Q&A with a NANOSCIENTIST who designs SLIPPERY SURFACES

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NANOOZE

THE BIOMIMETICS ISSUE

Tiny nanometer-scale structures are responsible for this baby tarantula's brilliant blue color.

LEARNING FROM NATURE TINY BIO-MOTORS

BLUE SPIDERS DNA BUILDING BLOCKS

NANOOZE
ALL ABOUT THE THINGS TOO SMALL TO SEE

Welcome to Nanooze!

What is a Nanooze? (Sounds like nah-news.) Nanooze is not a thing, Nanooze is a place to hear about the latest exciting stuff in science and technology. What kind of stuff? Mostly discoveries about the part of our world that is too small to see and making tiny things using nanotechnology. Things like computer chips, the latest trends in fashion, and even important stuff like bicycles and tennis rackets. Nanooze was created for kids, so inside you'll find interesting articles about what nanotechnology is and what it might mean to your future. Nanooze is online at www.nanooze.org, or just Google "Nanooze"—you'll find interviews with real scientists, the latest in science news, games and more!

How can I get Nanooze in my classroom?

Copies of Nanooze are **FREE** for classroom teachers. Please visit www.nanooze.org for more information or email a request for copies to: info@nanooze.org.

WHAT IS BIOMIMETICS?

Ever look at a bug and wonder how that tiny little critter manages to do things like climb up walls and survive long periods of time without food or water? Life on Earth is full of examples of plants and animals that have evolved to do amazing things. They have evolved to function in environments as hot as the Death Valley or as cold as the Antarctic.

Sometimes scientists and engineers study biology to learn how to build better stuff. A few billion years of evolution have given time for a vast number of design, build and test cycles. Those things that work out survive and those that don't? Well...

The field of biomimetics is the use of biology to help guide the design of man-made things.

These biological models involve a lot of moving parts and special materials, so the challenge for researchers is to create those parts in the lab. In this issue we look at different kinds of biomimetic inspirations such as the sticky feet of geckos and the water-repellent materials found on the wings of beetles that live in the deserts of Namibia. Part of the mystery is figuring out how these mechanisms work, and the other part is building them to function as well as the ones found in nature. The field is revolutionizing the division between life and inanimate objects.

Antilles Pinktoe adult (above) and spiderling (left)

Adult spider: Wikipedia / Graphicos

ON THE COVER
This tiny blue tarantula is a baby *Caribena versicolor,* also known as the Antilles Pinktoe. It lives in trees on the Caribbean island of Martinique. As it grows, its color changes from bright blue to a pattern of green, pink and purple.

TARANTULA SAFETY
We worked with spider expert Kristie Reddick of The Bug Chicks to handle this Pinktoe safely. This is a docile species and can be kept as a pet but, remember, all spiders have venom!

NANO KNOW-HOW

Learning about nano stuff is fun but it can be complex, so it helps to keep these four important facts in mind:

1. All things are made of atoms.

It's true! Most stuff, like you, your dog, your toothbrush, your computer, is made entirely of atoms. Things like light, sound and electricity are not made of atoms, but the sun, the earth and the moon are all made of atoms. That's a lot of atoms! And they're incredibly small. In fact, you could lay one million atoms across the head of a pin.

2. At the nanometer scale, atoms are in constant motion.

Even when water is frozen into ice, the water molecules are still moving. So how come we can't see them move? It's hard to imagine that each atom vibrates, but they are so tiny that it's impossible to see them move with our eyes.

3. Molecules have size and shape.

Atoms bond together to form molecules that have different sizes and shapes. For instance, water is a small molecule made up of two hydrogen atoms and one oxygen atom, so it is called H_2O. All water molecules have the same shape because the bonds between the hydrogen atoms and the oxygen atom are more or less the same angle.

Single molecules can be made up of thousands and thousands of atoms. Insulin is a molecule in our bodies that helps to control the amount of sugar in our blood. It is made up of more than one thousand atoms! Scientists can map out the shapes of different molecules and can even build most types of molecules in the lab.

4. Molecules in their nanometer-scale environment have unexpected properties.

The rules at the nanometer scale are different than what we usually encounter in our human-sized environment. For instance, gravity doesn't count because other forces are more powerful at the molecular level. Static and surface tension become really important. What is cool about nanotechnology is that we can make things that don't behave like we expect.
Things are really different down there!!

Q&A

with nanoscientist Tak-Sing Wong

Photo courtesy of Information Services Office, The Chinese University of Hong Kong.

Tak-Sing studies nanoscale structures on the surfaces of plants.

What is your current job and what do you like about it? I am currently an assistant professor of mechanical and biomedical engineering. My research involves the study of natural and biological systems and translating their clever strategies into synthetic materials for various industrial and biomedical applications. Through my research, I am amazed how nature can always come up with interesting solutions to solve problems. I also enjoy interacting with my students both in the classroom and laboratory. I instruct a class in bioinspired interfacial engineering, where I teach about how some plants, insects and animals use their surfaces to solve engineering problems in liquid repellency, adhesion and optics. Last year my research group went to the USA Science & Engineering Festival to showcase our nature-inspired technologies to the general public, which was a lot of fun!

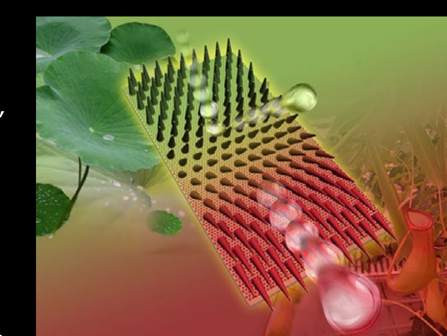
What is a typical day like for you? During the semester, my typical day involves teaching in the classroom and discussing research with my graduate students and postdoctoral researchers. From time to time, I will also work with my students in the laboratory for experiments. In addition, I will spend some time during the day browsing through the internet to learn about new science and technology from literature or science news. When there are upcoming opportunities for potential research funding, I will also spend my time in writing proposals to acquire funding to support my research.

When you were a kid, what did you want to be? And if it wasn't a scientist, what was it and why did you change your mind? When I was a kid, I dreamed of becoming an architect one day. I was amazed by how people can build large and beautiful buildings. I also dreamed of becoming a mechanic who could build many different things—specifically racing cars! That was mostly influenced by my father, who built simple furniture from scratch when needed. I did also enjoy reading about stories of scientists when I was a kid, where I started to have early appreciation of their work. I guess because of a combination of these childhood dreams and experiences, I became a mechanical engineer and a professor!

What did you do to get your current job, and what kind of education did you need for it? I did my undergraduate degree in automation and mechanical engineering at The Chinese University of Hong Kong, where I began my research in micro- and nano-machines and sensors since freshman year. Then I was given an opportunity to study at UCLA, where I eventually obtained my PhD in mechanical engineering, specializing in micro- and nanotechnology. My PhD thesis was to study why natural water-repellent surfaces require surface textures of nanometer size. After my PhD post, I went on to conduct postdoctoral research at the Wyss Institute of Biologically Inspired Engineering at Harvard University. Over there, I developed a pitcher plant–inspired surface called Slippery Liquid-Infused Porous Surfaces (SLIPS) that can virtually repel anything. After my postdoctoral research, I began my professorship at Penn State, where I continue to do research in nature-inspired engineering.

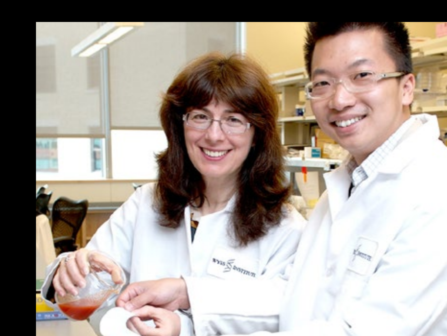
Tell us something fun about yourself? And it doesn't have to be about science!

I love watching science fiction and futuristic movies. And sometimes I get my "crazy" research ideas from them!



Tak-Sing Wong

A nanoscale surface, developed by Tak-Sing's team, that can switch between slippery and superhydrophobic states. It was inspired by the lotus leaf and the pitcher plant.



Tak-Sing Wong

Tak-Sing at work in the lab.

Learning from Nature

A gecko's sticky feet

These lizards have feet covered with little nanometer-sized structures that can adhere to a lot of different surfaces. Since they stick to all sorts of stuff, they can even climb walls. Spiderman climbing the walls? Maybe someday!

Cliff Mathisen, FEI Company

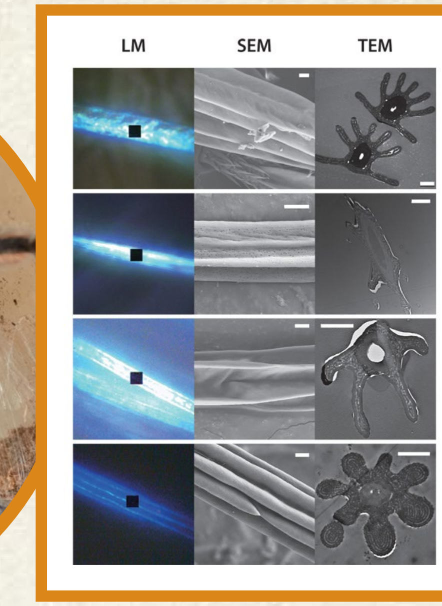
Gecko feet are covered with millions of superfine hairs, called setae, that attach to surfaces.

A pitcher plant's slippery inside

The inside of the pitcher plant is filled with super-slippery nanomaterial—when a bug lands on it, it slides down into the flower to its doom. Knowing how plants make this material will help scientists design new motors that don't require lubrication.

H.F. Bohn, W. Federle

A scanning electron microscope image of the ridges inside a pitcher plant that makes bugs slip and slide right into the pitcher.



Bor-Kai Hsiung et al / Science Advances

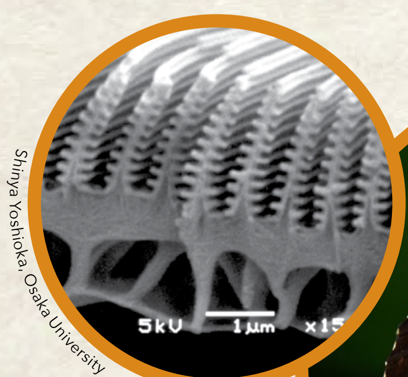
Light micrograph, scanning electron microscope and transmission electron microscope images reveal the complex structures of different blue tarantula hairs.

Iridescent tarantulas

Some tarantulas have tiny nanometer-sized structures that diffract only a narrow wavelength of light, so they look blue. Some day scientists hope to use these designs from nature to make materials that have different "colors" but don't involve dyes. These materials might even have the ability to change color—your blue shirt could suddenly turn to red in the blink of an eye.

Brilliant blue butterfly wings

The nanometer-sized ridges on this butterfly's wings diffract specific wavelengths of light, making them look blue. These structures found in nature might be the inspiration for a whole new class of fabrics that have color without using any chemical dyes.

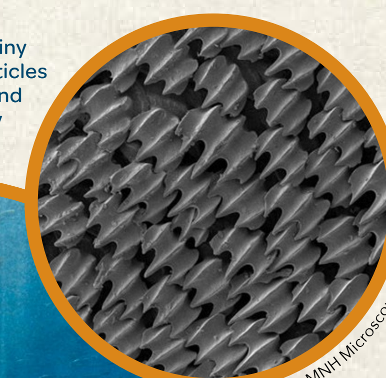


Shinya Yoshioka, Osaka University

A cross-section of a Blue Morpho's wing reveals the tiny structures that reflect light to create iridescent colors.

Blue Morpho butterfly

Shark skin is made up of tiny scales called dermal denticles that reduce turbulence and help the shark glide easily through water.



AMNH Microscopy / Rebecca Rudolph

Super-slick shark skin

Sharks are very efficient swimmers and need a lot less energy to slide through the water than people do. Scientists are re-creating shark skin in the laboratory to help us move through the water faster and easier.

Water-collecting beetles

The surface of the desert-dwelling Namibia beetle *(Stenocara gracilipes)* is superhydrophobic and can collect moisture from the air. Water drops form until they are big enough for the beetle to drink. With similar technology, we could make big sheets of superhydrophobic materials and collect water in the desert.

Andrew Parker

A scanning electron microscope image of the beetle's superhydrophobic surface.

Hans Hillewaert / Wikipedia

Tiny Bio-motors built like bacteria

A TINY MOTOR CHALLENGE

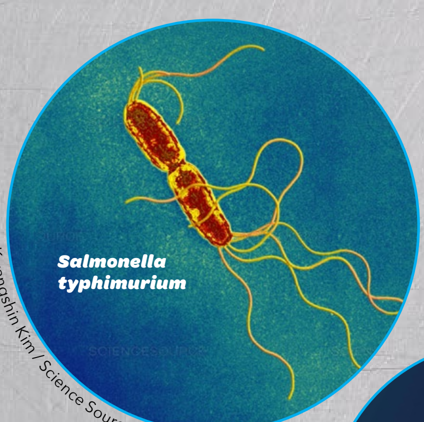
Back in 1959, Richard Feynman, one of the most famous nanotechnologists on the planet, challenged the world to build a motor that was less than 1/64 in^3. That is about the volume of 3–4 drops of water. There was no such thing as nanotechnology then, at least the way we now make tiny nanometer-sized parts like computer chips. Feynman was hoping for some revolutionary breakthrough, but the man who won the contest, Bill McLellan, was just a very skilled machinist who used tiny tools, including feathers, to make a very, very small but conventional motor.

FLAGELLA-INSPIRED

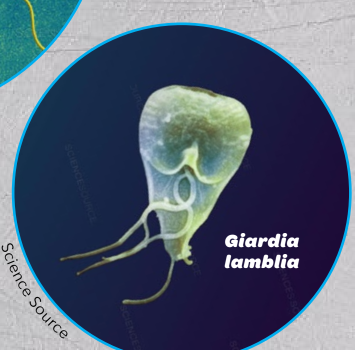
Today, biology is being studied to find new types of motors that can be built on a nanometer scale. In nature, there are a lot of tiny motors. For instance, bacteria have motors that whip hair-like things called flagella in a rotary motion, which help bacteria move through liquids. Flagella are only about 20 nanometers wide, but can be as long as 10,000 nanometers. And they can move bacteria pretty fast—humans can move about five times their body length in a second, while bacteria can move almost twice as fast!

HARNESSING ATP

Scientists have made motors in the laboratory similar to the ones that power flagella. These are hybrid motors—part biology, part man-made—and they do simple things like spin around or move from one place to another. Instead of using electricity to make them work, they use ATP (that's adenosine triphosphate), which is nature's chemical energy supply. Some day scientists think that they can use these little bio-motors to move tiny little devices that might be able to go into very small spaces. The big challenge is how to power them—some scientists think we might be able to harness energy from the environment to help propel them along. It would be great to have these tiny motors use some energy source that is found in the environment instead of relying on a battery.

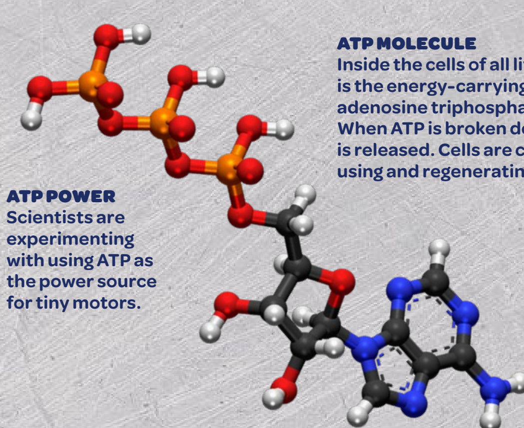


Kwangshin Kim / Science Source



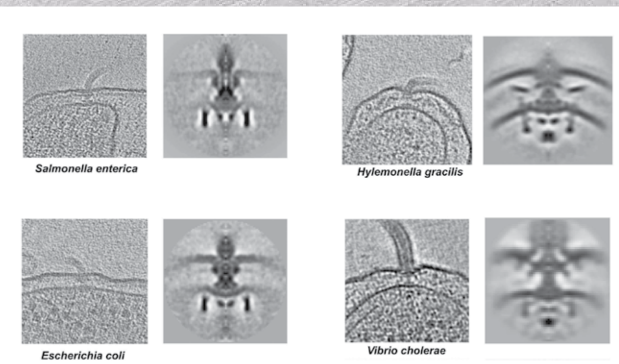
Science Source

POWERFUL FLAGELLA
Many types of bacteria move around using a strong flagellum, a long tail that moves in either a rotary or bending motion.



ATP MOLECULE
Inside the cells of all living things is the energy-carrying molecule adenosine triphosphate, or ATP. When ATP is broken down, energy is released. Cells are constantly using and regenerating ATP.

ATP POWER
Scientists are experimenting with using ATP as the power source for tiny motors.



Songye Chen et al / The EMBO Journal

FLAGELLAR MOTOR PARTS
These electron cryotomography images show the complex parts that make up various nanoscale biological motors that power flagella. Each flagella is only about 20 nanometers across.

Scientist Bor-Kai "Bill" Hsiung's thumb.

AUSTRALIAN PEACOCK SPIDER
This teeny spider is only about 5mm long. The nanoscale structures that create the blue color on its abdomen are being studied by scientists.

Phil Masturzo / Akron Beacon Journal

Spooky Spiders that look super cool

PIGMENTS OR NANOSTRUCTURES?

Peacocks, butterflies and even tarantulas all have brilliant colors that have evolved mostly to attract a mate. In nature, you have to be flashy if you're going to make sure your species survives! Some molecules are colored because they absorb and transmit specific wavelengths of light. For example, a blue shirt looks blue because a pigment or dye is absorbing all the colors except for blue. In other cases, there are tiny physical structures that diffract specific wavelengths of light. This is called structural color. The colors in a rainbow appear because of the way light hits tiny drops of water floating in the air. These tiny drops of water help to take white light and create a series of different colors—a rainbow of colors!

BLUE BUT NOT BLUE?

Scientists study colorful animals like the blue tarantula to figure out how nature makes structures appear to be a particular color. The blue tarantula is pretty rare; its formal name is *Poecilotheria metallica.* Blue is one of the rarer colors found in nature, but these tarantulas aren't blue because they have a pigment. Instead, they have evolved to have tiny structures about 450 nanometers in size that reflect blue light, making them *appear* to be blue.

IN THE LAB

Scientists like Bor-Kai "Bill" Hsiung have used the structure found in the blue tarantula to make non-iridescent structures in the laboratory. Iridescent colors appear to shimmer, while the blue tarantula's blue color doesn't. So in the lab, Hsiung and his colleagues re-created the blue tarantula's color using 3D nano laser fabrication to make layers, tubes and other structures, then measured the colors they produced. They discovered that when the tiny structures had surface grooves they produced the desired blue color.

Scientists around the world are studying nature to find different kinds of materials that can produce colors and even someday produce colors that change like a chameleon. Then we could go out with blue sneakers, flip a switch and change them to green ones. Why would that be important? It might not be, but it sure would be cool!

COLORFUL BEETLES
Many other animals owe their brilliant color to nanostructures.

BLUE TARANTULA
The rare *Poecilotheria metallica* tarantula is about 6 inches long and lives in the forests of southern India. Nanostructures are responsible for its brilliant blue color.

DNA

the building block of a lot of things

WHAT IS DNA MADE OF?

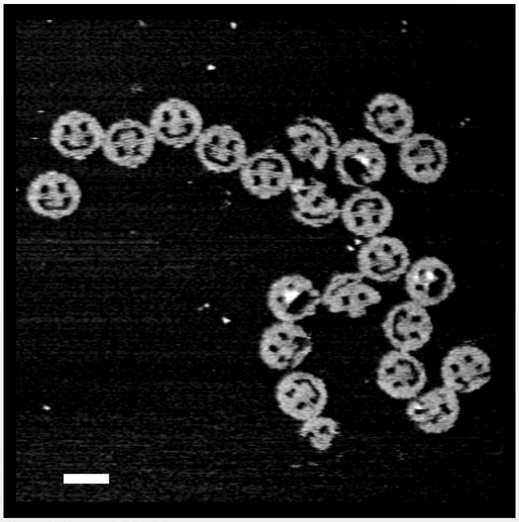
Deoxynucleic acid (DNA) is where the blueprint of life is encoded. Seemingly simple, it consists of four basic molecules called nucleotides: adenine, guanine, cytosine, and thymidine. Virtually everything that a cell needs to do is coded in its DNA. In your average bacteria there are about three million nucleotides, and in your average human cell there are about a thousand times that.

THE DOUBLE HELIX AND MOLECULAR ORIGAMI

Like all molecules, DNA has a shape that comes from the various interactions between the atoms making up the nucleotides, which then makes up a strand of DNA. Back in the 1950s, Francis Crick and James Watson—with a lot of help from other folks, including Rosalind Franklin—figured out the basic structure of double-stranded DNA, the famous double helix. That discovery was just the beginning and, using a lot of tricks that involve enzymes, scientists have been able to make more complicated structures than just the plain, old double helix. It turns out that DNA is a pretty predictable building block to make all sorts of structures in various shapes. They fold up all by themselves, a kind of molecular origami.

DESIGNING WITH DNA

What is really cool is that you can design these structures on a computer and make almost exactly the structure that you want. This *de novo* (Latin for "from new") approach has been used to make structures ranging from a few nanometers up to hundreds or even thousands of nanometers that can release medicines in the human body on demand. Scientists have made a number of different DNA-based structures that are not just shapes with different sizes, but that also do some pretty amazing stuff. What would you make?



Paul W.K. Rothemund / Caltech

DNA ORIGAMI SMILEY FACES
These teeny faces are only about 100 nanometers across. That's only 1/1000 the width of a human hair! Their shape is pure fun, but they also demonstrate that just about any shape can be folded from DNA.