ANTHOCYANINS — **Properties**: H_2O-soluble -- vacuolar -- may appear red, purple, or black (depending on pH) -- belongs to the flavonoid class synthesized via the phenylpropanoid pathway -- can occur in all tissues of higher plants, including leaves, stems, roots, flowers & fruits -- derived from anthocyanidins by adding sugars -- odorless, mildly astringent -- **In Plants:** coloration provided by anthocyanins may attract animal pollinators -- in fruits, this coloration may aid in seed dispersal by attracting herbivorous animals to the potentially edible fruits bearing these colors -- may have a protective role in plants against extreme temperatures (tomatoes protect against cold stress w/ anthocyanins countering reactive oxygen species, leading to a lower rate of cell death in leaves -- **Light absorbance:** absorbance pattern responsible for the red color of anthocyanins may be complementary to that of green chlorophyll in photosynthetically-active tissues such as young kermes oak leaves -- may protect the leaves from attacks by herbivores that may be attracted by green color -- **Occurrence**: found predominantly in outer cell layers (epidermis, peripheral mesophyll cells) -- in cacti, anthocyanins are replaced by betalains (they have never been found on the same plant) -- sometimes bred purposely for high anthocyanin content, ornamental plants such as sweet peppers may have unusual culinary & aesthetic appeal -- highest recorded amount in the seed coat of black soybean (2 g per 100 g) -- **Autumn Foliage**: autumn colors of leaves are derived from anthocyanins -- unlike carotenoids, anthocyanins are not present in the leaf throughout the growing season, but are produced actively, toward the end of summer -- develop in late summer in the sap of leaf cells, resulting from complex interactions of factors inside & outside the plant -- their formation depends on the breakdown of sugars in the presence of light as the level of phosphate in the leaf is reduced -- orange leaves result from a combination of anthocyanins & carotenoids -- **Quantitative measurements:** present in 10% of tree species in temperate regions, although in certain areas such as New England, up to 70% of tree species may produce anthocyanins -- **pH**: gen. degraded at higher pH -- some glycosides (petanin) are resistant to degradation at pH 8 & may be used effectively as a food colorant -- red or pink in acidic solutions, purple in neutral solutions, greenish-yellow in alkaline solutions & colorless in very alkaline solutions (14-15), where the pigment is completely reduced -- **Visual markers**: fluoresces, enabling a tool for plant cell research to allow live cell imaging w/out a requirement for other fluorophores

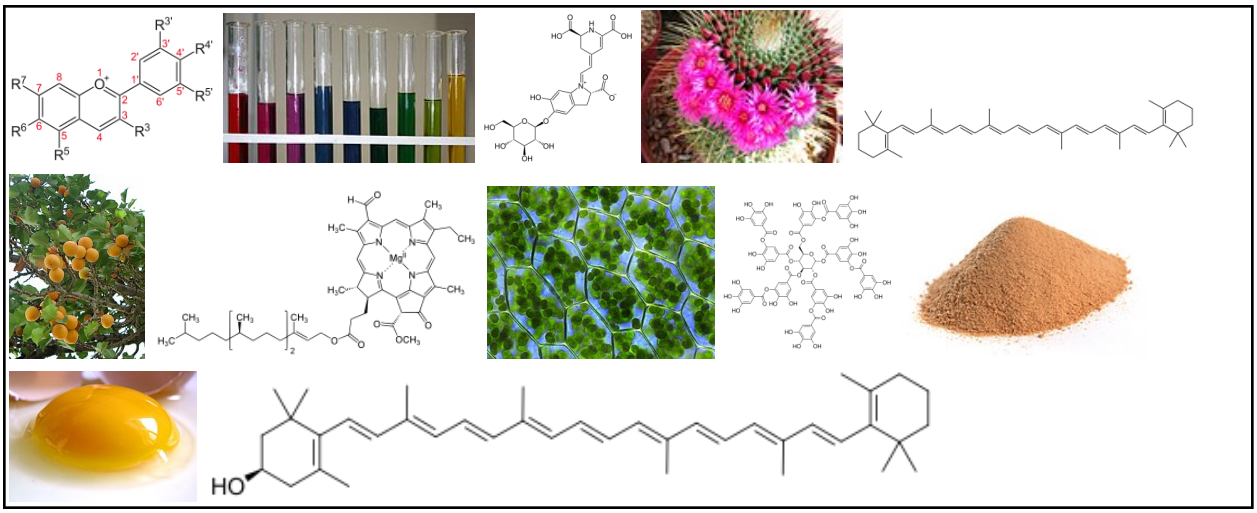
BETALAINS — red & yellow tyrosine-derived pigments found in Caryophyllales, where they replace anthocyanins -- also occurs in higher orders of fungi -- often noticeable in the petals of flowers, but may color the fruits, stems, leaves & roots of plants that contain them -- include pigments such as those found in beets -- name comes from the Latin name of the common beet (Beta vulgaris) from which betalains were first extracted -- distinctive red to purple shades unlike that of anthocyanin; also contains nitrogen -- functions uncertain -- **Betacyanins:** reddish-violet betalain pigments -- includes betanin, isobetanin, probetanin, neobetanin -- **Betaxanthins**: yellow to orange -- includes vulgaxanthin, miraxanthin, portulaxanthin, indicaxanthin

CAROTENE — Name comes from the Latin *carota,* "carrot" -- used for many related unsaturated hydrocarbon substances having the formula $C_{40}H_X$, which are synthesized by plants but in general can't be made by animals -- no O_2 atoms -- **In Plants**: found as alpha-, beta-, gamma-, delta-, epsilon- & zeta-carotene -- responsible for the orange color of the carrot as well as sweet potatoes, mangoes, pumpkin, tomatoes, red bell peppers, papayas, wolfberries, spinach, kale, broccoli, winter squash, chanterelle & orange cantaloupe melon -- also responsible for the orange (but not all yellow) colors in dry foliage -- impart the yellow coloration to milkfat & butter -- **Light Properties:** absorb UV, violet & blue light -- scatters orange or red light & (in low concentrations) yellow light -- **Chemistry**: polyunsaturated hydrocarbons containing 40 C atoms/molecule, variable #s of H atoms & no other elements -- some are terminated by rings, on 1 or both ends of the molecule -- all are colored, due to the presence of conjugated double bonds -- tetraterpenes (derived from 8 5-C isoprene units or 4 10-C terpene units)

CHLOROPHYLL — 2 types: chlorophyll-a & -b -- green pigment found in cyanobacteria & in the chloroplasts of algae & plants -- comes from the Greek *khloros* (pale green) & *phylllon* (leaf) -- allows plants to absorb energy from light -- **Light**: absorb light most strongly in the blue & red portions of the EM spectrum -- poor absorber of green & near-green portions of the spectrum -- hence chlorophyll-containing tissues appear green because green light, diffusely reflected by structures like cell walls, is less absorbed -- **Functions**: absorb light -- transfer of that energy by resonance energy transfer to a specific chlorophyll pair in the reaction center of the photosystems -- this specific pair performs the final function of chlorophylls: charge separation, which produces the unbound protons & electrons that separately propel biosynthesis -- **Chemistry**: derivatives of chlorin by the presence of a 5th, ketone-containing ring beyond the 4 pyrrole-like rings -- bind magnesium to the N_4 center -- usually includes a long phytyl chain ($C_{20}H_{39}O$) -- ***a* vs. *b***: *a* has a methyl group & *b* has a formyl group -- *a* is more commonly found in plants

TANNINS — Name from the word meaning "oak bark" -- commonly found in gymnosperms & angiosperms -- **Measurements**: most families of dicot contain tannin-free species (tested by their ability to precipitate proteins) -- the best known families of which all species tested contain tannin are Aceraceae, Actinidiaceae, Anacardiaceae, Bixaceae, Burseraceae & Combretaceae for dicot & Najadaceae & Typhaceae for monocot -- to Fagaceae, 73% of the species tested contain tannin -- the most abundant polyphenols are the condensed tannins, found in virtually all families of plants, comprising up to 50% of the dry weight of leaves -- **Location**: in all vascular plants studied, tannins are manufactured by a chloroplast-derived organelle, the tannosome -- mainly physically located in the vacuoles or surface wax of plants -- these storage sites keep tannins active against plant predators, but also keep some tannins from affecting plant metabolism while the plant tissue is alive -- **Contained In**: pomegranates, strawberries, cranberries, nuts (oak acorns, hazelnuts, walnuts, pecans, almonds), cloves, tarragon, cumin, thyme, vanilla, cinnamon, legumes (red beans, peanuts w/ shells, chickpeas), chocolate liquor -- **Purpose**: gives immature fruits (such as persimmons) & wines their astringent taste

XANTHOPHYLL — yellow pigments that occur widely in nature & 1 of the 2 major division of the carotenoid group -- from the Greek *xanthos* (yellow) & *phyllon* (leaf) due to their formation of the yellow band seen in early chromatography of leaf pigments -- **vs. Carotene**: contain O atoms while carotenes are *purely hydrocarbons* (no O) -- this O content causes xanthophylls to be more polar (in molecular structure) than carotenes & causes their separation from them in paper chromatography -- carotenes are usually more orange than xanthophylls -- **Occurrence**: found in highest quantity in the leaves of most green plants, where they act to modulate light energy & perhaps serve as a non-photochemical quenching agent to deal w/ triplet chlorophyll (an excited form of chlorophyll), which is overproduced at high light levels in photosynthesis -- the yellow of chicken egg yolks, fat & skin comes from ingested xanthophylls (primarily lutein, which is added to chicken feed for this purpose) -- the yellow of the macula lutea in the retina of the human eye results from the presence of lutein & zeaxanthin; protects the eye from ionizing light (blue & UV) which they absorb) -- xanthophylls in humans are derived from a plant diet -- **Food**: found in all young leaves & in etiolated leaves (leaves grown in partial or complete absence of light; has long, weak stems; smaller leaves, longer internodes; chlorosis/pale yellow color) -- rich sources include papaya, prunes, peaches, squash; others include kale, peas, squash, pistachios, parsley, spinach



Anthocyanin, pH of anthocyanin from 1-13, betalain, cacti containing betalains, beta-carotene, apricots (rich in carotenoids), chlorophyll, plant chloroplasts seen under a microscope, tannin, tannin powder, the color of egg yolk (resulting from xanthophyll), cryptoxanthin