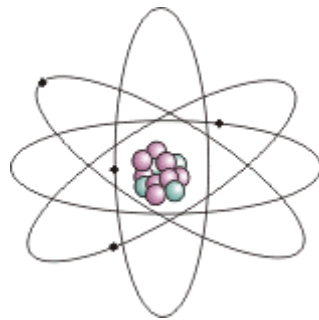


Atomic structure



In this simplified picture, we see the protons and neutrons at the center of the atom, and the electrons “orbiting” the central nucleus. This image, known as the Bohr model, is a bit inaccurate, in that it fails to portray three key features of an atom:

1. Scale. The nucleus accounts for .01% of the volume of an atom. As an analogy, if the nucleus were the size of a basketball, the entire atom would be the size of the Earth.
2. Electron ‘shape’. These particles are not little dots, as the picture would have us believe. They are more like vibrational states, oscillating around the nucleus, more like a cloud than anything else.
3. Electron energy levels. The electrons organize themselves into levels, or ‘shells’, rather than just randomly circling the nucleus. These levels are important in determining the atom’s behavior in nature.

Simplified Periodic Table of the Elements

	I	II	III	IV	V	VI	VII	VIII
1	1 Hydrogen H 1							2 Helium He 4
2	3 Lithium Li 7	4 Beryllium Be 9	5 Boron B 11	6 Carbon C 12	7 Nitrogen N 14	8 Oxygen O 16	9 Fluorine F 19	10 Neon Ne 20
3	11 Sodium Na 23	12 Magnesium Mg 24	13 Aluminum Al 27	14 Silicon Si 28	15 Phosphorus P 31	16 Sulfur S 32	17 Chlorine Cl 35	18 Argon Ar 40
4	19 Potassium K 40	20 Calcium Ca 40	(plus others in here)				35 Bromine Br 80	(etc.)

Glossary of Chemical Terms

Acid. A *compound* which, when dissolved in water, forms H^+ *ions*. This usually has the effect of lowering the *pH* of the solution. Acids are the opposites of *bases*.

Anion. An *ion* that is negatively *charged*.

Atom. The smallest unit in which an *element* can exist. Atoms are composed of a *nucleus*, *electrons*, and much empty space. Scientific understanding of atoms has progressed continuously since 500BC, and the current model emphasizes a central nucleus surrounded by ‘clouds’ of randomly-moving *electrons*. The electrons exist at discrete *energy levels*.

Atomic number. The number of *protons* in an *atom* or *ion*.

Atomic weight. The number of *protons* plus the number of *neutrons* in an *atom* or *ion*.

Base. A *compound* which, when dissolved in water, forms OH^- *ions*. This usually has the effect of raising the *pH* of the solution. Bases are the opposites of *acids*.

Bioavailability. The extent to which a *compound* can be used by the human physiology. This depends on many factors: *solubility*, transit time, size, and processing by the digestive system and the liver, for example.

Bonding. The process of joining two or more atoms to form a *compound*. *Ionic* bonding relies on the different *charges* of the *ions* to attract each other. *Molecular* (also called ‘covalent’) bonding relies on *atoms* sharing their *electrons*.

Cation. An *ion* that is positively charged.

Charge. The quality of being either a positive (+) or negative (-). Atoms, in their *elemental* state, have no charge. *Compounds* also have no overall charge, although certain areas of the compound may be more positive and others more negative. *Ions* always have a charge, which they obtain by giving or receiving electrons.

Compound. A substance formed by two or more *elements*, *bonded* together.

Dipole. A *polar* molecule (‘having two poles’).

Dipole moment. The number measuring the difference in intensity between the two *charges* of a *dipole*.

Electron. A subatomic particle responsible for negative *charge*. Electron movement is the basis for electricity. Electron trading and sharing is the basis for all chemical *bonding*.

Element. A substance that can no longer be chemically divided; elements are the basic ‘building blocks’ of matter in the universe. We know of 92 naturally occurring elements; another 20 or so more have been artificially created in the lab (but they never last long).

Energy level. The state at which an *electron* exists inside the *atom*. Each energy level (also known as ‘energy shell’) can hold a certain number of *electrons*: the first can hold two, and every other one can hold eight. *Atoms* in nature tend towards filling up their energy levels, either by going up to eight or down to zero. They accomplish this by trading or sharing *electrons* with other atoms.

Hydrocarbon. An *organic molecule*. These compounds are so called because they consist primarily of hydrogen and carbon.

Inorganic chemistry. The branch of chemistry that deals with *ions*, solutions, *elements*, *molecules* and *compounds* generally not produced by life.

Ion. A substance made of one or more *elements* that has a different total amount of *protons* and *electrons*. This difference gives the ion an overall *charge*, either positive (more *protons*) or negative (more *electrons*). Ions are formed when an *atom* or *compound* is *ionized*.

Ionic compound. A *compound* held together by the attraction of positive and negative *ions*.

Ionization. The process of adding or removing electrons from an *atom* or *molecule*. This can be accomplished through intense heat, electric current, or suitable chemical pairings. These pairings occur between *atoms* that can trade *electrons* amongst themselves to fill their atomic *energy levels*.

Molecule. A *compound* held together by the sharing of electrons, rather than trading. *Atoms* in a molecule fill their *energy levels* on a 'time-share' basis.

Non-polar. A *molecule* with no *dipole moment*.

Nucleus. The 'core' of the *atom*, containing its entire weight, but occupying only .01% of its volume (*atoms* are not very dense). The nucleus is made up of *protons* and neutrons, and provides a net positive *charge*.

Organic chemistry. The branch of chemistry that deals with *molecules* generally comprising *hydrocarbons*, and originally named because it studied *compounds* produced by living beings.

Nowadays, it comprises the study of plastics and petrochemicals as well as amino acids and essential oils.

Oxidation. The process of changing an *atom*, *ion* or *compound* to one with a greater (more positive) *charge*.

pH. The degree of acidity of a solution. The lower the pH, the more acidic it is. The pH scale is logarithmic, meaning that a difference of one point in the pH scale represents ten times the acidity; a difference of two points implies one hundred times the acidity.

Polar. Having a non-zero *dipole moment*.

Polarity. The quality a *molecule* can exhibit of having two sides, or poles, like a magnet. High polarity binds molecular liquids and gases more tightly together, and influences *solubility* in water (which is a highly polar substance).

Precipitate. A *compound*, either *ionic* or *molecular*, that has a *solubility* so low that it settles out to the bottom of a solution.

Reduction. The process of changing an *atom*, *ion* or *compound* to one with lesser (more negative) *charge*.

Saturation. The condition a solution reaches when, for a given temperature, it has the maximum amount of *solutes* in it.

Solubility. The degree to which a *solute* dissolves in a *solvent* – salt, for example, has a higher solubility in water than sugar.

Solute. The *compound* you wish to dissolve.

Solvent. The substance responsible for dissolving or extracting a given *compound* (the *solute*).

Terpene unit. A hydrocarbon chain made of 10 Carbon atoms and 16 Hydrogen atoms. It is the basis for classification for a variety of organic molecules, many of which are volatile. The classes are based on the number of terpene units in each molecule:

-monoterpenoids, C₁₀ H₁₆

-diterpenoids, C₂₀ H₃₂

-triterpenoids, C₃₀ H₄₈

-sesquiterpenoids, C₁₅ H₂₄

Volatile. Naturally vaporizes at room temperature. Usually, these *compounds* have a strong smell (such as essential oils, for instance).

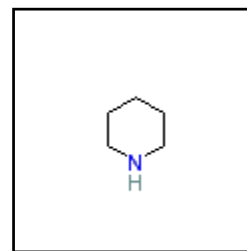
Major Organic Phytochemical classes

Alkaloids

These organic compounds are some of the most biologically active molecules that plants produce. At their simplest, they consist of a carbon ring into which a Nitrogen (N) atom is inserted (a simple piperidine *alkaloid* is pictured at right).

There are many sub-groups, the detail of which is beyond the scope of this course. Some examples are Nicotine (Tobacco), Lobeline (Lobelia), Morphine and Codeine (Opium poppy), Atropine (Belladonna), Cocaine (Coca), Caffeine (Coffee), Hydrastine and Berberine (Goldenseal), Ephedrine (Ephedra),

Mescaline (Peyote), Quinine (Cinchona spp.), Taxol (Yew). From this list you can get a good idea of their powers: they are very intense, heroic medicines that can be quite toxic in high doses.



Iridoids

These are a subclass of altered monoterpenoids. They are also called *lactones*. They generally have a bitter taste (and are often responsible for the effect of 'herbal bitters'). Some salient examples are Kavalactones (from Kava-Kava), Nepetalactone (from Catnip), and the Valepotriates (from Valerian). In general, most iridoids/lactones are *sedative, laxative, bitter* and *salilagogue*.

Saponins

As the name implies, these compounds are soap-like and are fairly well soluble in water. They can help dissolve other, more oily, compounds as well because of their nature. You can find saponins in many plants, including lots of food plant families (especially the Pea family), and notably in Ginseng and Licorice with Glycyrrhizin. If you shake an infusion, decoction or tincture and a stable foam remains on the surface, you are probably witnessing saponins at work. They have a variety of actions, some due to their 'soapiness' (although they are mostly broken down in the stomach), others due to the effect of their metabolites. I think of saponins as being crucial in the *adaptogen* class, helping to stimulate our body/minds into better tone. As such, they are *adaptogenic, hepatoprotective, immune modulators, anti-bacterial, expectorant, anti-inflammatory, diuretic* and *alterative*.

Steroidal saponins

A sub-class of the saponins, these compounds have similar activities, bordering on the phytosterols. They are found in plants such as Astragalus, Black Cohosh, Ginseng (Ginsenosides), and Wild Yam (Diosgenin).

Cardio glycosides

These are a specific sub-class of steroidal saponins that have a tonic effect on the heart, however only in small doses! In larger doses they are quite toxic. David Hoffman tells how butterflies, who in general are immune to these glycosides, store them in their tissues to dissuade birds (who can die from them) from eating them. Convallotoxin, from Lily of the Valley, and Digitalis, from Foxglove (of Dr. Withering fame), are two prime examples. They are *cardio-tonic* in tiny doses, stimulating the heart to work much more efficiently.

Phytosterols

There has been much talk of these compounds in recent years as different phytosterols have been isolated from Red Clover and other herbs and are being touted as 'estrogenic' replacements for synthetic hormones. Their presence may or may not be responsible for the anti-hot-flash activity of some herbs. Some sterols you may have heard of are Cholesterol and Testosterone (mostly found in

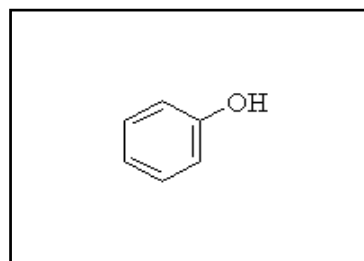
animals, although also in some plants), Estradiol (found in members of the Pea family), Stigmasterol from soybeans. They are fairly water-soluble, and in general, they possess *anti-tumor* and *anti-inflammatory* activity.

Resins

These are sticky, oily substances that are often exuded from tree barks. Myrrh, Pine pitch, Frankincense, and Dragon's blood are some examples. Other plants possess a fair amount of resin in their tissues – the most striking example is Grindelia, a sticky plant whose flowers secrete an aromatic white resin. Propolis is a collection of various resins collected by bees to protect their hives; this hints well at their action which tends to be *antiseptic*, *anti-bacterial*, *expectorant*, *nervine* and *rubifacient* externally.

Phenols

Under this heading that comprises molecules with both a hydroxy (-OH) group and an aromatic resonant ring (C6 – six carbons) we find a huge variety of different structures. The simplest, phenol, is pictured on the right. From this basic compound, different atoms and functional groups can be added, or the structure itself can be repeated multiple times. In general, phenolics are fairly water-soluble, and exist in every plant in one way or another.



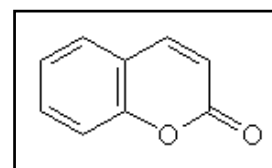
The simple phenols include such compounds as Salicin (in Willow and Meadowsweet), Arbutin (in Uva-Ursi), and Vanillin (from Vanilla). In general, they are *antiseptic*, *anti-inflammatory*, *analgesic* (*anodyne*), *blood-thinning*, and *rubifacient* externally. What follows are descriptions of additional phenolic compounds, classed under the broad heading of *polyphenols*.

Phenolic acids

These compounds are simple variations on phenols with the addition of a *carboxylic* group (-COOH) that gives them a slightly acidic pH and increases their solubility. A prime example is Salicylic acid (aspirin), derived from modifying Salicin. These compounds are *anodyne*, *anti-inflammatory*, and *anti-pyretic*.

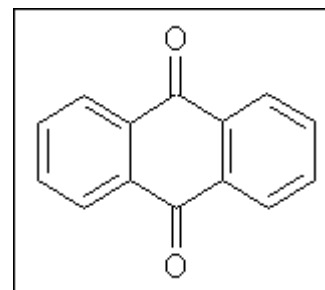
Coumarins

Here we begin to add additional rings to the basic phenol structure. In this class, we have our original C6 aromatic ring to which is attached another ring with C3, or 3 Carbons. In Coumarin itself (from Turmeric), pictured at right, the additional slot on the adjacent ring is taken up by an Oxygen (O). These compounds are *anti-inflammatory* and *antiseptic*, and although they can possess a variety of other actions depending on how different they are from the basic structure above, these two will always be present.



Quinones

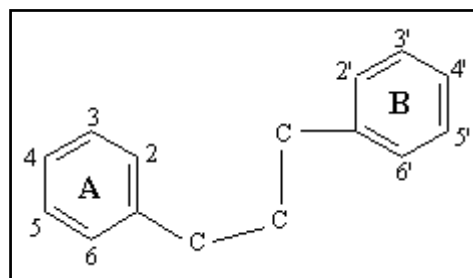
These molecules can get quite large and complex. Simple *Anthraquinones* are derived from Anthracene, a three-ring structure, and their basic setup is pictured at right (C6 – C2 – C6). Sennoside and Rhein (found in Senna, and Rhubarb to some extent) are compounds that you may be familiar with: the anthraquinones are *laxative* and can be quite strong. They seriously stimulate peristalsis,



and can be habit-forming. They are also *alterative* because of their function in tissue elimination. There are many other quinones as well, with the *napthaquinones* being a two-ring structure (C6 – C4), and much more complex quinones involving stacked tiers of multiple carbon rings, like Hypericin (from St. John's Wort). These compounds are *antiviral*, *antiseptic* and *anti-bacterial*.

Flavonoids

The next class of phenolic compounds we will discuss consists of the *flavonoids*, the basic structure of which is pictured at right: it is made of two rings, connected by a three-carbon (C3) chain. These compounds are responsible for pigmentation in plants and for many medicinal effects. Primarily, you will have heard of them in relation to their *antioxidant* power, but usually possess a certain degree of *antiseptic*, *immune-modulating*, and *circulatory stimulant* power. Some sub-classes of this huge family include the *anthocyanidins* and *oligomeric pro-anthocyanidins [OPCs]* (Pine bark extract, Blueberries), *catechins* (Green Tea), *flavonols* (Quercetin), *isoflavones* (Red Clover, and Soy). There is extensive research around these compounds for fighting tumors, improving memory and circulation, fighting allergies, protecting the liver (Sylimarin is a bioflavonoid), aiding in hormone regulation, helping the nervous system, and more.



Lignans

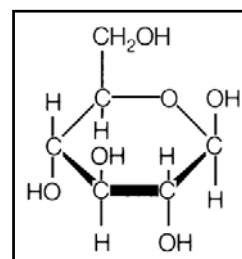
These are *polymers* of phenolic compounds, meaning they consist of simple phenols and/or flavonoids linked together in long, complex chains. They are found in woody tissues of plants. They have *adaptogenic*, *antioxidant*, *anti-tumor* and *antiviral* activities, and are partly responsible for the medicinal effect of Chaparral, for example.

Tannins

Very often *astringency* in plants will be due to the presence of these compounds. White Oak is a great example of an herb rich in tannins. There is some cross-over between these compounds and the *proanthocyanidins* of the flavonoid class. The primary chemical property to remember here is that they bind proteins, making them difficult to absorb by reducing their solubility in water. They are probably chemical protectors for the plants themselves, ensuring the integrity of cell walls and internal tissues. For our purposes, they are *astringent*, *vulnerary*, *anti-tumor*, and help with diarrhea.

Carbohydrates

These are our simple sugars (glucose, a *monosaccharide*, is pictured on the right) and also include more complex *polysaccharides* and *starches*. Their function, especially of the monosaccharides, is primarily nutritive and as a source of energy for the body. The more complex sugars can have interesting *adaptogenic* and *immuno-modulating* power (such as, for example, the polysaccharide fraction of Echinacea or Larix), and the starches often contribute to plant structure, along with the lignans. Combining with amino acids, we can see *glucosaminoglycans*, of which Glucosamine (N-acetyl-d-glucosamine) is perhaps the most famous. They also often combine with phenolic compounds and become known as *glycosides*, such as



flavonoids (Ginkgo's *flavo-glycosides* are an example, Rutin is another *flavo-glycoside*); anthraquinones (Sennoside, from Senna, is an *anthraquinone glycoside*); saponins (Ginseng's Ginsenosides are *saponin glycosides*); we have already encountered *cardio-glycosides*. When combined in these forms, they take on and contribute to the action of the relative class.

Mucilages

These are a specific class of polysaccharides that form soothing, healing, often slimy solutions in water. Marshmallow root, Comfrey, Cornsilk and Slippery Elm are good examples of this sub-class, and all of them have strong *demulcent* action.

Lipids

These are naturally occurring fats and oils. For our purposes, the most important class of lipids are the *essential fatty acids*, or EFA's, of which γ -Linoleic acid is perhaps the best known. It is found in Flax, Evening Primrose, Borage, and Black Currant seeds. These are an essential part of the diet (hence the name), and possess *anti-cholesterol*, *anti-inflammatory*, *anodyne*, and *hormone-regulating* power. They are not very water soluble, so administration occurs by ingesting the crushed seeds or an oil extract, or by emulsion with a saponin.

Proteins

This is a very, very large family of compounds, providing the building blocks for cell membranes, musculature, hemoglobin in animals and chlorophyll in plants, DNA and RNA in cell nuclei, most all enzymes that allow the metabolism to work, and much more. They are, in fact, essential for life to exist because all body processes are mediated by proteins. They all come from a single dietary source: amino acids. Even when we eat complex animal proteins, our body breaks them down into their constituent amines. They have a huge variety of structures, but always possess an *amine* group (-NH₂) somewhere. They can combine with other molecules, forming *amides*.