ANTHOCYANIN

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Introduction

The red coloration found in carnivorous plants is caused by plant pigments known as anthocyanins. Because of the interest in pigment-free forms of certain carnivorous plants, Barry Meyers-Rice asked me to write a brief summary of the biochemistry of these pigments. While somewhat technical, it is a fascinating topic. If you are interested in learning more about this topic and how it is related to the biology and evolution of these plants, read on.

Biology

Anthocyanins are members of a class of nearly universal, water-soluble, terrestrial plant pigments that can be classified chemically as both flavonoid (related to flavone/isoflavone, $C_{15}H_{10}O_2$) and phenolic (related to phenol, C_6H_5OH). They are found in most land plants, with the exceptions of the cacti and the group containing the beet. They contribute colors to flowers and other plant parts ranging from shades of red through crimson and blue to purple, including yellow and colorless. (Every color but green has been recorded). Everyone who has drunk cranberry juice is familiar with anthocyanin: it is the chemical that imparts the characteristic red color!

Anthocyanins apparently play a major role in two very different plant processes. The first is in attracting insects for the purpose of pollination. The pigments absorb strongly in the UV (ultraviolet), and to insects which see using UV wavelengths the flowers may be particularly conspicuous. These pigments play major roles in both pollination and predation in carnivorous plants, attracting insects into both the flowers and the trap apparatus. The second role anthocyanin-related pigments serve is as a protective UV screen. The pigments are produced in response to UV exposure, and protect the plant's DNA from damage by sunlight. (UV causes the paired strands of genetic material in the DNA double helix to become cross-linked, preventing cell division and other vital cellular processes like protein production).

In a related defense mechanism, anthocyanin production can be induced by ionizing radiation, which can damage DNA as readily as UV can. Chemical messengers apparently signal the damage to DNA and induce anthocyanin production in these plants.

The biosynthesis of this class of pigment is accomplished by a series of enzymes that are bound to cell membranes. Through a series of discrete chemical steps, they help convert two central biochemical building blocks (acetic acid and the amino acid phenylalanine) found in the cell's cytoplasm into the final pigment. The pigment is then excreted on the other side of the membrane into vacuoles in the epidermal cell layer. Significant genetic change in the DNA coding for the production of these enzymes results in a decrease in pigment production.

Anthocyanin pigments can be produced by growing plant cells in tissue culture. Plants showing no pigmentation in cultivation may produce anthocyanin in tissue culture (Bell & Charwood, 1980).

Environmental factors affecting anthocyanin production include light (intensity and wavelength, with blue and UV being most effective), temperature, water and carbohydrate levels, and the concentrations of the elements nitrogen, phosphorous and boron in the growth medium. Anthocyanin production can be induced by light, blue being the most effective color. Low light levels also induce the formation of different flavonoid pigments, which is another interesting adaptive response on the part of plants.

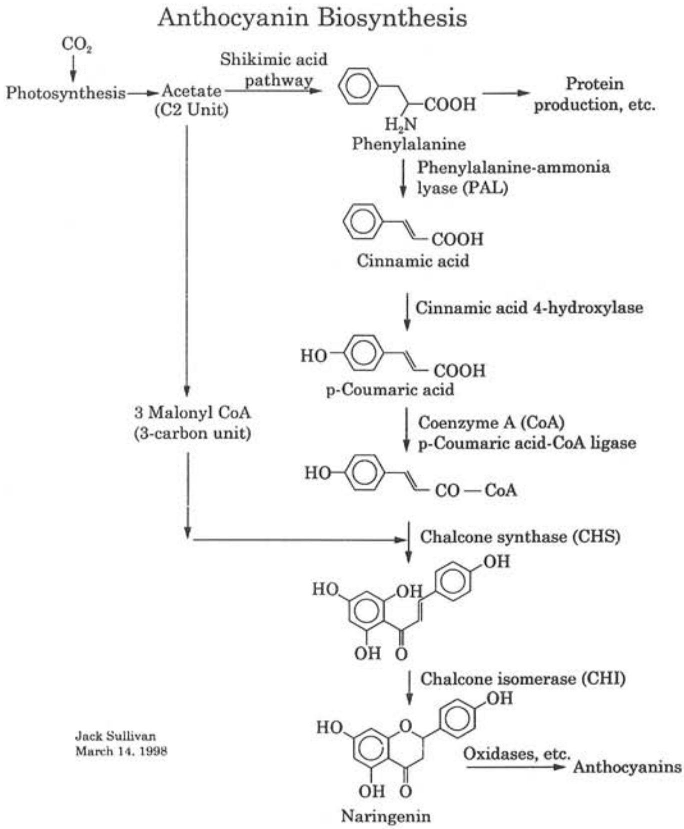
Evolution

Anthocyanin-type pigments are not found in animals, marine plants or in microorganisms. It is often theorized that anthocyanin production is an evolutionary response to plants first venturing onto the stark primordial landscape under intense UV radiation. (Significant screening of the Earth's surface from the effects of UV radiation did not occur until after the advent of terrestrial plants. Oxygen in large amounts first had to be generated by the photosynthesis of land plants before the protective ozone layer was formed).

The evolution of insect vision's response to the unique wavelengths of light presented by these plants is an interesting scenario, as is the evolution of carnivorous plants to take advantage of the insect's attraction to the sight of anthocyanin. Obviously, the plants came first and developed anthocyanin as a defense mechanism long before the first insect evolved. Carnivorous plants subsequently modified the pollination attraction mechanism to serve as an effective visual lure for their prey.

Anthocyanin pigments are assembled from two different streams of chemical raw materials in the cell: both starting from the C2 unit acetate (or acetic acid) derived from photosynthesis, one stream involves the shikimic acid pathway to produce the amino acid phenylalanine . The other stream (the acetic acid pathway) produces three molecules of malonyl-Coenzyme A, a C3 unit. These streams meet and are coupled together by the enzyme chalcone synthase (CHS), which forms an intermediate chalcone by a polyketide folding mechanism that is commonly found in plants. The chalcone is subsequently isomerized to the prototype pigment naringenin, which is subsequently oxidized by enzymes like flavonoid hydroxylase and coupled to sugar molecules to yield anthocyanins. More than five enzymes are thus required to synthesize these pigments, each working in concert. Any even minor disruption in any of the mechanism of these enzymes by either genetic or environmental factors would halt anthocyanin production.

Anthocyanin production was used as a visual marker in early studies of chemotaxonomy, which studies the relationships of organisms based on their biochemical constituents. It gave support to the one gene-one enzyme theory that is a central tenet in the field of molecular biology.



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