I BET YOU DIDN'T KNOW...

Which facemask you should wear

Dr Alison Trew, PSTT Area Mentor and Website Resources Developer, links **cutting-edge research** with the **principles of primary science**

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Across the world, people have been wearing face masks in 2020 and 2021 to protect themselves from COVID-19, a disease caused by a coronavirus (SARS-CoV-2) (Figure 1). Like many viruses and bacteria, this coronavirus is spread from person to person through droplets in the air. By covering our mouths and noses we reduce the likelihood of spreading the virus to other people and so governments in many countries have asked people to wear facemasks when they are in public places to reduce the spread of the disease (Figure 2). Face masks of different materials, shapes and sizes are sold in shops, and some people have made their own using scraps of fabric that they had at home (Figure 3).

Questions children might like to consider:

- Which facemasks do you think would be best for you? Why?
- Do different people need different types of facemasks? Why?

Figure 1. This image is a computer-generated representation of COVID-19 virions (SARS-CoV-2) under an electron microscope. The spikes on the outer edge of the virus particles give coronaviruses their name, crown-like.

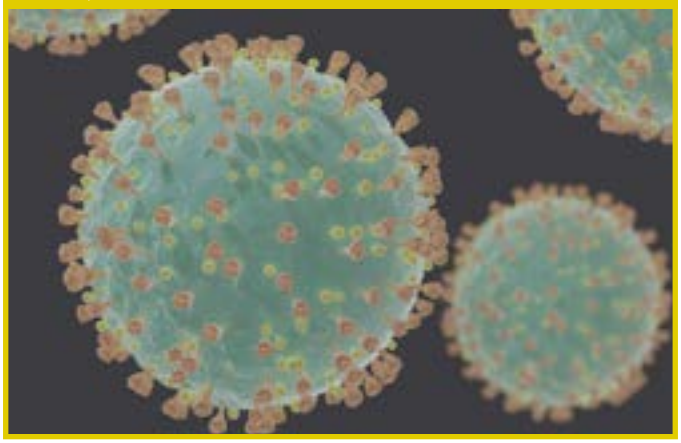


Figure 2. A boy wearing a facemask.

Figure 3. Different types of face masks (from left to right): a homemade woven cotton mask which could have one or more layers, a surgical mask has three-layers of nonwoven plastic (polypropylene), a 'filtering facepiece' (FFP2) has four-layer protection. The cotton facemask can be washed and reused but the others are non-reusable.

Why are scientists changing the focus of their research?

Materials scientists study the structure and the properties of various materials to develop new materials to solve problems or to suit new applications. Now, a team of scientists at the National Institute of Standards and

Technology (NIST), in the United States, are using powerful *scanning electron microscopes* to examine fabrics at very high *magnifications* to find out how some face masks filter out particles better than others. Before the COVID-19 *pandemic*, one of the scientists, Edward Vicenzi, spent his time looking at meteorites and museum specimens under the microscope. In spring 2020, he joined a team of researchers with expertise in measuring tiny amounts of substances, at the Materials Measurement Laboratory. They wanted to work together to contribute to the fight against COVID-19 and they started to study face-covering materials.

There has been little research on cloth masks since the 1918-1919 influenza pandemic. Most recent research has been on the effectiveness of single-use masks used in hospitals and healthcare. In 2020, the World Health Organisation (WHO) called for research to be carried out on the efficiency of different materials used in facemasks.

Questions children might like to consider:

- Why do you think the WHO wanted to know more about this?
- Why do you think it is important to test the efficiency of different materials?

If people are wearing cloth masks in nonmedical settings, we need to know whether cloth masks will offer people protection from coronavirus in water droplets, and if they do, which are the best fabrics to use?

What did the scientists already know?

In studies before 2020, the effectiveness of cotton-based fabrics was found to be much lower than face-coverings produced for medical purposes, but one recent study suggested that a cloth filter may be better, depending on the type of cloth and layering.

When we breathe out, some of the air we exhale contains droplets of fluid from our lungs. When we talk, sing or cough, we may produce droplets from our mouth. Together, these processes produce approximately 400g of water in 'respiratory fluid' per person per day. This means that a facemask could get rather wet when worn.

Scientists wanted to find out which materials made the most effective filters and how well they would work when worn on a person's face.

What did they do?

In 2020, Zangmeister and his team tested 32 different cloth materials (some *natural*, some *synthetic*) that can be used in cloth masks. They used powerful microscopes to examine the structure of the materials and the materials were sprayed with *aerosols* containing different size particles (50 to 825 *nanometres* (nm)) to see how effective they were at trapping the particles. These sizes were chosen because the scientists knew from other research that the diameter of the COVID-19 virus is between 250 – 500 nm. For comparison, they also tested some medical filters such as surgical masks, a HEPA vacuum bag, a coffee filter and a paper towel - **which of these filters do you think will be most effective in preventing the spread of the coronavirus and why?**

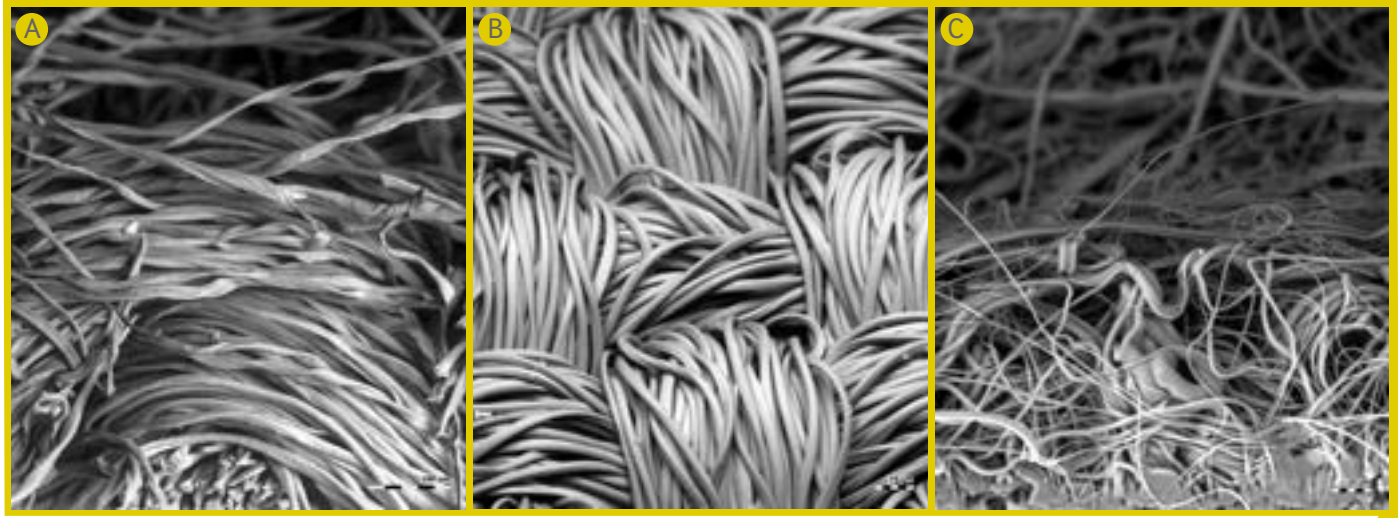
In 2021, Zangmeister and his team tested more fabrics under moist conditions to mimic the environment around a facemask when it is worn (i.e. when we breathe, talk and cough).

What did the scientists find out?

They found that three of the best five materials for facemasks were woven 100% cotton and two were woven synthetic fabrics. In contrast to other studies, mixing the types of materials did not significantly improve the masks but the masks made of lightweight flannel did improve with more layers, suggesting that multi-layered cloth masks may offer increased protection from nanometre sized particles.

When the conditions were moist, the 100% cotton samples took up 12-20 mg water and the efficiency of

Figure 4. Magnified images of fabrics (A) Woven cotton flannel (B) Polyester (C) N95 mask. Scale bars represent 0.1 mm, 0.075 mm and 0.025 mm respectively.



the filter improved. The water uptake of the synthetic fabrics was 0.6 – 4.3 mg water but there was no observable change in the efficiency of the filter.

How does this research help us?

With evidence that woven cotton facemasks are some of the most effective filters for COVID-19 size particles, people can be confident that their cotton face masks (home-made or shop-bought) are going to offer them some protection from the spread of the coronavirus. People need not be concerned that their facemask becomes moist from exhaled droplets when they are wearing it.

The texture at a microscopic level can explain each fabric's ability to filter out particles. The wrinkled texture and complex shapes such as kinks, bends and folds in cotton fibres probably allows cotton to trap more *nanoscale* particles than other fabrics. Polyester fabrics have highly organized, mostly straight and smooth fibres, which makes them less efficient as face masks (Figure 4).

These studies measured the filtration efficiency of the fabrics tested but this is only one variable in how effective your facemask will be. The performance of a facemask depends on what material it is made from, the design (does it include layers?), the fit, and the environmental conditions in which it is used.

Questions for children to consider and investigate:

- What do you think is the best fabric for a facemask? Why?
- What do you think is the best shape for a face mask? Why?
- How many layers do you think are needed? Is there a maximum?
- Can you carry out an investigation to find out?

Practical activities and investigations which enable children to mirror the research of the scientists are described in the accompanying Teacher Guide.

GLOSSARY

aerosol
a suspension of particles dispersed in air or gas

magnification
the process of enlarging the appearance of an object, but not actually changing its real size

nanometre
one thousand-millionth of a metre,
i.e. 1 metre = 1,000,000,000 nanometres

nanoscale
having dimensions of less than 100 nanometres

natural
substances that are produced by nature (not by humans)

pandemic
a disease occurring worldwide or over a very wide area, crossing countries and affecting a large number of people

scanning electron microscope
a type of microscope that produces images of a sample by scanning the surface with charged particles (electrons)

synthetic
a substance made by humans using methods different than those nature uses, and these substances may or may not be found in nature

Two papers inspired this article:

Filtration Efficiencies of Nanoscale Aerosol by Cloth Mask Materials Used to Slow the Spread of SARS-CoV-2.

By Christopher D. Zangmeister[1], James G. Radney[1], Edward P. Vicenzi[2], and Jamie L. Weaver[1,2].

Published in JACS Nano 14, 9188–9200 (2020) https://dx.doi.org/10.1021/acsnano.0c05025 last accessed 06.04.21

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Hydration of Hydrophilic Cloth Face Masks Enhances the Filtration of Nanoparticles.

By Christopher D. Zangmeister[1], James G. Radney[1], Matthew E. Staymates[1], Edward P. Vicenzi[1,2] and Jamie L. Weaver[1,2].

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