



**Left:** Coloured three-dimensional computed tomography (CT) scan of the heart and its blood vessels

# Medical imaging

## GCSE key words

Electromagnetic spectrum  
Radio waves  
Microwaves  
Infrared radiation  
X-rays  
Gamma rays

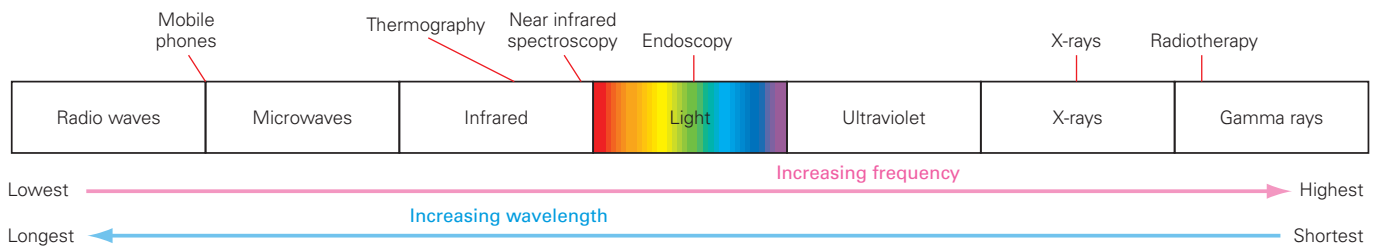
*Microwaves, infrared, ultraviolet and X-rays are all electromagnetic waves. Why are some used to create medical images and others to treat disease? Here, we focus on how the electromagnetic spectrum is used by medical physicists to create images of body organs. In the next issue, we will look at how radioactivity is used in diagnosis and therapy.*

**M**ost people have had an X-ray. It might have been at the dentist's or to identify a broken bone. X-rays are particularly good at generating images of teeth and bones because they cannot pass easily through the calcium in these hard tissues. Bones and teeth absorb X-rays more than soft tissues, such as muscle and fat, so they show up on an X-ray image as shadows. In the 110 years since X-rays were discovered, they have become an important tool for doctors.



**X-rays are produced by X-ray machines or linear accelerators; gamma rays come from radioactive sources.**

**Left:** This fuzzy image is the first medical X-ray picture. It was taken by Professor Wilhelm Röntgen in 1895 and is an image of his wife's hand. The bones of her hand and her wedding ring absorb X-rays strongly so they show as a shadow in the image



**Figure 1** The electromagnetic spectrum

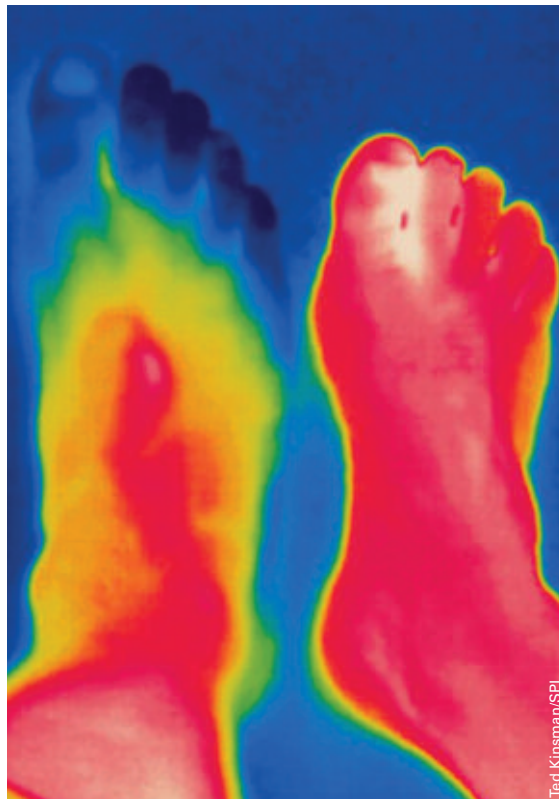
More recently, other parts of the electromagnetic spectrum (Figure 1) have been used by medical physicists to investigate the body (**diagnosis**) and to treat illnesses (**therapy**). This article looks at how extraordinary images of structures in the body can be created and how inaccessible parts of the body can be examined using various parts of the electromagnetic spectrum.

### Thermography

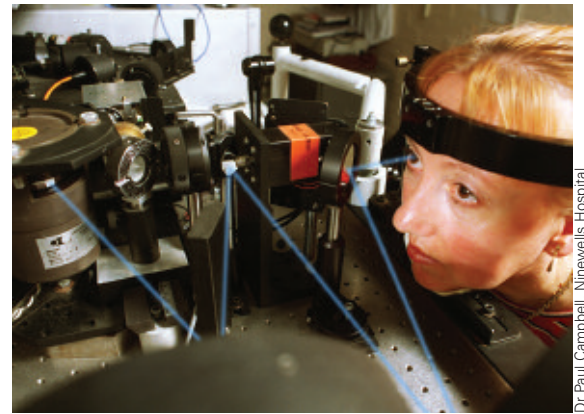
Blood comes from the core of the body and is warmer than the skin, so measuring skin temperature lets us determine whether the blood circulation is healthy or not. A thermogram is a picture of the body which shows the skin temperature.

The first thermogram was done by Hippocrates in Ancient Greece in about 400 BC, although he did not use a camera! He covered the body with clay and watched where it dried out first. The place where it dried out first was the warmest part of the body and might show an infection or other inflammation. Nowadays, we use a camera that is sensitive to infrared light.

Radiations in the electromagnetic spectrum all travel at the speed of light in space — 300 million m/s.



**Right:** Thermogram of poor circulation in a human foot (left) compared to a normal foot (right). The temperature range goes from hot (white) to cold (blue)



A scanning laser ophthalmoscope

### Lights in your eye

Bright light in visible wavelengths allows an ophthalmologist (an eye doctor) to examine a patient's eyes. A scanning laser ophthalmoscope, for example, detects light reflected from the back of the eye and can detect problems with the retina. Blue light gives information about the surface of the retina, while red light can pass through the first layers and tell us about deeper layers. It can help to prevent blindness due to retinal damage in people with diabetes.

### Near infrared spectroscopy

Psychologists would like to know how the brain develops from birth to adulthood. Like muscles, the brain needs blood to bring oxygen to parts which are active. Infrared light is absorbed very strongly by blood. If a region of the brain becomes more active, it receives more blood, and so it will absorb near infrared light more strongly.

Taking measurements of infrared light absorption tells us about the location of activity and the speed of activation in the brain. This is a safe way to detect brain activity, which can be used in children and adults. The system can also be used to monitor and check the blood flow in brains of premature babies.

### Endoscopy

An endoscope is used to look deep inside the body. Traditional endoscopes were rigid and therefore uncomfortable. A modern endoscope is highly sophisticated and is so flexible it can even be steered around twists in the intestines.

The first flexible endoscopes used total internal reflection to direct visible light down an optical fibre



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An X-ray image of an endoscope coming down the oesophagus, into the stomach and across into the small and then large intestines

to illuminate the tissue, and then to carry light back up to the fibre to the viewer. Modern endoscopes may use miniature video cameras. They are used not only to make diagnoses, but also to guide instruments inserted through small incisions to carry out keyhole surgery.

### X-radiography

Computed tomography (CT) uses X-rays to make a three-dimensional image of the body. It is easier to identify different tissues in a CT image than in a normal X-ray image. Medical physicists make use of the improved contrast in this type of image to extract the shapes of bones and muscles.

### Mobile phones

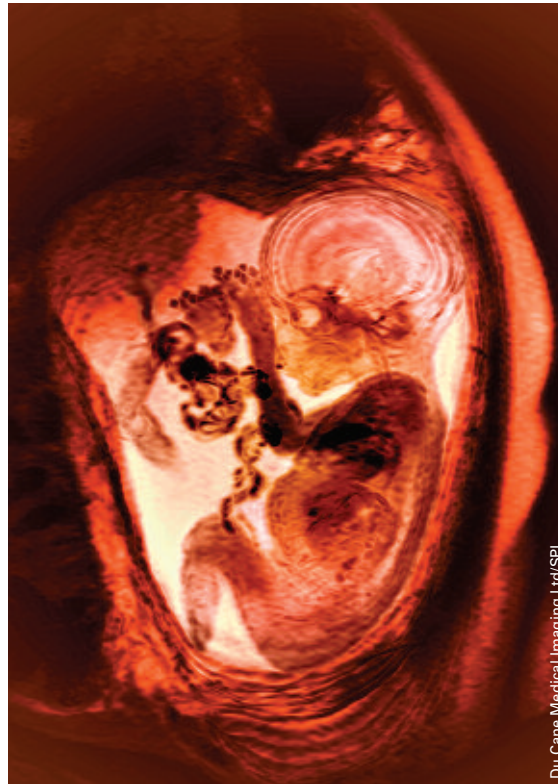
In the September issue of CATALYST we described the working of and issues raised by the use of mobile phones. Medical physicists are involved in examining the possible effects of mobile phones on our brains.

#### Box 1 Useful websites

Take a look at:

[www.crd.ge.com/esl/cgsp/projects/medical](http://www.crd.ge.com/esl/cgsp/projects/medical) where you will find some Quicktime movies constructed from CT scans.

See images from University College London at: [www.medphys.ucl.ac.uk/mgi](http://www.medphys.ucl.ac.uk/mgi)



Du Cane Medical Imaging Ltd/SPL

**Left:** Coloured three-dimensional MRI scan of a human foetus in the uterus

Mobile phones use electromagnetic radiation with a wavelength of between 30 cm and about 1 m, close to microwaves. Microwave ovens use higher energy radiation, with a wavelength of about 10 cm. If 10 cm waves can cook food, might wavelengths not that much longer heat you when you use your phone?

Medical physicists use computer programs to calculate the effect of mobile phones on our brains. Although their images show that any heating which may occur is not enough to worry about, mobile phone radiation may affect the brain in other ways. Therefore, following advice from medical physicists performing calculations like these, the government advises young people to make mobile phone calls only when necessary.

### Magnetic resonance imaging (MRI)

The production of MRI images depends on a natural property of matter, called nuclear magnetic resonance. In strong external magnetic fields the atomic nuclei of some elements align themselves in the field, rather like bar magnets. If a radio wave of a particular frequency is applied, the nuclei may realign themselves in the field. The energy absorbed from the radio wave promotes the nucleus to a higher energy level. When the radio wave is switched off the nucleus reverts to a lower energy state. As it does this it emits radio waves at characteristic frequencies. The way this occurs is characteristic of the chemical and physical environment of the nucleus.

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The shorter the wavelength of the electromagnetic radiation, the more likely it is to cause ionisation as it passes through living tissue. This means that gamma rays and X-rays are the most hazardous to living organisms.

Mobile phones now have a published SAR (specific absorption rate) value, which shows energy absorbed during a phone call.

• **Tomography** comes from a Greek word meaning 'to cut or slice'. It is linked to the word 'atom'. Find out how.