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# the colour red

**Vivienne Baillie Gerritsen**

**Plants cannot walk. Unable to drift down to the local café, attend this evening's book launch or gate-crash a party, flowers have had to resort to other ways of connecting. True, their roots may wander and branches may wave, but really what appears above ground level is pretty moored. Yet that is where their reproductive organs are, which need to meet so that the plant's pollen can be fertilized. This is achieved indirectly by using animal pollinators – whose attention, however, needs to be grabbed. Nectar fulfils this role wonderfully. A sweet liquid secreted by flowers, nectar is concocted to tempt insects or vertebrates whose bodies, as they feed off it, may inadvertently pick up pollen in one flower and deposit it, in all innocence, on another flower's stigma. So as not to be missed, a little like waving a flag, a flower's nectar may occasionally be brightly coloured: yellow, deep purple, blue, green, red or even black. In this light, the striking red nectar of *Nesocodon mauritianus*, a blue flower endemic to the island of Mauritius, seems to have evolved to attract a day gecko and is synthesized thanks to the close collaboration of three enzymes: Nec1, Nec2 and Nec3.**

Heather Angel / Natural Visions

Courtesy of the artist

It is estimated that an astounding 90% of flowering plants depend on animals to reproduce. This has been – and continues to be – an endless source of co-evolution down the years, as plants adapt to lure pollinators while pollinators adapt to find food. With time, plants have developed many different ways of attracting pollinators by using a complex combination of flower size, colour, shape, scent, taste and even landing platforms known as spurs! Mainly composed of sugars, nectar constitutes a rich food source for those who find it. It is secreted by a gland, called a nectary, which is either situated within the flower or external to it. Nectaries tucked inside flowers are intended for pollinators. Those found outside flowers seem to have a defensive role, attracting animals that lap up the nectar while also feeding off the odd plant-eating insect that happens to be present. In both cases, nectar can be seen as a form of reward where the animals are given something in return for their involuntary services.

Nectar is a rich sweet liquid mainly composed of sucrose, glucose and fructose in varying proportions. It may also contain certain antimicrobial or antifungal proteins – as in tobacco plants for instance – to defend the reproductive organs from pathogens. Nectar can also be delivered with a taste, a scent and sometimes too a colour. Each of these properties may change depending on the flower's reproductive maturity – since progeny is really what it is all about. As an example, some flowers give their nectar a bitter taste until they are ready to reproduce while others produce a bright colour only when they are ready. This is the case of *Nesocodon mauritianus*, the blue Mauritius bellflower, whose nectar goes from a 'not ready' yellow, to an 'almost there' orange and a final 'go for it' bright red. Not only does the bright red express sexual maturity but it is also a sure way of attracting a pollinator's attention – while still sending out an 'honest signal' since it also means there is something nourishing to eat.

What gives the nectar of *N.mauritianus* its colour? How does it turn red? Most floral nectars are not

coloured but usually as clear as water. The scarlet red nectar of the blue Mauritius bellflower is caused by a pigment that has been called 'nesocodin'. This bright red pigment stems from an initial aurone found in the nectary; a type of flavonoid that provides a yellow colour to flowers. It takes about 24 hours for the yellow to turn red, and this is achieved thanks to a very tight collaboration between three enzymes: a carbonic anhydrase (Nec1), a flavoenzyme (Nec3) and a ferritin-like catalase (Nec2). In a nutshell, Nec3 oxidizes sinapyl alcohol – exported from the nectary – to produce the pigment precursor sinapaldehyde. The red pigment nesocodin is then spontaneously formed by the condensation of sinapaldehyde and proline. However, these two reactions can only take place if there is an increase in the environment's pH, which is brought about by Nec1 thanks to the presence of bicarbonate, itself probably provided by nectary respiration. Finally, Nec2 protects nesocodin from degradation by breaking down the toxic by-product (hydrogen peroxide) which is released by Nec3.

Currently, of an estimated total of about 370,000 species of flowering plants worldwide, barely 70 produce coloured nectar – ranging from yellow, amber, red, brown, green, blue and black. Instinctively, one would suppose that coloured nectar attracts pollinators – and perhaps very specific pollinators – far better than nectar which has no colour or is just a honey-like pale yellow. Against its bright-blue petals, the scarlet red nectar in *N.mauritianus* flowers certainly strikes as being quite conspicuous, much like waving a flag for attention. Why choose red, you may wonder. Several arguments have been put forward. First, *N.mauritianus* grows on the island's steep cliffs – which makes it a plant difficult to reach. A bright-coloured nectar would act like a beacon. *N.mauritianus* may, also, have specifically evolved to produce red-coloured nectar to attract a particular vertebrate: the endemic *Phelsuma* day gecko that lives on the cliffs, has excellent colour vision and loves bright colours, namely red. This said, geckos may not be the only pollinators – the bellflower's red nectar may well attract certain birds too.

Painting nectar a scarlet red would send out a rather clear signal to any passing forager. But how can we be sure that geckos, or birds for that matter, see the same bright red we see in *N.mauritianus*? We cannot. But what has been observed is that *Phelsuma* day geckos not only prefer red nectar to yellow nectar but they also ignore red nectar which has been put into red flowers. It is therefore the contrast between the two colours which is important. And the bigger the contrast, the more attractive – or noticeable – the nectar must be. Of equal interest is the nectar of a flower found thousands of miles away from *N.mauritianus* and endemic to the mountainous Andean region of South America: *Jaltomata herrerae*. The nectar of this flower, visited by humming birds, is also red and the enzymes which produce the pigment are analogous (but not similar) to those used by *N.mauritianus*. This would imply that their genes have evolved independently and gained related functions to produce the same kind of nectar – in both instances very distinguishable in extreme topographies. In a way, it is a little vexing to realise that the astonishing array of colours, scents and shapes flowers display are never developed for the pleasure of human senses but for those of their pollinators – but we can thank Nature for the extent of her imagination.

## Cross-references to UniProt

Carbonic anhydrase Nec1, *Nesocodon mauritianus (*Blue Mauritius bellflower*)* : P0DO50
Ferritin-like catalase Nec2, *Nesocodon mauritianus (*Blue Mauritius bellflower*)* : P0DO51
Sinapyl alcohol oxidase Nec3, *Nesocodon mauritianus (*Blue Mauritius bellflower*)* : P0DO52

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