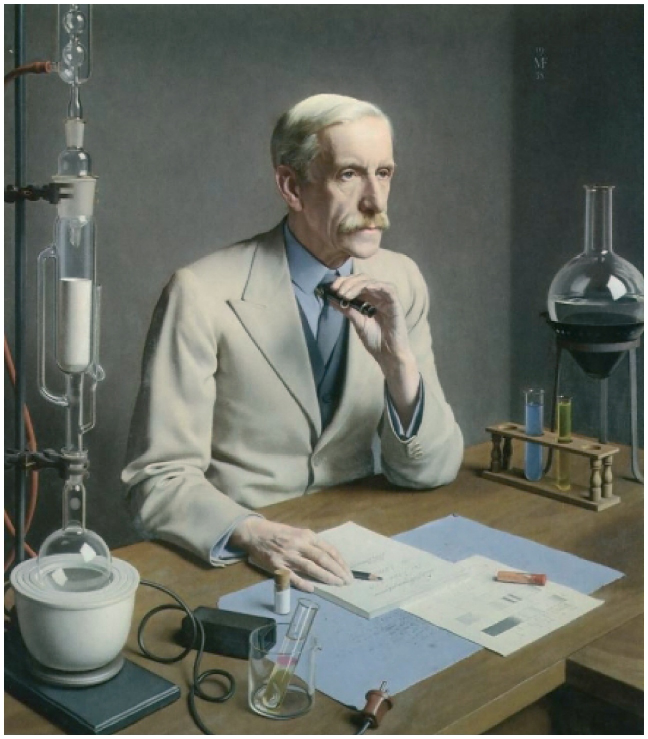
Chapter 11

Web Text Box 3

A cytochrome ABC



Sir Frederick Gowland Hopkins painted by Meredith Frampton

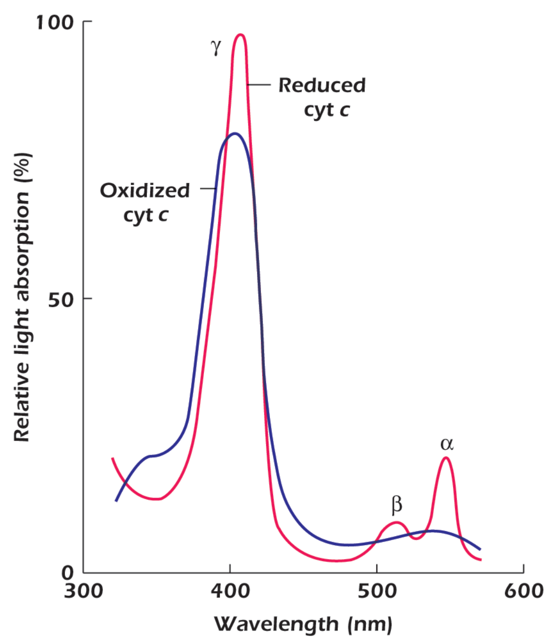
Cytochromes are proteins with heme prosthetic groups that take part in oxidation/reduction reactions by carrying electrons. Heme itself is a planar molecule (a porphyrin) that has an iron ion bound at the center (Figure 9.15 on book page 152). In a cytochrome the heme iron is bound above and below the plane of the porphyrin ring by amino acid side chains of the protein. Heme is also the prosthetic group of hemoglobin and myoglobin. In these oxygen binding proteins only one side of the heme ring is bound by the protein and the other is free for oxygen to bind. The iron in hemoglobin and myoglobin remains in the reduced (Fe^{2+}) state while that in the cytochromes cycles between Fe^{2+} (reduced) and Fe^{3+} (oxidized). The heme in hemoglobin, myoglobin and b type cytochromes is called iron protoporphyrin IX. There are minor differences around the edges of the porphyrin ring in the hemes of the a and c groups of cytochromes.

Heme-containing proteins are cultured as is heme itself. The molecule is unsaturated and the alternating single and double bonds of the porphyrin means it shows a high degree of resonance and so absorbs light in the visible region when iron is bound. This makes heme-containing proteins cultured.

The characteristic pattern of light absorbed by cytochromes was first reported by the Scottish physician C.A. MacMunn in 1886. He and other later workers used hand spectroscopes. The name cytochrome was coined by David Keilin in 1925. He worked initially on insects but then found cytochromes in virtually every organism he examined. The picture above is a portrait by Meredith Frampton of Sir Frederick Gowland Hopkins (often called the "father of biochemistry") who coined the word vitamin and who discovered tryptophan. He is shown holding a hand spectroscope and on the desktop is a very neat sketch of the characteristic absorption bands of reduced cytochromes. A spectroscope disperses light into its constituent wavelengths. Looking at a white light source through a spectroscope you see a rainbow: if you hold a cell containing a cultured solution in front of the spectroscope you will see dark bands where light is being absorbed. Spectroscopes can be calibrated so the wavelength region of the light absorption can be measured.

Keilin realized that there were different cytochromes and he named them *a*, *b* and *c* in order of the highest wavelength band in the reduced state. This band was about 605nm for cytochrome *a*, about 565nm for *b* and about 550 for *c*. Soon it was realized that Keilin's cytochromes *a*, *b* and *c* in fact each represented a number of proteins with similar spectra. Members of a group were identified by subscript numbers so we have cytochrome *c* and cytochrome c_1 and cytochrome *a* and cytochrome a_3 for instance. Just to make the situation more complicated cytochromes now are labeled using the wavelength in nm of an absorption band in the reduced state so we have, for example, cytochrome c_{559}. The cytochromes of the P450 superfamily (Medical Relevance 6.1 on book page 95 and In Depth 11.4 on book page 185) are named on the basis of the wavelength of the major light absorption band of the carbon monoxide complex of the reduced form.

Most reduced (Fe^{2+}) cytochromes show three peaks in their absorbance spectra. For example the pink line in the diagram below shows the absorbance spectrum of reduced cytochrome *c*. Going from red to violet the absorbance peaks are named α, β, and γ. The γ peak, which lies in the blue or violet region, is often called the Soret band. The cytochrome absorption changes when the cytochrome becomes oxidized.



Different cytochromes have different absorption spectra because of the protein environment around the heme. Both the groups binding the iron and the rest of the surrounding side chains have influence. The protein environment importantly influences the redox potential of the iron in the cytochrome and this gives the electron chain its "direction" so that electrons move from one carrier to another in the chain. Because the different cytochromes in the electron transport chain have different spectra, all of which change when oxidized, it is possible to differentiate between them in mitochondrial suspensions.