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Flowers' secret signal to bees and other amazing nanotechnologies hidden in plants

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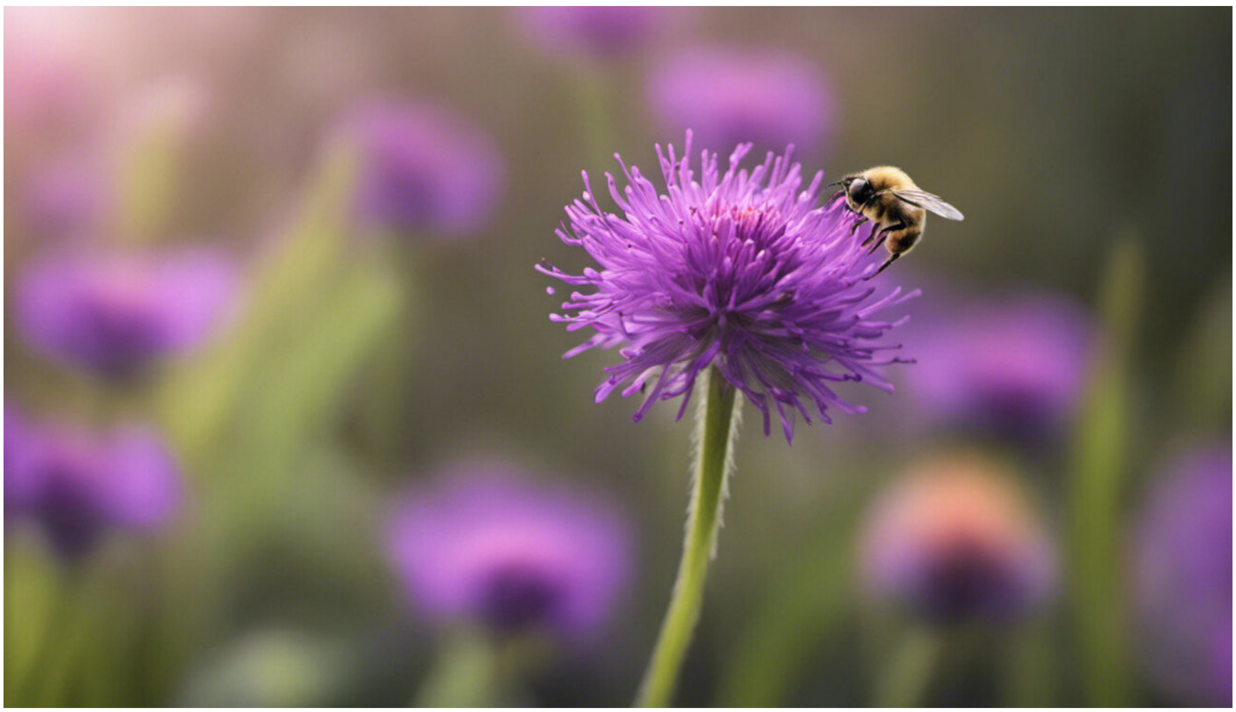

Credit: AI-generated image (disclaimer)

Flowers have a secret signal that's specially tailored for bees so they know where to collect nectar. And new research has just given us a greater insight into how this signal works. Nanoscale patterns on the petals reflect light in a way that effectively creates a "blue halo" around the flower that helps attract the bees and encourages pollination.

This fascinating phenomenon shouldn't come as too much of a surprise to scientists. Plants are actually full of this kind of "nanotechnology", that enables them to do all kinds of amazing things, from cleaning themselves to generating energy. And, what's more, by studying these systems we might be able to put them to use in our own technologies.

Most flowers appear colourful because they contain light-absorbing pigments that reflect only certain wavelengths of light. But some flowers also use iridescence, a different type of colour produced when light reflects from microscopically spaced structures or surfaces.

The shifting rainbow colours you can see on a CD are an example of iridescence. It's caused by interactions between light waves bouncing off the closely spaced microscopic indentations in its surface, which means some colours become more intense at the expense of others. As your viewing angle shifts, the amplified colours change to give the shimmering, morphing colour effect that you see.

Many flowers use grooves between one and two thousandths of a millimetre apart in the wax coating on their surface to produce iridescence in a similar way. But researchers investigating the way that some flowers use iridescence to attract bees to pollinate have noticed something odd. The spacing and alignment of the grooves weren't quite as perfect as expected. And they weren't quite perfect in very similar ways in all of the types of flowers that they looked at.

These imperfections meant that instead of giving a rainbow as a CD does, the patterns worked much better for blue and ultra-violet light than other colours, creating what the researchers called a "blue halo". There was good reason to suspect that this wasn't a coincidence.

Bees can see a blue halo around the purple region. Credit: Edwige Moyroud

The colour perception of bees is shifted towards the blue end of the spectrum compared to ours. The question was whether the flaws in the wax patterns were "designed" to generate the intense blues, violets and ultra-violets that bees see most strongly. Humans can occasionally see these patterns but they are usually invisible to us against red or yellow pigmented backgrounds that look much darker to bees.

The researchers tested this by training bees to associate sugar with two types of artificial flower. One had petals made using perfectly aligned gratings that gave normal iridescence. The other had flawed arrangements replicating the blue halos from different real flowers.

They found that although the bees learned to associate the iridescent fake flowers with sugar, they learnt better and quicker with the blue halos. Fascinatingly, it seems that many different types of flowering plant may have evolved this structure separately, each using nanostructures that give slightly off-kilter iridescence to strengthen their signals to bees.

The lotus effect

Plants have evolved many ways to use these kind of structures, effectively making them nature's first nanotechnologists. For example, the waxes that protect the petals and leaves of all plants repel water, a property known as "hydrophobicity". But in some plants, such as the lotus, this property is enhanced by the shape of the wax coating in a way that effectively makes it self-cleaning.

The wax is arranged in an array of cone-like structures about five thousandths of a millimetre in height. These are in turn coated with fractal patterns of wax at even smaller scales. When water lands on this surface, it can't stick to it at all and so it forms spherical drops that roll across the leaf picking up dirt along the way until they fall off the edge. This is called "superhydrophobicity" or the "lotus effect".

Wait a minute! This isn't a flower. Credit: Edwige Moyroud

Smart plants

Inside plants there is another type of nanostructure. As plants take up water from their roots into their cells, the pressure builds inside the cells until it is like being between 50 metres and 100 metres under the sea. In order to contain these pressures, the cells are surrounded by a wall based on bundles of cellulose chains between five and 50 millionths of a millimetre across called microfibrils.

The individual chains are not that strong but once they are formed into microfibrils they become as strong as steel. The microfibrils are then embedded in a matrix of other sugars to form a natural "smart polymer", a special substance that can alter its properties in order to make the plant to grow.

Humans have always used cellulose as a natural polymer, for example in paper or cotton, but scientists are now developing ways to release individual microfibrils to create new technologies. Because of its strength and lightness, this "nanocellulose" could have a huge range of applications. These include lighter car parts, low calorie food additives, scaffolds for tissue engineering, and perhaps even electronic devices that could be as thin as a sheet of paper.

Perhaps the most astonishing plant nanostructures are the light-harvesting systems that capture light energy for photosynthesis and transfer it to the sites where it can be used. Plants are able to move this energy with an incredible 90% efficiency.

We now have evidence that this is because the exact arrangement of the components of the light-harvesting systems allow them to use quantum physics to test many different ways to move the energy simultaneously and find the most effective. This adds weight to the idea that quantum technology could help provide more efficient solar cells. So when it comes to developing new nanotechnology, it's worth remembering that plants may have got there first.

More information: Edwige Moyroud et al, Disorder in convergent floral nanostructures enhances signalling to bees, *Nature* (2017). DOI: 10.1038/nature24285

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