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A Marine Creature's Magic Trick Explained

Tiny ocean creatures known as sea sapphires perform a sort of magic trick as they swim: One second they appear in splendid iridescent shades of blue, purple or green, and the next they may turn invisible (at least the blue ones turn completely transparent). How do they get their bright colors and what enables them to "disappear?" New research at the Weizmann Institute has solved the mystery of these colorful, vanishing creatures, which are known scientifically as Sapphirinidae. The findings, which recently appeared in the *Journal of the American Chemical Society*, could inspire the development of new optical technologies.

Tiny sea sapphires' iridescence, created by a regular array of thin, transparent crystal plates, is also the secret of their "disappearance"

Sapphirinidae belong to a subclass of crustaceans called copepods; and they live in fresh or salt water. These animals are barely visible to the human eye, ranging from around one to several millimeters in length. It is the male Sapphirinidae that display striking, iridescent colors, whereas the female is transparent. Scientists think that their unique magic trick could help Sapphirinidae escape predators when necessary, but still display their flashy colors when a female of the species – or possibly another male – is nearby.

The scientists, Profs. Lia Addadi and Steve Weiner, and Dvir Gur and Maria Pierantoni of the Weizmann Institute's Structural Biology Department; Prof. Dan Oron and Ben Leshem of the Institute's Physics of Complex Systems Department; and Dr. Viviana Farstey of the Interuniversity Institute for Marine Sciences, Eilat, Israel, investigated the makeup of a crystal layer on the backs of male Sapphirinidae of several species. They first measured the reflectance, which determines the color, and then, using a microscope technique called cryo-SEM, observed the organization of the crystals along with the cellular material holding them in place.

These colors are due to iridescence – the result of light reflecting off periodic (repeating) structures. These multilayer reflectors – a type of structure known to scientists as a photonic crystal – are composed of thin, transparent crystals of guanine. Guanine is more generally known as one of the nucleic acid bases found in DNA.

The research group found that the guanine plates in Sapphirinidae are stacked in incredibly precise periodic arrays. What gives each species its unique color? Their analysis revealed that the main factor determining whether an animal will be yellow, blue or purple is the spacing between plates, which is controlled by the thin layer of cellular material separating them.

The researchers also showed how this complex arrangement of plates enables some Sapphirinidae to disappear from sight: When certain species of male Sapphirinidae rotate their backs to the light at a 45-degree angle as they perform a spiral swimming maneuver, the wavelength of the reflected light is shifted out of the visible light range and into the invisible ultraviolet. In contrast, light hitting straight-on returns the beautiful blue color. In the ocean's light, which comes from above, the tiny creature can control its visibility, from neon to none, just by adjusting its rudder.

The spacing between the plates acts as a sort of "tuning" for the wavelength of the light and thus the organism's color: The closer the plates are to one another, the shorter the wavelength, that is, the bluer the light, reflected from them. This sophisticated strategy for manipulating light, say the scientists, could be used in the design of artificial photonic crystal structures – nanoscale structures that can manipulate the flow of photons. These could have many potential uses including adaptive or changeable reflective coatings, optical mirrors and optical displays.

Prof. Lia Addadi's research is supported by the Jeanne and Joseph Nissim Foundation for Life Sciences Research. Prof. Lia Addadi is the incumbent of the Dorothy and Patrick Gorman Professorial Chair.

Prof. Dan Oron's research is supported by the Crown Photonics Center; the Deloro Institute for Advanced Research in Space and Optics; the Willner Family Leadership Institute for the Weizmann Institute of Science; the Leona M. and Harry B. Helmsley Charitable Trust; and the Wolfson Family Charitable Trust.

Prof. Stephen Weiner's research is supported by the Helen and Martin Kimmel Center for Archaeological Science, which he heads; the Exilarch's Foundation; the European Research Council; and the estate of George and Beatrice F. Schwartzman; Prof. Weiner is the incumbent of the Dr. Walter and Dr. Trude Borchardt Professorial Chair in Structural Biology.

http://pubs.acs.org/stoken/presspac/presspac/full/10.1021/jacs.5b05289

Reversible Writing with Light

The medium is the message. Dr. Rafal Klajn of the Weizmann Institute's Organic Chemistry Department and his group have given new meaning to this maxim: An innovative method they have now demonstrated for getting nanoparticles to self-assemble focuses on the medium in which the particles are suspended; these assemblies can be used, among other things, for reversibly writing information.

This approach is an elegant alternative to present methods that require nanoparticles to be coated with light-sensitive molecules; these then switch the particles' state when light is shined on them. According to the group's research, which recently appeared in *Nature Chemistry*, putting regular, uncoated nanoparticles into a light-sensitive medium would be simpler, and the resulting system more efficient and durable than existing ones. The possible applications range from rewritable paper, to water decontamination, to the controlled delivery of drugs or other substances.

The medium, in this case, is made up of small "photo-switchable" (or "photoresponsive") molecules called spiropyrans. In the version of the photoresponsive molecule employed by Klajn and his group, absorbing light switches the molecule to a form that is more acidic. The nanoparticles then react to the change in acidity in their environment: It is this reaction that causes the particles to aggregate in the dark and disperse in the light. This means that any nanoparticles that respond to acid – a much larger group than those that respond to light – can now potentially be manipulated into self-assembly.

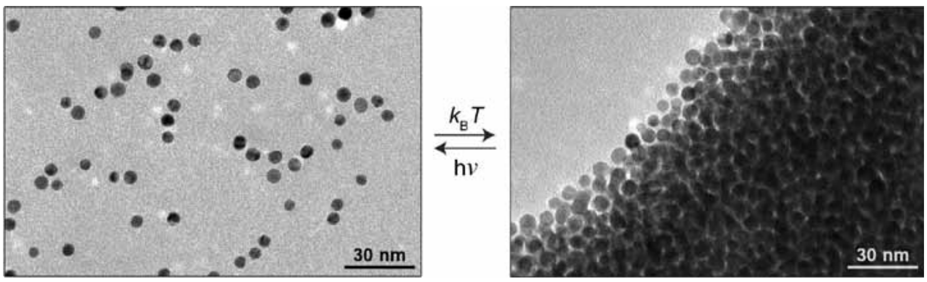
By using light – a favored means of generating nanoparticle self-assembly – to control the reaction, one can precisely govern when and where the nanoparticles will aggregate. And since nanoparticles tend to have different properties if they are floating freely or clustered together, the possibilities for creating new applications are nearly limitless.

Klajn points out that these molecules have a long history at the Weizmann Institute: "Two Institute scientists, Ernst Fischer and Yehuda Hirshberg, were the first to demonstrate the light-responsive behavior of spiropyrans in 1952. Later on, in the 1980s, Prof. Valeri Krongauz used these molecules to develop a variety of materials including photosensitive coatings for lenses. Now, 63 years after the first demonstration of its light-responsive properties, we are using the same simple molecule for another use, entirely," he says.

The advantages of the medium-based approach are clear. For one, the particles do not seem to degrade over time – a problem that plagues the coated nanoparticles. "We ran one hundred cycles of writing and rewriting with the nanoparticles in a gel-like medium – what we call reversible information storage – and there was no deterioration in the system. So you could use the same system over and over again," says Klajn. "And, although we used gold nanoparticles for our experiments, theoretically one could even use sand, as long as it was sensitive to changes in acidity."

In addition to durable "rewritable paper," Klajn suggests that future applications of this method might include removing pollutants from water – certain nanoparticles can aggregate around contaminants and release them later on demand – as well as the controlled delivery of tiny amounts of substances, for example, drugs, that could be released with light.

Dr. Rafal Klajn's research is supported by the Abramson Family Center for Young Scientists; the Rothschild Caesarea Foundation; the Mel and Joyce Eisenberg-Keefer Fund for New Scientists; the estate of Olga Klein Astrachan; and the European Research Council.



Nanoparticles in a light-sensitive medium. This method could be the basis of future "rewritable paper"

http://www.nature.com/nchem/journal/v7/n8/full/nchem.2303.html

How does Your Microbiome Grow?

It is increasingly clear that the thousands of different bacteria living in our intestinal tract – our microbiome – have a major impact on our health. But the details of the microbiome's effects are still fairly murky. A Weizmann Institute study that recently appeared in *Science* suggests approaching this topic from a new angle: Assess how fast the various bacteria grow. This approach is already revealing intriguing links between bacterial growth rates and such conditions as type II diabetes and inflammatory bowel disease. The new computational method can illuminate a dynamic process such as growth from a static "snapshot" of a single sample, and thus it may have implications for both diagnostics and new avenues of research.

Tal Korem and David Zeevi, research students in the lab of Prof. Eran Segal of the Computer Science and Applied Mathematics Department, led this research and collaborated with Jotham Suez, a research student in the lab of Dr. Eran Elinav in the Immunology Department, and Dr. Adina Weinberger, a research associate in Segal's lab. The study began with the advanced genomic sequencing techniques used in many current microbiome studies, which sequence all of the bacterial DNA in a sample. From the short sequences, they construct a picture of the types of bacteria and their relative abundance. But the Weizmann Institute team realized that this sequencing technique held another type of information.

"The sample's bacteria are doing what bacteria do best: making copies of their genomes so they can divide," says Segal. "So most of the bacterial cells contain more than one genome – a genome and a half, for example, or a genome and three quarters." Since most bacterial strains have pre-programmed "start" and "finish" codes, the team was able to identify the "start" point as the short sequence that was most prevalent in the sample. The least prevalent, at the other end of the genome, was the DNA that gets copied last. The researchers found that analyzing the relative amounts of starting DNA and ending DNA could be translated into the growth rate for each strain of bacteria.

The group tested this formulation experimentally, first in single-strain cultures for which the growth rate could be controlled and observed, then in multiple animal model systems, and finally in the DNA sequences of human microbiomes, in their full complexity.

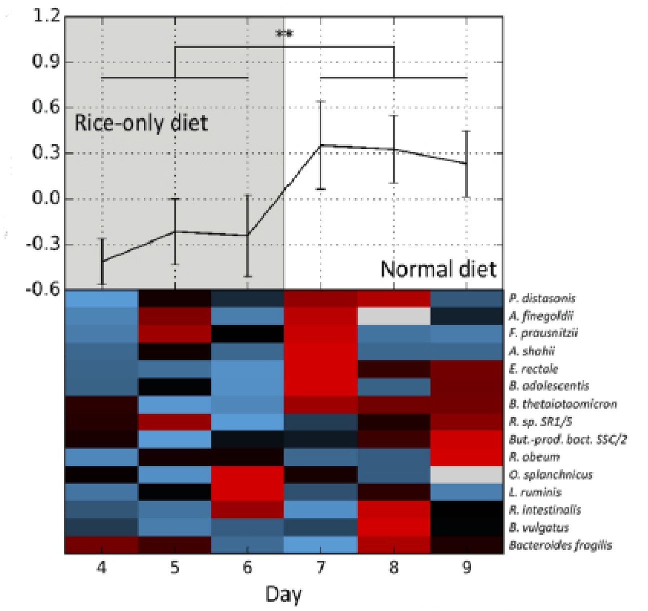
Their method worked even better than expected: The estimated bacterial growth rates turned out to be nearly identical to observed growth rates. "Now we can finally say something about how the dynamics of our microbiome are associated with a propensity to disease. Microbial growth rate reveals things about our health that cannot be seen with any other analysis method," says Elinav.

In their examination of human microbiome data, for example, the group found that particular changes in bacterial growth rates are uniquely associated with type II diabetes; others are tied to inflammatory bowel disease. These associations were not observed in the static microbiome "population" studies. Thus the method could be used in the future as a diagnostic tool to detect disease or pathogen infection early on, or to determine the effects of probiotic or antibiotic treatment. In addition, the scientists hope this new understanding of the microbiome will spur further research into the connections between the complex, dynamic ecosystem inside of us and our health.

Also participating in this research were Tali Avnit-Sagi, Maya Pompan-Lotan, Nadav Cohen and Elad Matot in Segal's lab; Christoph A. Thaiss and Dr. Meirav Pevsner-Fischer in Elinav's lab; Dr. Ghil Jona and Prof. Alon Harmelin of the Weizmann Institute; Dr. Alexandra Sirota-Madi and Prof. Ramnik Xavier of Harvard Medical School and the Broad Institute; and Prof. Rotem Sorek of the Weizmann Institute.

Dr. Eran Elinav's research is supported by the Abisch Frenkel Foundation for the Promotion of Life Sciences; the Gurwin Family Fund for Scientific Research; the Leona M. and Harry B. Helmsley Charitable Trust; the Crown Endowment Fund for Immunological Research; the Adelis Foundation; the Rising Tide Foundation; the Vera Rosenberg Schwartz Research Fellow Chair; Yael and Rami Ungar, Israel; John L. and Vera Schwartz, Pacific Palisades, CA; Alan Markovitz, Canada; Leesa Steinberg, Canada; Andrew and Cynthia Adelson, Canada; the estate of Jack Gitlitz; the estate of Lydia Hershkovich; and Mr. and Mrs. Donald L. Schwarz, Sherman Oaks, CA. Dr. Elinav is the incumbent of the Rina Gudinski Career Development Chair.

Prof. Eran Segal's research is supported by the Adelis Foundation; the Cecil and Hilda Lewis Charitable Trust; the European Research Council; Mr. and Mrs. Donald L. Schwarz, Sherman Oaks, CA; and Leesa Steinberg, Canada.



Bacterial growth rates computed with the new method (top, average; bottom, for specific species, red represents faster replication) for a human subject that underwent a radical dietary change. Compared are days in which only white boiled rice was consumed (grey area) and days of normal diet (white area). A global change in bacterial growth dynamics was observed between dietary regimens

http://www.sciencemag.org/content/early/2015/07/29/science.aac4812.full?sid=bdc9242e-5ff5-4e06-8187-51583cc7f0b0