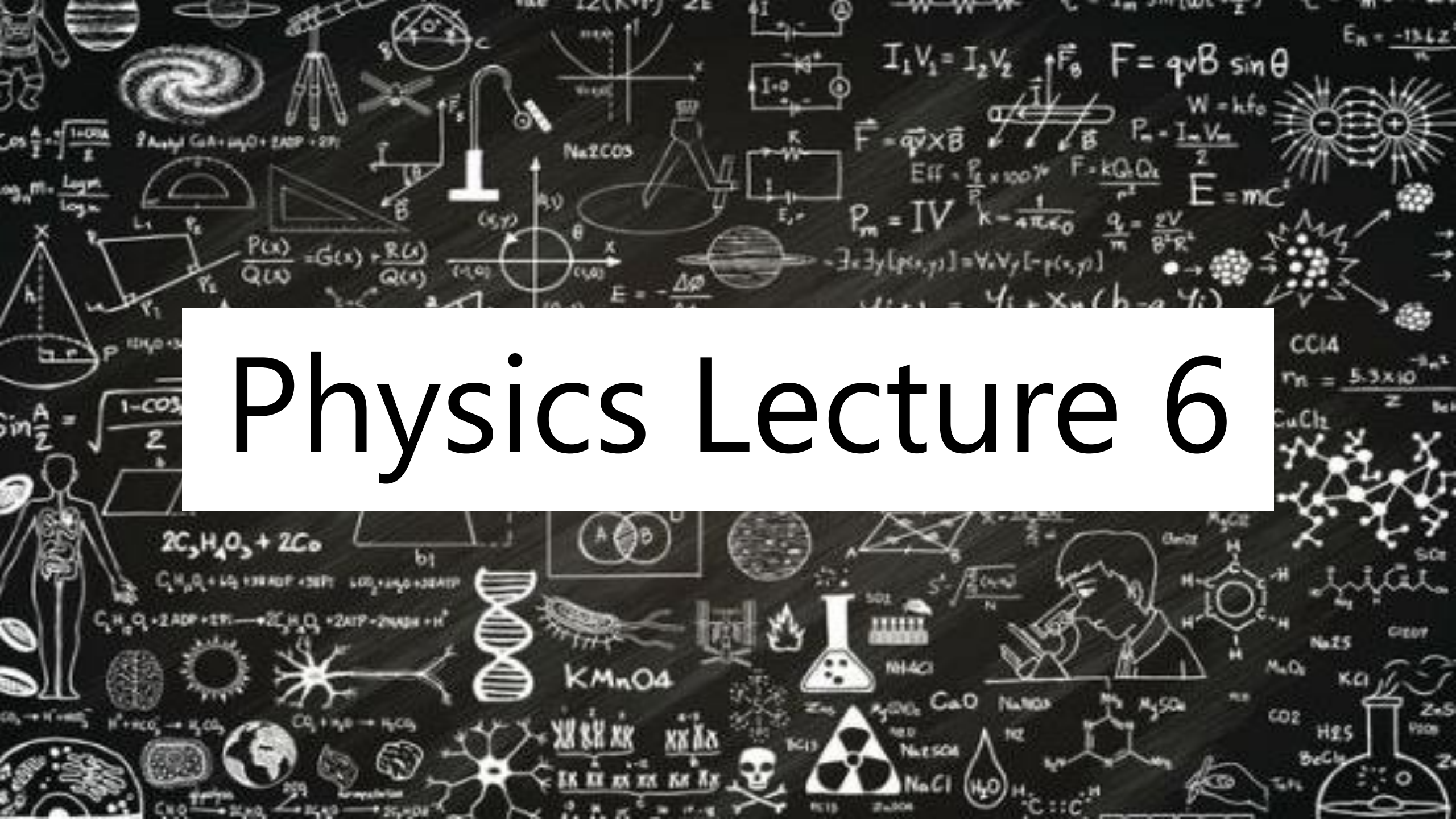


Physics Lecture 6

2: Key protocols

Watch the lecture with your microphone and camera off.

The lecture is being recorded

Post any questions the meetings conversation.

During slides with a black background you should listen and take notes.

During slides with a white background you should complete the task.

3: Questions?

- During the lecture → post on the meeting conversation
  → turn on your microphone and speak

- After the lecture → email me
- rowes@salesian.hants.sch.uk

4: Tasks at home – One Note

- More resources in One Note
- Complete the post-lecture tasks in OneNote Class Notebooks.
- Use the page titled **2020-06-09 Medical Physics**
- Tasks will be teacher reviewed.

5. Objectives

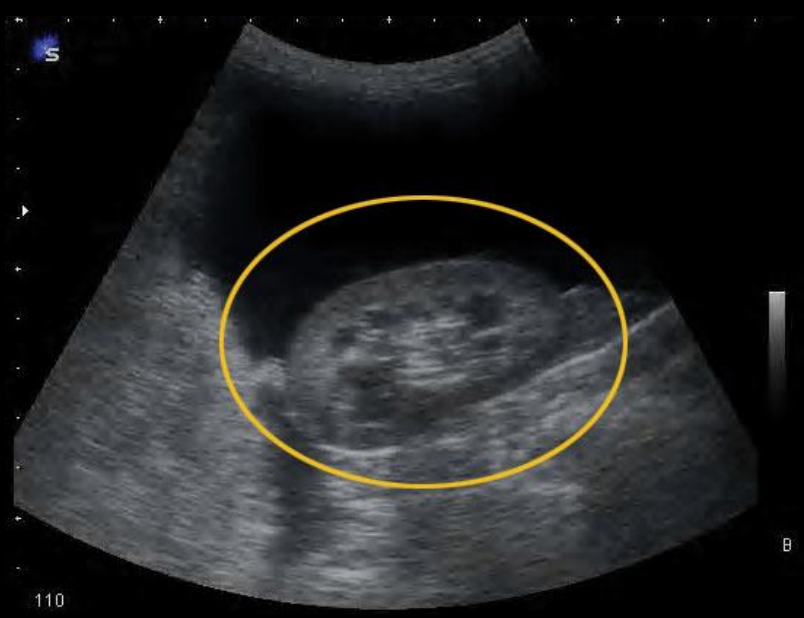
- To explore aspects of physics that are used in medicine:
  - Non- ionising radiation such as visible light and ultrasound
  - Ionising radiation such as gamma radiation and x-rays

- To explore medical techniques which have a firm basis in physics:
  - Endoscopy
  - Ultrasound
  - ECGs
  - Pulse Oximetry
  - X-rays
  - CAT scans
  - PET Scans

Ultrasound

7. Ultrasound Scans

- Ultrasound waves are at frequencies higher than humans can hear
- They travel through solid objects but are partially reflected as they travel from one tissue to another (e.g. skin to muscle)
- The ultrasound transducer both emits and receives the ultrasound waves
- Gel is used to reduce reflection as the ultrasound wave passes from the transducer into the skin
- When an ultrasound scan is carried out, the reflected waves are converted to an on-screen image that shows in real time



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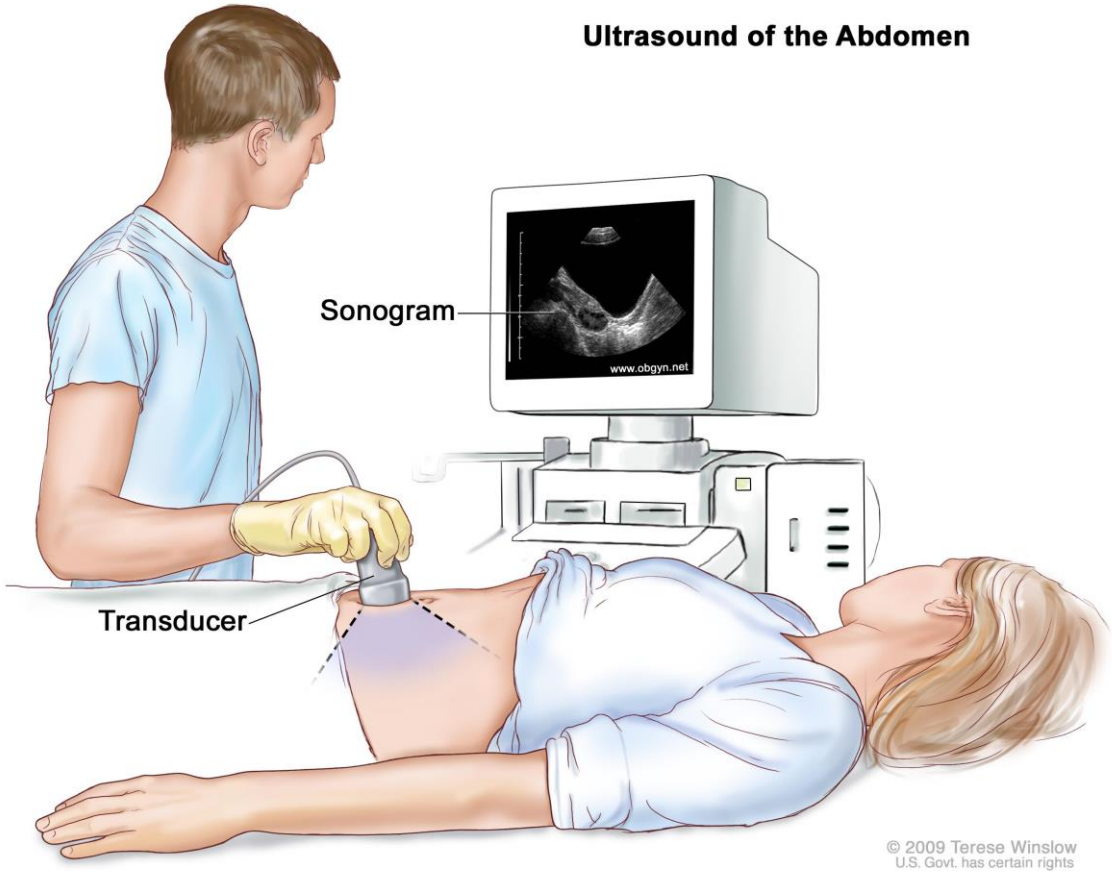
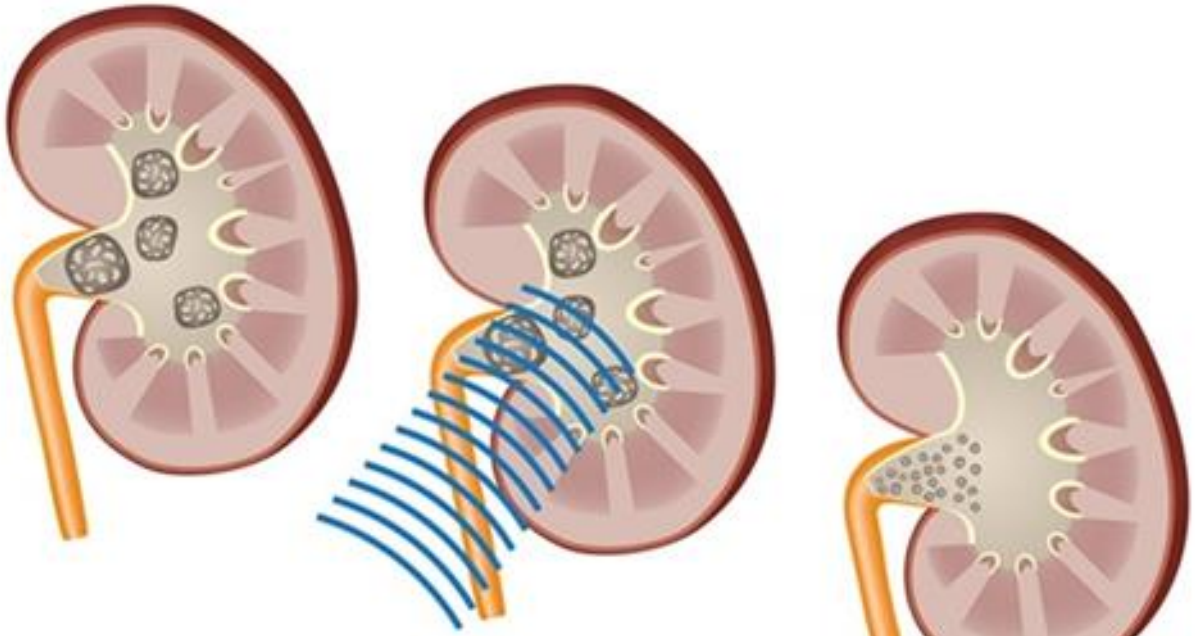
(2 mins)



9. Ultrasound in treatment

- The energy carried by ultrasound waves can be used to treat injured muscles
- Ultrasound waves can be focused and intensity controlled so just the right amount of energy can be delivered to a specific point in the body

KIDNEY STONES



Kidney stones are too big to pass through

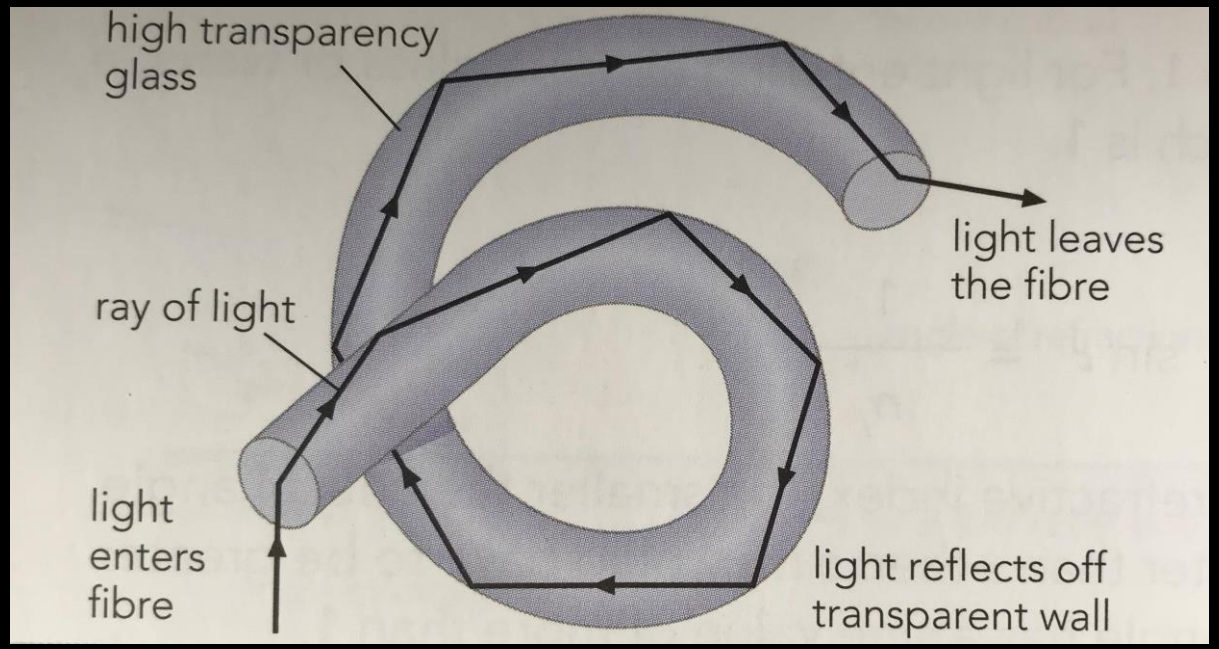
Ultrasound shock waves crush stones

Smaller pieces pass out with urine

Endoscopy

12. Endoscopes

- Relies on the use of optical fibres and on the principle of total internal reflection
- TIR occurs in a medium when the light ray approaches the interface at an angle greater than the critical angle
- The edge of the medium acts like a mirror
- If the optical bends, the light ray is repeatedly reflected back into the fibre



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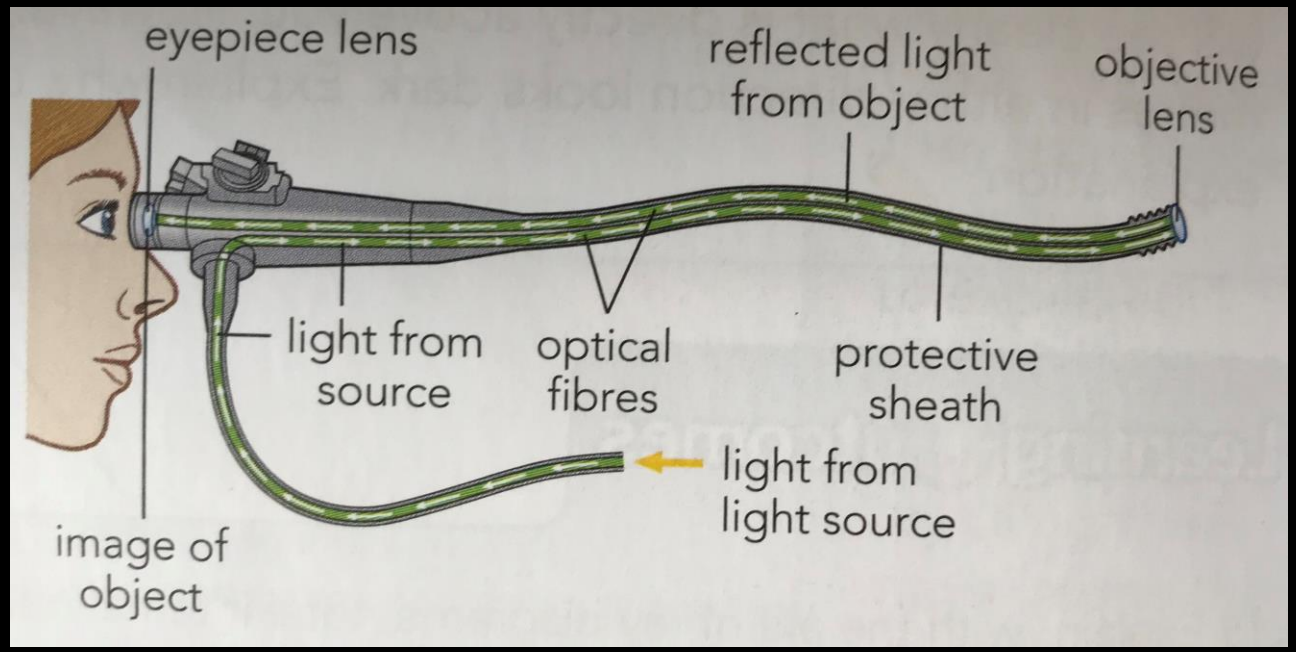
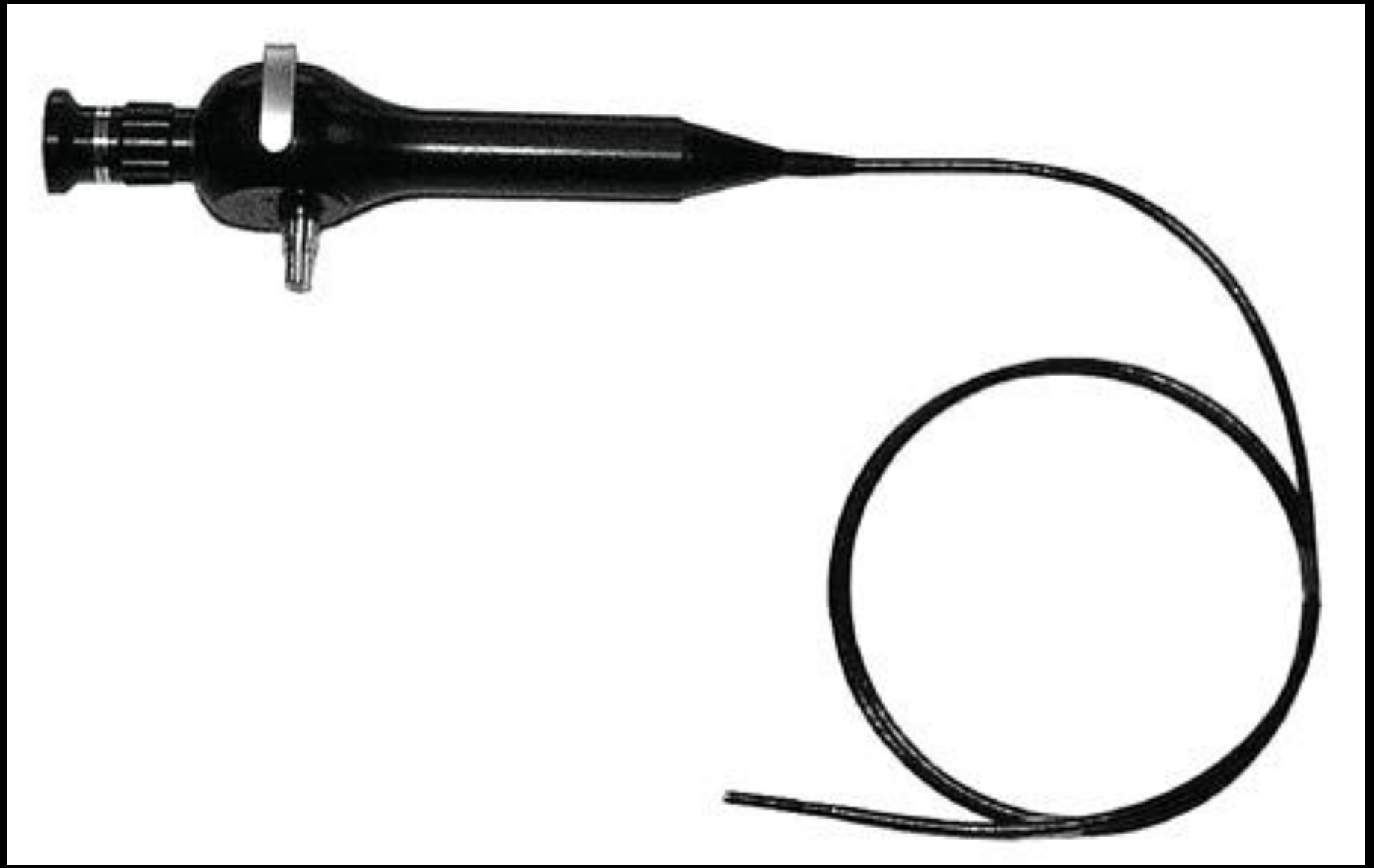
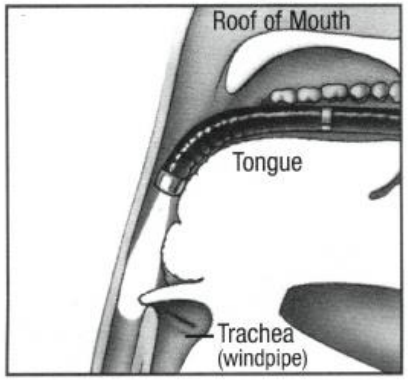
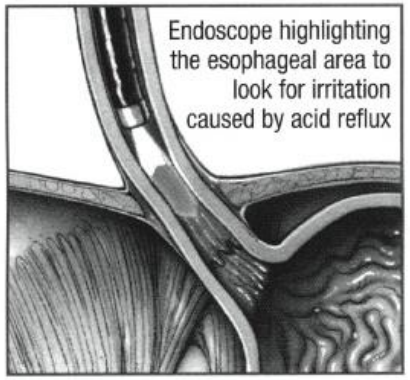


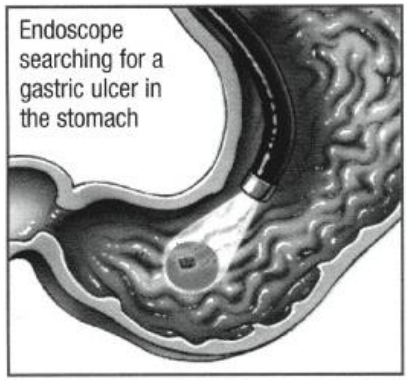
- The endoscope consists of a bundle of optical fibres in a flexible rod
- The rod is inserted into the body
- Some of the optical fibres carry light from an external source
- The light is reflected off the inside of the body, and travels back towards the operator’s eye along more optical fibres

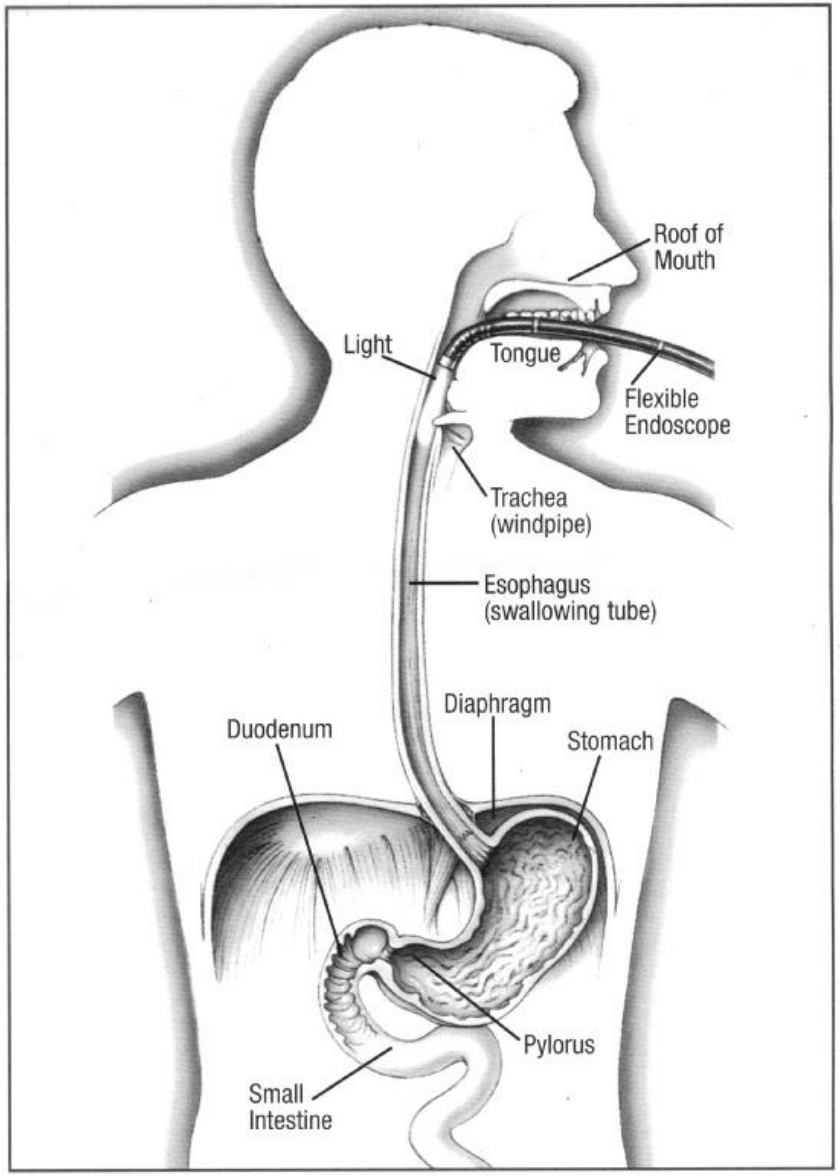


WHAT HAPPENS DURING AN EGD?

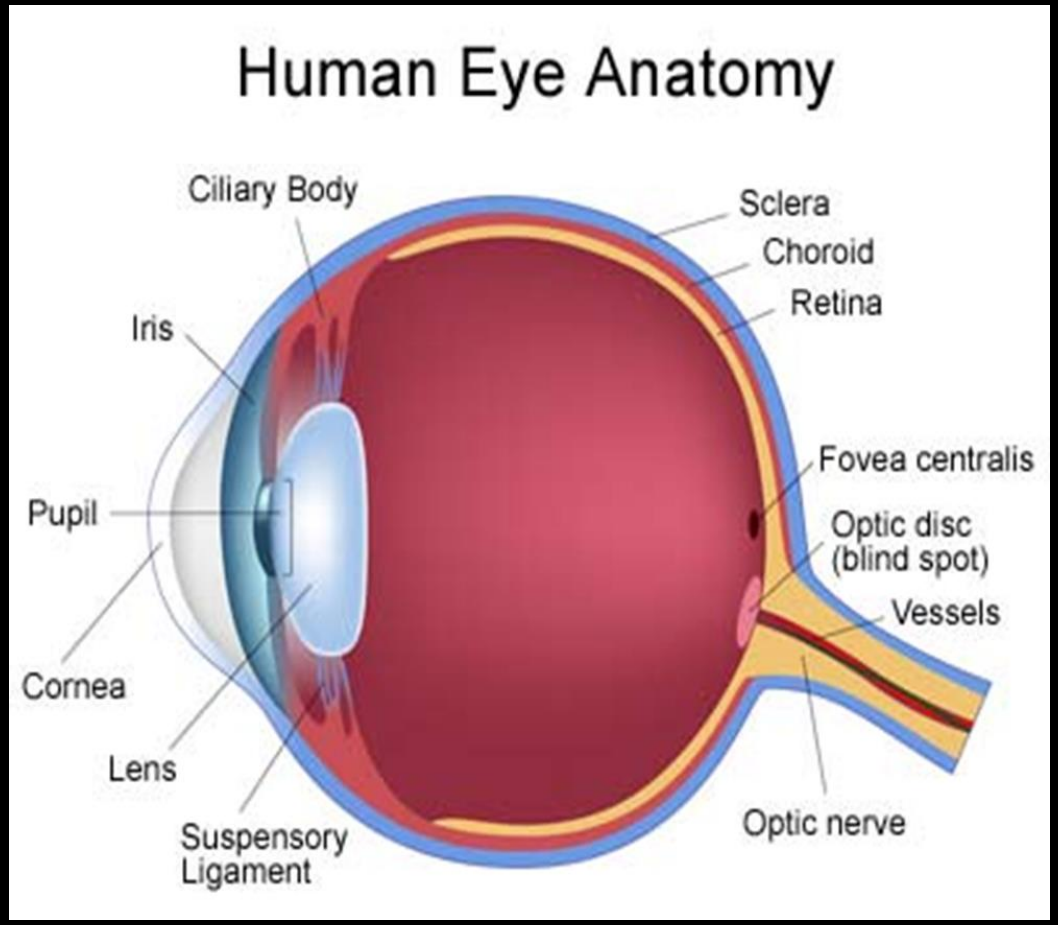








16 Sight Problems



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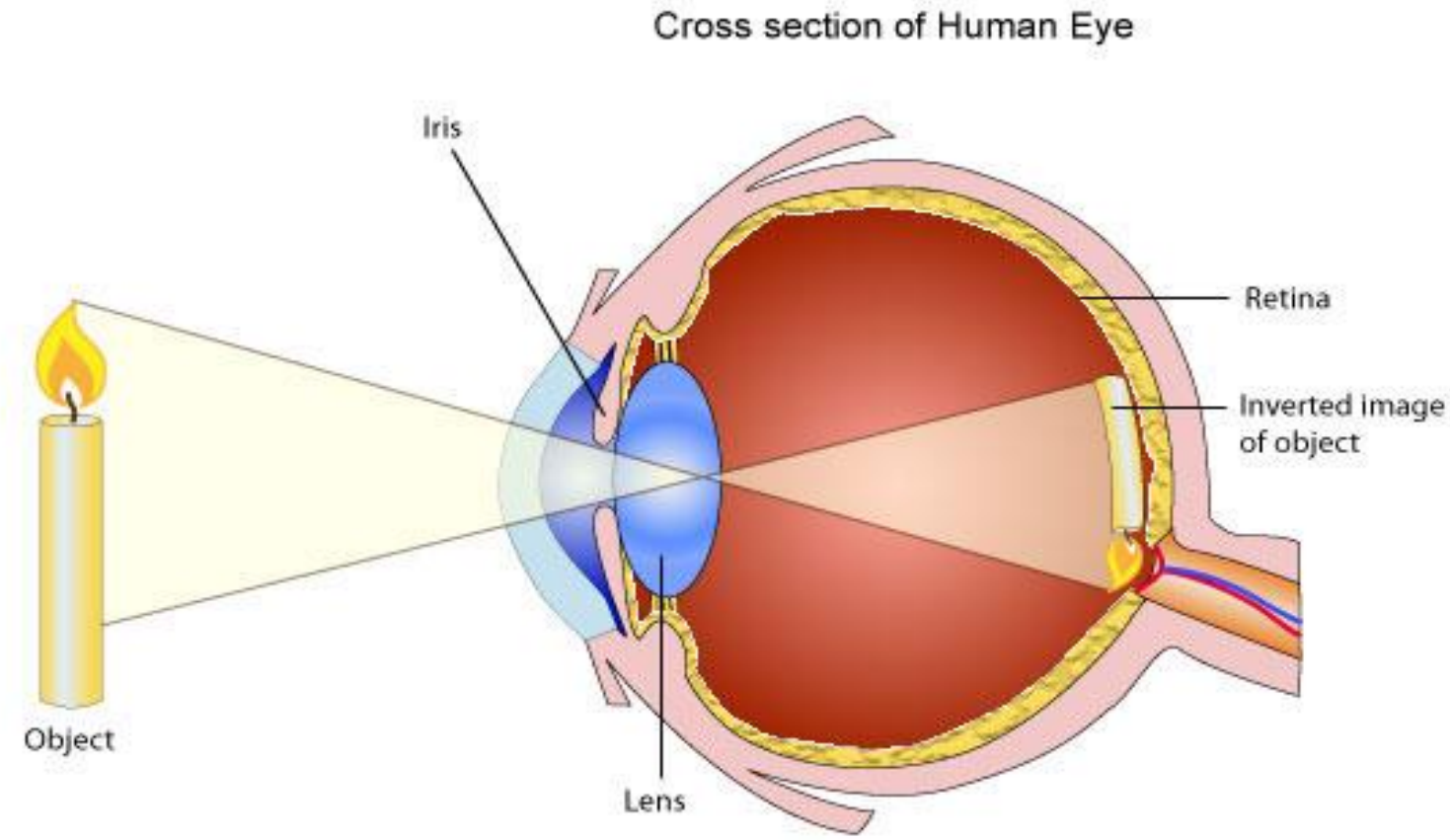
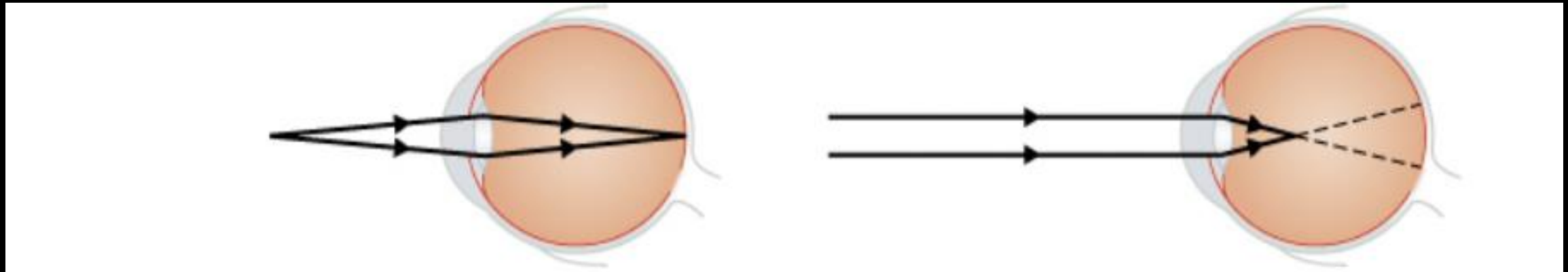
(2.5 mins)



18. Short sight



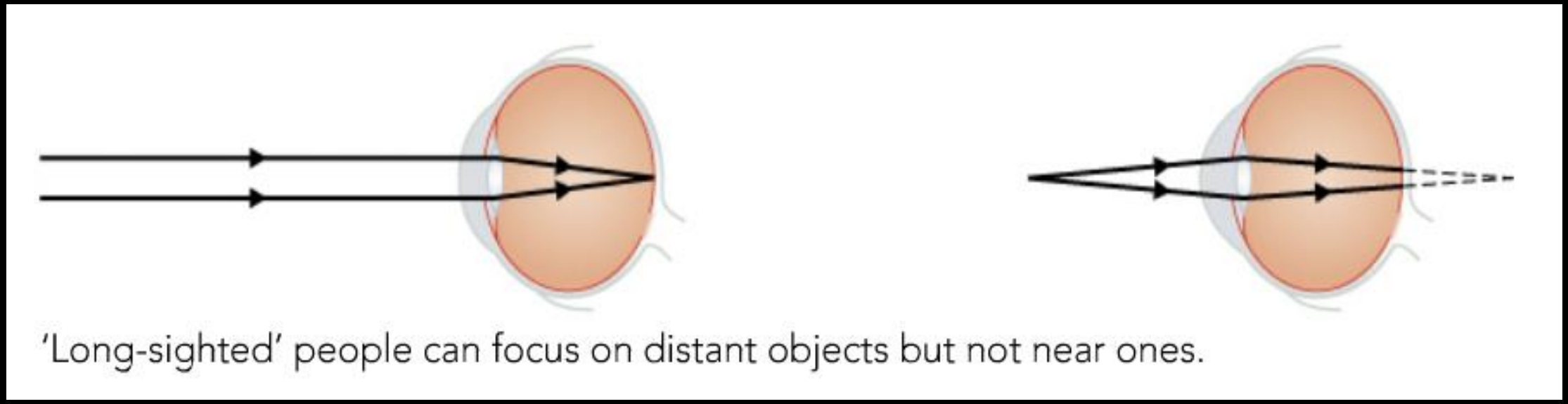
'Short-sighted' people can focus on close objects but not distant ones.

Eyeball may be too long
Cornea may be curved too sharply

In both cases, the incoming rays of light from a distant object are focused in front of the retina

Corrected with diverging lenses

19. Long sight



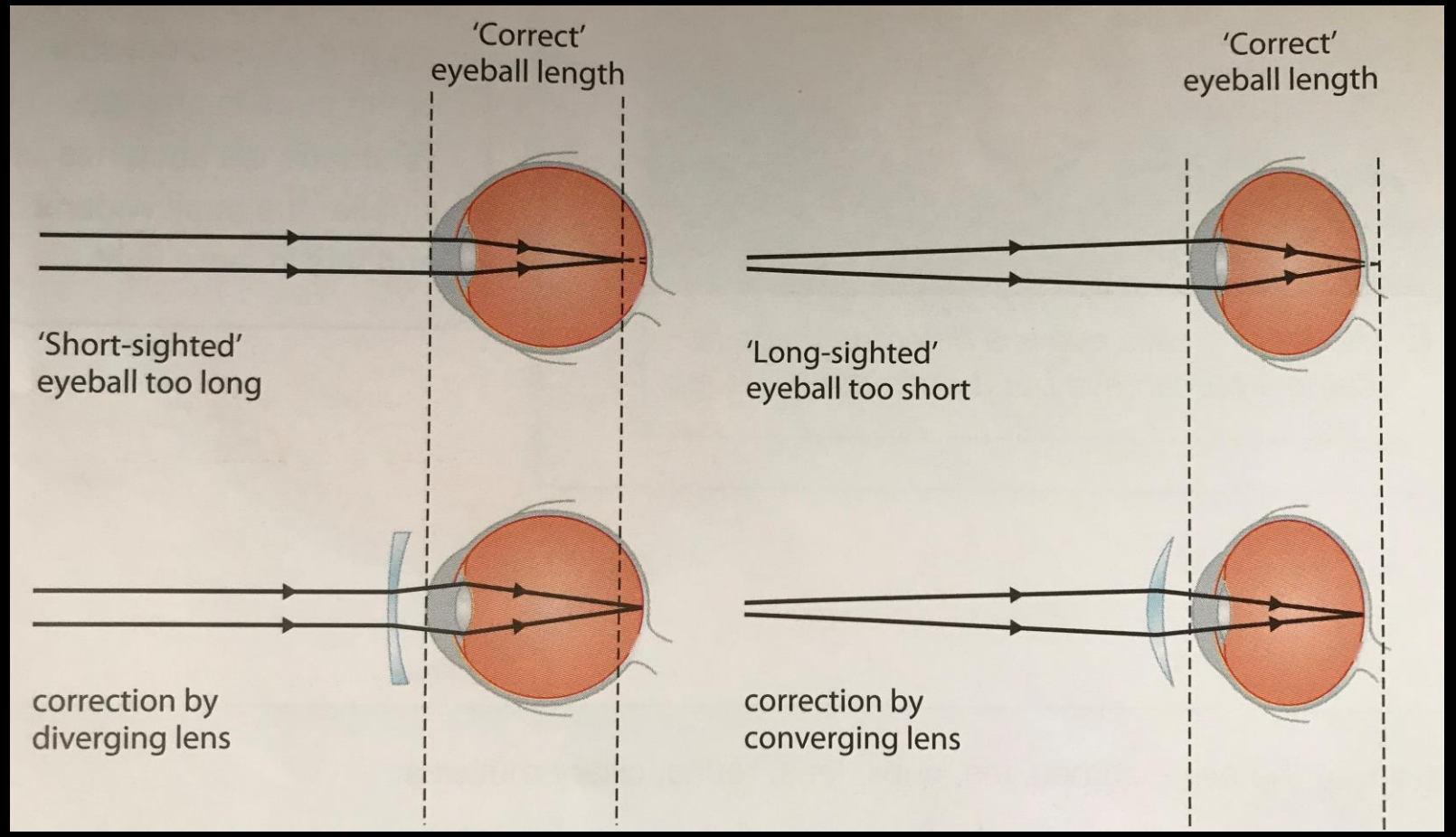
'Long-sighted' people can focus on distant objects but not near ones.

Eyeball may be too short
Lens may not be thick enough or curved enough

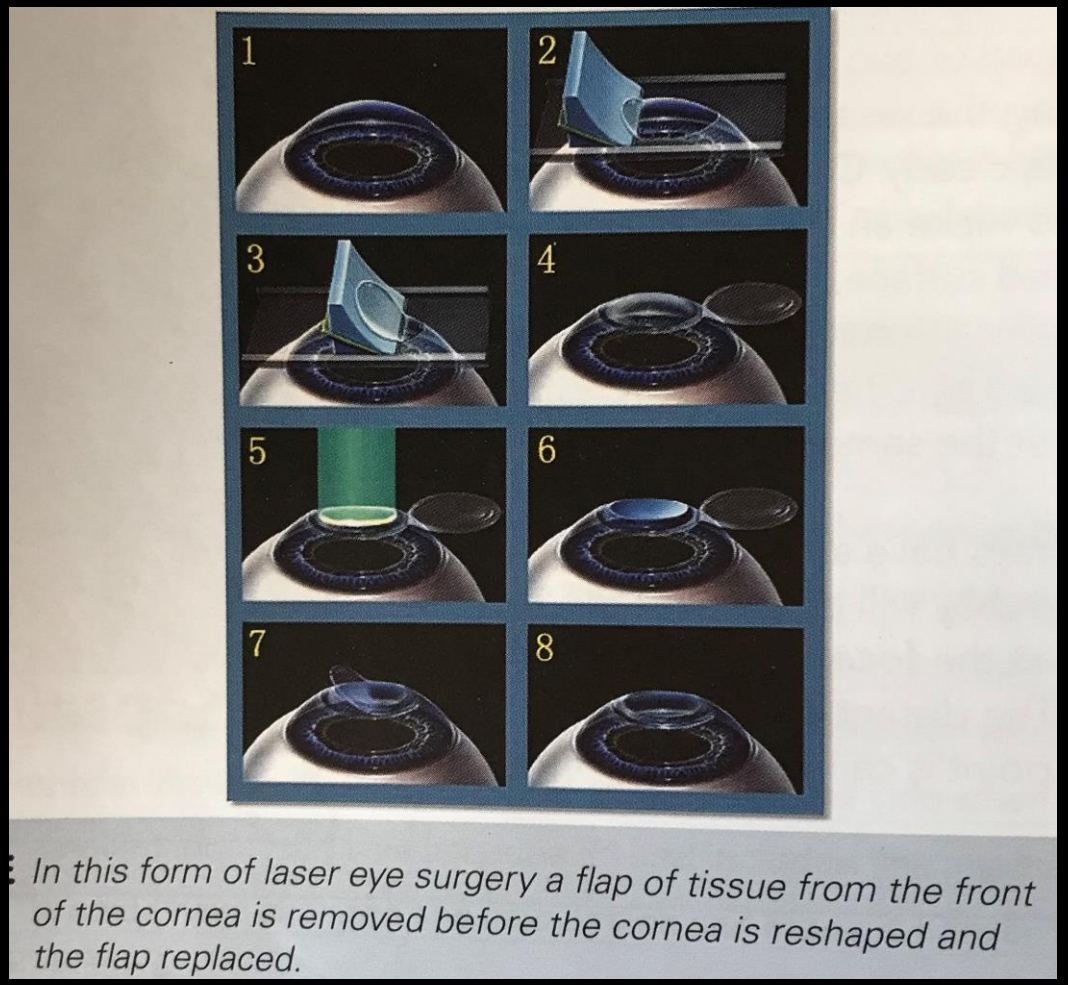
In both cases, the incoming rays of light from a close object are focused behind the retina

Corrected with converging lenses

20. Correcting Eye Problems with Lenses (Spectacles)



21. Laser Surgery



In this form of laser eye surgery a flap of tissue from the front of the cornea is removed before the cornea is reshaped and the flap replaced.

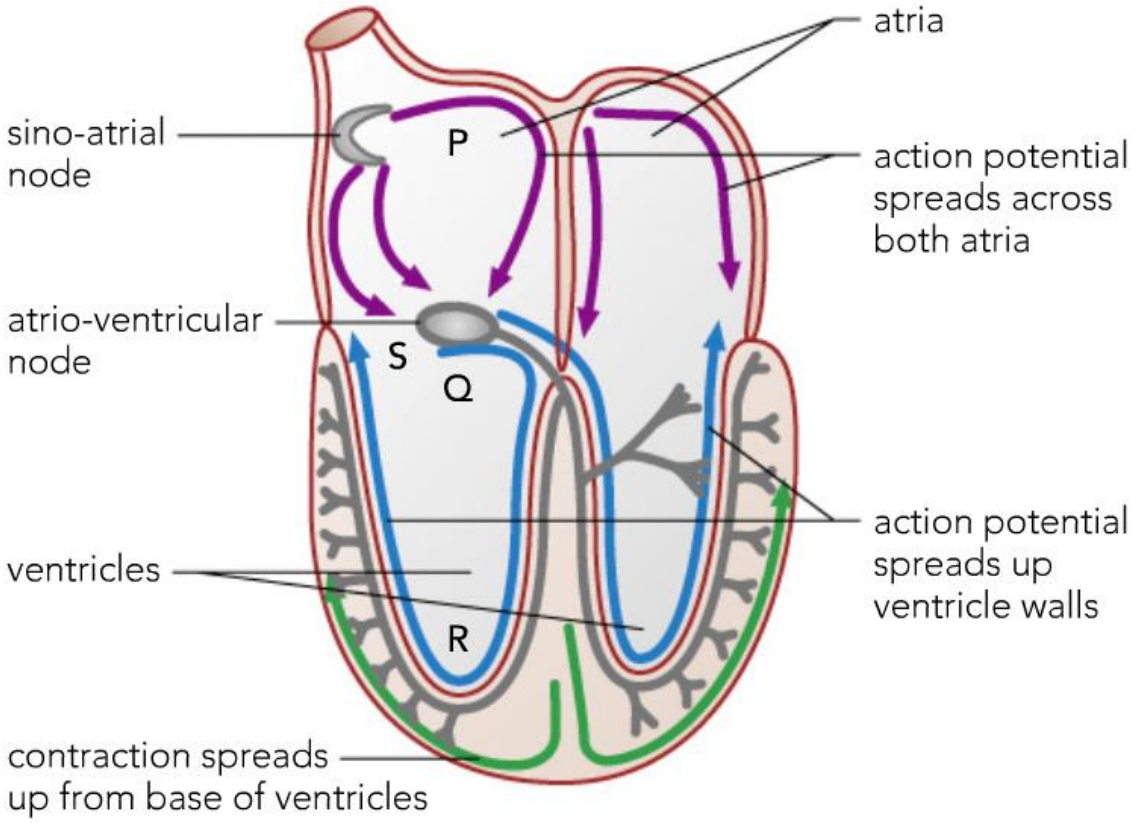
- Laser correction uses a finely controlled laser beam to reshape the front of the cornea
- A laser can make very precise incisions into tissue without damaging the surrounding area
- By permanently altering the shape of the cornea, the point at which light rays meet inside the eye can be changed

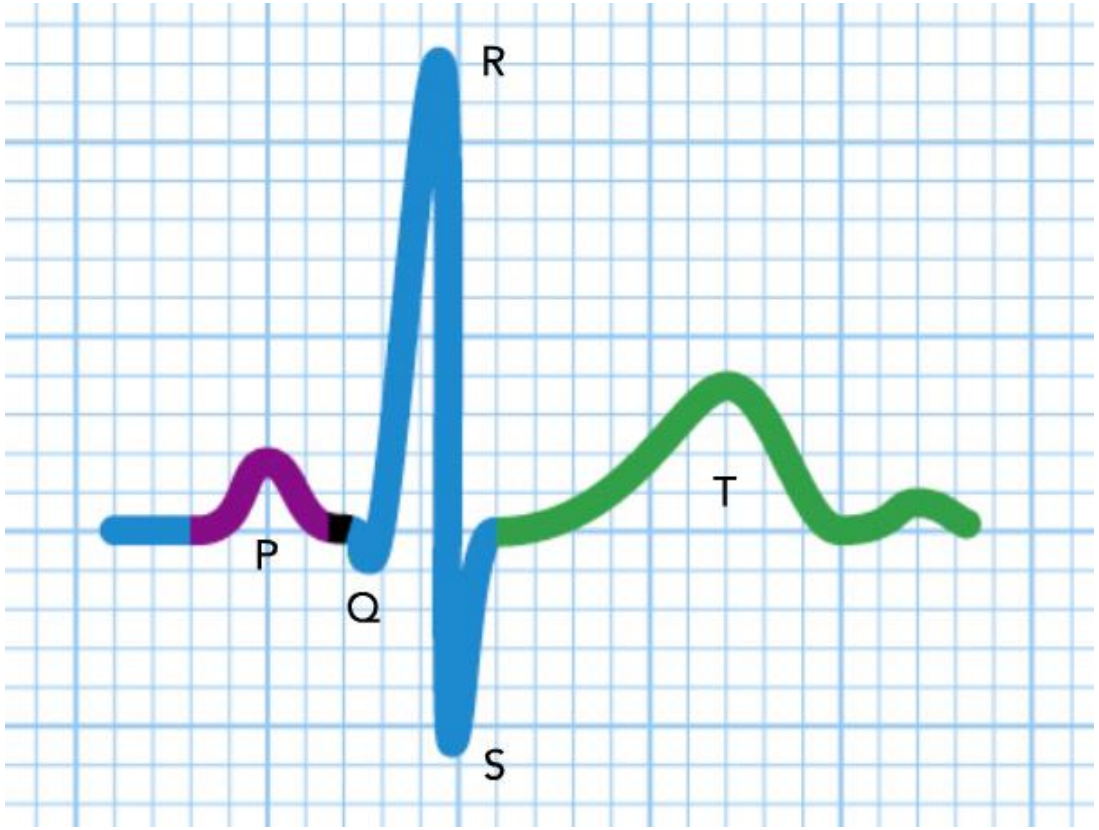
ECG

Heart action

(3.5 mins)

https://www.youtube.com/watch?feature=player_embedded&v=v3b-YhZmQu8

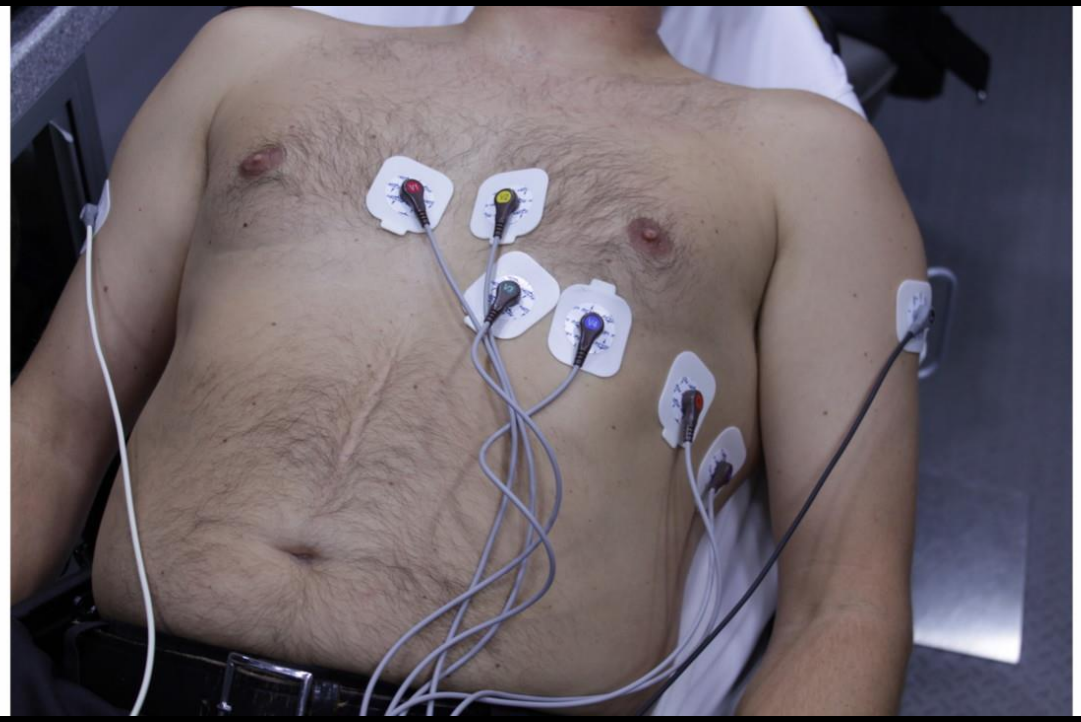




24. When a heart beats:

- Each muscle cell must contract at exactly the right moment to push the blood out of the heart
- An electrical signal (action potential) is sent to each muscle cell to tell it when to contract
- On the ECG:
  - Point P shows the initial electrical signal from the sino-atrial node in the atria – this tells the muscles in the atria to contract
  - Points Q, R, S show the initial sending of an electrical signal to the ventricle walls by the atrio-ventricular node. In the QRS section, the signal spreads through the ventricle walls causing the ventricle fibres to contract. The atria muscles relax at this time, but the signal is hidden by the strong QRS signal.
  - Point T shows the ventricle muscles relaxing

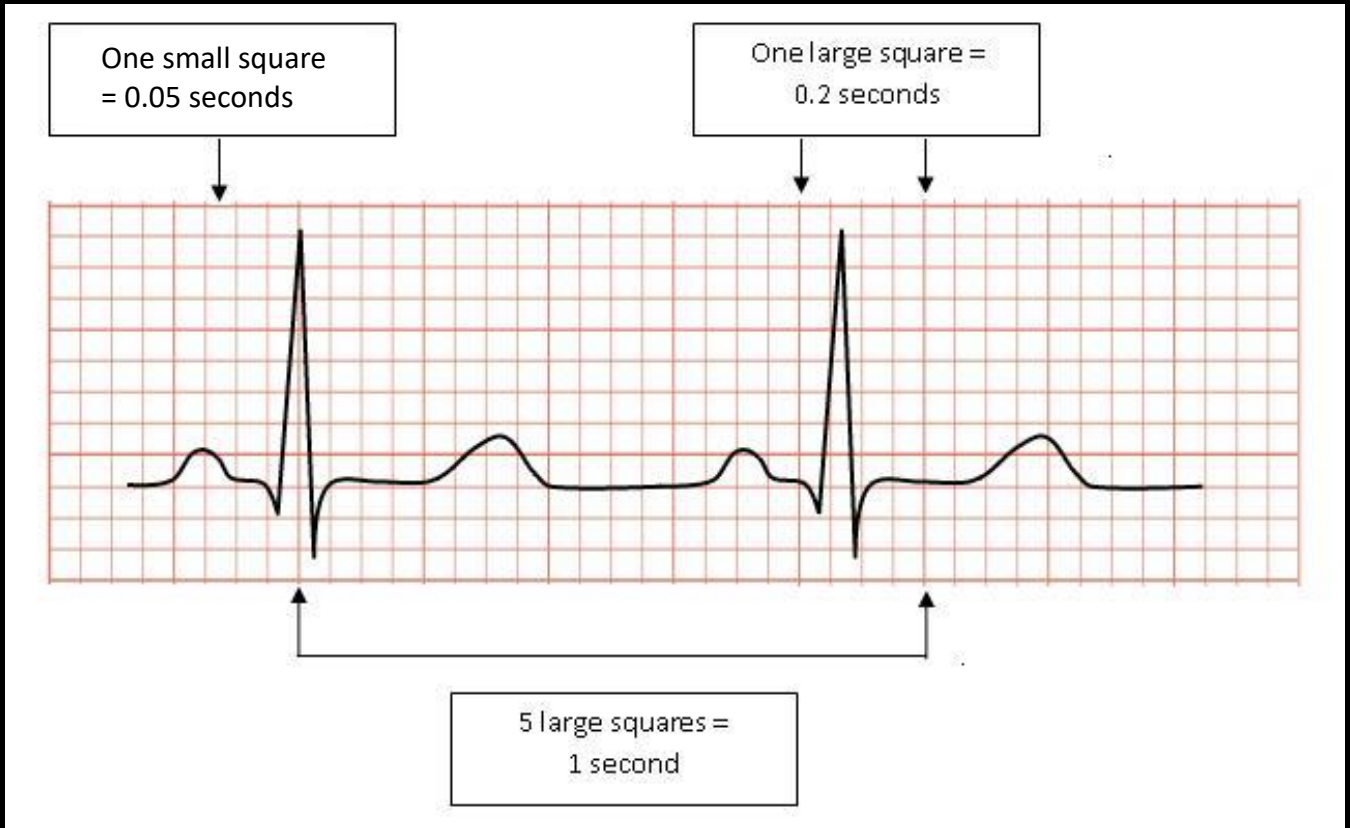
25. Undergoing an ECG



As the body contains a high proportion of water with salt dissolved in it, the action potentials are conducted through the body to the skin

Electrodes are placed at certain points on the body to detect these electrical signals

26. Working out the heart rate



- Horizontal scale is normally 0.2s for every 4 small squares (1 large square)
- Frequency (Hz) = $\frac{1}{\text{time period (s)}}$

On this ECG, time period = 4.2x0.2
= 0.84s

So frequency = 1/0.84 beats per second
= 1.19 beats per second

So beats per minute = 71

Pulse Oximetry

28. Pulse Oximetry

This technique uses two beams of light:

- red light
- infra-red light

29

- These two beams of light can let the pulse oximeter detect what colour the arterial blood is and it can then work out the oxygen saturation. However there are lots of other bits of a finger which will absorb light (such as *venous* blood, bone, skin, muscle etc.), so to work out the colour of the arterial blood a pulse oximeter looks for the slight change in the overall colour caused by a beat of the heart pushing arterial blood into the finger.

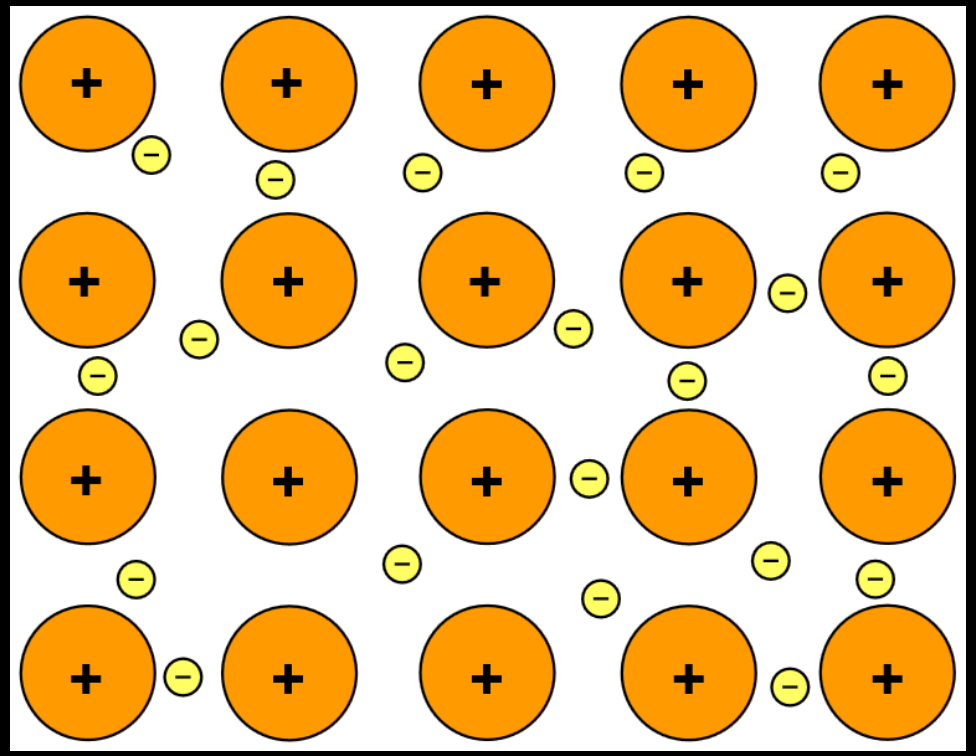
30

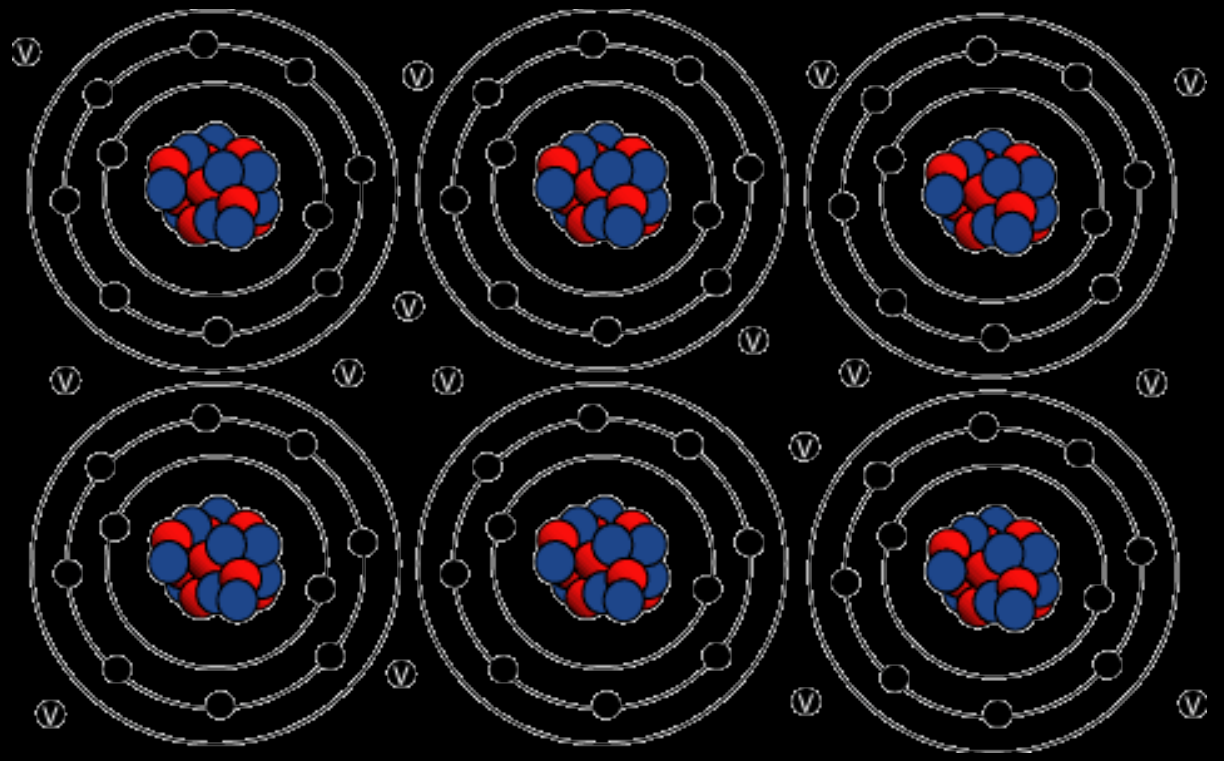
- This change in colour is very small so pulse oximeters work best when there is a good strong pulse in the finger (etc.) the probe is on. If the signal is too low the measured oxygen saturation may not be reliable and lower than this the pulse oximeter will not be able to work.

- SpO_2 reading: Normal readings in a healthy adult range from 94% to 100%.

X-Rays

32. Bonding in metals





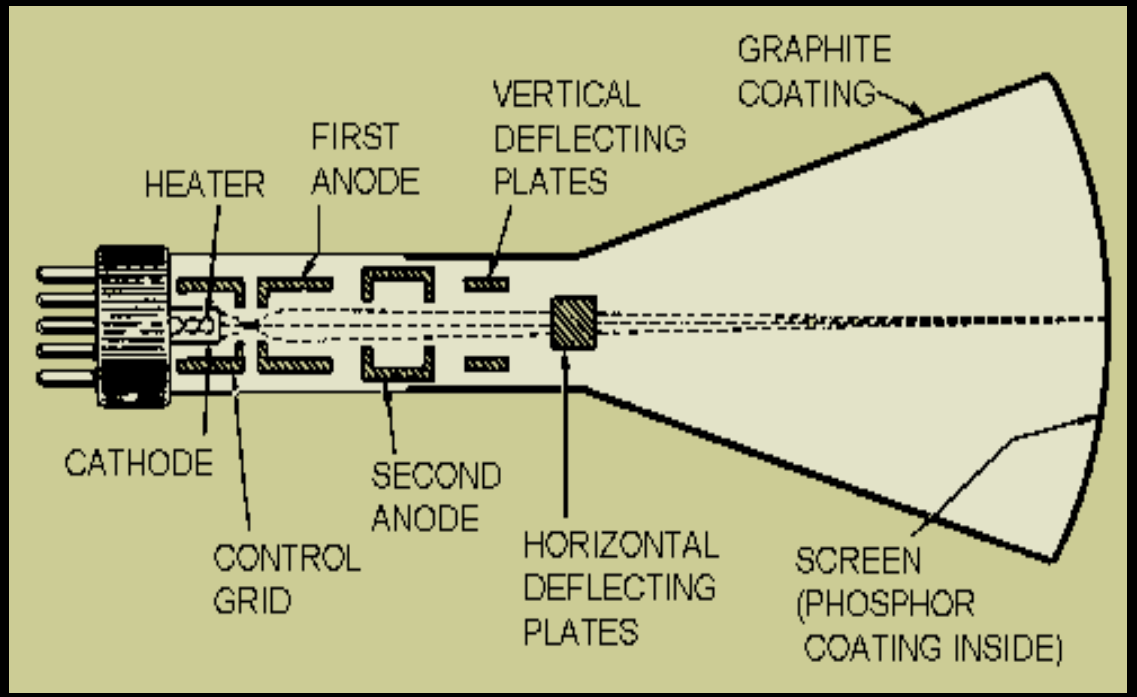
33. Getting electrons to leave the metal completely

- By applying a high voltage

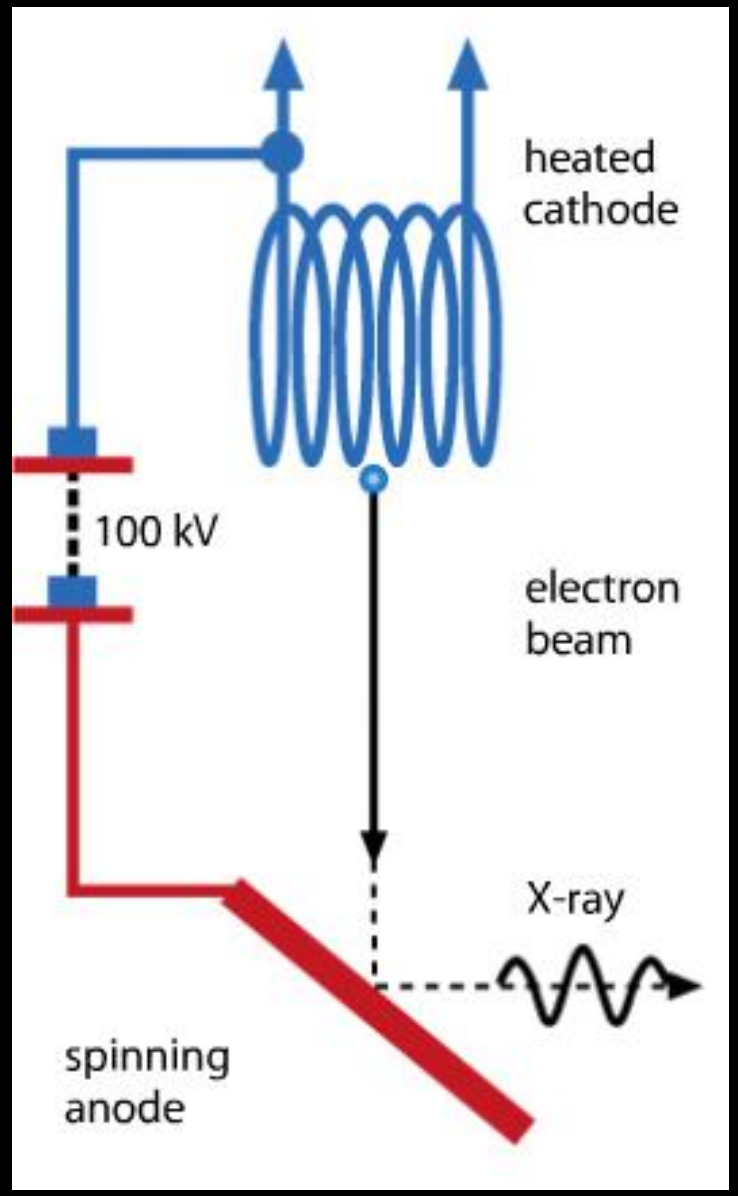
- By heating the metal – thermionic emission

- Electron gun:
  - a metal plate is heated by a small filament wire connected to a low voltage.
  - Some electrons are free to move in the metal – they are not bound to ions in the lattice
  - As the lattice is heated, the electrons gain kinetic energy. Some of them gain enough kinetic energy to escape from the metal surface
  - We sometimes say that the electrons are ‘boiled off’ the surface of the heated plate or that they ‘evaporate’ from it.

- The electrons can be pulled away from the hot surface of the plate by putting a positive electrode (anode) nearby. The anode is created by connecting an electrode to the positive terminal of a power supply, and the hot plate is connected to its negative terminal. The hot plate is then the negative electrode (cathode).



- As soon as the electrons are released from the surface of the hot plate, they are pulled towards the anode. They accelerate and crash into the anode. However, if there is a small hole in the anode, some electrons will pass through, forming a beam of electrons that came from the cathode – or a cathode ray



- The electron beam is a flow of charge so it is equivalent to an electric current and completes the circuit
- The apparatus operates under a vacuum so that the electrons in the beam do not collide with anything on their way to the anode
- When the electrons collide with the anode, they slow down very quickly. Most of their KE is converted to heat energy, but some is transformed into x-rays
- The higher the p.d. between the anode and cathode, the greater the energy of the electron beam and the greater the energy of the x-rays

36. Taking an X-ray image

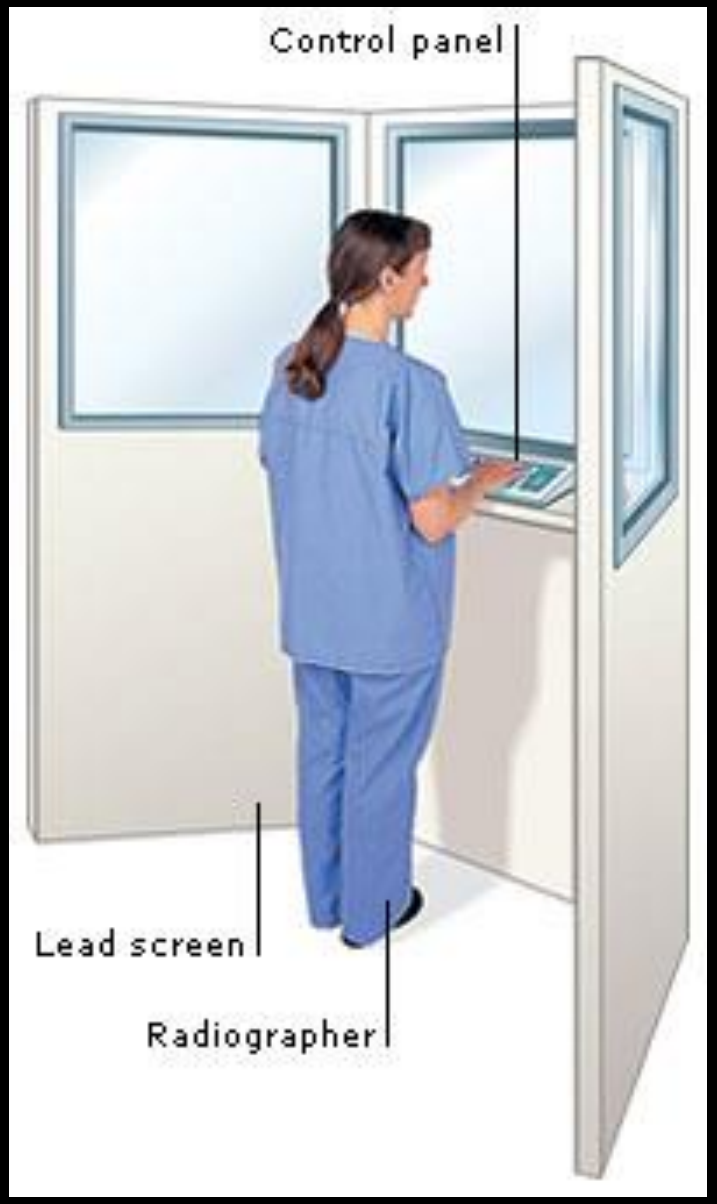
- The part of the body being investigated is placed over a photographic plate
- X-rays pass through the hand
- Different materials absorb different amounts of x-rays
- The denser the material, the more x-rays it absorbs

37. Absorption of x-rays

- Dark areas show that lots of x-rays have hit the photographic plate
- Light areas show where few x-rays have hit the plate
- Bone absorbs x-rays well, so few x-rays pass through to be detected on the photographic plate

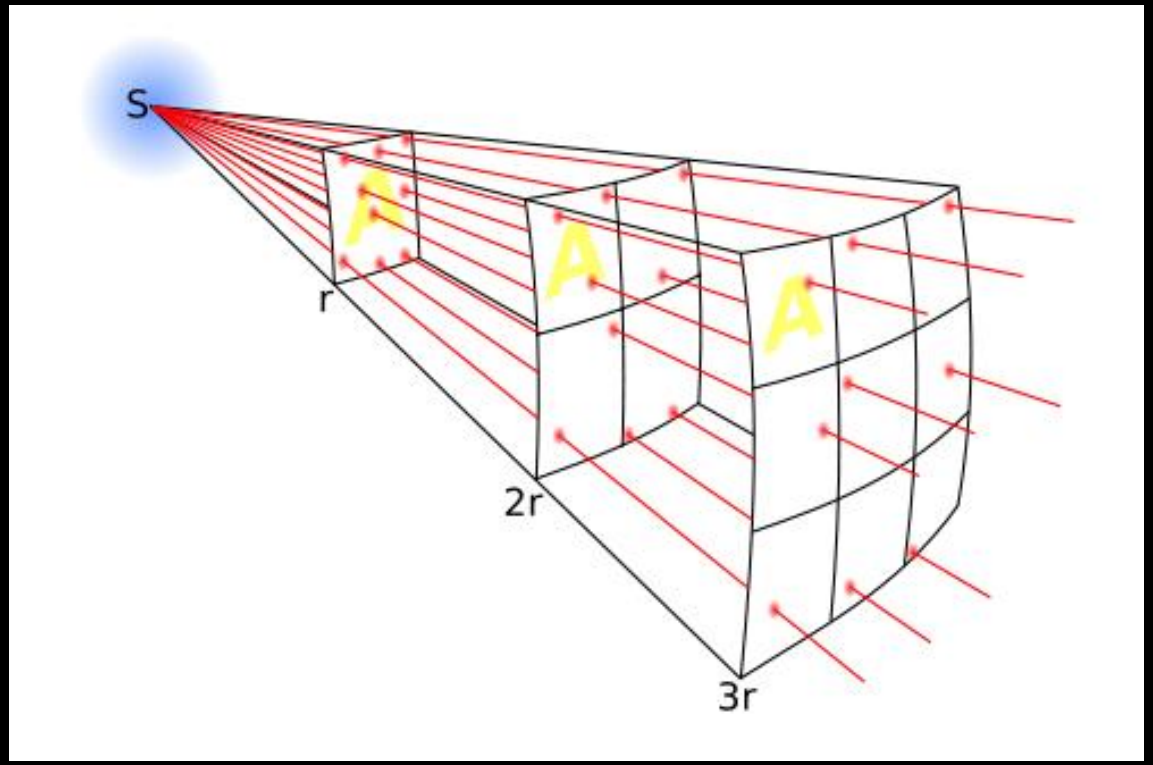
38. Safe Dose

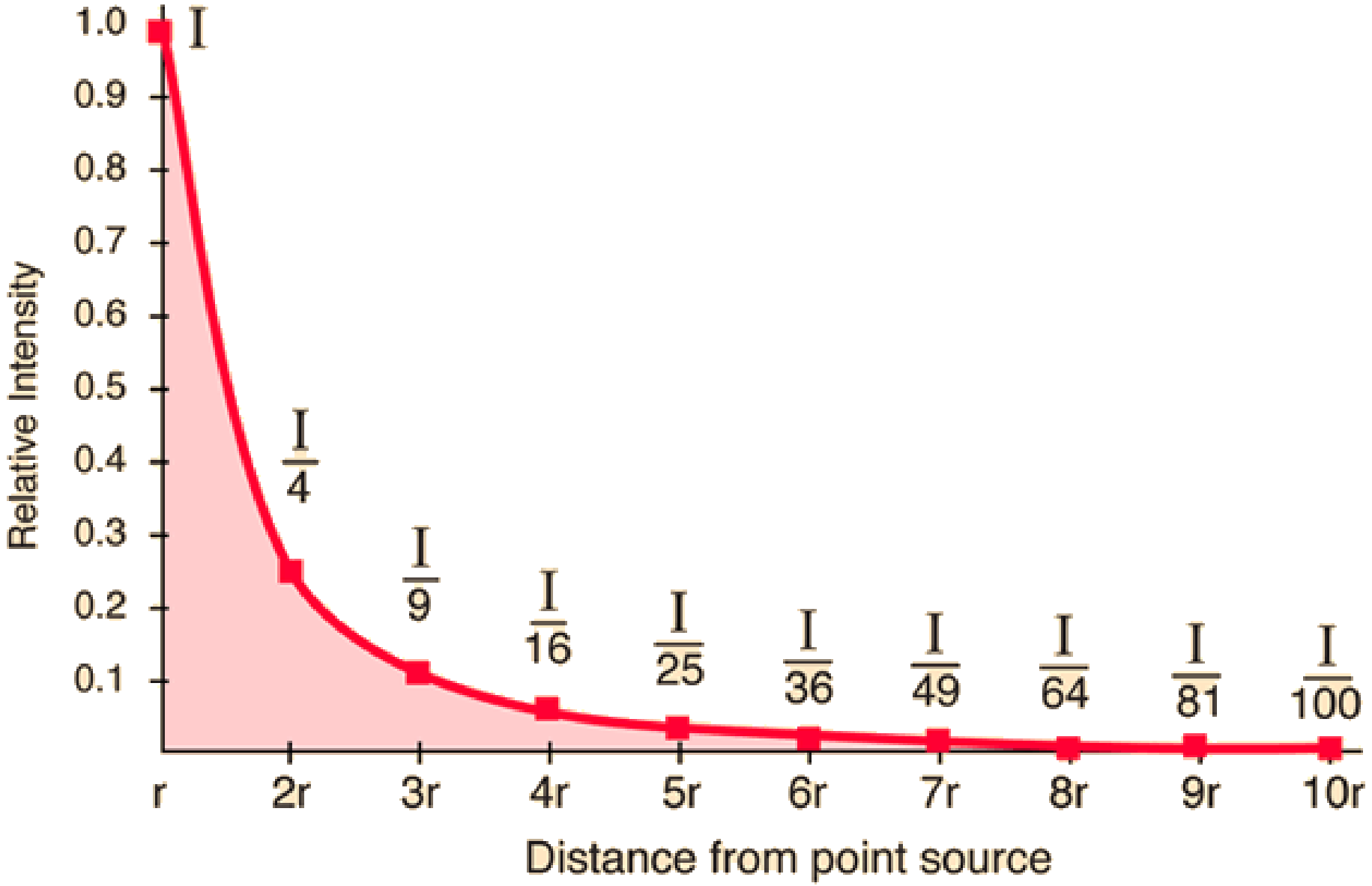
- X-rays are an example of ionising radiation and so prolonger exposure or high doses can be harmful
- Radiographers will stand behind x-ray absorbing screens when taking x-ray images to reduce their exposure.



39. The inverse square law

- The strength of x-ray radiation decreases as you move away from the source
- If the distance from the source doubles, the strength decreases to one quarter of the original strength
- The radiation received per $1m^2$ at a distance of 2r is one-quarter of the radiation received at a distance r

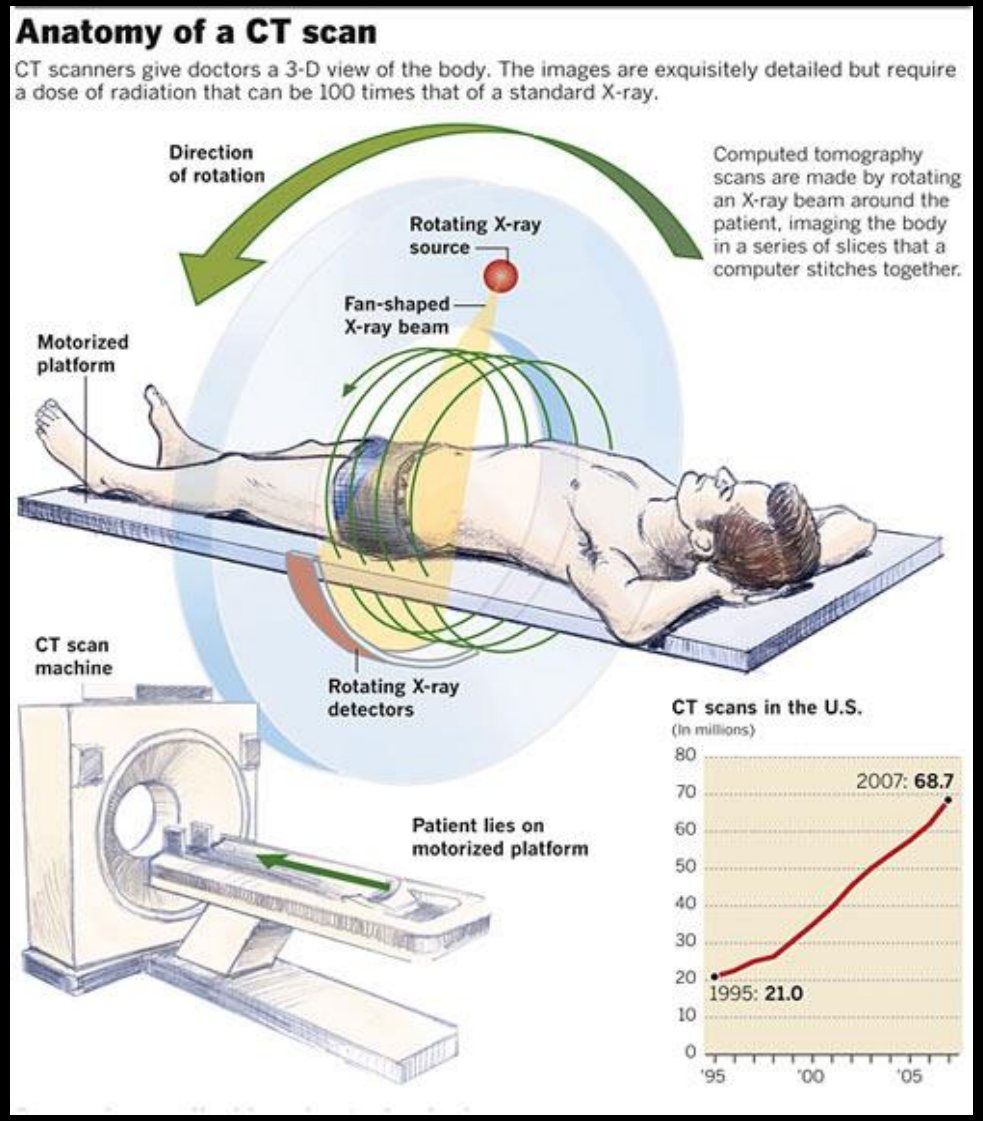



Relative Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
I
I/4
I/9
I/16
I/25
I/36
I/49
I/64
I/81
I/100
r
2r
3r
4r
5r
6r
7r
8r
9r
10r
Distance from point source

41. CAT (computerised axial tomography) scans

- In a CAT scan, the x-ray source is moved around the patient in a circle
- X-ray detectors are positioned opposite the x-ray source
- The x-rays detected are used to build up many cross-sectional views of the body
- A computer can be used to build up a 3-D image

42. CAT scans



CAT scan showing pneumonia

Unusually dark or bright areas can show abnormalities

43. Fluoroscopes

Used to show a patient's organs working in real time

The patient is placed between an x-ray source and an x-ray detector.

The detector is attached to a video camera.

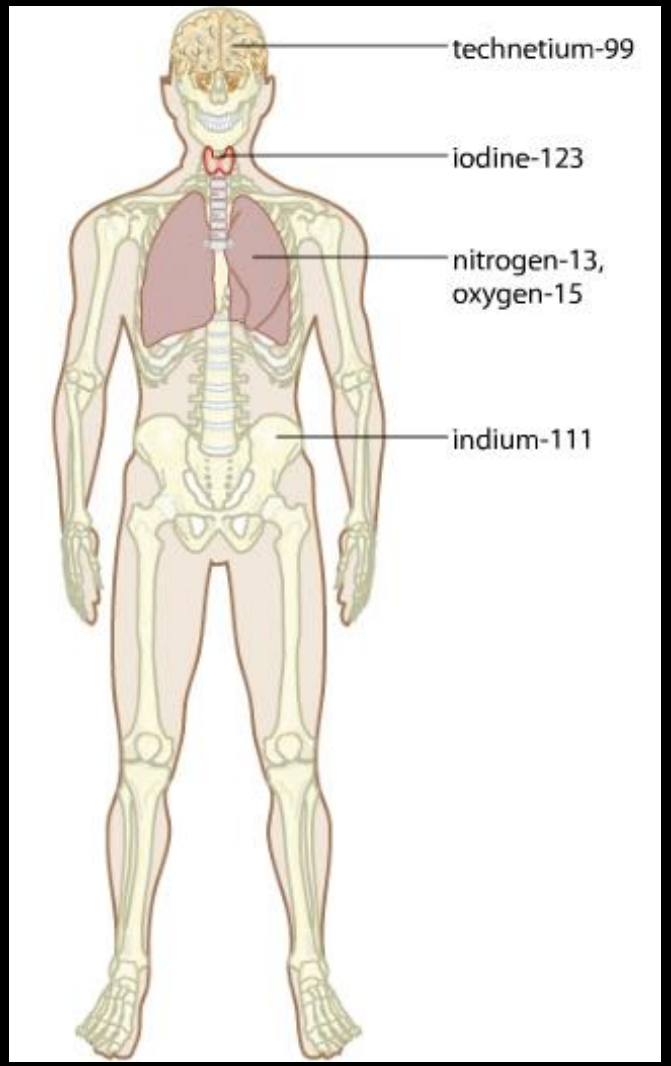
Fluoroscopes and CAT scans result in the patient receiving a much higher does of radiation than when a normal x-ray image is taken

- https://www.youtube.com/watch?feature=player_detailpage&v=umnnA50IDIY

PET Scans

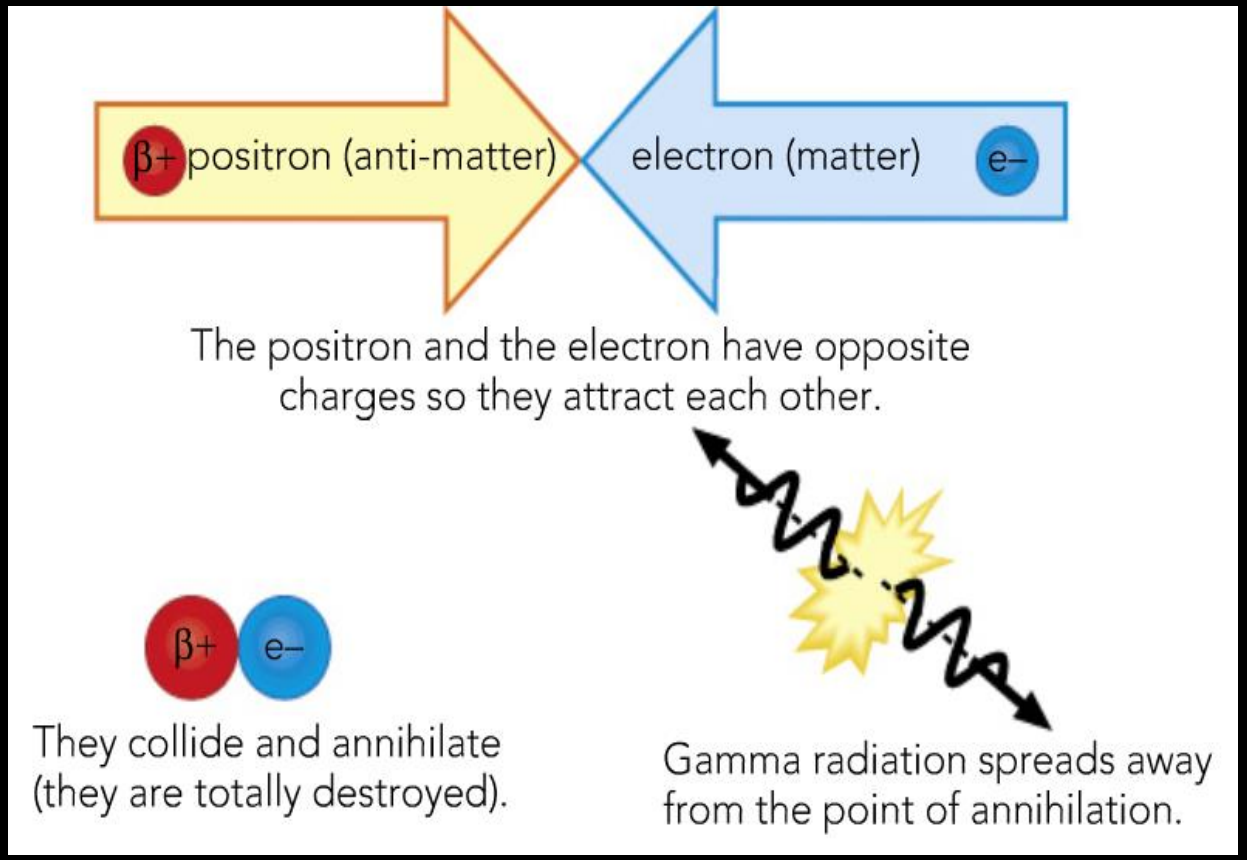
45. Use of radioisotopes in diagnosis

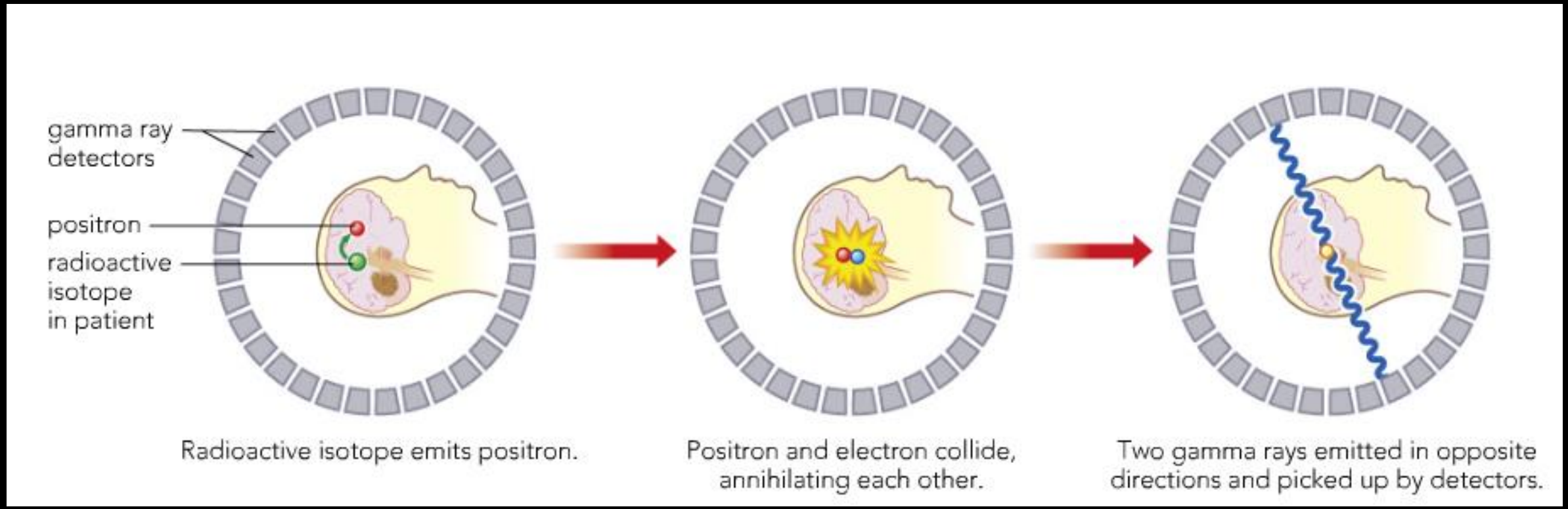
- A tracer molecule is made
- This contains radioactive isotopes
- The radioactive isotope is chosen such that uptake by cancer cells is high
- The tracer is injected or breathed in
- It will be absorbed by a specific part of the body
- A PET scanner is used to detect the radioactive isotope in the body
- Must have a short half life to minimise effects on other body parts – so must be made close to point of use



46. PET Scanners

- The tracer molecule emits a positron
- A positron is the anti-particle of an electron (same mass, opposite electric charge)
- When an electron and positron collide, they annihilate
- Two gamma rays are produced, moving in opposite directions
- The PET scanner detects the gamma ray pairs





The positrons will only travel a short distance before they meet an electron and undergo annihilation. This produces 2 gamma rays which travel in opposite directions.
The PET scanner detects the gamma ray pairs simultaneously on opposite sides of the body.
3 pairs need to be detected for triangulation to pin-point the origin of the gamma rays
Can build up a 3D picture of the internal organs

PET scanner used in oncology

This is the branch of medicine that deals with the prevention, diagnosis and treatment of cancer

49. Annihilation

- When a positron and an electron undergo annihilation, matter seems to have been destroyed
- 1905 – Einstein's idea of mass-energy equivalence (Einstein was 26 years old)

$$E = m \times c^2$$

Slide 50. Post lecture tasks

- Open the **Year 11 Physics Lectures Class Notebook**.
- Go to your own section. **Under Post Lecture Tasks** you should see a page labelled **Task Lecture 6**
- Complete the task and then insert your work into the **Tasks Lecture 6** page by **Tuesday 16 June.**