proteinspotlight
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Issue 251, October 2022
www.proteinspotlight.org

the many lives of colour

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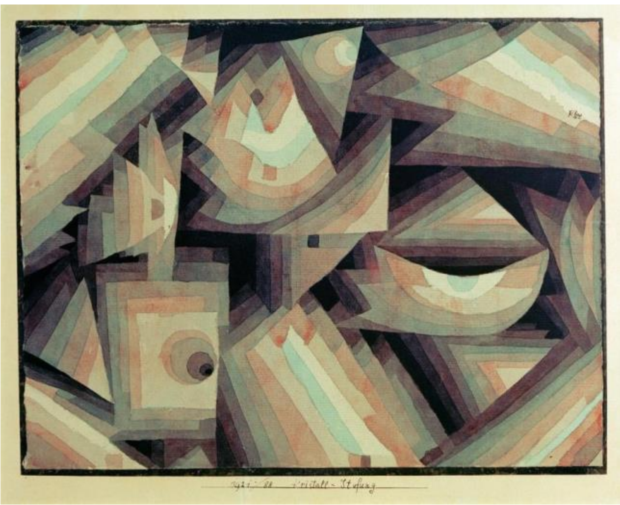
How bland Nature would be without colour. How drab a walk through the woods, how dull a visit to the zoo. From the bright pink of a rose to the emerald green of a beetle and the deep blue of a bird's feather, colour is everywhere. More prosaically, the colours we see are the result of daylight bouncing off molecules known as pigments – of which there are varying kinds. Pigments do not just add colour to life, however, but are part of processes in living organisms which serve as protection, attraction or even to trap energy as is the case with chlorophyll in plants and cyanobacteria for example. Melanin is a particular kind of pigment, well known in humans as it gives our skin a darker hue. However, we are far from the only organisms to use melanin – in fact many organisms do, even bacteria and fungi. Following the Chernobyl nuclear accident, fungi were among the very first organisms to creep back to the site and this may well be partly due to melanin. Scientists recently spotted an enzyme – a polyketide synthase – in the filamentous fungus *Paecilomyces variottii*, which acts in the very early steps of melanin synthesis to produce a pigment known as Ywa1, which may be involved in protecting the fungus from UV irradiation as well as using radioactivity as a source of energy.



Kristall-Stufung

Paul Klee (1879-1940)

Melanin is a widespread pigment among organisms – notably because it is used in so many different instances. The term 'melanin' is itself a broad term used to describe a group of different melanins of which there are five basic types: eumelanin, pheomelanin, neuromelanin, allomelanin and pyomelanin – the most common being eumelanin. Varying from a brownish black to a reddish yellow, melanin blackens the defensive ink fired by cephalopods, darkens human skin to protect it from solar radiation, is involved in microbial virulence, designs the coat pattern of mammals and orchestrates moth thermoregulation. In particular, melanin has the ability to impart to some organisms the means to survive in extreme conditions – such as high temperatures, chemical stress and even ionizing irradiation like that resulting from a nuclear accident.

What causes the colour of human skin was part of heated debates for thousands of years. The first known recording of texts discussing skin colour are over four thousand years old and seem to have stemmed from a pigment disorder known as vitiligo. The colour of human skin was first attributed to external influences, such as heat from the sun or even hot water falling from the sky or, many years later, coagulated blood situated just under the skin. It was only during the19th century with the aid of the optical microscope that things began to unravel and by the very early years of the 20th century, scientists had grasped that a pigment – dubbed melanin from the Greek 'melanos' meaning black – gave human skin its colour. The pigment is synthesized in specialized pigment cells, or melanocytes, within specific organelles named melanosomes. By 1917, scientists had understood that UV irradiation tanned human skin as a means of protection, and by the 1960s the metabolic pathway leading to melanin synthesis, or melanogenesis, had been elucidated.

Thus it is the variety of colours of human skin that ultimately led scientists to an understanding of melanogenesis and the protective properties of melanin. They soon discovered, however, that many other organisms use melanin for protective reasons too – notably fungi, many of which are able to thrive in extreme environments, namely high altitude, low temperatures and elevated electromagnetic radiation. The fact that melanin has evolved to become a protective material of diverse nature is thought to reside in its chemical structure, whose basic aromatic units can polymerize in varying ways giving rise to different types of the pigment. The electronic makeup of melanins is such that they are able to either scatter or trap photons and electrons – which may explain why melanotic fungi were among the very first organisms to adapt and grow on the site of the Chernobyl nuclear power plant after the disaster in 1986.

Moreover, fungi soused in radioactivity are not only able to grow but they also seem to actually move towards its source – which would imply that there must be some sort of benefit. How can it be explained? We need to know how things occur on the molecular level. As is the case for many other fungi, the filamentous fungus *Paecilomyces variottii* has colonised the Chernobyl accident site. Scientists picked some off the wall of one of the units of the Chernobyl nuclear power plant and, after close scrutiny, found a polyketide synthase (PKS) which was linked both to pigment synthesis and irradiation protection. However, the pigment produced was not melanin itself but one of its precursors: a yellow pigment known as heptaketide naphthopyrone, or Ywa1. In detail, PKS catalyses the biosynthesis of Ywa1 via the condensation of one unit of acetyl-CoA with six units of malonyl-CoA –which is one of the first steps in melanogenesis. It may be that Ywa1 is modified further still but this remains unknown to date.

So it is not quite melanin but one of its precursors that *P.variottii* synthesizes – and scientists hypothesize that Ywa1 behaves similarly to melanins. Like melanin, Ywa1 has an aromatic structure. Radioactivity, such as that produced at the Chernobyl nuclear plant site, is thought to modify the electronic properties of melanin in such a way that the pigment ends up by scattering the harmful radiation thus preventing damage to DNA. As a result, fungi are not hindered in their growth. Ywa1 would function in much the same way. It seems too that fungi actually move towards the source of radioactivity and their growth is increased – this has been explained by the melanin's possible capacity to harness electromagnetic radiation and use it as a source of energy – something Ywa1 may also be able to do.

What to make of this? Radioactivity did not appear with the advent of nuclear power plants. In fact, as it turns out, melanin seems to be a very ancient pigment, and fossilised melanotic fungal spores dating back to the Cretaceous suggest that this particular pigment was selected to enhance the survival of fungi – and of their hosts. Scientists have observed melanotic fungi grow towards radioactive soil particles and gradually destroy them. Could they be used to decontaminate radioactive sites? Could radiotrophic fungi be used as a shield to protect astronauts against radiation encountered in space? Could fungi provide pigments that humans could use to produce safe sunscreens? Who knows. Perhaps. Certainly, Nature continues to prove her multivalency and how she can adapt and even take advantage of life-threatening environments such as those humans create for themselves.

Cross-references to UniProt

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__Protein Spotlight__ (ISSN 1424-4721), http://www.proteinspotlight.org, is published by the Swiss-Prot group at the Swiss Institute of Bioinformatics (SIB).