Brien Holden Vision Institute

EYE OPTICS AND ACCOMMODATION

THINK

A mother of four children comes to see you. She tells you that she has always made her children's clothes herself, but recently she has been getting headaches whenever she sews.

What do you think might be causing her headaches?

AIM

This unit introduces you to how light focuses in the eye, and what happens when the eye fails to focus light correctly.

LEARNING OUTCOMES

When you have worked through this unit you should be able to:

- identify and name the parts of the eye's optical system
- describe how these parts work together to focus light and form a visual image
- define refractive error and list the different types of refractive errors
- explain how the eye can change its focus from distant objects to close objects
- explain why the ability to accommodate decreases as people get older
- recognise the symptoms of asthenopia.

REVIEW: EYE OPTICS AND ACCOMMODATION

HOW DOES THE EYE SEE?	Being able to see depends on three things: 1. The tear film, cornea, aqueous humour, crystalline lens, and vitreous must be clear so that the light can reach the retina without being interrupted. 2. The cornea and the crystalline lens must focus the light from the image, so that it forms a clear image on the retina at the back of the eye. 3. The optic nerve must carry the information received by the retina to the brain so that it can be translated into a meaningful visual image.
TEAR FILM	The tear film is the watery layer at the front of the eye.
CORNEA	The cornea is located at the front of the eyeball. The cornea is transparent (clear), like glass. The cornea can be thought of as the window of the eye. The cornea also helps to focus light that enters the eye.
THE LENS	The crystalline lens is located behind the iris and the pupil. The lens is normally transparent, like clear glass, and cannot usually be seen without special instruments. The lens is suspended behind the pupil by zonular fibres, or simply zonules. The zonules connect the ciliary muscle and the lens to each other. When the ciliary muscle contracts or relaxes, the zonules change the shape of the lens, which changes the focusing power of the lens. The purpose of the lens is to change the focus of the eye so that we can see things that are close to us. When we are young the lens is soft and flexible and we can focus on objects that are very close to the eye. This is called accommodation.
THE CILIARY MUSCLE	The ciliary muscle works to change the shape of the crystalline lens and change the focus of the eye. This is called accommodation. When the ciliary muscle contracts, the zonules (that connect the ciliary body to the lens) loosen and the lens becomes thicker – this increases the focusing power of the lens. When this happens we say that the eye is accommodating. When the ciliary muscle relaxes, the zonules become taut (stretched tightly) and the lens becomes thinner – this decreases the focusing power of the lens. As we get older, the lens slowly gets harder and less flexible and cannot change the focus so well. We can no longer hold things so close and still see them well. This is called presbyopia and can be corrected with reading spectacles. As the years go by the reading spectacles need to be made stronger because the lens gets harder.

LOOKING AT EYES

Light rays from an object enter the eye through the tear film and the cornea. They travel through the anterior chamber and the pupil. The light rays then pass through the crystalline lens and the vitreous before arriving at the retina.

Along the way, the light rays are converged (bent towards each other) – first by the cornea, and then by the crystalline lens. The bending or converging of the light allows the light to be focused. If the light is focused on the retina, a clear image will be formed.

At the retina, the light is changed into electrical signals which are sent to the brain via the optic nerve. These electrical signals are interpreted by the brain as a visual image.

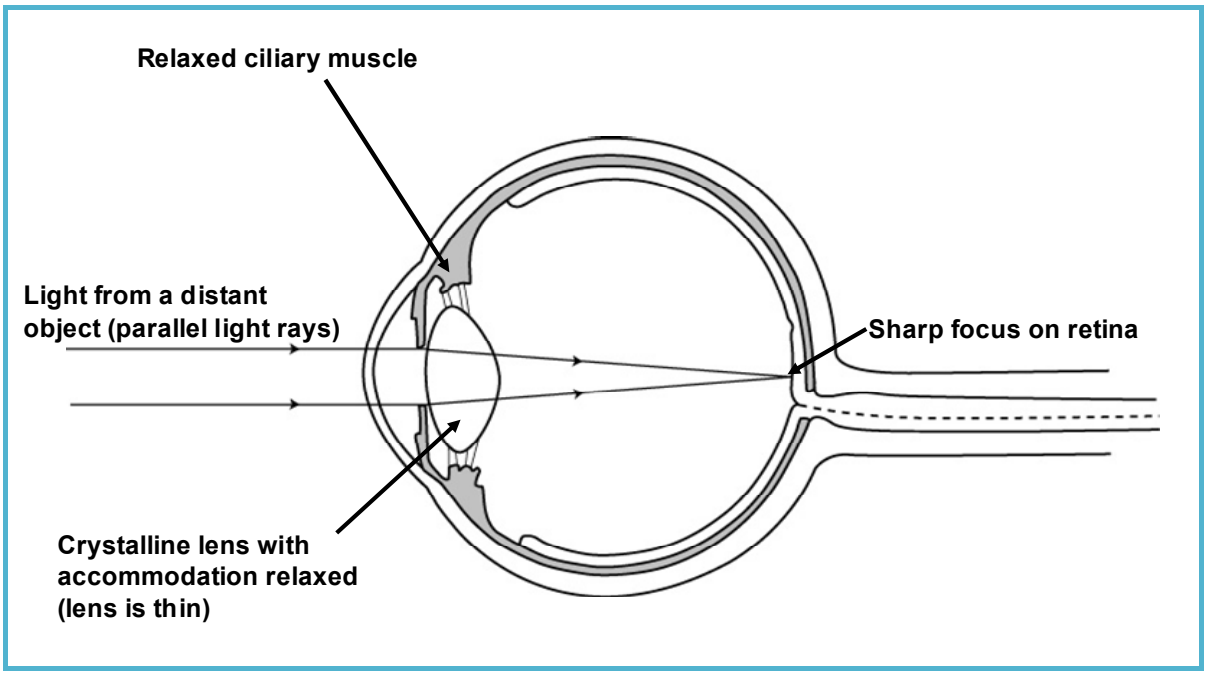

Figure 3.1: *Light from a distant object focusing on the retina*

FOCUSING LIGHT IN THE EYE

It is important to know that light rays coming from a distant object are parallel (Figure 3.1). A distant object is usually considered to be any object that is further than 6 metres (m) away.

Light rays coming from a close object are divergent (they bend away from each other). The closer the object is to the eye, the more divergent the light rays become.

For light rays to focus exactly on the retina, the eye must have the following:

- The cornea and the lens must bend (or converge) the light by the correct amount.
- The eyeball must be of the correct length (the distance between the cornea and the retina).

The eye must be of the correct size and shape to have clear, comfortable vision.

LOOKING AT EYES (cont.)

FOCUSING STRUCTURES OF THE EYE

The cornea and the lens work together to refract incoming light rays so that the light rays converge and focus on the retina.

- The cornea provides $^{2}/_{3}^{rds}$ of the eye's total focusing power.
  - It is the curved shape and thickness of the cornea that provides its focusing power.
  - The shape and thickness of the cornea cannot change, so the focusing power of the cornea does not change.

- The lens provides $^{1}/_{3}^{rd}$ of the eye's total focusing power.
  - The curved shape and thickness of the lens provide its focusing power.
  - The lens can change its shape to become thicker (provide more focusing power) when the ciliary muscle contracts, so the focusing power of the lens can change.

The cornea provides $^{2}/_{3}^{rds}$ of the eye's focusing power.

The lens provides $^{1}/_{3}^{rd}$ of the eye's focusing power, but it can also fine-tune (make small adjustments to) the eye's total focusing power by changing its shape.

WHAT IS REFRACTIVE ERROR?

REFRACTIVE ERROR

A person who has a refractive error will need to wear spectacles (glasses) or contact lenses so that they can see clearly and comfortably. This is because their eye is not the correct size and shape and light does not focus correctly on their retina.

A person with a refractive error will have eyes that look normal, but they will not see well.

The amount of refractive error that an eye has depends on:

- the steepness/flatness of the cornea; and/or
- the thickness/thinness of the crystalline lens; and/or
- the length of the eyeball.

A person may have a combination of any of these three things which make the eye the wrong size or shape, and will stop light from focusing perfectly on the retina (Figure 3.2). If light from a distant or a near object does not focus properly on the retina, the person will have a problem seeing because they have a refractive error.

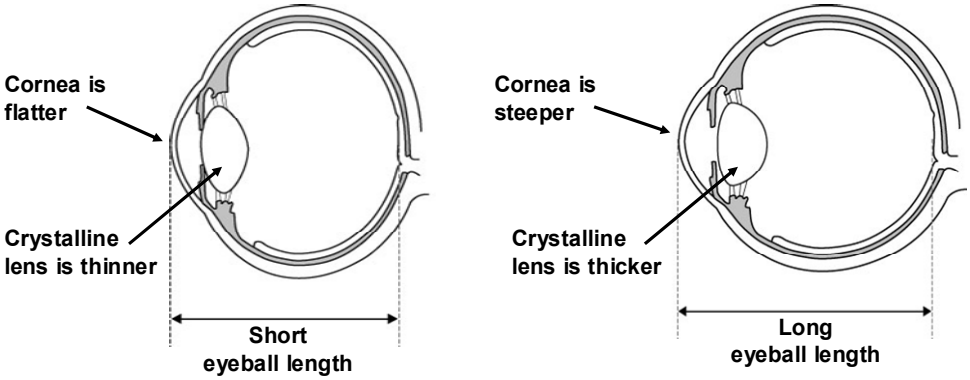

Figure 3.2: *Possible differences in eyeball length, shape of the cornea, and shape of the lens.*

When an eye does not have the correct size or shape, we say that the eye has a refractive error.

The amount of refractive error that an eye has depends on the size and shape of the cornea, the lens and/or the whole eyeball.

When an eye has the correct size and shape to focus light on the retina, we say that the eye is emmetropic.

WHAT IS REFRACTIVE ERROR? (cont.)

REFRACTIVE ERROR (cont.)

Depending on which part of the eye is the wrong size and/or shape, refractive error can be divided into four main types:

- **HYPEROPIA**
  (*also known as longsightedness, farsightedness or hypermetropia*)

  People with hyperopia (sometimes called “hyperopes”) can sometimes see far away, but might have difficulty with near vision. As hyperopes get older, even their distance vision could be affected.

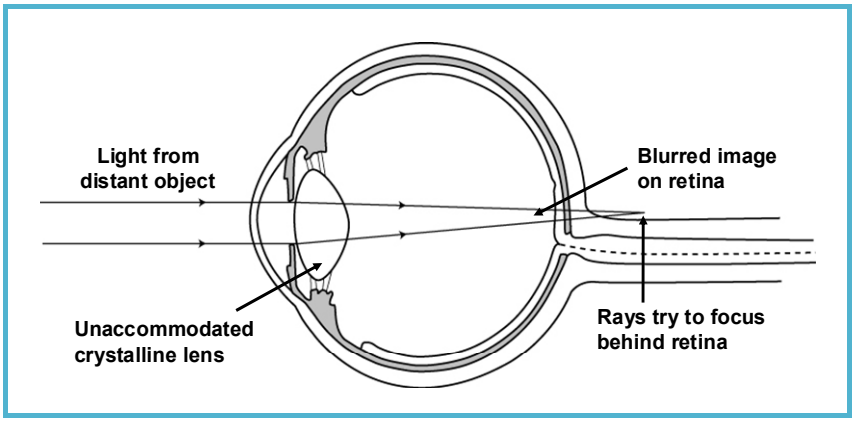

Figure 3.3: *A hyperopic eye – light rays from a distant object focus behind the retina*

- **MYOPIA**
  (*also known as shortsightedness or nearsightedness*)

  People with myopia (sometimes called “myopes”) can not see far away, but depending on the amount of myopia they have, their near vision might be good.

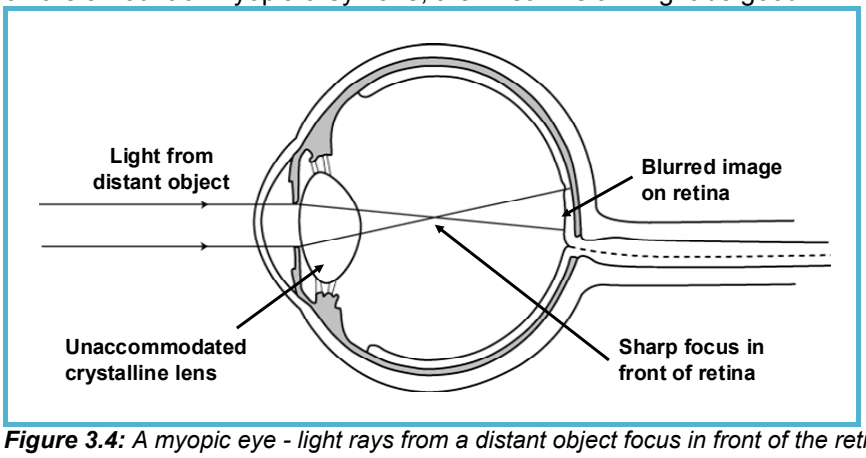

Figure 3.4: *A myopic eye - light rays from a distant object focus in front of the retina*

- **Astigmatism**
  An eye with astigmatism has different powers in different meridians of the eye. This causes light entering the eye to focus in different places, rather than at one single point.

  People with astigmatism (sometimes called “astigmats”) may have problems with both distance and near vision, because there is no distance at which a clear retinal image can form.

WHAT IS REFRACTIVE ERROR? (cont.)

REFRACTIVE ERROR (cont.)

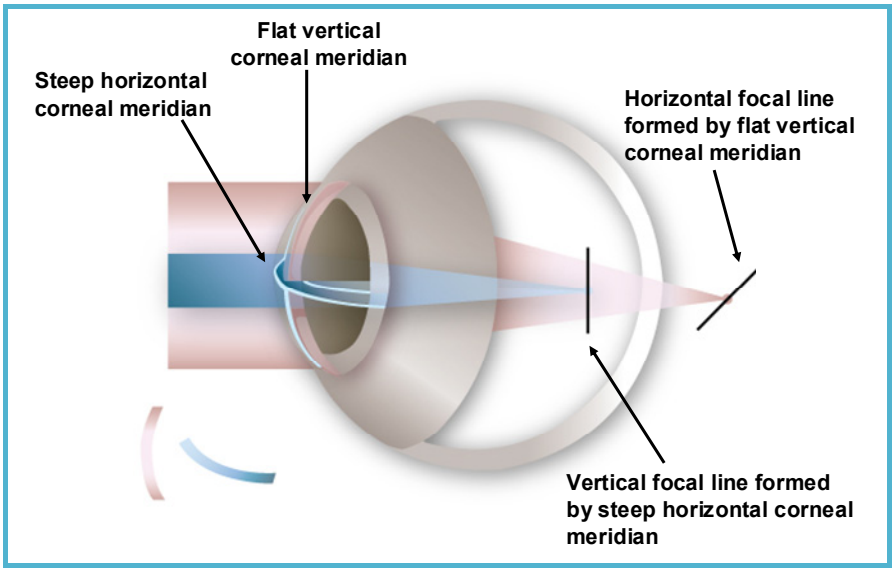

Figure 3.5: *An astigmatic eye – light rays from a distant object focus in two different places*

- **Presbyopia**
  Presbyopia develops as we get older (usually after the age of 40 or 45), when the lens of the eye is no longer able to focus light from near objects. People with presbyopia (sometimes called "presbyopes") have difficulty with near vision.

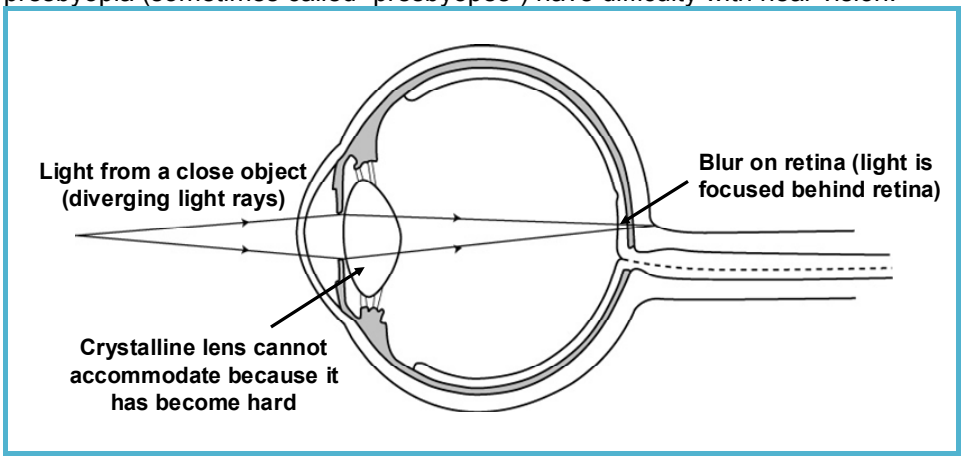

Figure 3.6: *A presbyopic eye – light rays from a near object focus behind the retina*

A person who has any of these refractive errors will need spectacles (glasses) in order to see clearly and comfortably.

A person's eye might just have one refractive error, or it might have a combination of different refractive errors. An eye may have any combination of refractive error, except myopia and hyperopia together. It is not possible for an eye to have both myopia and hyperopia at the same time.

To find out what sort of refractive error a person has, and how bad their refractive error is, the eyes must be examined in a special way.

An eye examination that tests for refractive error is called a refraction.

WHAT IS ACCOMMODATION

WHAT IS ACCOMMODATION

Accommodation occurs when the ciliary muscle contracts and changes the shape of the crystalline lens (makes it thicker).

When an eye accommodates, the focusing power of the eye increases. This allows a person to see close objects clearly (Figure 3.7).

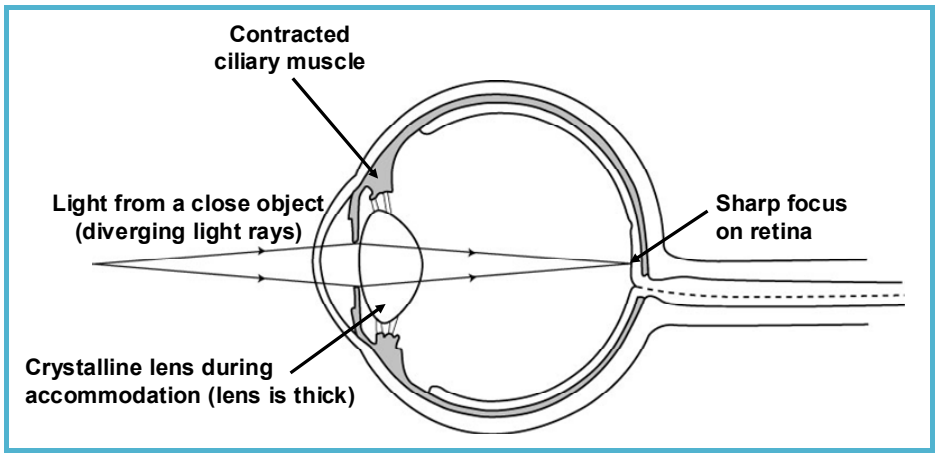

Figure 3.7: *Light rays from a close object focusing on the retina in an accommodating eye*

When the ciliary muscle is relaxed, a normal eye (an eye that is the right size and shape) will see objects in the distance (further away than 6 m) clearly. When this happens, we say that accommodation is relaxed, or that the eye is unaccommodated. Sometimes an eye with a relaxed ciliary muscle is also referred to as a relaxed eye.

When people accommodate they are usually unaware that they are doing so. A person who is accommodating will usually do so subconsciously (without thinking about it). They will not realise that they are using their ciliary muscle to accommodate.

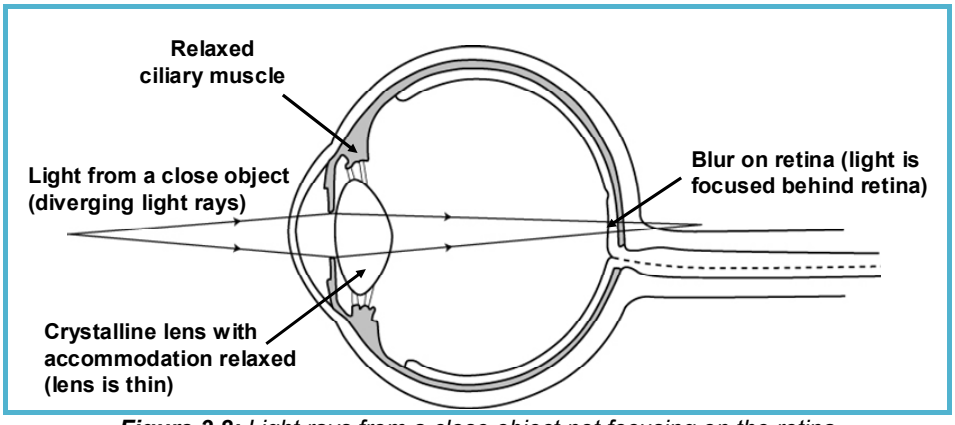

Figure 3.8: *Light rays from a close object <u>not</u> focusing on the retina in an eye that is not accommodating*

As we get older, the crystalline lens gradually gets harder and cannot change shape easily when the ciliary muscle contracts. This is a normal, natural aging process that is referred to as presbyopia. This means that an older person cannot accommodate (change the focus of their eye to see a close object) as easily as a younger person.

If the eye does not accommodate when looking at a close object, that object will appear blurry or out of focus (Figure 3.8). If a person cannot accommodate enough to see a close object, they will need glasses if they want to see things near to them clearly.

WHAT IS ACCOMMODATION (cont.)

AMPLITUDE OF ACCOMMODATION

A person's amplitude of accommodation is the total amount of accommodation that they have available. It is dependant on how much their lens can change its shape to increase its focusing power.

Children can accommodate about 15 D. This means that a child (who has no refractive error) is able to see things clearly even if what they are looking at is held only 7 cm from their eyes (Figure 3.9).

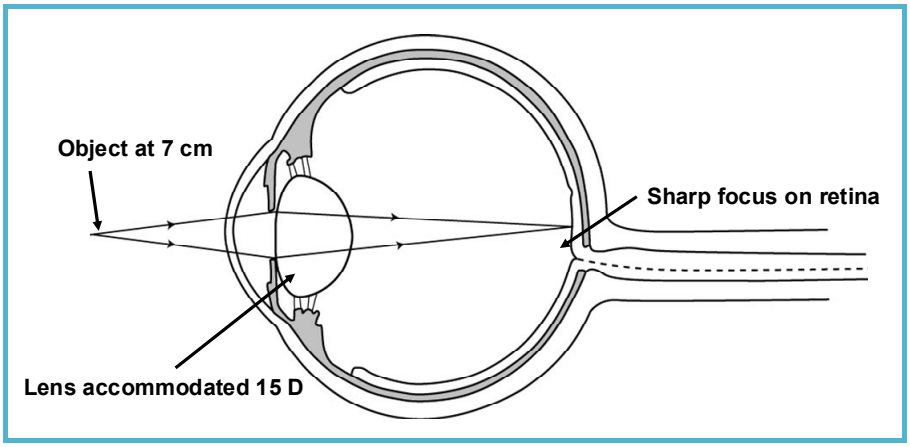

Figure 3.9: *The focal length formula is:* ***f = 100/F*** *(f in centimetres, F in dioptres)*

In this case the amount of accommodation is 15 D (=F) so **f** = 100/15 = **7 cm** approximately.

When we reach the age of 40, our eyes can only accommodate by about 5 D. A 40 year old person (who does not have myopia, hyperopia, or astigmatism) can only see objects clearly if they are 20 cm or further from the eyes (Figure 3.10).

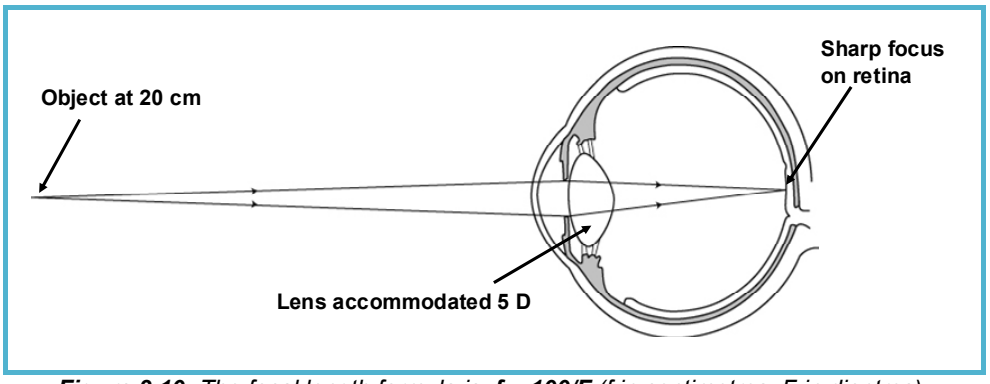

Figure 3.10: *The focal length formula is:* ***f = 100/F*** *(f in centimetres, F in dioptres)*

In this case the amount of accommodation is 5 D (=F) so **f** = 100/5 = **20 cm.**

WHAT IS ACCOMMODATION (cont.)

AMPLITUDE OF ACCOMMODATION (cont.)

By the time we are 60 years old there is almost no accommodation left.

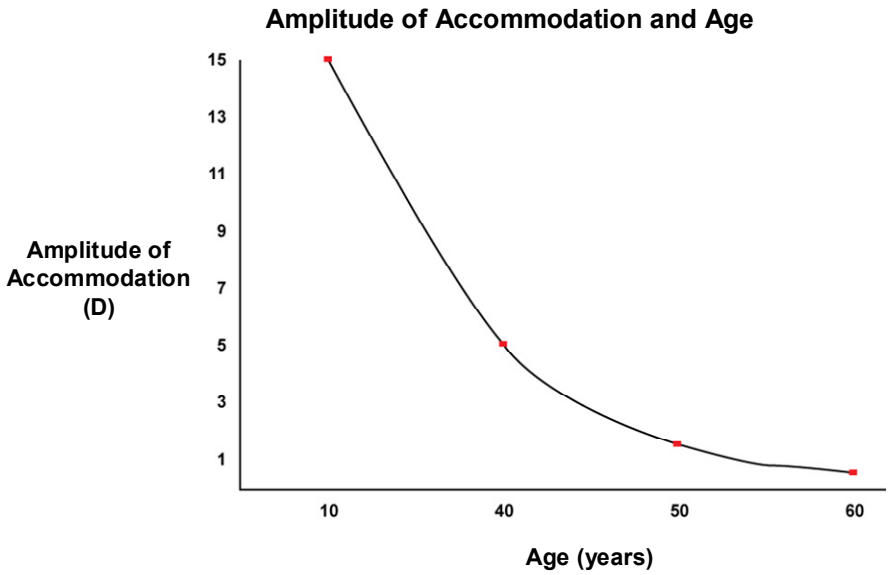

Figure 3.11: *Amplitude of accommodation decreases as age increases*

This graph is only an estimate, but it shows how our amplitude of accommodation decreases as we get older. Every person is different, and in reality some people who are the same age have slightly different amplitudes of accommodation.

ASTHENOPIA

It is not possible to use all of our accommodation all of the time – the ciliary muscle will get too tired. Our eyes were simply not designed to spend long periods of time reading, sewing, looking at a computer screen, doing craft work or other near tasks.

When the ciliary muscle gets tired it causes symptoms of asthenopia (visual fatigue).

Symptoms of asthenopia can include:

- sore, aching or burning eyes
- tired eyes
- headaches
- fatigue (general tiredness)
- falling asleep when doing near work
- loss of concentration
- blurry vision
- double vision
- itchy eyes.

A person who has asthenopic symptoms may have just one of these symptoms, or they may have several. Every person will be different.

WHAT IS ACCOMMODATION (cont.)

THE EYELIDS

A good way to think about accommodation is to think of the ciliary muscle as being like the muscles in your arms:

Imagine you go to the market and buy a very, very large bag of rice. You can pick the bag up, but if you try to carry the bag home, after a while it becomes too heavy and hurts your arms. Eventually you will not be able to carry the bag any further and you will have to put it down.

The same thing happens when you look at something that is very close to you. You might be able to accommodate to be able to see it clearly for a short period of time, but after some time, your ciliary muscle will get tired. Your eyes will hurt and your vision will go blurry.

Sometimes if you look at something that is close to you for too long you can get a cramp (spasm) in your ciliary muscle. This is like getting a cramp in your leg muscle when you are playing soccer. When you have a cramp your muscle cannot relax.

If a person wants to spend a long period of time doing near work, they can usually use half of their total amplitude of accommodation without getting asthenopia.

When a person has a cramp in their ciliary muscle they will not be able to relax their ciliary muscle – so their distance vision will be blurry. This problem is more common in young people.

Example:
A child might tell you that after they have been reading or writing for some time in the classroom, the blackboard looks blurry. After some time the blackboard will look clear again.

This is not myopia because it is not permanent. This is a near vision problem that has caused the ciliary muscle to cramp.

SUMMARY: PARTS OF THE EYE

THE NORMAL EYE

Light Entering the Eye

- Light rays entering the eye pass through the tear film, cornea, anterior chamber, pupil, crystalline lens and vitreous, before they reach the retina.
- Light rays are converged (focused) by the cornea and the crystalline lens.
- If the light rays focus correctly on the retina, a clear image will be formed.
- Light is changed at the retina into electrical signals (nerve messages).
- Information received by the retina is sent to the brain via the optic nerve.

Focusing Light in the Eye

- In a normal eye, light that enters the eye is focused on the retina because:
  – the cornea and the lens are the correct shape, and
  – the eyeball is the correct length.

THE EYE WITH REFRACTIVE ERROR

Refractive Error

- A person who has a refractive error will need to wear spectacles (glasses) or contact lenses so that they can see clearly and comfortably. This is because their eye is not the correct size and shape.
- There are four main types of refractive error: myopia, hyperopia, astigmatism and presbyopia.
- The amount of refractive error an eye has depends on:
  - the steepness of the cornea; and/or
  - the steepness of the crystalline lens; and/or
  - the length of the eyeball.
- A person with a refractive error will have eyes that look normal, but they will not see well.
- An eye examination to test for refractive error is called a refraction.

ACCOMMODATION

- Accommodation occurs when the ciliary muscle contracts and changes the shape of the crystalline lens (makes it thicker).
- This changes the optical focus of the eye so that close objects can be seen clearly.
- When accommodation in a normal eye (an eye without refractive error) is relaxed, objects in the distance are seen clearly.
- Presbyopia refers to the natural aging changes in the eye where the crystalline lens hardens with age. When this happens, the lens cannot change shape easily when the ciliary muscle contracts. This means that an older person cannot accommodate as much or as easily as a younger person.
- If a normal eye cannot accommodate (if a person has presbyopia), close objects will appear blurry.
- The amplitude of accommodation is the total amount of accommodation that is available to change the focus of the eye.
- Amplitude of accommodation decreases with age.
- Asthenopia (visual fatigue) happens when the ciliary muscle gets tired – when too much accommodation is being used.
- To avoid asthenopic symptoms during long periods of near work, usually only half the amplitude of accommodation should be used.
- Sometimes the ciliary muscle can cramp after too much near work. When this happens the distance vision will look blurry temporarily.

TEST YOURSELF QUESTIONS

1. **Please list (from front to back) the five transparent (clear) parts of the eye which light rays must travel through before they reach the retina:**

_____

_____

_____

_____

_____

2. **For light to focus correctly on the retina, the _____ must bend (or converge) the light by the correct amount, and the distance between the _____ and the _____ must be the correct length.**

3. **What is refractive error?**

_____

_____

4. **Name the four types of refractive error.**

_____

_____

5. **How does the eye accommodate?**

_____

_____

6. **Why is it more difficult for people to accommodate as they get older?**

_____

_____

7. **Why is it best for a person to use only half of their total amplitude of accommodation?**

_____

_____

8. **What are the symptoms of asthenopia?**

_____

_____

NOTES