Feeding a growing world: More to explore – Transformation

Background notes

Green fluorescent protein

Green fluorescent protein (GFP) has existed in jellyfish for over 160 million years. The crystal jelly *Aequorea victoria* of the northern Pacific produces a luminescent protein, aequorin, which emits blue light. GFP converts this blue light to green light, creating the glow that we see.

Many corals also contain GFP. It acts as a molecular sunscreen by absorbing UV light and re-emitting it at another, longer wavelength. This gives the organism a selective advantage, as UV light can damage DNA. The fluorescence cannot be seen during daytime as sunlight is brighter, but it can be seen when UV light is shone onto the organism in dim light.

The luminescent protein consists of 238 amino acids, within which is a sequence of three amino acids – usually serine–tyrosine–glycine but sometimes threonine–tyrosine–glycine – held deep inside the folded protein. Glycine bonds with serine or threonine to form a closed ring, which spontaneously dehydrates. Oxygen can then attack a bond in tyrosine, forming a new double bond and giving rise to a fluorescent chromophore.

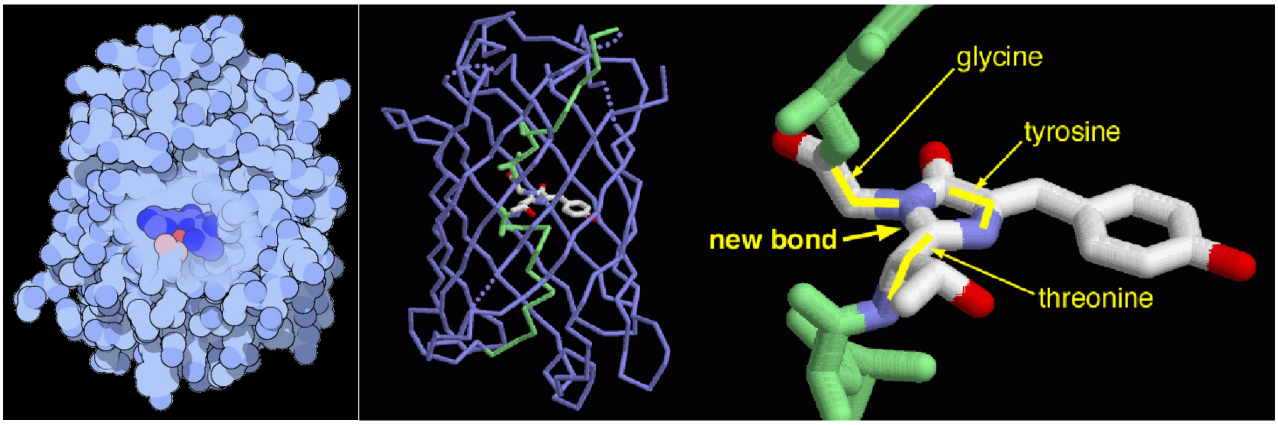

Image from the RCSB PDB June 2003 Molecule of the Month feature by David Goodsell (doi: 10.2210/rcsb_pdb/mom_2003_6)

Figure 1 The structure of green fluorescent protein.

The backbone of the entire protein is shown on the left of Figure 1 as a space-filling model and in the centre as a chain. The protein chain forms a tube (shown in blue), with one section of the chain (green) threaded straight through the middle. The chromophore is in the centre of this section, shielded from the surrounding environment. This shielding is essential for the fluorescence. The jostling water molecules would normally rob the chromophore of its energy when it has absorbed a UV photon. Inside the protein, however, it is protected and instead releases the energy as a slightly less energetic photon of visible light. The chromophore (shown in the close-up on the right of Figure 1) contains an unusual, five-membered ring formed spontaneously from three consecutive amino acids: glycine, tyrosine and threonine or serine.

This protein is a useful research tool because it makes its own chromophore as it folds. If the *gfp* gene is inserted into an organism along with another gene for a desired genetic modification, scientists can easily observe the fluorescence of the expressed protein in the phenotype, and thus see if and where the novel genes are being expressed.

GFP can be attached to other proteins within cells to see how those proteins move about within the cell. It can also be used to tag a virus to see how the virus spreads throughout the host during an infection. As this protein is small and inert, it does not interfere with any metabolic reactions within the tagged organism. It has been introduced into many types of organisms, including bacteria, fungi, worms, insects, fish and mammals.

Did you know?

GFP is now used in biosensors. For example, one form of the modified protein can detect zinc ions. When zinc binds to the modified chromophore, the protein gives off blue fluorescence.

The *gfp* gene has been modified by introducing mutations, and a range of coloured fluorescent proteins can be produced, including blue, pink, yellow and a brighter green.

Artists have begun to use *gfp* transformations: Eduardo Kac famously produced a green fluorescent rabbit.

Zebrafish that glow under UV light are available as pets under the trade name GloFish®.

Research background and further reading

Development journal editorial about food security:
www.palgrave-journals.com/development/journal/v57/n2/full/dev201486a.html

World Food Programme: Ebola outbreak effects on food security:
www.wfp.org/content/impact-west-africa-ebola-outbreak-food-security-and-staple-food-prices

gfp gene: Nobel Prize in Chemistry 2008 for the discovery and application of GFP:
www.nobelprize.org/nobel_prizes/chemistry/laureates/2008/illpres.html

Shimomura O. The discovery of aequorin and green fluorescent protein. *J Microsc*. 2005; 217: 3–15.

Shaner NC *et al*. Improving the photostability of bright monomeric orange and red fluorescent proteins. *Nat. Methods*. 2008; 5: 545–551.

Websites describing the GFP revolution:

Green fluorescent protein: **www.conncoll.edu/ccacad/zimmer/GFP-ww/GFP-1.htm**

Potatoes with jellyfish gene glow when thirsty:
www.organicconsumers.org/old_articles/gefood/glowingpotato.php

Genetic Literacy Project: **geneticliteracyproject.org/2013/10/29/how-bioluminescent-jellyfish-revolutionized-plant-biology/**