coffee or tea, and a single cup is reputed to be sufficiently stimulating to counteract feelings of fatigue. The powdered seeds are also available in tablet form. If you suffer from insomnia, never drink a bottle of guaraná or take guaraná tablets at bedtime.

The cola shrub is native to the African countries of Ghana and Nigeria. The cola seed (cola nut) is rich in caffeine, and is used in many popular cola beverages. In western Africa the cola nut is chewed by native people to inhibit fatigue and hunger. The original Coca Cola® was made from cola beans and coca leaves (**Erythroxylum coca**). The tropane alkaloid cocaine from coca leaves gave the beverage an even stronger boost. Other popular non-caffeine beverages, such as rootbeer and ginger ale, contain different extracts and flavorings, including sarsaparilla from **Smilax officinalis** (Liliaceae) and ginger from the rhizome of **Zingiber officinale** (Zingiberaceae), an important spice used in ginger ale, ginger beer and gingerbread.

The chocolate or cacao tree (**Theobroma cacao**) is believed to have originated in the Amazon Basin on the eastern equatorial slopes of the Andes. It is a small, shade-loving understory tree of wet tropical lowland forests. Many Indian tribes believed the plant came from the gods, hence the generic name **Theobroma**, meaning "food of the gods." In fact, it was so revered by native people that the seeds were used as currency by Aztecs and Mayas. In true cauliflory fashion, the curious blossoms grow directly out of the main trunk and branches. According to Daniel Janzen (**Costa Rican Natural History**, 1883), the flowers are believed to be pollinated by small ceratopogonid midges, although other small moths and beetles may be involved. The large, oblong fruits contain five rows of large seeds which are roasted and processed into cocoa. The seeds are dispersed by small mammals and monkeys as they break through the pod wall and eat the sugary pulp, leaving the seeds behind. Humans are very fond of the powdered seeds, especially when they are blended with milk and sugar to make highly caloric, heavenly-flavored confections, desserts and drinks. The seeds also contain the alkaloid theobromine, a caffeine relative with many reputed attributes, from a mild stimulant to a pleasant aphrodisiac. The latter quality may have evolved into the tradition of giving a box of these tasty morsels to a special romantic friend.

Cacao: Cauliflorous Tropical Tree
Coffee Plantation On Island Of Kauai
Mate Gourd & Bombilla From Argentina
Guaraná: Stimulant Beverage From Brazil
Cola Nuts From Cola nitida & C. acuminata

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10. Muscarine Alkaloids: Single carbon ring containing oxygen and one nitrogen (N). This group of alkaloids includes muscimol (sometimes spelled muscimole), which is derived from ibotenic acid--an amino acid. Muscimol is found in the bright red fly agaric mushroom (**Amanita muscaria**), so named because of its toxicity to flies. In Europe the mushrooms were reportedly left in open dishes to kill flies; however, according to some authorities, the flies are merely stunned or stupefied by the toxin, and may even regain control and fly away. Although it is poisonous to humans, there are other species of **Amanita** that are much more dangerous and are potentially lethal if ingested. Some of these dangerously poisonous species are death cap (**A. phalloides**), death angel (**A. ocreata**), and panther amanita (**A. pantherina**).

When ingested by humans, **Amanita muscaria** may produce visions and delirium, and it is perhaps one of the oldest known hallucinogens. Recent studies suggest that this mushroom was the mysterious God-narcotic "Divine Soma" of ancient India. Apparently not everyone agrees that the "Divine Soma" is **Amanita muscaria**. According to Terence McKenna (**Food of the Gods**, 1992), the active alkaloid in fly agaric mushrooms (muscimol) doesn't produce the psychoactive effects described in the **Rig Veda** and other literature. Some scholars believe that the original story of Alice's Adventures in Wonderland, where Alice speaks to a green caterpillar who is seated on a red- and white-capped mushroom, is actually the interpretation of a mushroom experience by the author, Rev. C.L. Dodgson of Christ Church College in Oxford (better known by his pen name of Lewis Carroll).

Read About The Famous Fly Agaric Mushroom
Photo Of The Beautiful Fly Agaric Mushroom

B. Alkaloids Without Hetercyclic Nitrogen Atoms: Nitrogen atoms not within a carbon ring, but located in a carbon side chain. See mescaline from peyote cactus and capsaicin from chile peppers.

1. Ephedrine Alkaloids (Amine Alkaloids): One or more carbon rings with a nitrogen atom (N) on a carbon side chain. One of the most interesting alkaloids in this group is mescaline from the peyote cactus (**Lophophora williamsii**). Mescaline has a molecular structure that is remarkably similar to the brain neurotransmitter dopamine. [See the structure of mescaline and dopamine compared.] It is also structurally similar to the neurohormone norepinephrine (noradrenalin) and to the stimulant amphetamine. In the peyote cactus, mescaline is formed in a complex pathway from the amino acid tyrosine. A similar pathway in humans produces epinephrine (adrenalin) and its demethylated precursor norepinephrine from tyrosine. Dopamine and its precursor L-dopa are also derived from a tyrosine pathway. Mescaline also occurs in several other cactus species, including the commonly cultivated, night-blooming, South American San Pedro cactus (**Trichocereus pachanoi**).

Contrary to popular rumors, mescaline is not found in the bright red, poisonous seeds of the beautiful, drought-resistant shrub called mescal bean (**Sophora secundiflora**); however, they do inhabit a similar range in the arid lands of the southwestern United States and Mexico. Mescaline is also not related to the highly intoxicating beverage called "mescal" or "mezcal," made from the fermented and distilled juices of several North American species of **Agave**, including **A. americana** and **A. atrovirens**. Incidentally, the fermented juice is called pulque, and the highly-alcoholic distilled products include mezcal and tequila. The seeds of mescal bean contain another potent and dangerously poisonous alkaloid, cytisine, which was ingested by some North American Indian tribes in a vision-seeking "Red Bean Dance" prior to the widespread use of peyote.

Read About The Famous Peyote Cactus
Photos Of Peyote And San Pedro Cactus

Another alkaloid called ephedrine has a molecular structure similar to that of mescaline. The chinese species **Ephedra sinica** was the original source of ephedrine, a common decongestant in popular allergy and hay fever remedies. Since ephedrine has a chemical structure similar to epinephrine (adrenalin), it works like a powerful cardiac stimulant that may cause cardiac arrest in infants and heart patients. New synthetic drugs based on the ephedrine/epinephrine ring structure are now marketed as effective and safer bronchodilators. Pseudoephedrine, an isomer of ephedrine, also occurs in species of **Ephedra**, and may be produced synthetically. Compared to ephedrine, it causes fewer heart symptoms such as palpitation, but is equally effective as a bronchodilator. It is used in over-the-counter drugs such as Sudafed®. **E. sinica** and other species are also marketed under the name of "ma-huang," a popular herbal stimulant and decongestant.

Note: The hormone epinephrine (adrenalin) is often administered to victims of honey bee stings, particularly people with extreme hyperallergic sensitivity to proteins in honey bee venom. An injection of epinephrine may prevent the serious effects of anaphylactic shock, including circulatory failure and death.

Ephedra: The Source Of Ephedrine

Colchicine is a 3-ring amine alkaloid derived from the corms of autumn crocus (**Colchicum**

autumnale), a member of the lily family (Liliaceae). Like the anticancer indole alkaloids, vinblastine and vincristine, it is a spindle poison causing depolymerization of mitotic spindles into tubulin subunits. This effectively stops the tumor cells from dividing, thus causing remission of the cancer. Because colchicine can stop plant cells from dividing after the chromatids have separated during anaphase of mitosis, it is a powerful inducer of polyploidy. Seeds and meristematic buds can be treated with colchicine, and the cells inside become polyploid with multiple sets of chromosomes (more than the diploid number). Polyploidy in plants has some tremendous commercial applications because odd polyploids (such as 3n triploids) are sterile and seedless. Polyploid plants (such as 4n tetraploids) typically produce larger flowers and fruits. In fact, many of the fruits and vegetables sold at supermarkets are polyploid varieties, including wheat, triticale, sisal, cotton, tobacco, sweet potatoes and apples. Colchicine has another medical use for people because it reduces the inflammation and pain of goit.

Citrus Fruits & Genetics
Interesting Plant Hybrids
Cereal Grasses & Genetics
Hybrid Mustards And Beets
Making Seedless Watermelons
Genetics Of Seedless 3n Bananas
Plants Producing Medical Alkaloids

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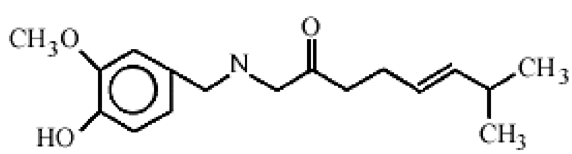
2. Capsaicin Alkaloids:



Capsaicin from Chile Peppers

Another fascinating alkaloid occurs in chile peppers of the genus **Capsicum** in the nightshade family (Solanaceae). According to D. Dewitt and P. W. Bosland (**Peppers of the World: An Identification Guide**, Ten Speed Press, Berkeley, California, 1996), there are 5 species of **Capsicum** peppers native to the New World: **C. pubescens**, **C. baccatum**, **C. annuum**, **C. frutescens** and **C. chinense**. The hottest chile peppers belong the **C. chinense** group, including the notorious habanero. Although this species is named "**chinense**," it is not from China. Its center of origin is thought to be the Amazon Basin of South America. The active ingredient causing the intense burning pain is the alkaloid capsaicin (cap-SAY-sin). So potent is the alkaloid that one millionth of a drop can be detected by the human tongue. Capsaicin is not broken down during the digestion process--this is why you often get burned several hours later after dining on chile peppers. Like other alkaloids in the chemical arsenal of plants, capsaicin may serve to discourage mammalian fruit predators. Botanists believe that birds are immune to the burning sensation of capsaicin, and may serve to disperse the seeds. Capsaicin may prevent hungry mammals from devouring the fruits, so that they can be eaten by fruit-eating birds who are attracted to bright red fruits. Passing through the bird's digestive tract relatively unharmed, the small seeds are dispersed to other favorable regions.

For serious pepper connoisseurs, there is a simple taste test that measures the tongue-scorching capsaicin content of these fruits. The highest capsaicin concentration is found in the placental region where the seeds are attached. Human laboratory animals are asked to taste a series of peppers and rate their hotness. Since veteran pepper eaters tend to be desensitized to the intense heat, the test is performed on people who are not regular pepper eaters. The amount of heat is expressed in Scoville Heat Units (SHUs). Bell peppers have a value of zero because they are homozygous recessive and lack the dominant gene for capsaicin production. Jalapenos and cayenne varieties may vary from 3,500 to 35,000 SHUs, and ripe tabasco peppers flame in at 50,000 SHUs. With values of 200,000 to 300,000, habanero peppers can be absolutely excruciating. A heavy duty pepper spray unit (resembling a small fire extinguisher) sold in Montana for grizzly bear protection has a SHU rating of two million. A technique called High Performance Liquid Chromatography has been developed to measure the concentration of capsaicin in Scoville Heat Units.

Chile Peppers & Pepper Spray
Photos Of Assorted Chile Peppers
Chart Of The Hottest Chile Peppers

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