



## **Physics**

# **Lenses: Bending Light**

This lesson is about light and lenses. In this lesson you will investigate the following:

- How do we see?
- How is refraction useful?
- What is the difference between a convex lens and a concave lens?
- How might the latest advances in microscopes help the developing world?

Let's shine some light onto the lenses that changed the world.



This is a print version of an interactive online lesson.  
To sign up for the real thing or for curriculum details about the lesson  
go to <http://www.cosmosforschools.com>

# Introduction: Lenses (P1)

**COSMOS**  
LIVE LEARNING

## Smartphone microscope



**An Australian scientist has found a cheap and simple way to turn a smartphone into a microscope.** And like many great inventions, he found it by accident.

The discovery was a new lens, like the kind you find in microscopes. Lenses have curved surfaces that bend light to make an image either bigger or smaller. Traditionally, lenses — like those in microscopes — are made from glass, requiring skilled specialists to grind the glass into the perfect curved shape.

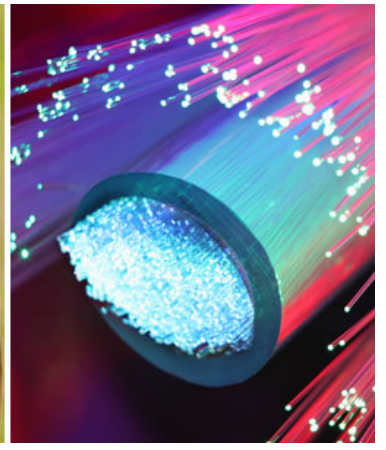
Some newer lenses, however, are made of a polymer — a kind of plastic. Usually this polymer needs to be heated up, liquefied and put in a mould to shape it into a lens.

But one day the scientist discovered that some small drops had escaped his mould — and had formed perfect curved surfaces all by themselves.

This droplet lens has interesting potential. For example, it could be put on your smartphone's camera to make it act like a microscope. This would help doctors in remote areas diagnose diseases and farmers look for small insects on their plants.

And, where microscopes cost hundreds, or even thousands of dollars, the new plastic droplet lens costs only a few cents to make.

Read or listen to the full *Cosmos* magazine article [here](#).



Credit: iStock

### Question 1

**Identify:** We are surrounded by optical gadgets, including smartphones, telescopes, prescription glasses, optic fibre cables and binoculars. Some of these technologies are used for fun, but many are an essential part of our lives. List at least three other things that use light in some way.

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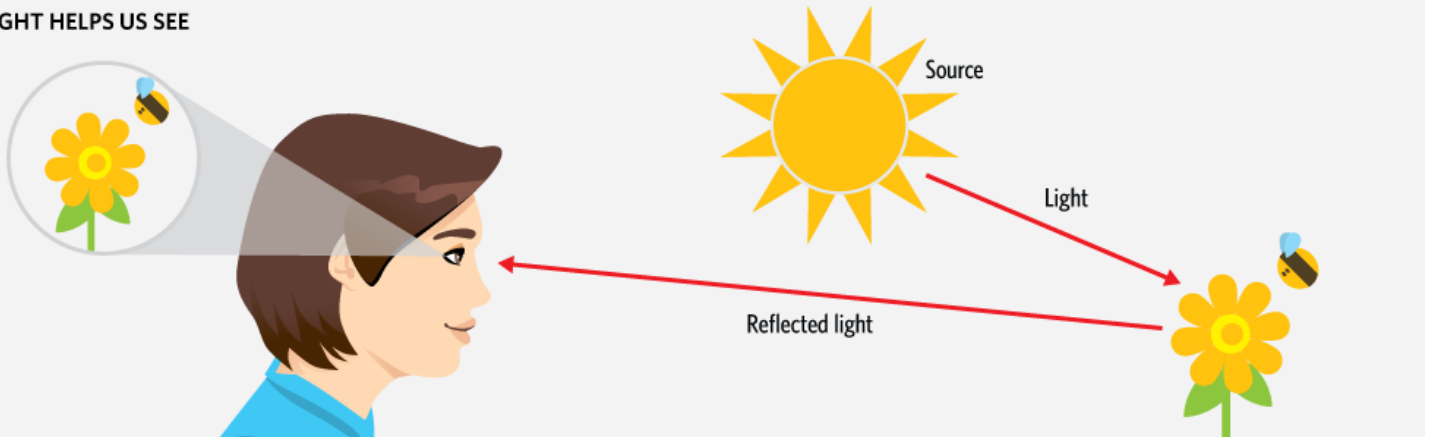
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# Gather: Lenses (P1)

## LIGHT HELPS US SEE



## How we see

No matter how many carrots you were told to eat as a child, you still cannot see in the dark. However, with the lights turned on, you can suddenly see. Your eyes are advanced optical gadgets — they use light to make images.

We see an object because the light energy from the source bounces off the object and is collected by our eyes. This means that if no light enters our eyes from a particular direction we interpret that direction as being dark.

In a room where the lights are switched on, there is usually no area that appears dark since the room is filled with reflecting objects — the walls and everything else — so that light is reaching our eyes from all directions.

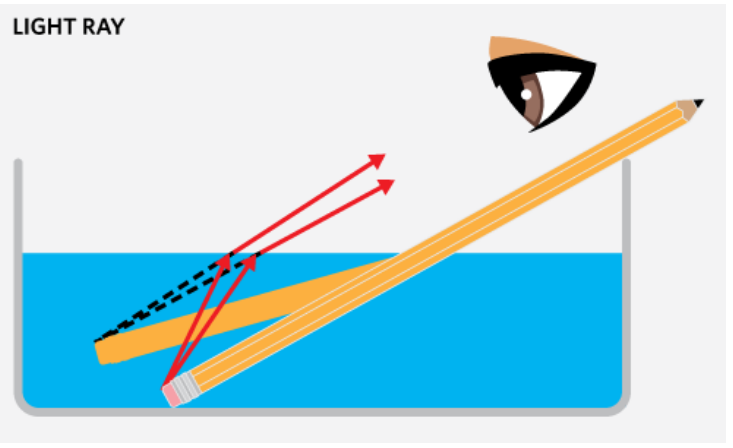
### *Did you know?*

Did you know that approximately 75% of the information we receive about our environment comes through our eyes, making sight the most important of our five senses?

## Refraction

Unless it encounters an object, light energy always travels through the air at the same speed and in a straight line. However, when light travels from the air to water, glass or anything that lets the light through, it changes speed and direction. The change in the direction of a beam of light is called *refraction*.

Refraction can be observed if you place a straight object, such as a pencil, at an angle into a glass of water. When you look at the pencil in the glass it appears to be bent. However, our brains learn to correct for this perception and we know that the pencil is still straight.



Left: Are you seeing straight? Right: The water "bends" light making the pencil seem crooked when we look at it. Image credit: Southern Illinois University / Getty Images



Credit: JamJarMMX & YouTube.

### Question 1

**Recall:** Light travels at the same speed through all materials.

- True
- False

### Question 2

**Summarise:** Using the information in the media clip above, and in your own words, describe the behaviour of light rays when they encounter a transparent object.

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## Lenses

A lens is a curved piece of transparent glass or plastic that refracts light. Since a lens is curved on at least one side, light rays strike different parts of its curved surface and so change direction by different degrees. Depending on the shape of the lens, the light rays either diverge (spread out) or converge (concentrate).

### Concave lenses

Concave lenses are thinner in the middle and thicker at the edges.

A concave lens is a diverging lens since parallel rays of light that pass through the lens are spread out (they diverge). The rays of light refract (change direction) as they move between the air and the lens. Because the rays diverge in this way they appear to come from one point. This is called the focal point.

The image formed by a concave lens is always smaller than the original. Many doors, especially in hotels, include a small concave lens put in the door that allows people to see who is outside without having to open the door. Concave lenses are used because

they condense light to give a wider viewing angle therefore allowing you to see more of the person on the other side of the door.

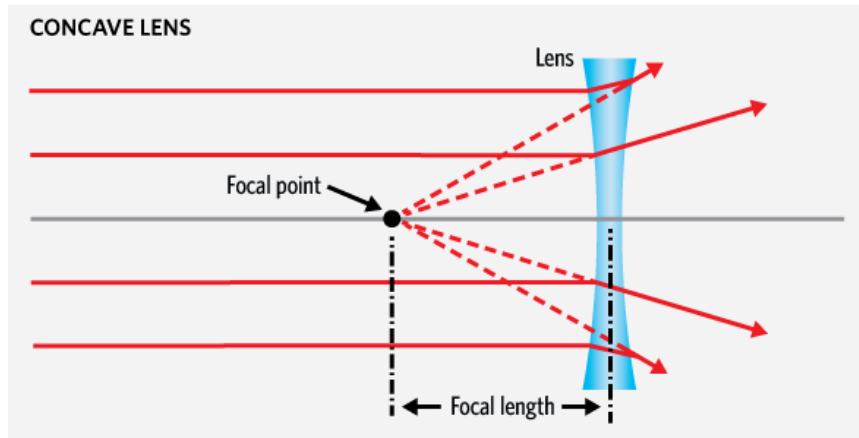


Image credit: iStock

### Question 3

**Recall:** A concave lens is also called a converging lens.

- True
- False

## Convex lenses

Convex lenses are thicker in the middle and thinner at the edges.

A convex lens is a converging lens since parallel rays of light that pass through the lens are brought closer together (they converge). The rays of light refract as they move between the air and the lens - the shape of the convex causes the rays to converge at one point called the focal point. The distance between the focal point and the centre of the lens is called the focal length.

Images are formed by placing objects at different distances from the convex lens. The theory behind this is quite complex, since convex lenses can produce both larger and smaller images depending on the distance of the object from the lens. Lenses will be studied in more detail in senior Physics classes.

A magnifying glass is a convex lens that can produce a magnified (larger) image of an object. For the magnified image to be observed, the object must be placed between the lens and its focal point.

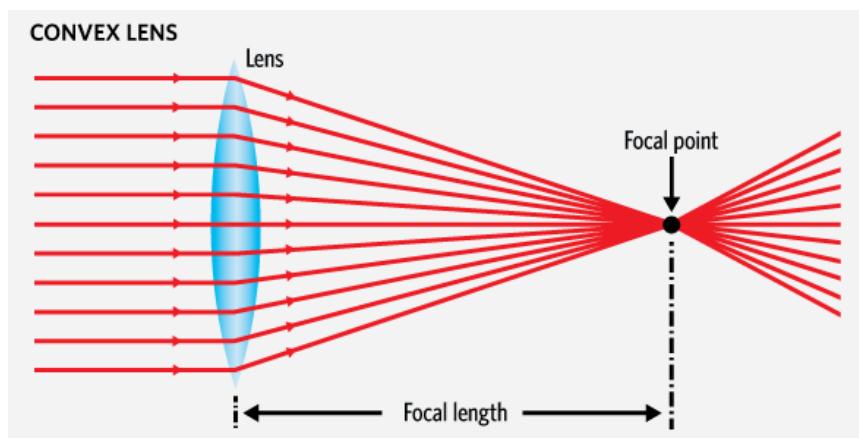


Image Credit: Relaximages/Getty Images



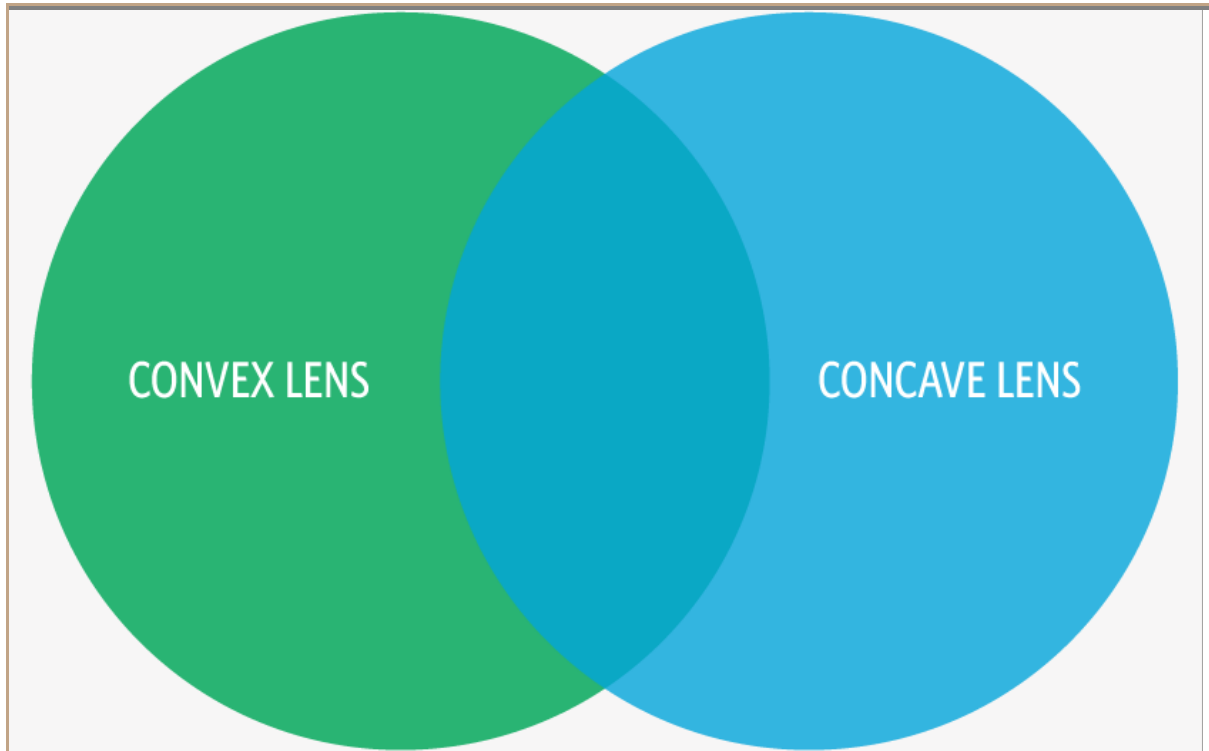
 Question 4

**Recall:** A convex lens causes light rays passing through it to refract.

- True
- False

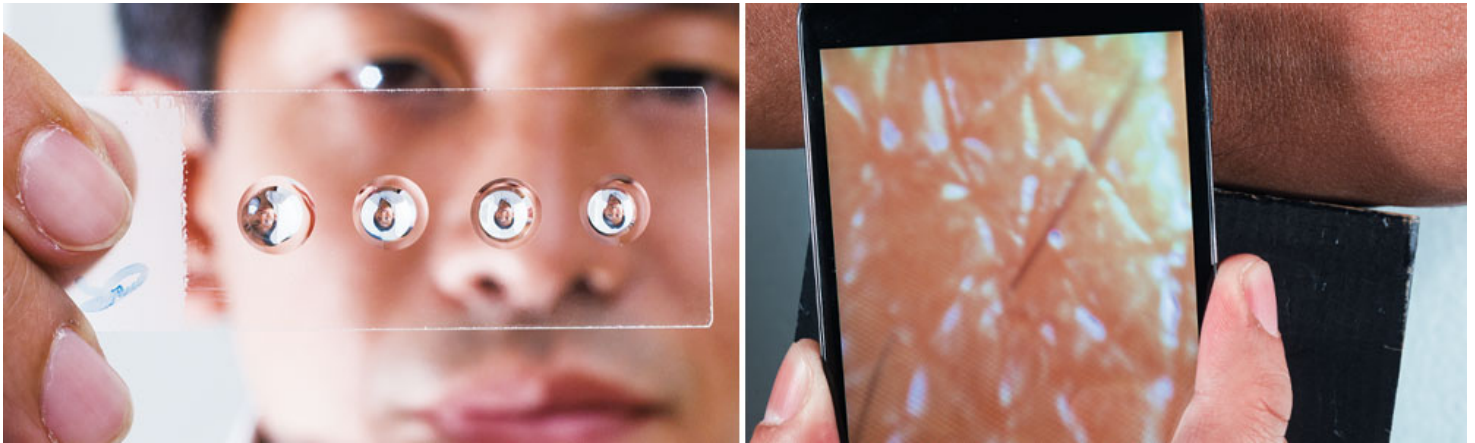
 Question 5

**Summarise:** To organise your understanding of light and lenses, complete the following Venn diagram with as much detail as possible.



# Process: Lenses (P1)

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LIVE LEARNING



Left: These are the polymer droplets that are described in the introduction. The droplets on a microscope slide are baked to set the shape. Smaller drops allow higher magnifications. Right: If the polymer droplet is placed on top of a smartphone camera lens it turns the camera into a microscope. Credits: ANU / Stuart Hay.

## The microscope

Telescopes and microscopes are excellent examples of how lenses are used every day. Telescopes are able to see very distant objects and magnify them so we can see the details. Microscopes enlarge very small objects that are close to us.



Credit: Scishow / YouTube.



### Question 1

**Recall:** Galileo's telescope magnified the image from a distant object using

- convex lens
- both convex and concave lenses
- concave lens







### Question 2

**Recall:** The first microscope could magnify small objects by

- 9 times
- 3 times
- 270 times

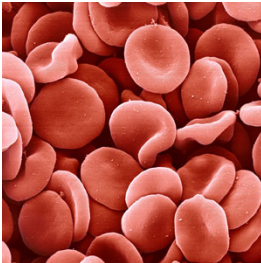
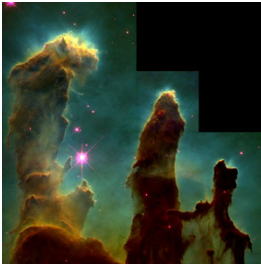
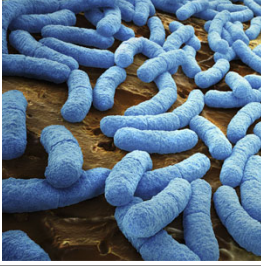

### Question 3

**Match:** The terms endoscope, microscope and telescope are used in either the *Cosmos* magazine article or the video clip above, or both. In the sketchpad below draw lines to connect the apparatus with the image it could have been used to capture.

telescope	microscope	endoscope
		
		

### Question 4

**Classify:** In the table below is a selection of images. Name the objects in the images and, with the aid of an internet search, identify how large they are. Also determine whether these images were produced using a microscope or a telescope and explain your reasoning.

Image	Name of object	Estimated size of object	Microscope or Telescope	Reasoning
				
				
				
				

### Question 5

**Calculate:** The *Cosmos* article mentioned that the polymer drop has a magnification of 160x. How big would a five cent coin appear to be when viewed using this device?

*Hint: Five cent coins have a diameter of 19.4 mm.*

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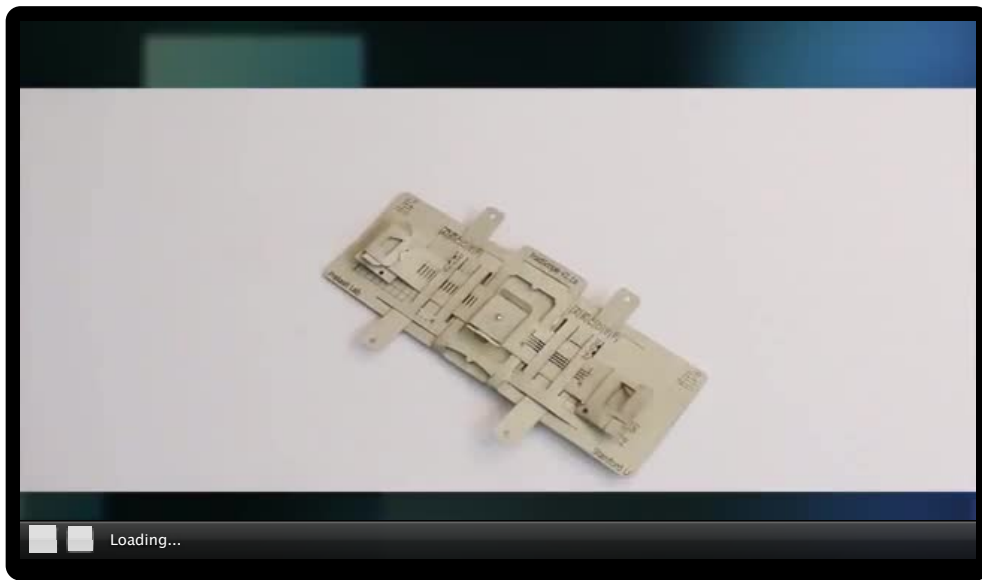
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Credit: Buzz60 & YouTube.

### Question 6

**Compare:** With the aid of an internet search, describe the benefits and limitations of the polymer drop lens and the origami microscope for the developing world.

*Hint: You may wish to supplement your answer with images and videos.*

# Apply: Lenses (P2)



## Lenses shape the world



Coloured scanning electron micrograph (SEM) of cyanobacteria (formally known as blue-green algae, pink) growing on an evening primrose pollen grain. Cyanobacteria are photosynthesising bacteria that are found in most habitats where water is present. Magnification: x5000 when printed at 10 centimetres wide. Credit: Steve Gschmeissner/Getty Images

Scientific advancement is always built on previous progress. As such, the recipe for any scientific discovery or development requires just the right people at the right time in history who are able to use the resources around them in an innovative way.

The first media clip in the *Process* section discusses a range of microscopes and scientists. Take another look at this video and use their ideas as a starting point to find out more about how lenses have changed the world.

### Question 1

**Create:** Your task is to prepare an engaging visual presentation about how lenses have changed the world. You may choose to focus on one particular scientist or one type of optical technology. In setting the scene for your presentation, you should include a brief summary of the historical and political environment at the time.

Your presentation may take the form of a poster, brochure or a video and must include a bibliography.

A bibliography is where you list the sources of your images, quotes and background research. It is important that you consider the credibility of the information you have found and then make a decision about whether or not to include this information. For example is the author a renowned academic or someone who has no expertise in the area?

When referencing internet-based materials in your bibliography, make sure to include the following:

1. title of page
2. name of the author
3. when the site was last updated
4. when you accessed the website
5. URL of the website

# Career: Lenses (P2)



FACULTY OF  
SCIENCE

Brought to you by Macquarie University

**You can now turn your cell phone into a microscope just by baking your own lens, thanks to physicist Steve Lee.** But that's just one of the many exciting inventions to come out of Steve's busy lab. Steve hopes to use his scientific knowledge to develop cutting-edge technologies in optics.

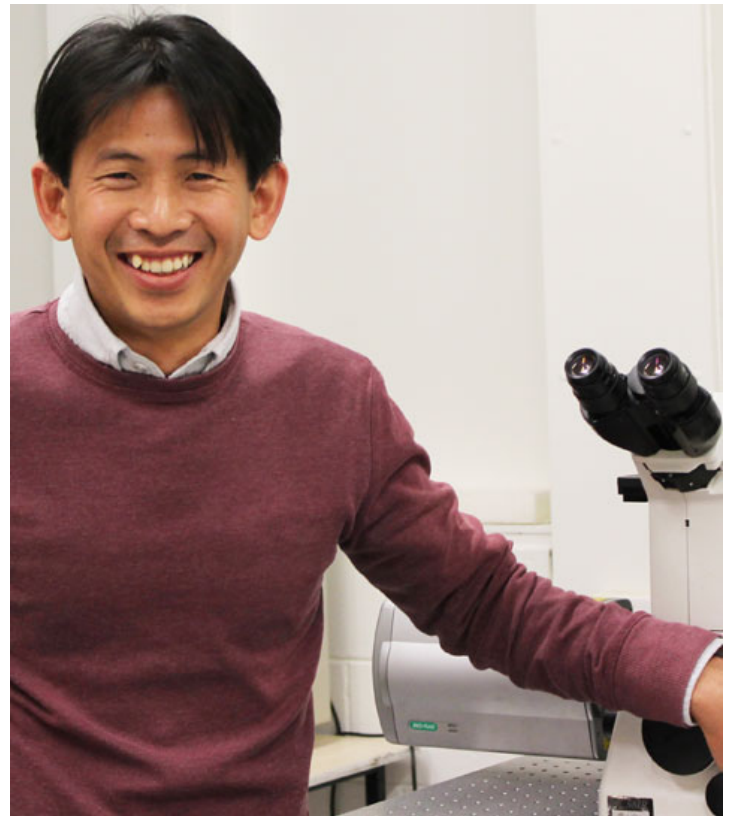
Growing up in the sunny island of Singapore, Steve had always been a fan of the cool technology and inventions he saw on sci-fi shows. His father, an engineer, played a large part in fostering Steve's interest in science by bringing home fancy new gadgets that Steve would promptly take apart – not always to his father's liking. But Steve wanted to know what made these things work.

Now he runs his own laboratory at the Australian National University, where he works on harnessing the power of optics to detect and treat diseases.

Steve spends his days developing new optical technologies and techniques – the sort of work he would have found irresistible as a child. Apart from the silicone lens you read about earlier in the lesson, he is also trying to invent a new 3-D imaging system that can create holograms of living biological cells. It sounds like something straight out of a sci-fi movie, but Steve is determined to turn it into a reality. His other projects include utilising astronomy techniques to turn biological tissues transparent, and high-resolution miniature endoscopes to detect tiny cancer cells that would otherwise be hidden in a living body.

Although running a lab involves a diverse range of responsibilities, his favourite task is to brainstorm new projects. Steve loves innovating and coming up with fantastic new ideas to solve difficult problems.

When he isn't working, he enjoys practicing a form of martial arts called Wushu. He also looks forward to his early morning jogs.



## Question 1

**Imagine:** You are a software developer and have just been informed that Steve Lee's lens will be built into an upcoming smartphone. What app would you develop with this new lens in mind and why?

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