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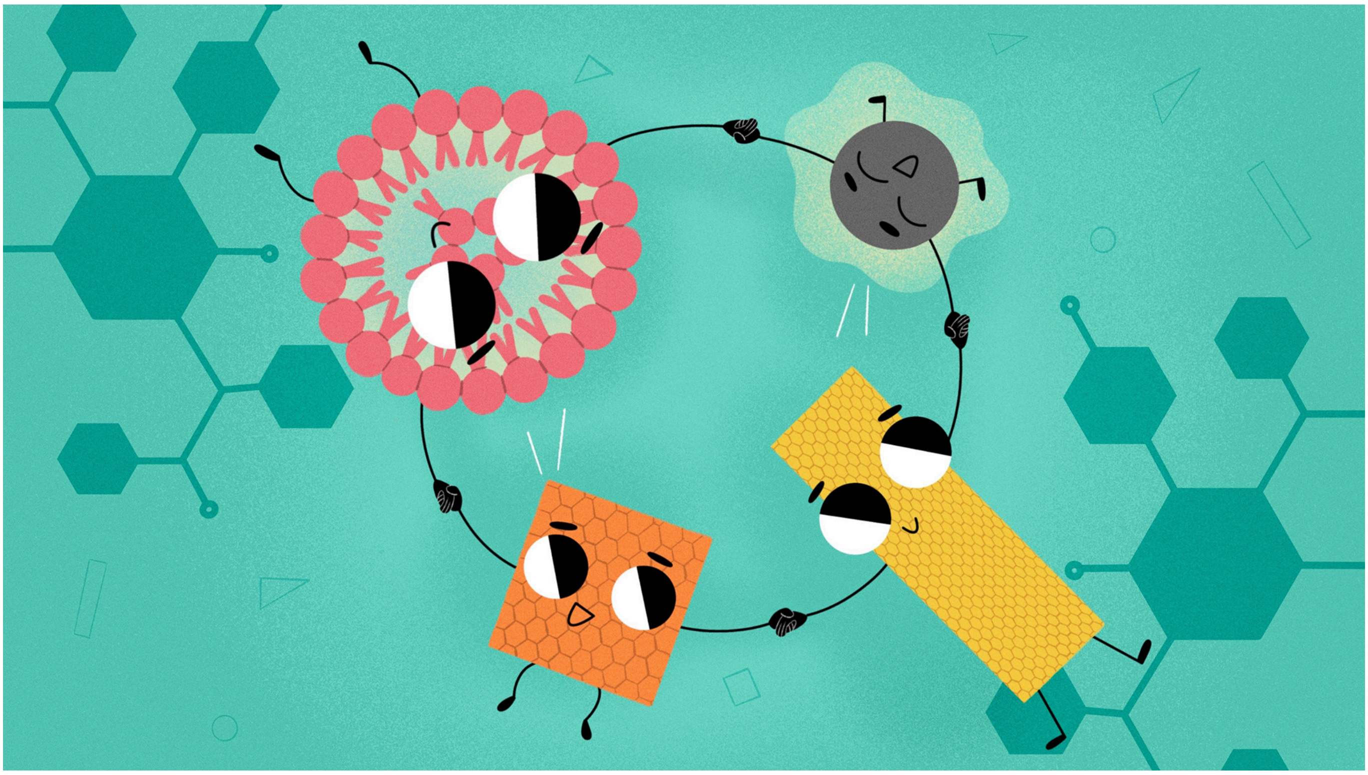

SIZES, SHAPES, AND TYPES OF NANOMATERIALS

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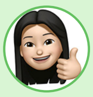
YOUNG REVIEWERS:


HARKIRAT
AGE: 10


STEPHANIE
AGE: 13

Nanomaterials are tiny particles, made by breaking down bulk products or by grouping atoms, to form small things, called nanoparticles. Nanoparticles have a size of 1–100 nm, so a person can only see them with a powerful microscope, as they are smaller than the width of a single hair! Nanoparticles are the building blocks of nanotechnology, which is a science used to make many things in our daily lives, like our electronic gadgets, farming chemicals, and medicines. Nanomaterials can come in various shapes, like balls, wires, and rods. They can be flat or have many dimensions. Scientists can produce nanomaterials from carbon, metal, or plastic, giving the nanomaterial special powers, like conducting electricity, absorbing light, or even changing color. These unique powers make each type of nanomaterial useful for a different kind of job. The size, shape, and type of nanomaterial can be seen using many different laboratory methods.

TINY BUT MIGHTY

NANOMATERIALS

Very small particles too tiny to see that are used to make everyday items.

Nanomaterials have been around for a really long time—they are even older than your great-great grandparents! They were first used in the 4th century, which is about 1,700 years ago. The very first nanomaterial was a glass cup that could change colors depending on the light. This cup had tiny particles of silver, gold, and copper inside [1]. Today, nanomaterials are still used in many things, so it is good to understand what they are and how they are made.

NANOPARTICLES

Tiny molecules that are building blocks for nanomaterials.

Nanomaterials are tiny particles that have layers like onions: a core, a surface layer and a shell layer (Figure 1A). They are really small, with sizes ranging from 1 to 100 nanometers (nm, 1 nm is one-billionth of a meter). Nanomaterials can be made in two ways: by breaking down bigger items into tiny pieces or by bringing together really small pieces, such as atoms, to form **nanoparticles** (Figure 1B). These two ways of making nanomaterials can happen naturally, like during volcanic eruptions or forest fires, or because of human activities, like driving cars or using fuel [2].

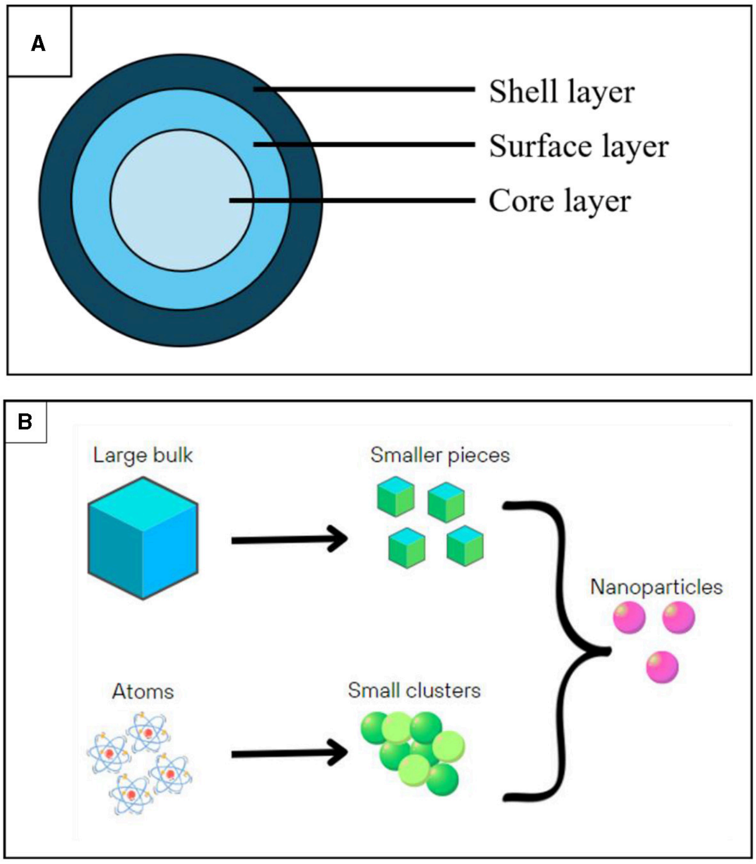


Figure 1

Figure 1

(A) Different layers of nanomaterials. Nanomaterials have a core, followed by a surface layer then a shell layer on the outside. **(B)** Nanomaterials can be made in two ways. A large piece of material can be broken down into smaller pieces (top) or tiny components, like atoms, can be joined together to form small clusters (bottom).

NANOTECHNOLOGY

A science using nanoparticles to create many new things that can help us.

Nanomaterials are like tiny building blocks that are used in the field of **nanotechnology**... almost like the nanobots in the movie *Big Hero*

6! They are found in things that are used every day, such as fertilizers for farming, medical equipment, medicines, and even electronics like cellphones [3]. The nanomaterials used in farming help make sure that the fertilizers do not break down too quickly. The ones used in medicines are super sensitive to conditions in the human body, helping the medicines to get to exactly where they need to go in our bodies.

TRANSMISSION ELECTRON MICROSCOPY

A special type of super-powerful microscope used to view tiny structures.

DYNAMIC LIGHT SCATTERING

A tool that uses light to help scientists learn how big molecules are.

Did you know that nanomaterials are super tiny that they are 10,000 times smaller than the diameter of a single strand of your hair? They are so small that that we may not be able to see them with just our eyes, so we would need special tools to see them. The two very unique tools that scientists use to see these tiny nanomaterials close up: **transmission electron microscopy** (TEM) and **dynamic light scattering** (DLS). The TEM helps us to see the sizes of individual nanoparticles, while DLS shows us how big or small nanoparticles are when they stick together to form clusters in numbers [4]. The DLS can also tell us if nanomaterials have a positive or negative charge on their outer layer. This charge is important because it can affect their clustering, and it can tell us if nanomaterials like or dislike attaching to cells or organisms [5].

Nanomaterials have different sizes and shapes, which can be seen with TEM. We can see that nano-copper oxide nanoparticles (Figure 2A) are bigger than nanodiamonds (Figure 2B). The biggest nano-copper oxide particle is 31 nm, while the biggest nanodiamonds are 7 nm. This means that nano-copper oxide is almost four times bigger than nanodiamonds!

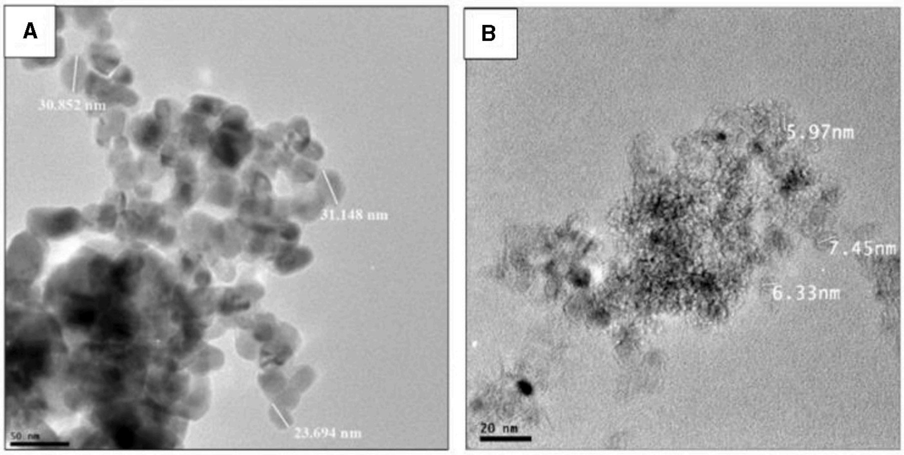


Figure 2

Figure 2

Transmission electron microscopy images of **(A)** nano-copper oxide and **(B)** nanodiamonds. From the sizes in the image, you can see that nanodiamonds are almost four times smaller than nano-copper oxide.

Nanomaterials come in many shapes and dimensions as well. There are four different kinds of dimensions: 0-D, 1-D, 2-D, and 3-D (where D stands for dimensions) [3]. An example of 0-D would be a tiny dot, like quantum dot nanomaterials (they can be fluorescent, almost like they can glow!); 1-D would be a straight line, like nanorods; 2-D would be a square/rectangle, like nanosheets; and 3-D would be two or more structures that are joined together (Figure 3).

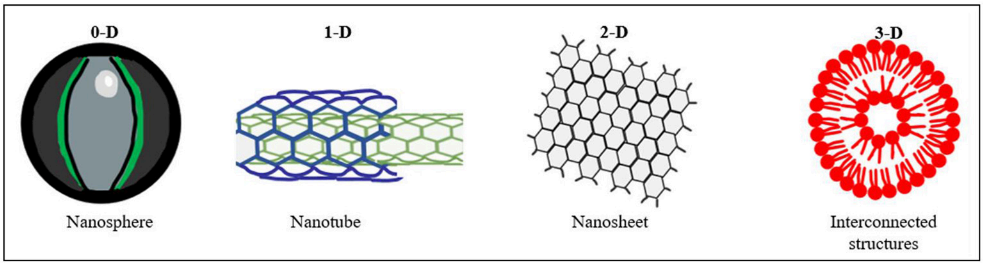


Figure 3

Figure 3
Nanomaterials come in different shapes and dimensions—from dots to tubes to sheets to multiple structures joined together.

Other shapes of nanomaterials include stars, cubes, and cylinders [2]. Nanosheets are found in hair coloring; nanotubes and nanospheres are found in makeup and lotion [6]; and nanodiamonds are used in medical equipment.

WHAT TYPES OF STUFF ARE NANOMATERIALS MADE FROM?

The shapes and sizes of nanomaterials give rise to unique properties, which include the ability to conduct electricity, trap light, if it is strong or weak, and its magnetic strength [2]. Now you know that nanomaterials can come in all shapes and sizes, but what are they made of?

Nanomaterials can be made from four different types of materials: carbon, organic substances, inorganic substances, or composites [3].

Carbon

Carbon is a chemical element that is found in all living organisms. Two different kinds of carbon nanomaterials are graphene [3] and nanodiamonds. Graphene is found in the lead of pencils, which is what we use to write/draw with every day! Nanodiamonds have a special shape called tetrahedral, which means they look like tiny pyramids. They are very strong, which is why nanodiamonds are often used in hospital equipment that helps doctors to see inside our bodies.

Organic substances

Organic substances are substances that have carbon atoms, typically bonded to hydrogen atoms, and may also contain other elements such as oxygen, nitrogen, sulfur, and others. This is a broad category of substances that includes everything from simple molecules like the gas methane (CH_4) to complex structures, like proteins and DNA. Organic nanomaterials include lipids and micelles [3, 7], which can be found in delicious treats like creams, chocolates, and cakes.

ORGANIC SUBSTANCES
Materials from living things, such as plants or animals.

Inorganic substances

INORGANIC SUBSTANCES

Materials made from non-living things, such as metal or air.

Inorganic substances do not have carbon atoms. Metals, metal oxides, and semiconductors can be used for many different purposes [3]. Metals are only made up of one kind of material/element, like copper or zinc. Metal oxides, which are metals attached to oxygen molecules, include copper oxide and zinc oxide. These nanomaterials can have different dimensions, either 0-D, 1-D, 2-D, or 3-D. Finally, semiconductors are interesting as they can have a super strong magnetic force, no magnetic force, or a little bit of a magnetic force. Semiconductors are often used in electronic devices [3].

Composites

COMPOSITES

Materials made from two or more particles.

Composites are combinations of different kinds of nanoparticles [3]. Some composite nanomaterials are made of metal, some are made of ceramic, and others can be made of a special kind of plastic called polymers. They can be found in vacuum cleaners and phone covers, for example.

SUPERHERO OR SUPERVILLAIN?

Nanomaterials are used in things that we use every day, and they often help these things to work even better. But even though they help us sometimes, in other cases nanoparticles can cause problems for other organisms.

Shrimp are water-living animals with a hard covering on their bodies, known as an exoskeleton, that they can remove when it gets too small for them. They can live in freshwater or saltwater and are important in the environment's food webs. We wanted to find out how nanomaterials, like nano-copper oxide and nanodiamonds, affect the shrimp that live in freshwater rivers. Our study found that these nanomaterials made the shrimp breathe more rapidly and act differently than they usually do. This means that the shrimp were stressed out. So, when these nanomaterials are released into the water by humans, they can harm other living organisms, such as shrimp and fish, living in the waters.

Nanomaterials are used to make our lives better, but when they are disposed of incorrectly, they can have bad effects on animals living on land or in the water. So, although they are beneficial for us, we need to be extra careful with them. The use of nanomaterials needs to be "perfectly balanced, as all things should be"—*Thanos: Avengers Infinity War.*

ACKNOWLEDGMENTS

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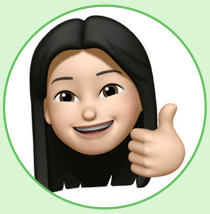
CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

HARKIRAT, AGE: 10

Hi, I am a 4th grader who loves to dream, doodle, and solve puzzles! I really like unicorns, I am super good at hopscotch, and I can solve Rubik's cubes super-fast! One day, I want to try all the cookies and find the yummiest one. When I am not in school, I am either reading cool books, building awesome stuff with my Legos, or challenging myself with tricky puzzles.



STEPHANIE, AGE: 13

My name is Stephanie and I am 13 years old. I am a seventh grader in middle school and my hobbies include singing, playing tennis, and playing the clarinet. My favorite subject in school is ELA and I enjoy reading and writing mystery and dystopian stories. I have performed for the UniverSoul Circus before and I have been a reviewer for some scientific articles in this journal.

AUTHORS

NICHOLE DONOUGH

Nichole's journey as a researcher began with a deep sense of curiosity and passion for issues relating to water systems and how to fix them. She became really fascinated learning about ecotoxicology, especially metal and nanomaterial contamination. Through her studies, she learned that organisms can be used as indicators in helping us assess the health of a water system and understanding the impact it has on aquatic life. Learning about pollutants in aquatic ecosystems is very important, not only because of the harm it as on animals living in those systems, but also due to the potential harm it can inflict on our health. Nichole's research in ecotoxicology continues to ignite her curiosity where every day is an opportunity to learn something new and to share what she learns with others.*nicholedon@gmail.com

VICTOR WEPENER

Victor Wepener is a Professor of Zoology at North-West University, South Africa. He co-leads a group known as the Water Research Group, and he has written multiple papers, books, and reports on how chemicals, like nanomaterials, affect our water systems and the animals within it. Wepener has taught many young scientists about aquatic systems and their pollutants, and he is the chairperson of a large group known as the South African Department of Science and Innovations Environment, Health and Safety Nano Risk Assessment research platform. He also represents the South African Bureau of Standards at the ISO nanotechnologies

TC229. This means that he works with important organizations to help ensure that new technologies are safe. Wepener is the head of a laboratory known as the National Aquatic Bioassay Facility (funded through the National Nanotechnology Equipment Programme), which is a high-tech laboratory to do experiments in, like studying water contamination and the effects it has on aquatic organisms.

TARRYN LEE BOTHA

Having clean water is a human right, and as aquatic scientists it is part of our job to ensure that safe, clean water is available to everyone. Contaminated water can be cleaned using nanotechnology in water purification, but just like with any new technology, it needs to be tested to ensure it is safe to use. Many organisms, like earthworms, fish and crustaceans like daphnia, are used to test waters for nanomaterial contamination and we have even conducted some of these tests in a state-of-the-art laboratory. An important concept is an Adverse Outcome Pathway Approach, and this includes looking at responses of an organism, such as their growth, respiration, heart rate and behavior, to ensure that all the right points are monitored. This approach is like following a roadmap to make sure nothing important is missed, and we can use this roadmap data to tell us how it might affect human health.