Microscopic Da Vincis and the Curious Case of Photokinetics

Leonardo da Vinci, the Renaissance polymath from Italy, might have left us in 1519 AD, but a million of microscopic da Vincis have painted a miniature replica of his masterpiece Mona Lisa in 2018! Sounds crazy? Hold your thoughts and ask Dr. Giacomo Frangipane, a post-doctoral researcher of physics at the University of Rome, Italy, if you don't believe me!

A millimetric replica of Mona Lisa, formed by approx. 1 million *E. coli* bacteria that were genetically engineered to respond to light.

The minute da Vincis in question are none other than the famous Escherichia coli bacteria, found in the lower intestine of warm-blooded animals naturally and a favourite among scientists. These bacteria (many strains) are mobile and they move with the help of a specialised, whip-like appendage called flagellum (plural: flagella). Flagella are primarily used for locomotion by single-cell organisms, and they are propelled by a motor, a rotary engine made of proteins. Like any other engine, this motor requires energy to function, and in the case of E. coli it operates by using oxygen. Recently, scientists discovered a protein (proteorhodopsin) in some marine bacteria which absorbs light to power the motor in their flagella, through a process called photokinetics.
All good and fine. So, how did the E. coli paint the Mona Lisa? The clue lies in the light! To remotely control their movement, Frangipane and colleagues genetically modified their E. coli to produce the photo-sensitive proteorhodopsin. This made the otherwise oxygen-modulated flagella to now move with the help of ambient light, much like mounting a solar panel on a car! Next start the painting. For that, the scientists projected light through a microscope lens and explored how the bacteria change their speed while swimming through areas with varying degrees of illumination. "Much like pedestrians who slow down their walking speed when they encounter a crowd, or cars that are stuck in traffic, swimming bacteria will spend more time in slower regions than in faster ones," explained Frangipane. "We wanted to exploit this phenomenon to see if we could shape the concentration of bacteria using light." They projected the light uniformly onto a layer of bacterial

Einstein to Darwin in 5 minutes

cells for five minutes, before exposing them to a more complex light pattern – a negative image of the Mona Lisa. They found that bacteria started to concentrate in the dark regions of the image while moving out from the more illuminated areas. After four minutes, a recognizable bacterial replica of the masterpiece emerged.

After creating the Mona Lisa, Frangipane and his team manipulated the E. coli into a face-changing portrait that transformed from a likeness of Albert Einstein to that of Charles Darwin in just five minutes!

Although using photokinetic bacteria to paint famous portraits is fun, there are serious implications of this research as intended by the scientists. Controlling bacteria in this way means it could be possible to use them as micro bricks for building the next generation of microscopic devices. For example, they could be made to surround a larger object such as a machine part or a drug carrier and then used as living propellers to transport it where it is needed. Furthermore, they can be applied for creation of biomechanical structure or microdevices for the transport of small biological cargoes inside miniaturized laboratories.

Source and Photo:
1. Press release:
https://elifesciences.org/for-the-press/3950c3b2/light-engineered-bacterial-shapes-could-hold-key-to-future-labs-on-a-chip
2. Original research:
Frangipane, G., Dell'Arciprete, D., Petracchini, S., Maggi, C., Saglimbeni, F., Bianchi, S., … Di Leonardo, R. (2018). Dynamic density shaping of photokinetic E. coli. *ELife*, *7*. https://doi.org/10.7554/eLife.36608

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