BioUpdate Foundation

Plants and the Origin of Haemoglobin

Haemoglobin, the protein which carries oxygen around our bodies, and something we are quite familiar with, has been studied in great detail at the molecular level. It is a protein we tend to associate exclusively with animals. Surprisingly, however, haemoglobin, is also present in some plants.

The legume family of plants, peas, beans, lentils, for example, are well known for their ability to fix nitrogen in their root nodules. If you pull up a legume and squeeze a root nodule between your fingers, you will find a red colour. It's haemoglobin, though in this case it is generally called leghaemoglobin. The root nodules also contain symbiotic bacteria, the Rhizobia, and it is the Rhizobia that are responsible for the ability to fix nitrogen.

The leghaemoglobin, however, is not a bacterial protein, quite remarkably it is the molecular basis of the symbiosis. The iron containing haem porphyrin prosthetic group is synthesised by the bacteria, but the protein is coded for and synthesised by the plant. It is a plant protein, a plant haemoglobin, but structurally it is clearly related to animal haemoglobin.

Although this structural relationship might not seem very strong, Kidney Bean leghaemoglobin (component a) is only 22% identical with the human embryonic γ-haemoglobin, it is clearly related (see Lehtovaara and Ellfolk, Eur. J. Biochem. 54 577-584, 1975). The first question that comes to mind is how did a plant acquire an animal gene? Perhaps it didn't, perhaps it is an example of convergent evolution, but there is another possibility - a more intriguing and likely possibility.

Leghaemoglobin, unlike animal haemoglobin is not an oxygen transporting protein, but an oxygen binding protein. The nitrogen fixing reactions require a very low oxygen tension, and the function of leghaemoglobin is essentially to bind any free oxygen and remove it from the root nodule environment.

Although generally regarded as essential to aerobic life, oxygen is in fact toxic. It is a very reactive molecule and the earth's primordial atmosphere was essentially oxygen free. Early life developed under anaerobic conditions. About 2000 to 2500 million years ago, the ancestors of the present day blue green algae developed photosynthetic reactions. These reaction produced oxygen – a toxic substance which would have threatened survival of anaerobic life forms. In many ways respiration has developed as a detoxification mechanism. Although enzymes have evolved to deal with oxygen toxicity, superoxide dismutase for example, proteins which bound oxygen would have provided an early defence mechanism by removing it from the atmosphere. As aerobic respiration developed, haemoglobin may have evolved as a reversible oxygen binding carrier. Leghaemoglobin may, however, be the closest present day molecule to a common ancestor which by binding oxygen irreversibly was quite simply the difference between life and death.

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