McGraw-Hill Ryerson

BC Science Connections 8

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UNIT 3

Energy can be transferred as both a particle and a wave

TOPIC 3.5

How does light behave when it moves from one medium to another?

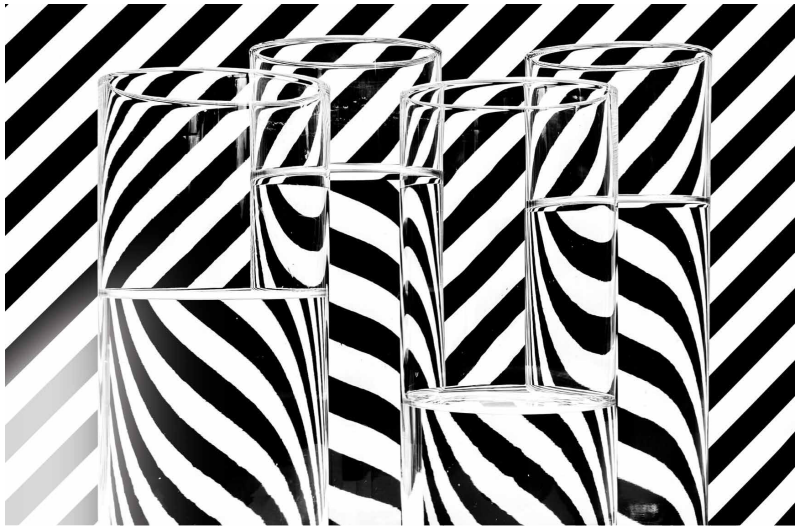
Topic 3.5: How does light behave when it moves from one medium to another?

- Photo shows several glasses of water place in front of diagonally striped paper
  - Refraction causes the path of light to bend when it travels from one medium to another
  - Refraction can trick your brain into "seeing" some of the diagonal lines where they are not

Glasses of water in front of diagonally striped paper

Concept 1: Light changes direction and speed when it moves from one medium to another.

- Light travels in a straight line through the same medium
- Light refracts (bends) when it travels form one medium to another (example: air to water)
  - What causes this refraction?



Glasses of water in front of diagonally striped paper

Refraction: Light Travels at Different Speeds and Changes Direction

- Refraction occurs because light travels at different speeds in different media
  - Example: Light travels at a different speed through air than it does through water
- When light changes speed as it moves from one medium to another, the direction also changes

Describing Refraction Using the Wave Model and Ray Model of Light

Use the wave model and ray model of light to visualize why the path of light changes when light changes speed

- **Wave front**: a specific part of a wave that can be followed
  - Crests of the waves are wave fronts
- **Ray**: shows the direction in which the waves are travelling
  - Perpendicular to the wave fronts

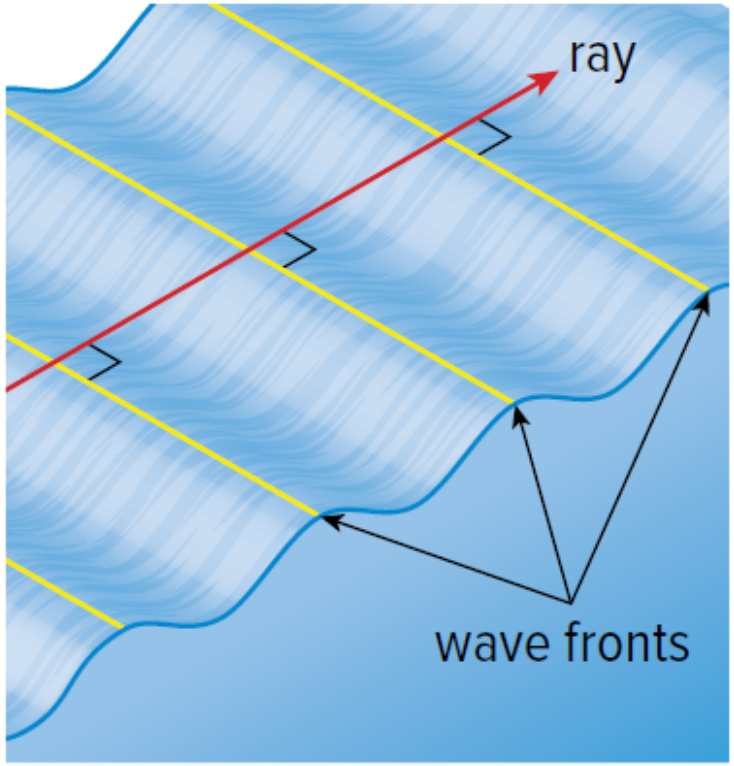


Figure 3.36: All the points on a wave front move together in the direction in which the wave itself is moving.

Describing Refraction Using the Wave Model and Ray Model of Light

What happens when a wave front of light reaches the surface between two media?

- Imagine each wave front is a line of roller skaters holding hands

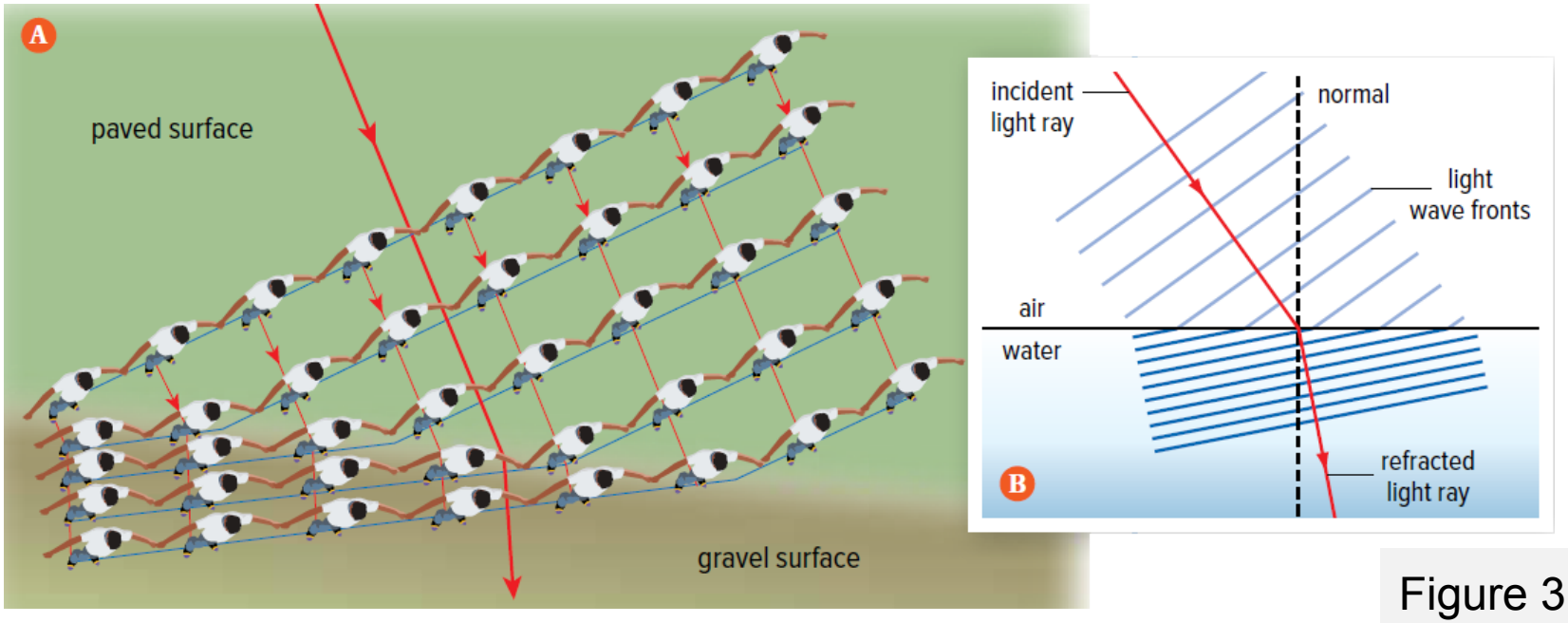


Figure 3.37

Describing Refraction Using the Wave Model and Ray Model of Light

- The skaters go from a paved surface to a gravel surface
- The skaters slow down going into the gravel surface (the speed of the wave front slows down)

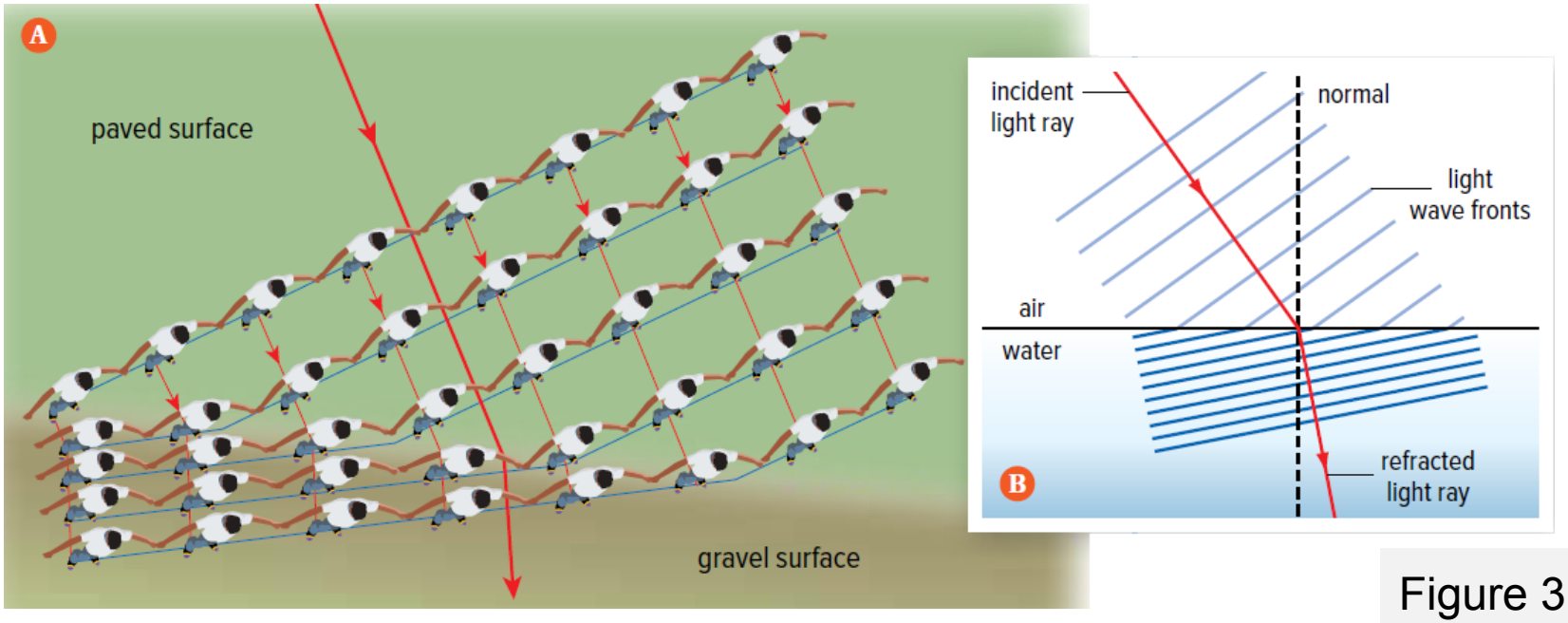


Figure 3.37

Describing Refraction Using the Wave Model and Ray Model of Light

- Direction of the skaters changes (direction of wave front changes)
- Direction is bent toward the normal as they slow down in the gravel

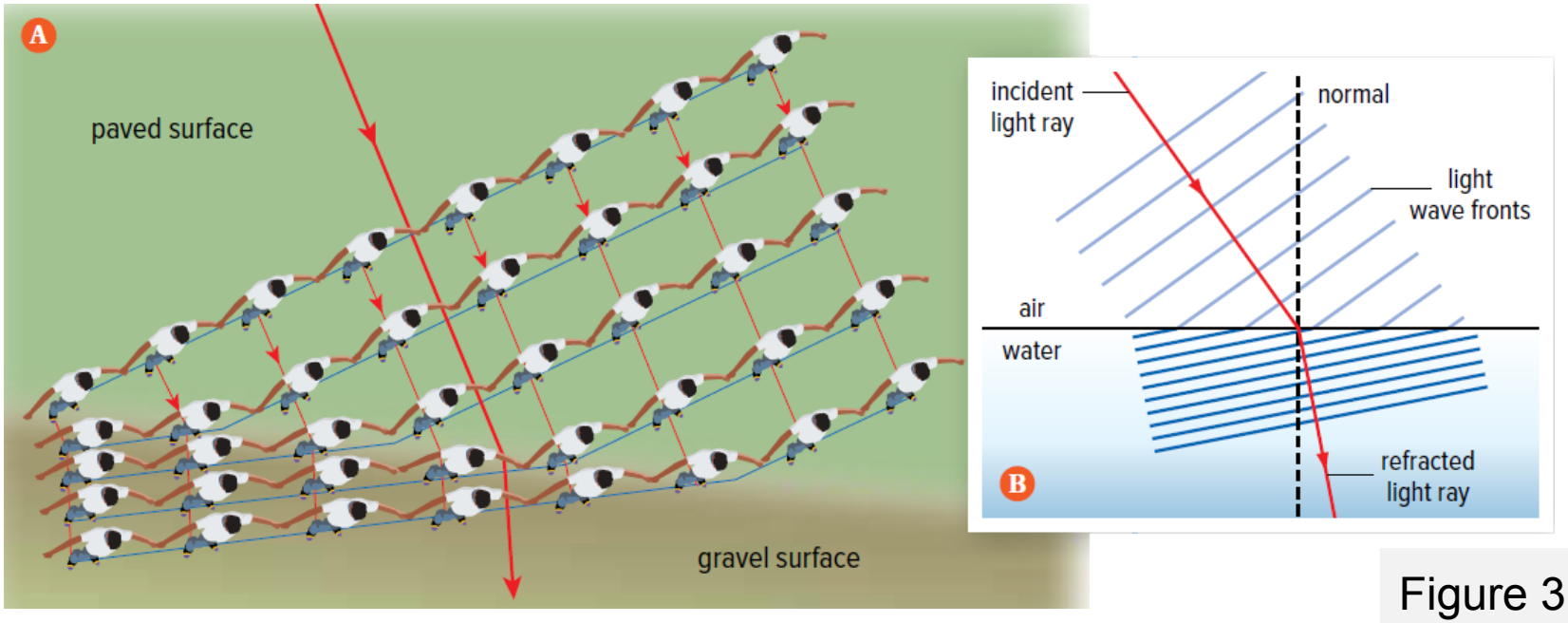


Figure 3.37

Speed and Direction Change When a Light Waves Moves from One Medium to Another

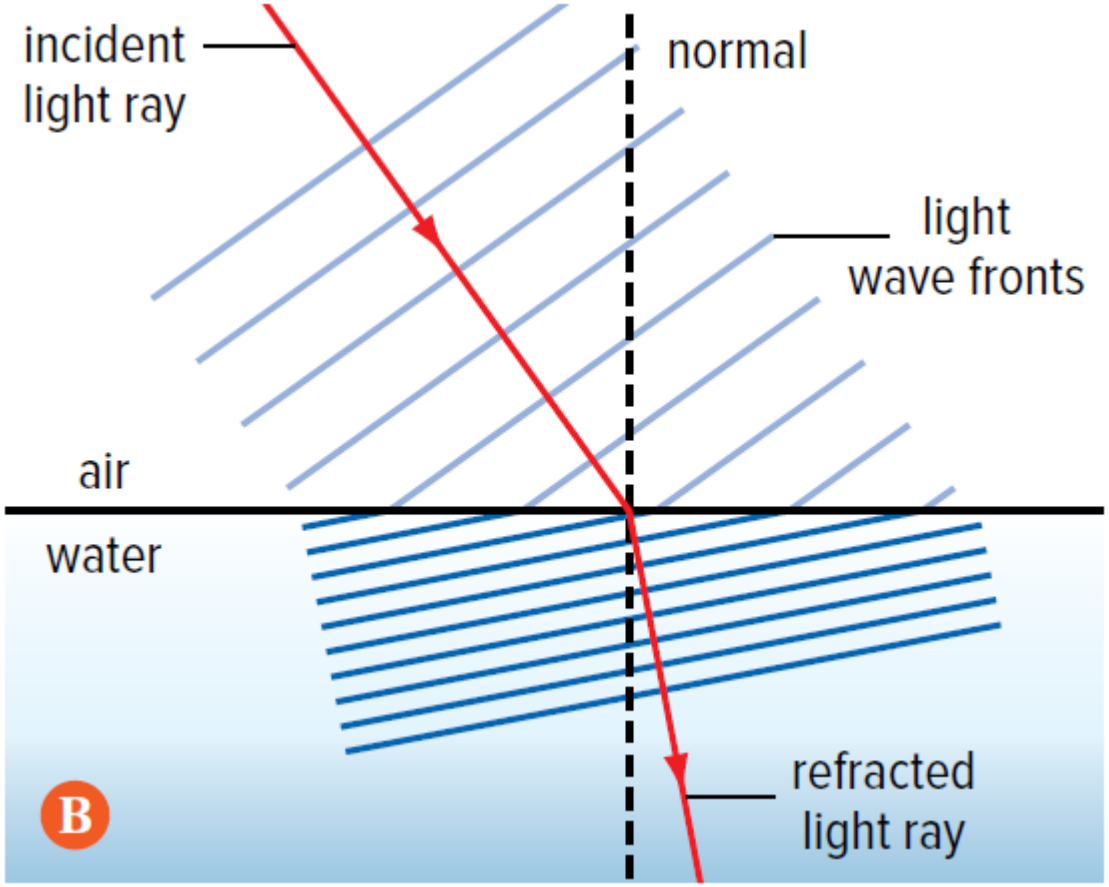
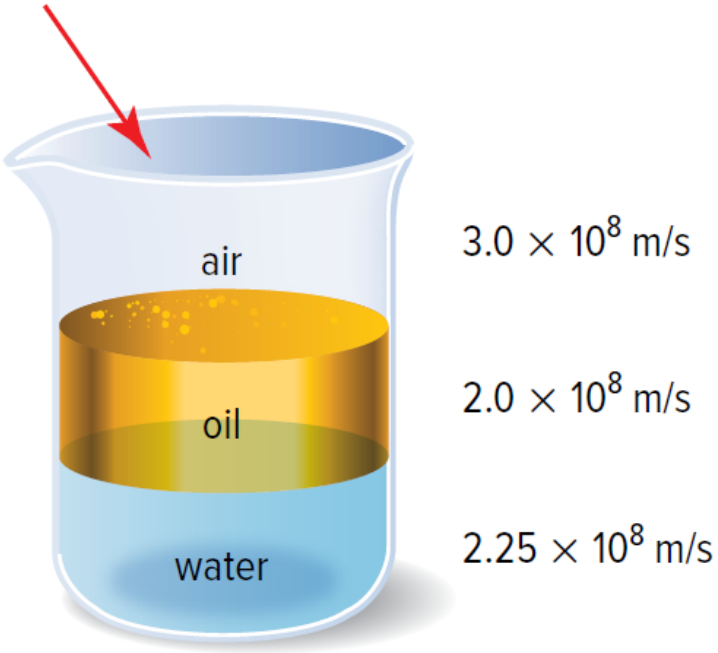


Figure 3.37B: This visual shows how light waves behave in a similar way when they pass from one medium to another.

Density of Media Determines if Light Waves Slow Down or Speed Up

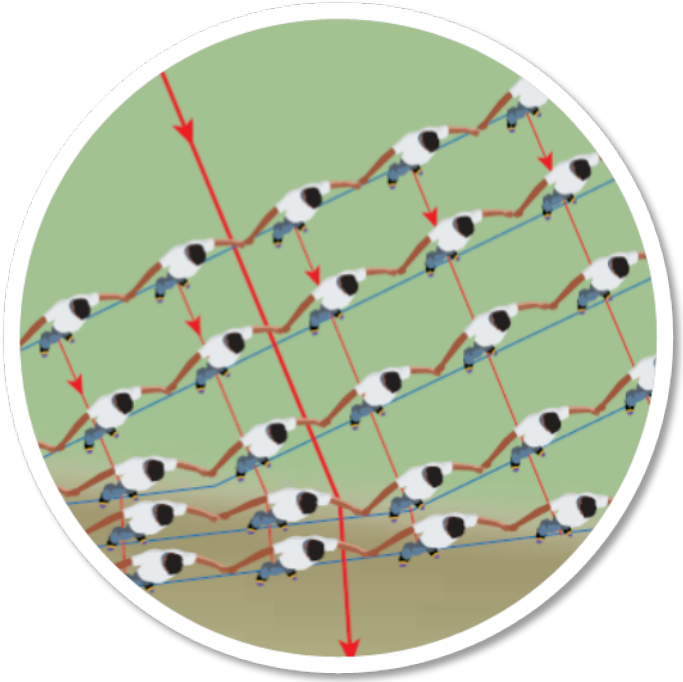
- Light travels more slowly in a more dense medium than in a less dense medium
  - Light travels from a less dense to a more dense medium: ray bends toward the normal
  - Light travels from a more dense medium to a less dense medium: ray bends away from the normal



The red arrow indicates a light ray entering the beaker. The speed of light for the three media are shown.

Discussion Questions

- Come up with another analogy that you could use to visualize how refraction occurs.



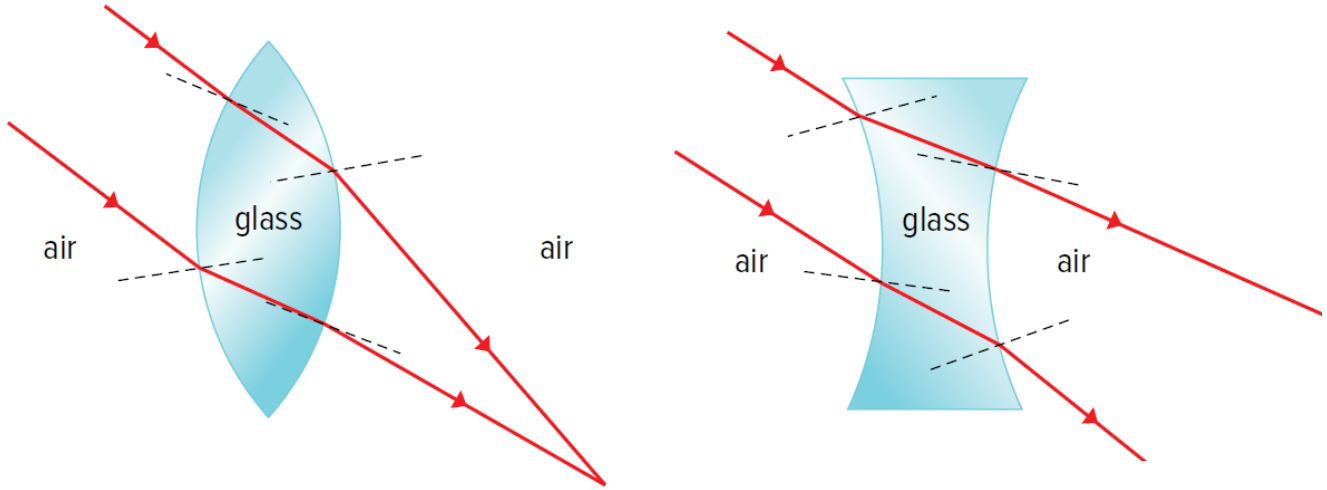
Concept 2: Light refracts as it passes through lenses.

- Lens: a transparent object that causes light to refract and has at least one curved side
  - Comes in different shapes, sizes, and materials

Figure 3.38: These lenses are made of glass, plastic, and even liquid.

Two Types of Lenses: Converging and Diverging

- Lenses have two sides:
  - Either side can be plane, concave, or convex
  - At least one side must be curved
- Two types of lenses: converging and diverging



Converging lens (left) and diverging lens (right)

Converging Lenses

- **Converging lenses**: a lens that brings parallel light rays toward a common point
  - Have one or two convex surfaces
  - Thicker in the centre

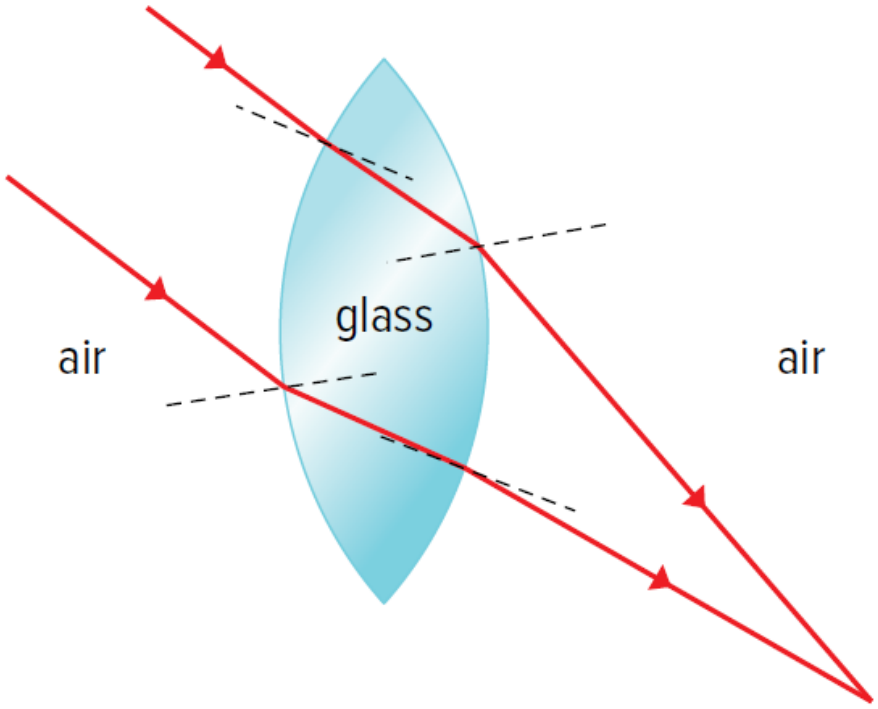


Figure 3.39: Converging lens

Converging Lenses

- When rays enter the lens, they move from a less dense medium (air) to a more dense medium (glass)
- Rays refract toward the normals and converge slightly

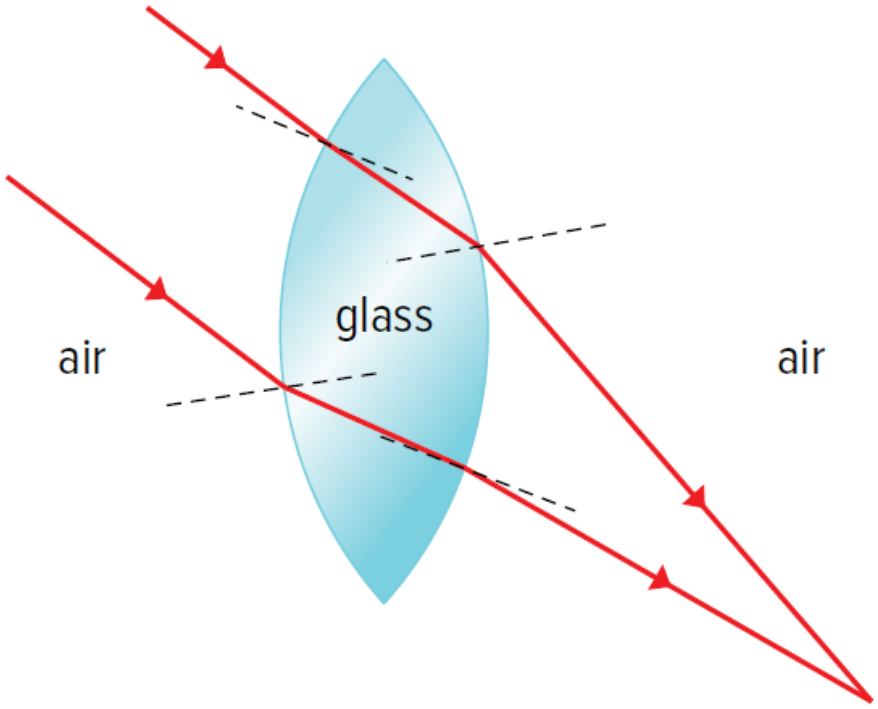


Figure 3.39: Converging lens

Converging Lenses

- When rays leave the lens, they move from a more dense medium (glass) to a less dense medium (air)
- Rays refract away from the normals
- Rays converge after passing through the lens

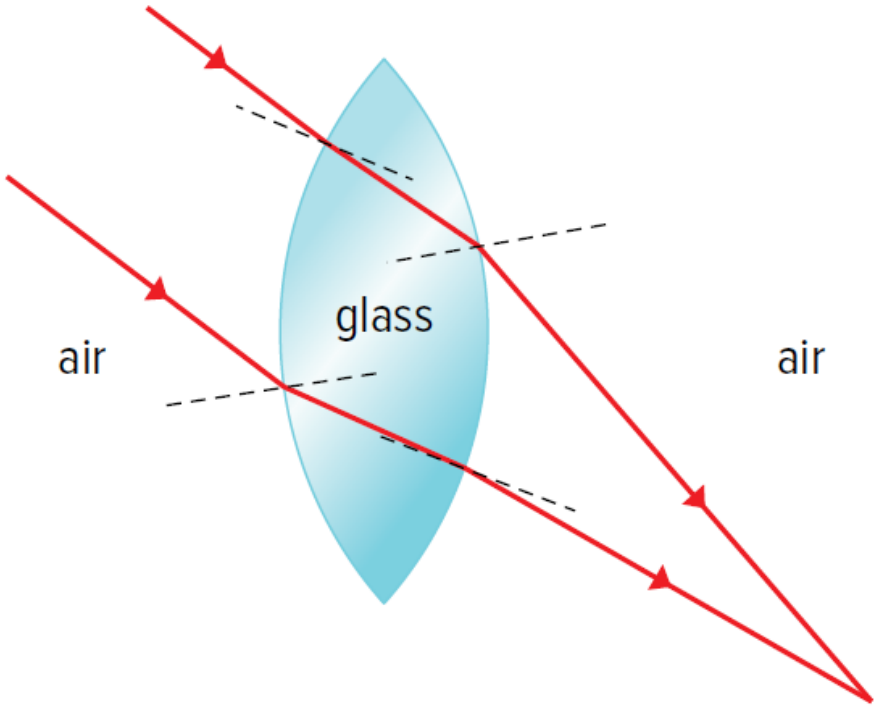


Figure 3.39: Converging lens

Diverging Lenses

- **Diverging lenses**: a lens that spreads parallel light rays away from a common point
  - Have one or two concave surfaces
  - Thinner in the centre

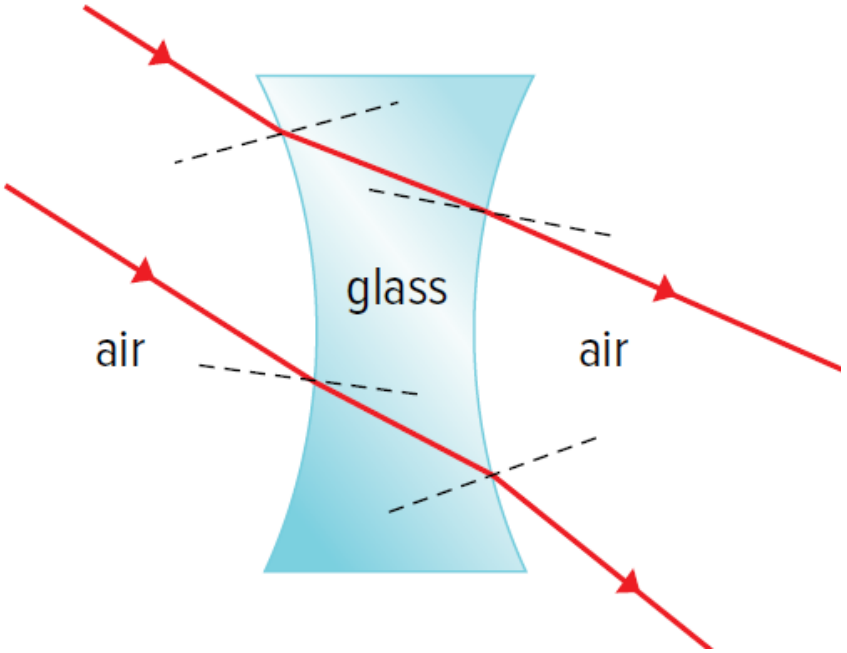


Figure 3.40: Diverging lens

Diverging Lenses

- When rays enter the lens, they move from a less dense medium (air) to a more dense medium (glass)
- Rays refract towards normals
- Rays diverge slightly

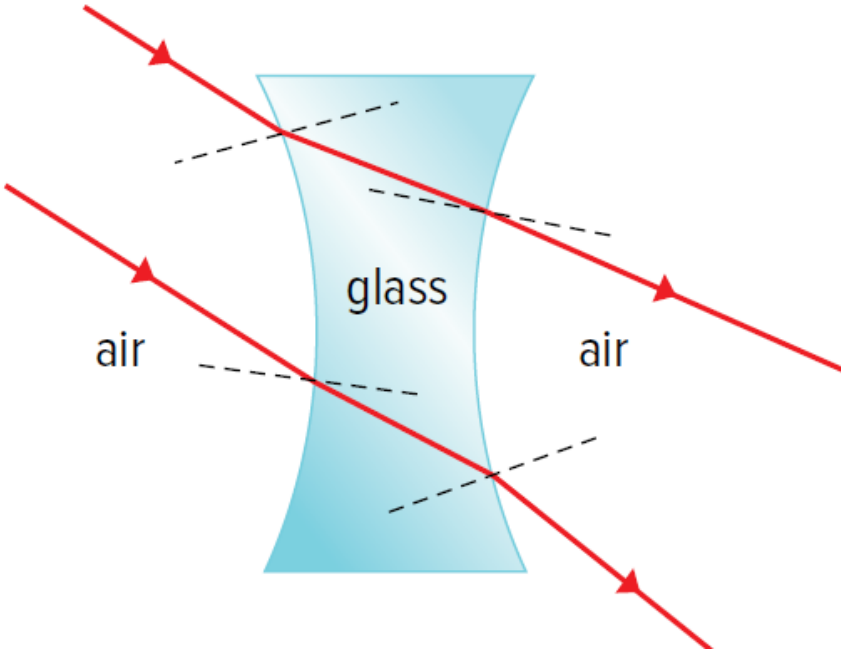


Figure 3.40: Diverging lens

Diverging Lenses

- When rays leave the lens, they move from a more dense medium (glass) to a less dense medium (air)
- Refract away from the normals
- Rays diverge as they leave the lens

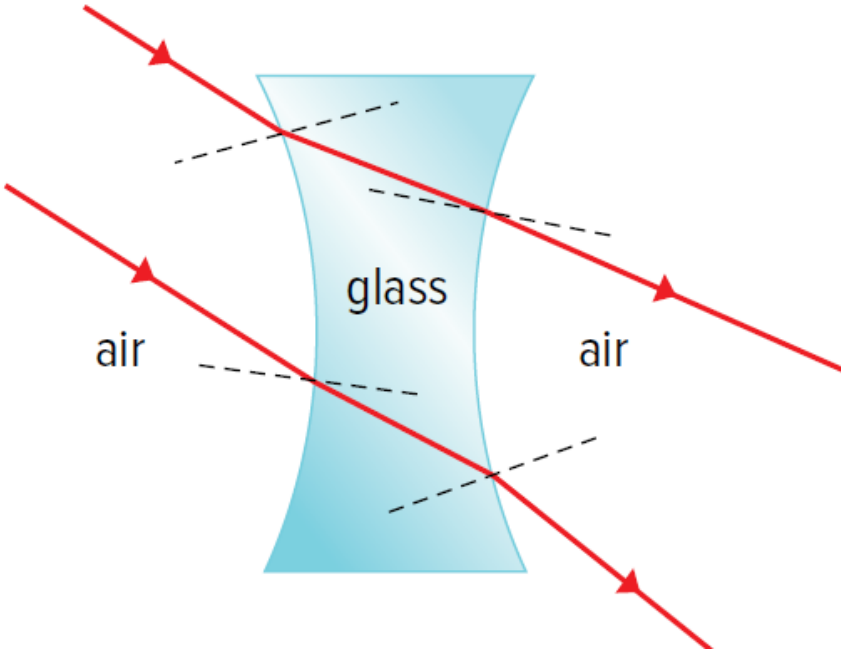
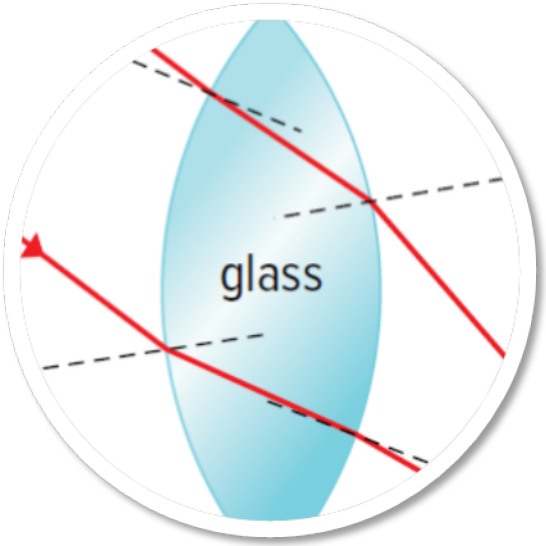


Figure 3.40: Diverging lens

Discussion Questions

- What characteristic makes one lens converging and another diverging?



Concept 3: Refraction plays a role in human vision.

- Human eye:
  - Can focus on objects at different distances
  - Can form images more accurately than a camera
  - Refraction makes image formation in the eye possible

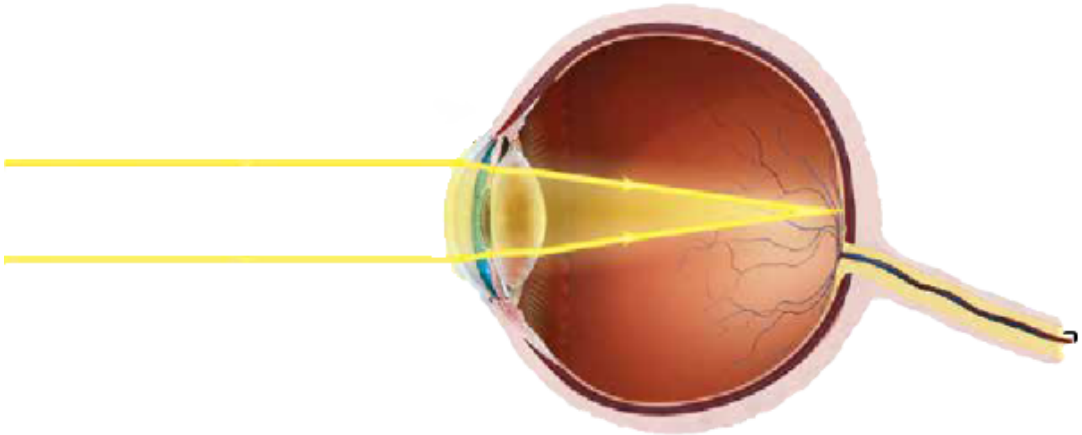
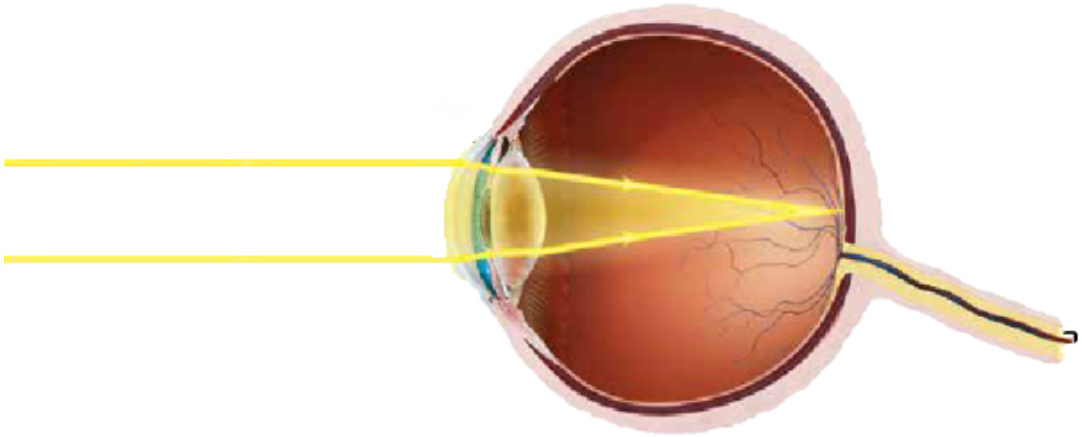


Figure 3.41 This diagram shows the path of light from a source or object through the human eye.

The Front of the Eye Refracts Light

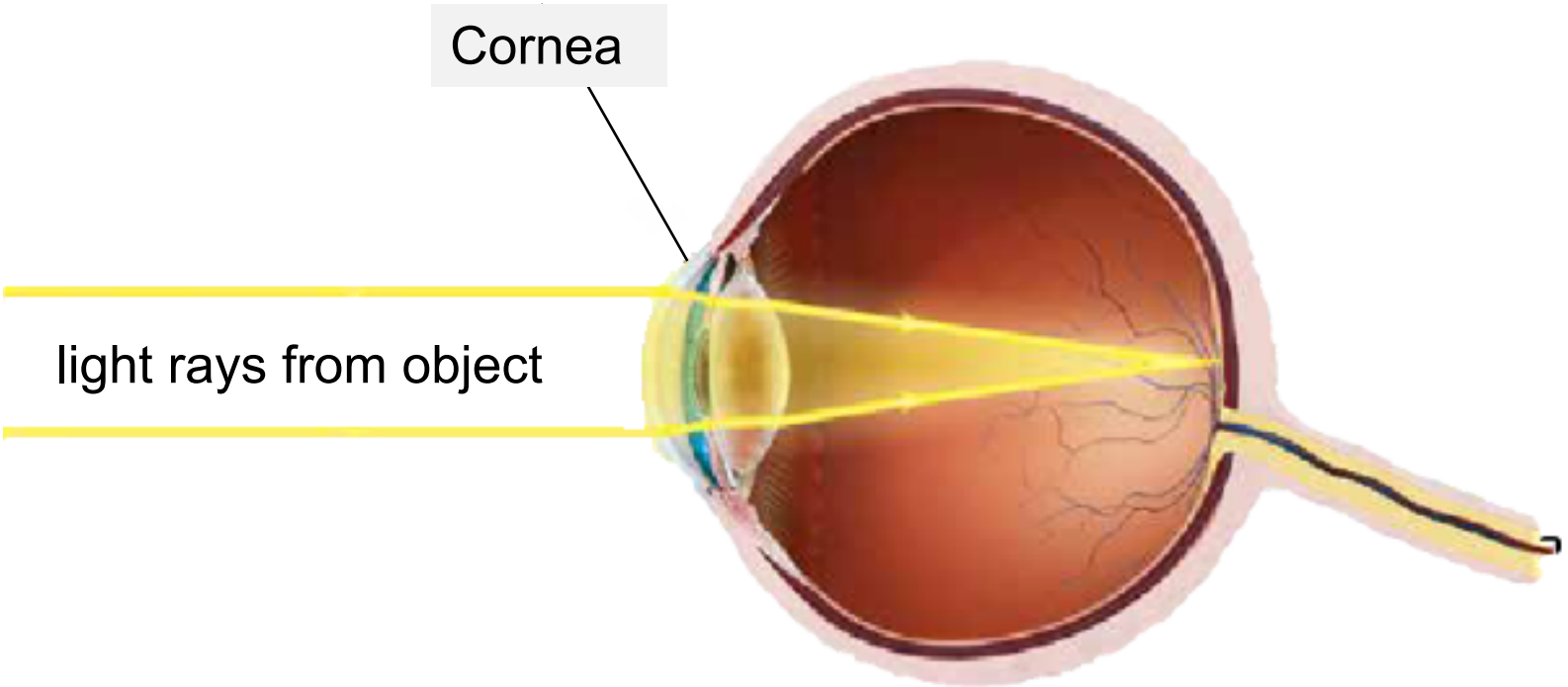
- Front of the eye: refraction and focusing take place
- Back of the eye: Refracted light forms an image here
- Brain interprets the image

Figure 3.41 This diagram shows the path of light from a source or object through the human eye.



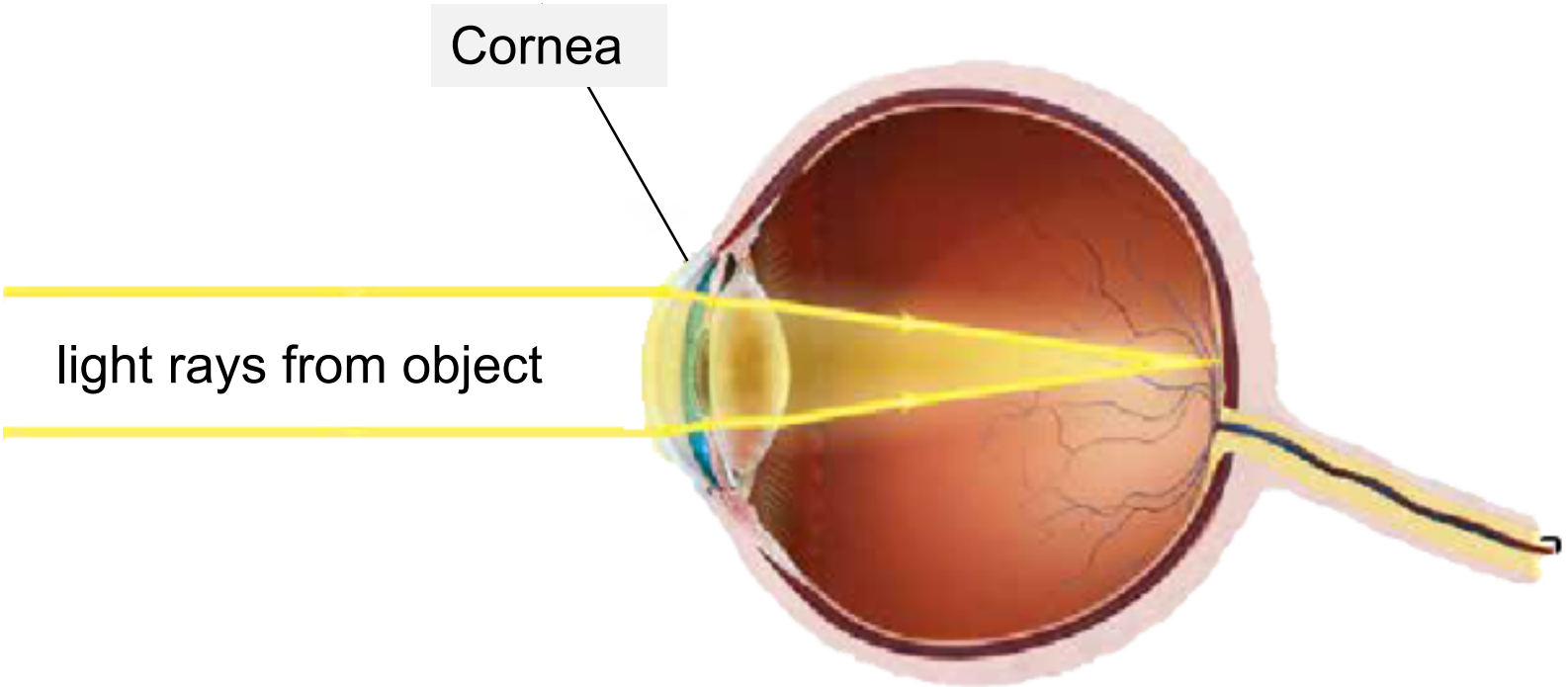
Front of the Eye: Refraction and Focusing

- Light travels in a straight line from an object or source to eye
  - First travels through the cornea (lens in front of the eye)
  - Travels from less dense medium (air) to more dense (cornea)



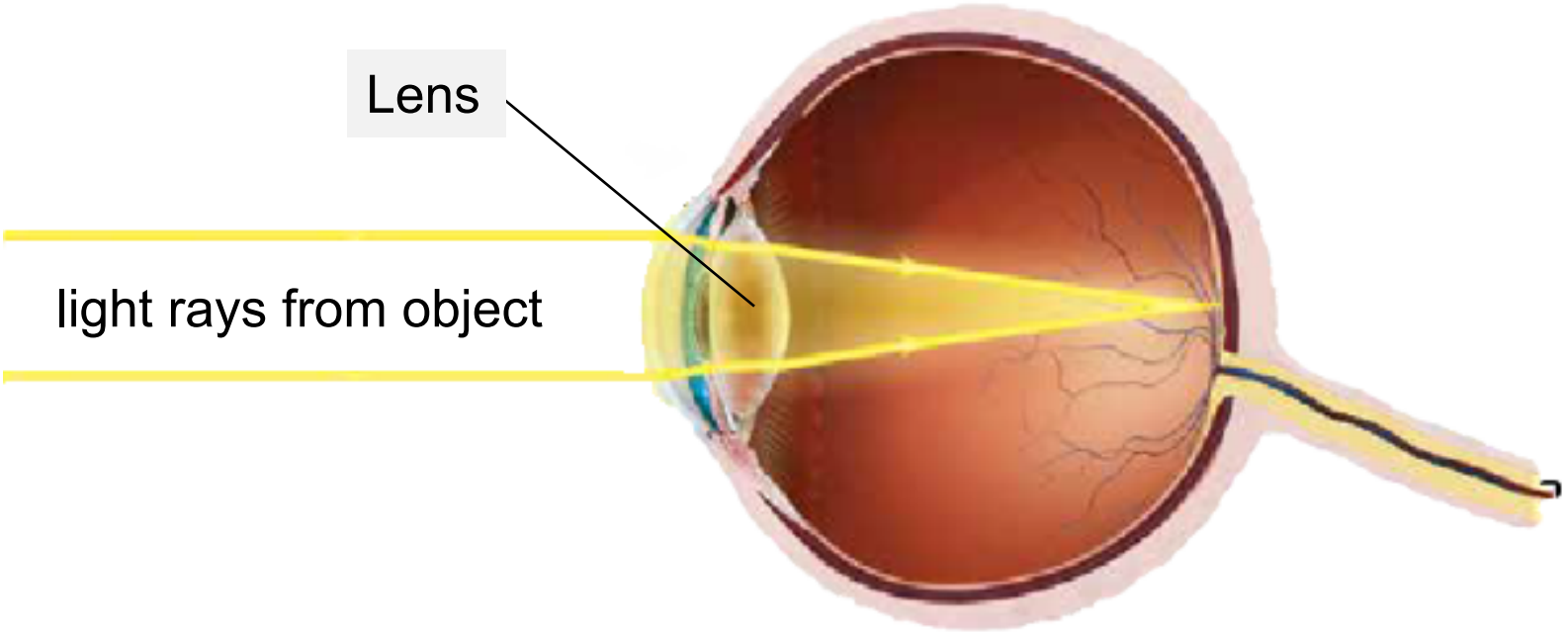
Front of the Eye: Refraction and Focusing

- Path of light bends toward the normal
- 80% of refraction takes place where light moves from air to cornea



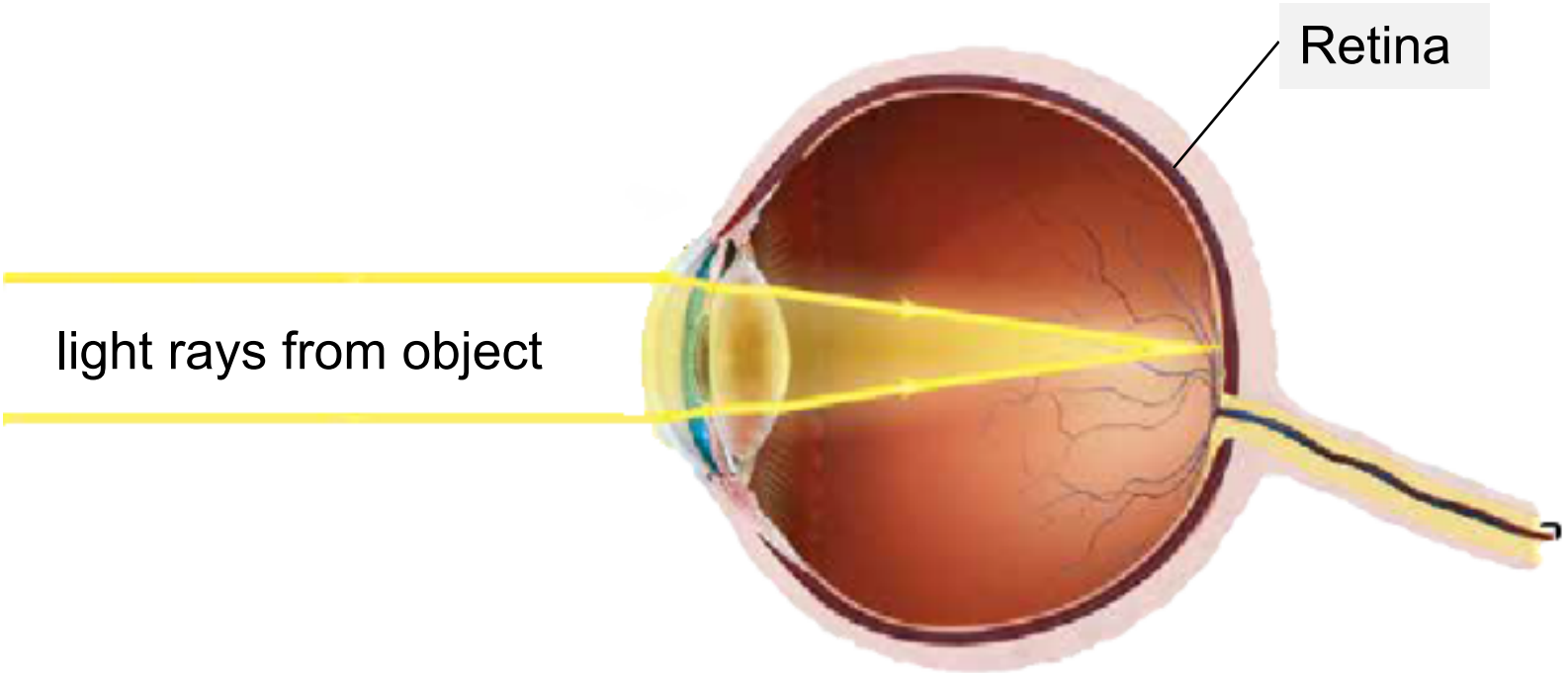
Front of the Eye: Refraction and Focusing

- Light passes through the lens
  - Lens also refracts light toward the normal
  - 20% of refraction occurs as light passes through lens
  - Lens is responsible for focusing on close objects



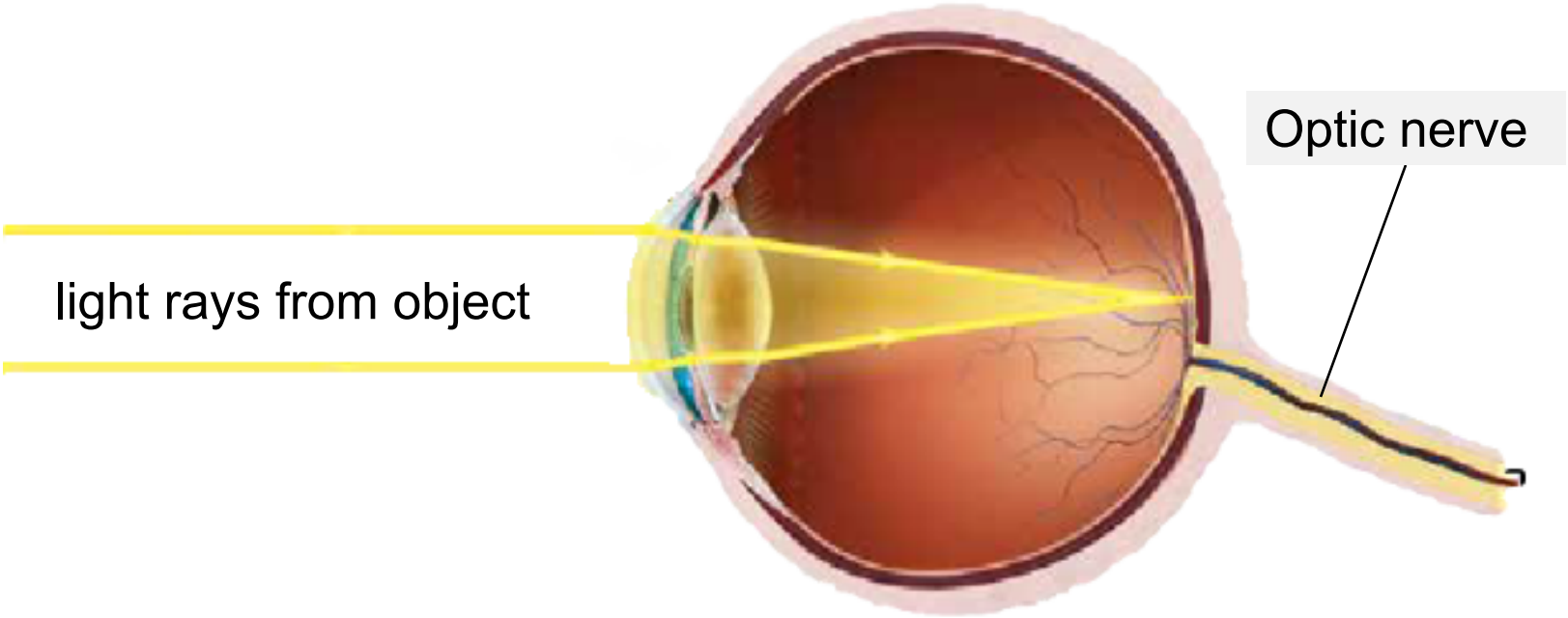
Back of the Eye: Image Formation

- Light strikes the back of the eye (retina) and forms an image
- Retina: layer of cells that respond to light



Back of the Eye: Brain Interprets the Image

- Cells in retina send nerve impulses to the brain through the optic nerve
- Brain interprets impulses as sight



The Lens Focuses on Near and Distant Objects

- Lens focuses on near and distant object
- Circular muscle around the lens contracts and relaxes to change shape of lens
  - Allows lens to refract light to a different extent and focus light from near and distant objects on retina

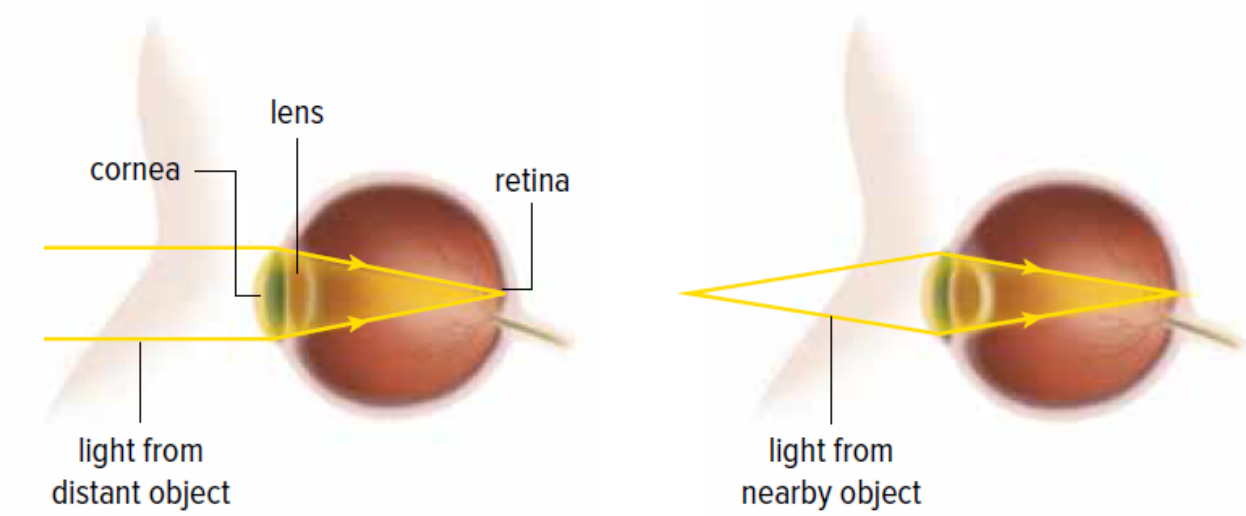


Figure 3.42: Lens focusing on distant (left) and nearby (right) objects

The Lens: Focusing on a Distant Object

Focusing on a distant object:

- Light from distant object enters eye
- Muscle around lens is relaxed
- Lens retains normal shape
- Lens focuses distant object correctly on retina

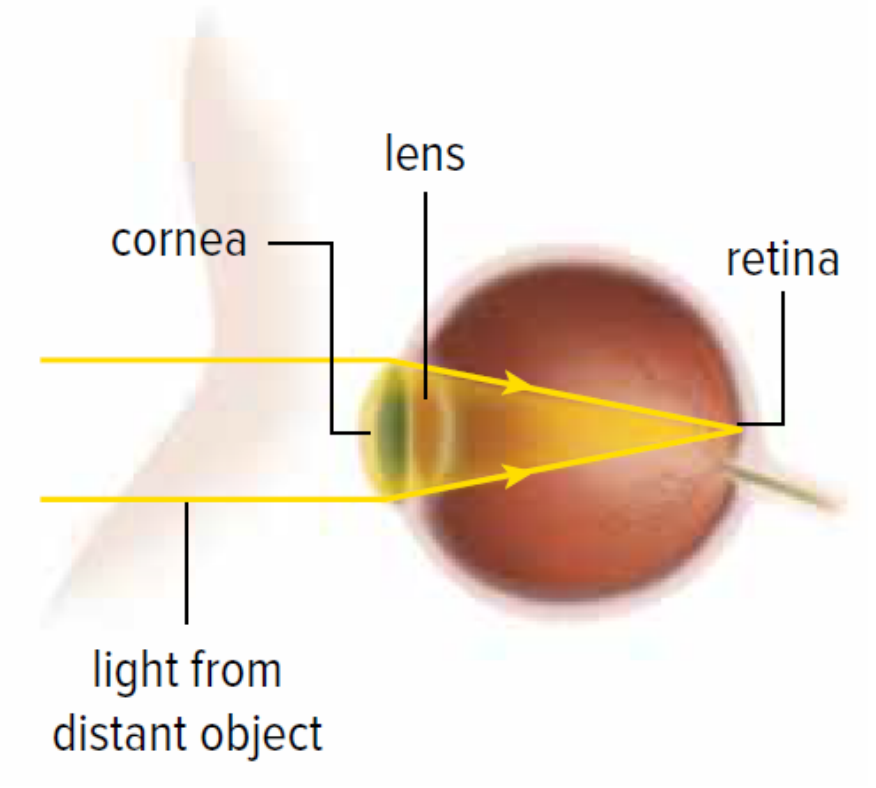


Figure 3.42A: Lens focusing on distant object.

The Lens: Focusing on a Nearby Object

Focusing on a nearby object:

- Light from nearby object enters eye
- Muscle around lens is contracted
- Lens becomes shorter, thicker, and more curved
- Lens focuses nearby object correctly on retina

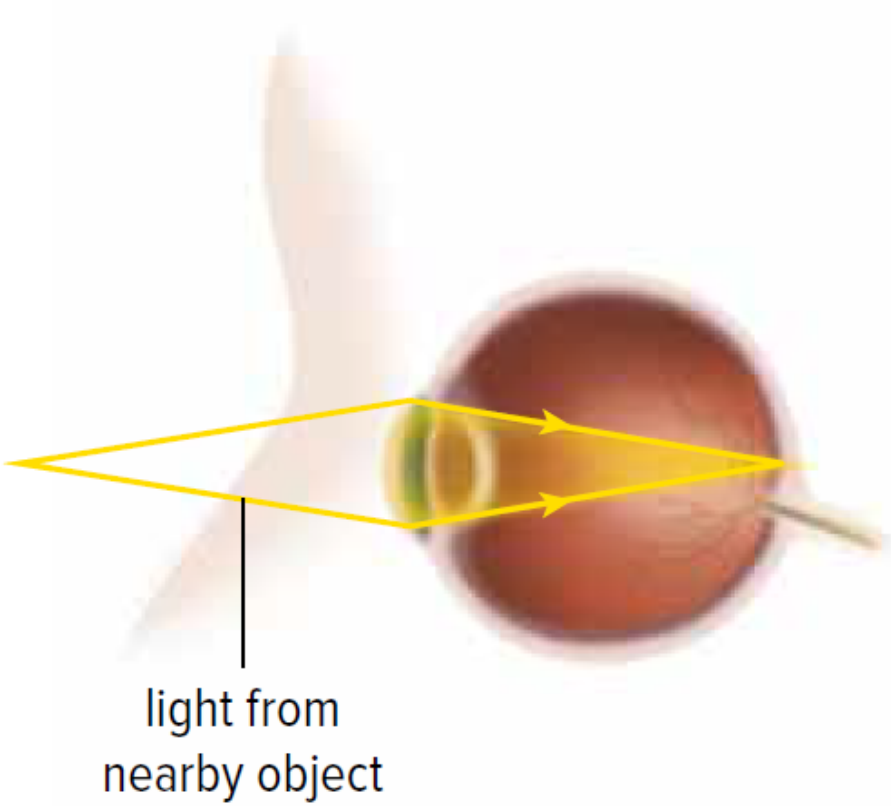
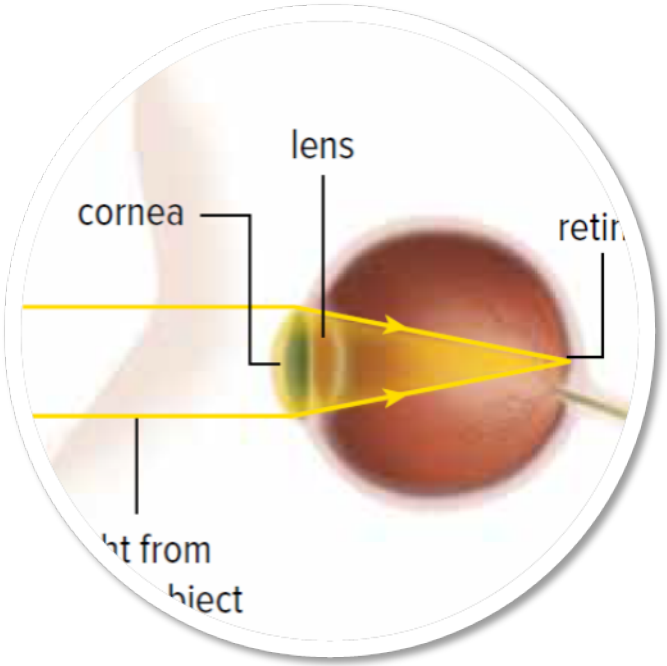


Figure 3.42A: Lens focusing on nearby object.

Discussion Questions

- Explain how the lens can focus images on both distant objects and nearby objects on the retina.

- As a person ages, the lenses of the eyes become stiff. The muscles around the lenses can no longer make them change shape. How might this affect a person's vision?



Concept 4: Many technologies take advantage of light's behaviour when it moves from one medium to another.

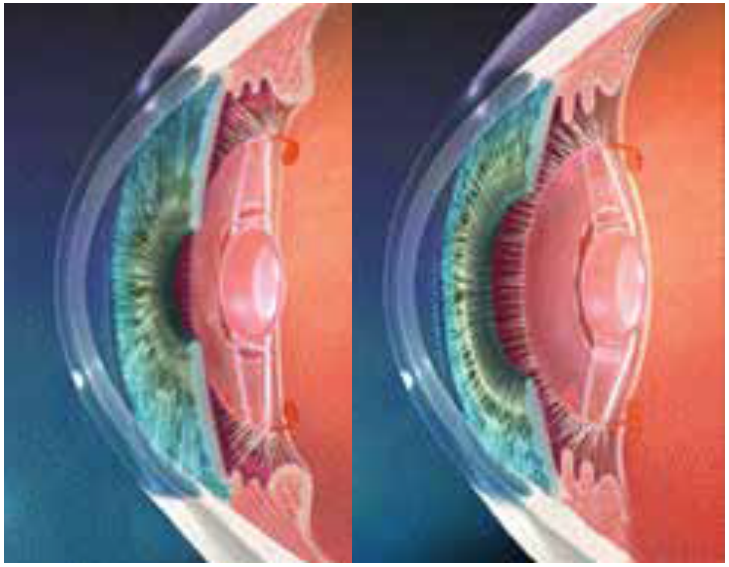
- Modern technologies in which refraction plays an important role:
  - Artificial Lenses
  - Heads-Up Display (HUD)
  - Wavefront Technology

Artificial lens

Artificial Lenses

Artificial lenses: used to treat cataracts

- Cataracts: clouding of the lens that affects vision
- Treatment: surgery that removes the cloudy lenses and replaces them with artificial lenses
- Most artificial lenses cannot change shape like natural lenses
- New artificial lenses have hinges that allows the lens to bend slightly when the muscle around them contracts



(A) Relaxed muscle around the artificial lens. (B) When the muscle contracts, it presses on the lens, causing it to bend.

Heads-Up Display (HUD)

Heads-Up Display (HUD)

- Refracts light from a projector through a prism
- Makes an image (computer display) appear in front of the user's eye
- Image is an overlay that hovers over the user's view of the real world
- Used in wearable head gear by pilots, scuba divers, skiers
- Users can check speed, distance, depth, and altitude without taking their eyes from their view

HUDs can be used to get information about speed, altitude, and direction.

Wavefront Technology

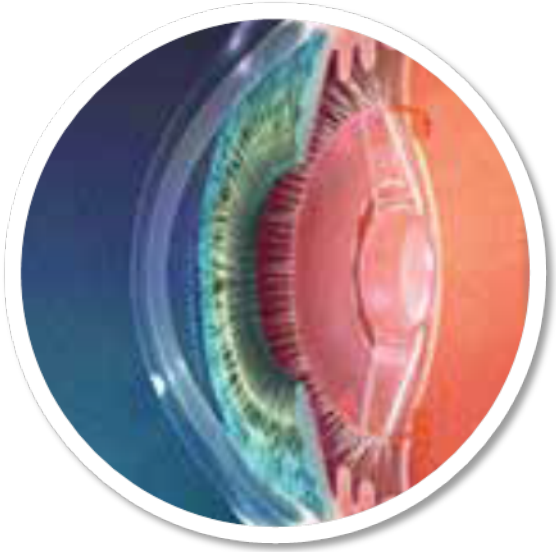
Wavefront Technology

- Used by eye doctors to map irregularities in the cornea and lens
- Tracks how a wave front of visible light refracts as it passes through the eye
- Wavefront anaylzer: directs light waves into a patient's eye; measures how the light waves travel in and out of the eye
- Helps doctors perform laser eye surgery and diagnose vision problems

Wavefront technology may one day make eye chart tests a thing of the past.

Discussion Questions

- Describe how new artificial lenses may allow people to see better.



- Why do you think wavefront technology is an improvement over eye tests that use traditional eye charts?

- Suggest another use for a HUD.

Summary: How does light behave when it moves from one medium to another?

- Light changes direction and speed when it moves from one medium to another.
- Light refracts as it passes through lenses.
- Refraction plays a role in human vision.
- Many technologies take advantage of light's behaviour when it moves from one medium to another.