Pupil Researcher Initiative

Project Rainbow

Setting the Scene

Project Rainbow is a real research project taking place at the University of Reading looking at the problems visually handicapped people face getting about in public buildings, and devising solutions to some of the problems. You will carry out a research project in your school or college to find out what proportion of young people suffer from one or more common eye defects. You may follow this with an investigation into colour brightness.

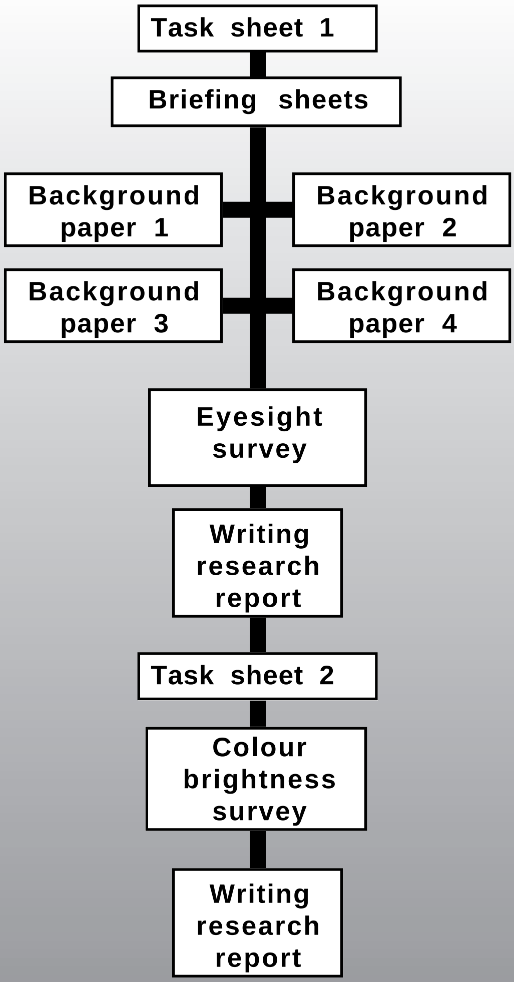
Pupil Research Brief

Study Guide

Syllabus Targets *Science you will learn about in this Brief*

- ❑ short-sightedness means near objects can be seen clearly but not distant ones
- ❑ in short-sightedness either the lens cannot be made thin enough or the eyeball is too long
- ❑ in short-sightedness light from a distant object is focused in front of the retina
- ❑ long-sightedness means that distant objects can be seen clearly but not near ones
- ❑ in long-sightedness either the lens cannot be made thick enough or the eyeball is too short
- ❑ in long-sightedness light from a near object is not focused before it reaches the retina
- ❑ short and long-sightedness can be corrected using lenses

Route through the brief



Outcome Checklist

You will write a report based on your survey into the number of young people in your school or college who suffer from one or more of four common eye defects. You should make sure you produce the following items as you work through the Brief.

Briefing sheets

- ❑ account of the problems described in the briefing sheets
- ❑ account of why it is important that the problems are tackled
- ❑ description of how research might solve some of the problems

Background papers

- ❑ highlighted sections which you did not understand
- ❑ list of suggestions about how the eye defect can be diagnosed
- ❑ design for a diagnostic test
- ❑ results table

Task sheets 1, and 2 (if done)

- ❑ design for the survey or investigation
- ❑ record of your results
- ❑ account of how you analysed your results
- ❑ investigation report

Task sheet 1

This sheet guides you through your research project. You will follow the steps a science or engineering researcher would take when carrying out their research.

Why do you need to carry out the research?

Read the two newspaper articles on Briefing sheet 1 and write down:

- *what problems are described by the articles*
- *why it is important that the problems should be tackled*
- *how might research help to solve some of the problems*.

What do you need to know so that you can carry out the research?

You should already have covered the structure and function of the eye and refraction of light. You may find it useful to review these topics quickly before you carry on. There are four background papers to read. They describe four common eye defects. Your group's task is to read one of them and to devise a simple test which you could use to find out if a person being tested does or does not suffer from the eye defect. You should be able to devise a test based on the information in your paper. You should:

- *read through the paper*
- *highlight any section which you do not understand*
- *help each other in the group to understand the highlighted sections, using textbooks or other sources*
- *make suggestions about the way that the eye defect can be diagnosed (detected)*
- *design your diagnostic test, including any apparatus or diagrams you need to use, and a results chart.*

Carrying out the research

Each group will then report back to the whole class. The report should include a description of the eye defect you have been studying, and a description or demonstration of the test you have devised. The task for the whole class is to put together the four diagnostic tests into a research questionnaire. You will also need to decide what other information about the individuals being tested you need to record. Age? Sex? What else might be important? You may find that designing a computer database to record your results would be useful.

Select the target population for your questionnaire. This may be your class, your year group, or the school or college population. You will need to check this with the teacher. If you are taking a sample of a large population, then make sure you select a representative group of pupils - the survey has to be a fair test. For instance, if the school population has 50% girls, then your sample should have 50% girls. What other factors should you consider in selecting your sample?

- *Carry out your survey and record your results.*
- *Identify any trends,or patterns in your results.*
- *Present your results in tables and graphs to make the patterns easier to see.*

Reviewing your work and telling people what you have found out

Write a report of your findings, including an evaluation of your research project. Discuss with your teacher how your report is to be presented. Did you gather enough data to be able to make firm conclusions? What further research could be carried out? When you have finished the report, you could carry out the second investigation set out on Task sheet 2. Check with your teacher first.

Briefing sheet 1

Morning Telegraph 23 October 1995

Noisy protest at opening of Town Hall extension

A group of about 150 visually-impaired people staged an angry demonstration today as the mayor officially opened the multi-million pound Town Hall extension building.

They were protesting about the lack of consideration given to their special needs. "The architect seems to think that 'disabled access' just means a few ramps for wheel-chairs" said a spokesperson for the group. "This building does nothing to make it easier for the blind or the partially-sighted to find their way around the place, let alone work here. We are furious that this building should be so badly designed for us, when just a little bit of thought, and some consultation, could have made a huge difference."

The Town Hall extension contains the Housing Department, the Social Services Department and the Treasury. A council spokesman said "We are disappointed that this demonstration happened at all, and we have agreed to meet a delegation from the protesters to see if we can find a way of addressing their concerns".

Dropping eye tests short-sighted says local Parents Association

Controversial plans to drop regular school eye tests for teenagers were criticised by a local Parents Association yesterday. A spokesperson said, 'When I was at school there were eye tests at age 13 and 15. Now our children will go through their secondary education until they are 15 without being tested. This is unacceptable. We know that many eyesight problems begin to show up in this age range, and without even basic tests hundreds of school children are not going to have their eyesight problems spotted and their education could suffer'.

The Parents Association will be pressing the authorities to reverse their decision to drop the testing of 13 year olds. A meeting of the Association branch yesterday voted unanimously to seek an urgent meeting with Local Authority officials to see if the decision can be overturned.

News Extra October 29 1995 page 6

Briefing sheet 2

The two newspaper articles you have just read are fictitious. The problem they describe is not. People with certain types of visual impairment do sometimes find it difficult to find their way around public buildings. This is a serious problem, and is often overlooked by designers and architects. Not all visually impaired people are blind. Many suffer from conditions which reduce the quality of vision, for instance, colour blind people may have perfect vision in terms of being able to see things clearly, but cannot distinguish between certain colours. Other conditions may result in blurred sight, or a reduced field of view. It is people with these, and other conditions, who are often neglected when buildings are being designed. The article below, taken from the Engineering and Physical Sciences Research Council's *Newsline* journal (July 1995) describes *Project Rainbow*, a research project based at the University of Reading which is trying to find out how we can overcome such problems.

Project Rainbow
at the University of Reading

Colour code to help visually impaired

The correct choice of colour schemes in buildings from office blocks to railway stations could help people who suffer from visual impairments find their way around.

About 1 million people in Britain suffer from some form of visual impairment. Often their ability to discriminate between colour combinations and contrasts is affected, as in the case of glaucoma sufferers.

Construction professionals such as architects and builders are becoming increasingly aware of the need to provide buildings which are acceptable and accessible to everyone. But there is often a lack of properly researched information, especially regarding questions of colour.

A team at the University of Reading is working with the Royal National Institute for the Blind (RNIB), the Guide Dogs for the Blind Association (GDBA) and ICI Paints, on *Project Rainbow*. The aims of *Project Rainbow* are to devise a system of colour combinations and contrasts for use in buildings and to prepare a colour design guide for use by architects and building managers. The guide would not prescribe what colours should be used, but would suggest effective contrasts for chosen schemes.

Briefing sheet 2 continued

As public access buildings are refurbished and repainted at regular intervals, the project should lead to a cost-effective method for helping those with sight problems.

The Research Director explained that the idea for the project came about following discussions with the RNIB, which pointed out that colour perception was a major problem faced by visually impaired people in buildings.

Colour contrast should help to identify the elements that visually impaired people need to find in buildings - including light switches, fire extinguishers, notice boards, electrical points, doors and lavatories. “For instance, fully-sighted people can pick up the width of a corridor automatically, but the visually impaired may not. They would have much more confidence if there were particular background colours along the corridor which would give them an idea of the width,” explained Mr. Bright.

ICI Paints is providing a building at Slough, which the researchers can decorate in different styles, using many colour schemes. Members of a panel of visually impaired people will move through the building and their performance in finding certain objects in a particular background colour scheme will be recorded on video cameras. ICI’s quick-drying paints will enable the researchers to try out many different colour and contrast combinations.

The visual impairments that the research team will consider are: macular degeneration, glaucoma, cataract, retinitis pigmentosa and diabetic retinopathy.

The importance of eyesight testing

The second newspaper article highlights the fact that young people should have regular tests and that this may not be happening because of the decline in regular eyesight screening in schools over recent years. Many minor eyesight problems in teenagers can easily go undetected, and in some cases school work could suffer.

Colour blindness

The Retina

The back of the eye (the retina) is covered in millions of receptor cells that convert light into tiny electrical signals. *Figure 1* shows that these cells are of 2 different types: rods and cones. The greatest number of these cells (at least 120 million) are rods. These cells can only register black and white images. The cone cells are the ones that register colour. There are no more than 7 million of these. The way rods and cones are distributed around the retina is shown in *Figure 2*. We can see that nearly all cones are concentrated into a tiny spot in the middle of the retina. This is called the fovea. It is about 1mm in diameter.

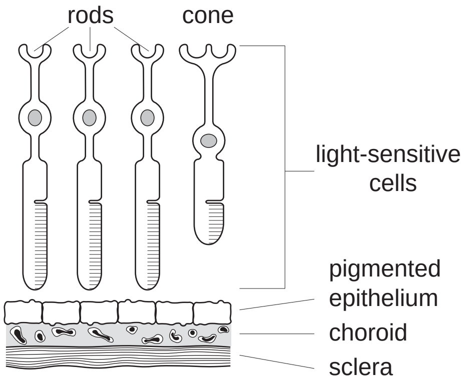
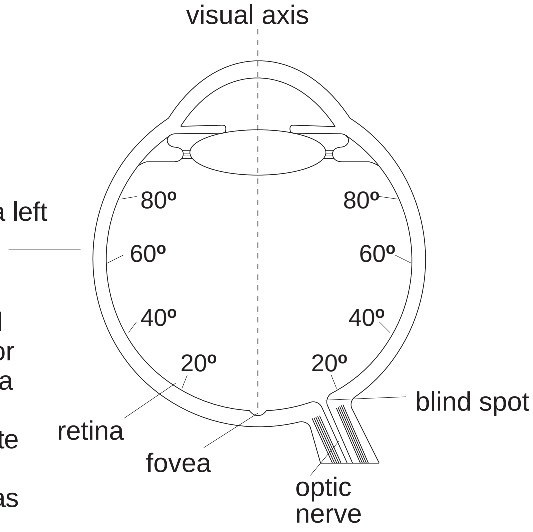


Fig. 1 The light sensitive cells covering the retina



Distribution of rods and cones along the equator of an eyeball. The fovea has no rods but many cones. Rods predominate in the area outside the fovea. The blind spot has no rods or cone

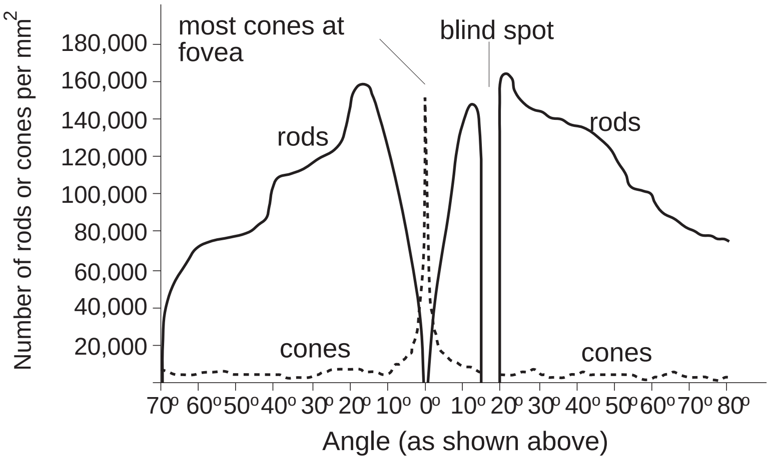


Fig. 2 The distribution of rods and cones in the retina

Seeing in colour

The cone cells can be split into 3 types. One third of them is sensitive to blue light, one third responds to red light and the remaining one third detects green light. These three colours are the primary colours. By mixing light (not paint) of these 3 colours it is possible to obtain every colour we can see, including white. So, the way these 3 types of cell are affected by coloured light allows us to see all colours. Obviously, colour blindness has got something to do with the cone cells. The name “colour blindness” is a poor description of the condition. It leads people to think that a person who is colour blind can only see images in black and white.

Colour deficiency

In fact total colour blindness is very rare (about 1 in a million) but it can be induced by brain damage. A better term would be colour deficiency. A colour deficient person has one or two sets of cones either missing or not working. The result of this is that the person cannot tell the difference between certain colours. The most common type of colour deficiency is one where the person cannot tell the difference between red, green and grey. A rarer type of deficiency is one where the person is unable to distinguish between blue, yellow and grey

Colour deficiency is a condition people are born with. It is passed on from generation to generation, and it is usually inherited by males. Roughly 8% of males are affected and less than 1% of females. Generally speaking, the daughters of colour deficient men pass on the condition to their sons. Colour deficient fathers do not pass on the problem to their children. Colour deficient children of a colour deficient father must inherit it from their mothers.

Various tests have been devised over the years to find out if someone is colour deficient, but the most well known test was invented by Professor Ishihara. Cards are covered with an irregular pattern of colour dots, but some of the dots form numbers or letters. These figures differ from the background in colour, but not in lightness, and they can only be read by people with normal vision. Different cards are designed to detect different forms of colour deficiency.

Colour deficiency is generally not a major handicap for those with the condition. Only in certain jobs does colour deficiency cause difficulties (colour television service engineers, for example).

Short-sightedness
Myopia

Refraction

When light rays enter the eye they are refracted and brought to a focus on the retina. Most people think that the eye lens focuses the rays, but in fact most of the refraction is done by the cornea, as can be seen in *Figure 1*. The lens "fine-tunes" the focusing. It is usual to regard the cornea and lens as a single focusing system, which is what will be done in this paper.

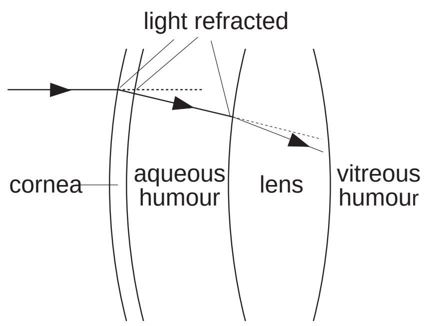


Fig.1 Refraction of a light ray entering the eye

Accommodation

The fact that the eye lens is flexible means that the muscles surrounding the eye, the ciliary muscles, can pull the lens into a different thickness. *Figure 2* shows how this happens.

When the muscles are relaxed the suspensory ligaments attached to the lens pull hard, making the lens thin. This

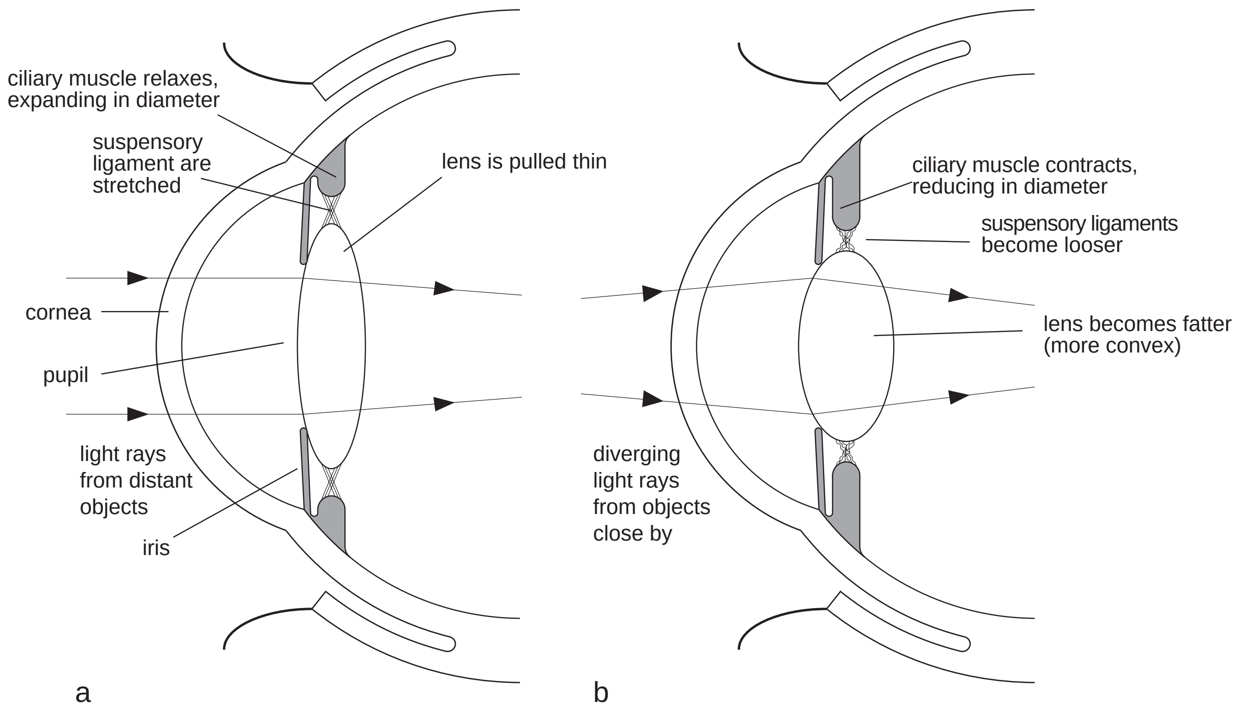


Fig. 2 The ciliary muscles adjust the position of the lens for far (a) or near (b) focusing. Note: refraction at the cornea has not been shown, to simplify the diagram.

allows light rays from objects far away to be brought to a focus on the retina. Light rays from distant objects enter the eye almost parallel to one another.

Light rays from objects near to the eye are diverging as they enter the eye. These rays need a more powerful lens to focus them on the retina. So the ciliary muscles contract, the suspensory ligaments relax and the lens becomes “fatter”, or more convex.

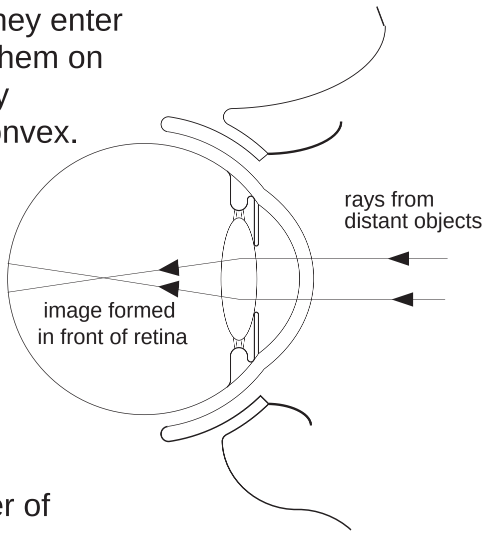


Fig. 3 A person who is myopic cannot focus light from distant objects

The power of a lens is defined as

$$\frac{1}{\text{focal length of the lens}}$$

(focal length measured in metres)

The power is measured in dioptres (D).

So a lens with a focal length of 25cm (0.25m) has a power of

$$\frac{1}{0.25} = 4\text{D}.$$

The fatter the lens the shorter its focal length and so the more powerful it is. The changes in shape of the eye lens as it focuses on objects different distances away is called accommodation. Normal eyes can accommodate for distances between 25cm and infinity.

Myopia

If the cornea bulges out too much or if the eyeball is too long the focusing system will be too strong to focus light rays from distant objects onto the retina. This is a defect of vision called myopia, commonly known as short-sightedness. A short-sighted person can see things close up in focus, but his or her far-point is drastically reduced. This means that objects more than a few metres away will be blurred.

Fig. 4 The Snellen Eye Chart

Diagnosis of myopia

Short-sightedness often arises in teenagers when the body is growing quickly. There are a number of ways of discovering if someone is myopic, but the most common one is the eye chart. The eye chart that everyone knows is the Snellen Eye Chart The letters on the chart go from about 9cm high down to about 1cm (see *Figure 4*). The person being tested stands 6m away and covers one eye. He or she reads the letters down to the row that can be read comfortably.

The other eye is then tested. The numbers down the side of the chart in *Figure 4* describe the sight of the person tested. A person with normal sight can only read the letters on the next to bottom line comfortably.

This person is said to have "6/6 vision". If someone can only read the letters on the third row down, she or he has "6/24 vision". This means that this person can read letters 6m away that a person with normal sight could read at a distance of 24m. A person with 6/24 vision has only one quarter of normal distance vision.

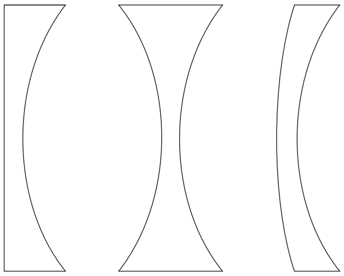


Fig. 5 Cross sections through different types of concave lens
a - plano-concave lens
b - bi-concave lens
c - meniscus concave lens

Correcting short-sightedness

The focusing system of a short-sighted eye can only bring rays that are diverging to a focus on the retina. Rays from objects a long way off enter the eye almost parallel. So, the way to correct short-sightedness is to fit a lens that makes parallel rays diverge (move apart). Lenses that do this are called concave (or diverging) lenses.

The concave lenses fitted to glasses are not like the ones found in laboratories (see *Figure 5a* and *b).* Lenses in glasses are called meniscus lenses (see *Figure 5c*). They are made to match the curvature of the eye, reducing distortion as you look through them.

The concave lens makes parallel rays of light diverge so that they appear to come from the far-point of the short-sighted person. The focusing system can now cope and the rays are focused onto the retina (see *Figure 6*).

Note: since concave lenses always produce a diminished upright image, you can tell if someone is myopic by holding their spectacles above a book. If the print is made smaller by looking through the lenses the owner of the spectacles is short-sighted.

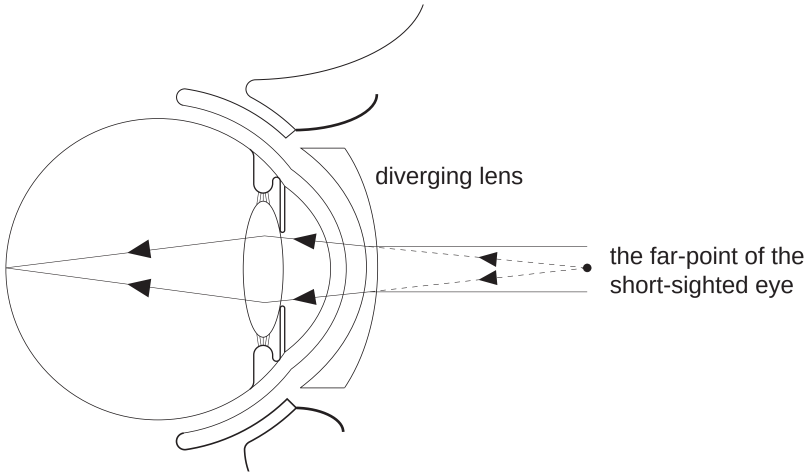


Fig. 6 Correction of myopia with a concave lens

Long-sightedness

Hypermetropia

Hypermetropia is a common defect of vision. It is also known as hyperopia, but its more common name is long-sightedness.

When we look at something in the distance and then look at something close up, our eye lenses change shape (or accommodate) to focus light rays from the close object. This means that the lens changes its focal length. The distance between the lens and retina for the average adult is about 0.02m. People with normal vision have a near-point (the closest distance from the eye that can be seen in sharp focus) of 0.25m.

The far-point is the furthest distance that an object can be brought into focus. For people with normal eyesight the far-point is at infinity. This means that we can see any object in focus at any distance away from us beyond the near point.

People who are long-sighted often have excellent distance vision. They have no difficulty reading the letters on a standard eye chart. Their problem is that they have great difficulty in focusing on objects close to them (see *Figure 2*). Special eye charts, which have to be held 33 cm away from a person's eyes can be used to diagnose hypermetropia.

Those people who suffer from long-sightedness often realise they have the defect when they try to read a book. For normal-sighted people a distance of 0.4 to 0.5m is comfortable for reading. A long-sighted person has a near-point much further away than normal, and so they often have to hold books at arm's length to get the pages in focus.

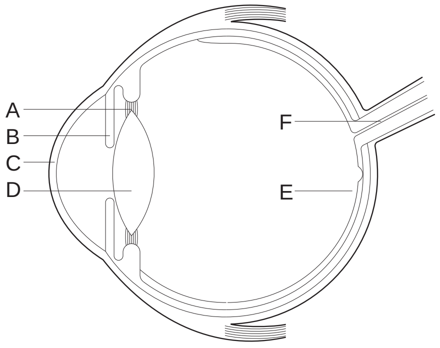


Fig. 1 Section through a human eyeball
A suspensory ligament
B iris
C cornea
D lens
E retina
F optic nerve

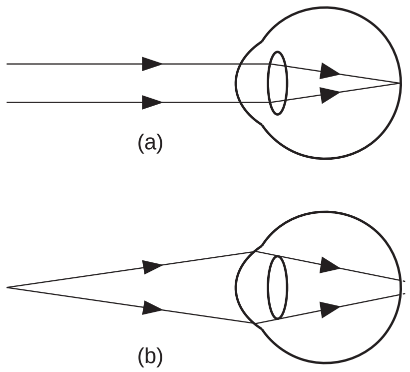


Fig. 2 A person who is long sighted can focus light rays from a distant object (a), but light from a close object (b), cannot be focused

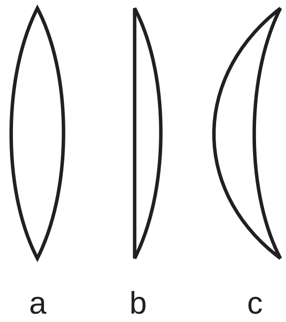


Fig. 3 Types of convex lens
a - bi-convex lens
b - plano-convex lens
c - meniscus convex lens

Correcting long-sightedness

Long-sightedness is caused by short eyeballs or lenses that cannot change shape to a small enough focal length to focus diverging rays. Since the eye lens can cope with parallel rays of light, the way to treat long-sightedness is to put a lens in front of the eye that can bend diverging rays so that they become parallel. Convex or converging lenses do this (see *Figure 3*).

If an object is placed at the focal point of a convex lens, light from it will be refracted into a parallel beam of light, as shown in *Figure 4*.

So, a convex lens with the focal length equal to the near-point distance of the long-sighted person is fitted, and the defect is corrected (see *Figure 5*). Spectacles prescribed for long-sighted people are often described as "reading-glasses". The lenses in these spectacles are convex, and so if they are held above some print they will act as magnifying lenses and make the words look bigger.

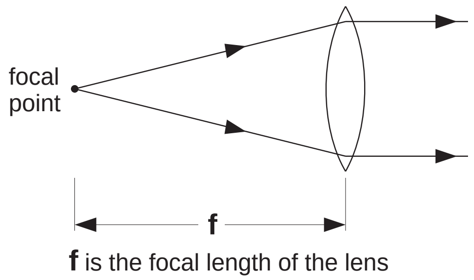


Fig. 4 A convex lens refracting light from its focal point

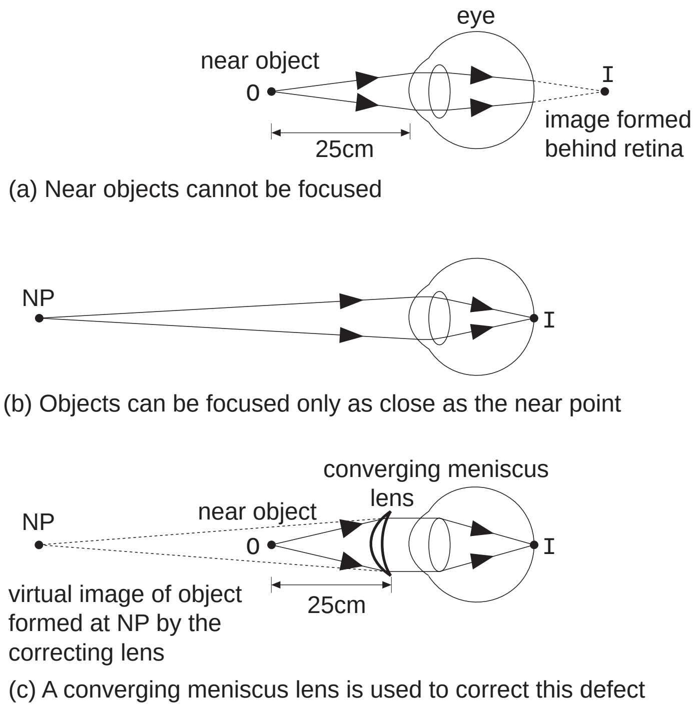


Fig. 5 Corrections of long-sight using a convex lens

Astigmatism

What is astigmatism?

Before this question can be answered, we need to know how our eyes focus light rays onto the retina. The lens inside the eye is not rigid like a glass lens. It is elastic. It is attached by ligaments to a series of muscles, called the *ciliary* muscles that can pull the lens to make it thicker or thinner. Thick lenses have a short focal length and refract light rays strongly. Thin lenses are less powerful and do not bend light rays as much. The eye lens needs to change shape so that rays from near or distant objects can be focused onto the back of the eye (the retina). The eye's ability to do this is called *accommodation.*

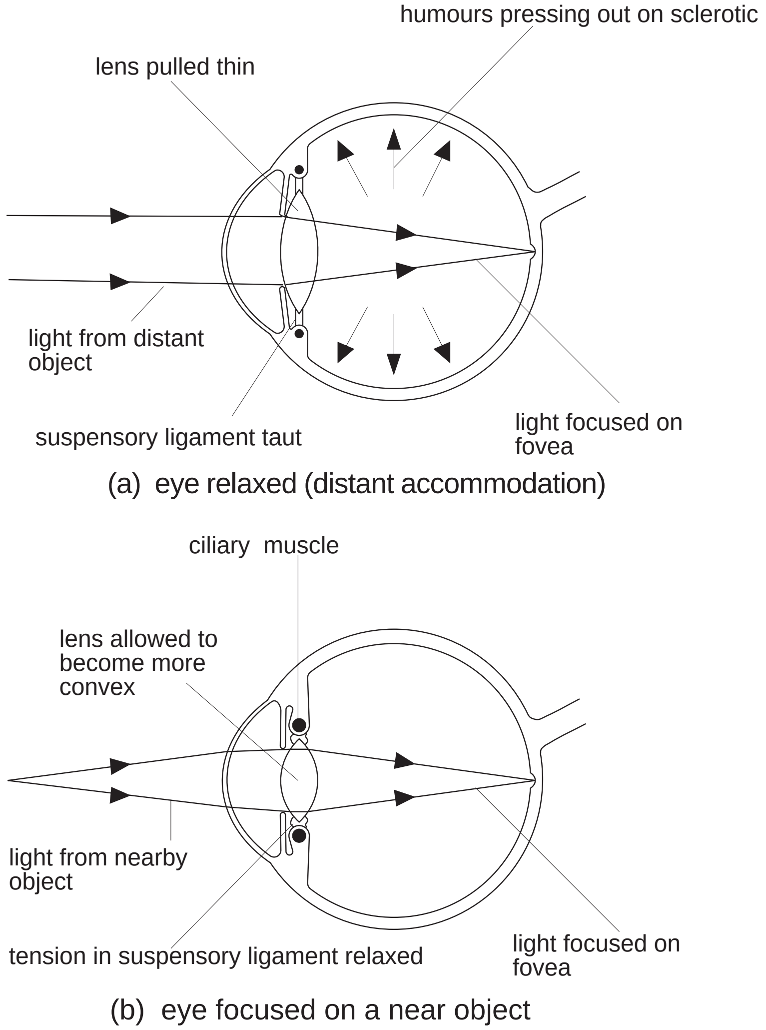


Fig. 1 Accommodation

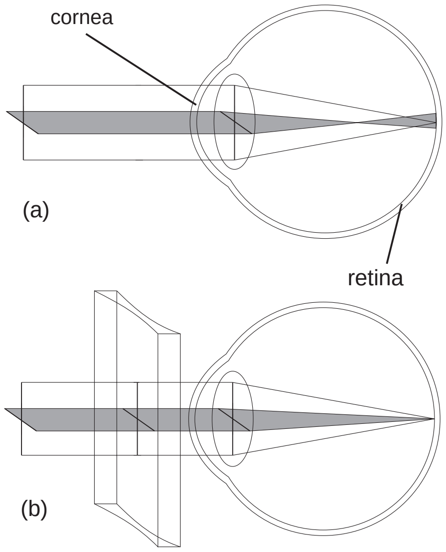


Fig. 2 (a) how light is focused by an astigmatic eye (b) correction of astigmatism with a cylindrical lens

The lens is not the only part of the eye that bends light. The cornea also does this, and it is a defect in the cornea that is responsible for astigmatism.

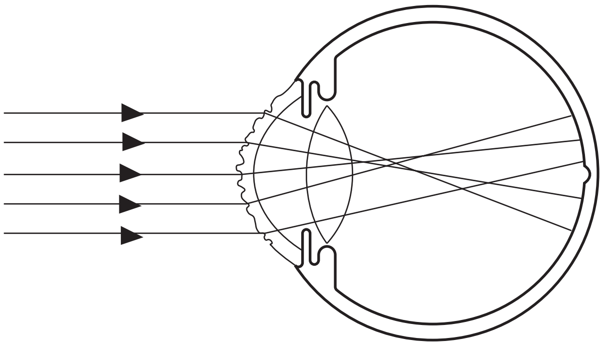
A normal cornea has the same curvature in all directions, but in an astigmatic person the shape of the cornea is not like this. Someone who has regular *astigmatism* will have a cornea shaped rather like the back of a spoon, where the curve in the direction along the bowl is longer than the curve across. As a result the eye does not have an exact point of focus. (The word "astigmatism" means "lack of focus".)

So, the position of the image varies depending on the angle the light enters the eye. A vertical beam of light would be sharply focused but a horizontal beam would not. This means that if an astigmatic person looked at a pattern of, say, vertical lines on top of rows of horizontal lines when the horizontal lines are clearly seen, the vertical lines will be blurred.

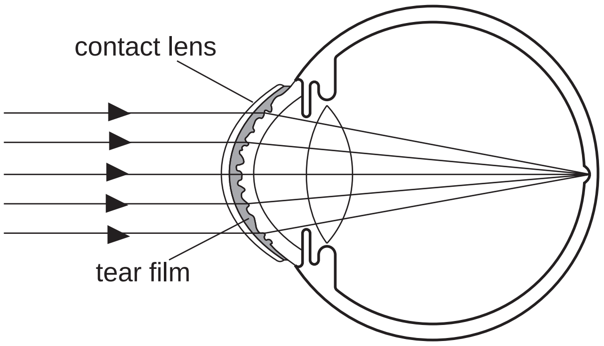
Regular astigmatism can be corrected with cylindrical lenses (*see Figure 2*). These refract light in one direction only, unlike normal spherical lenses which bend light rays in all directions.

Irregular astigmatism

Irregular astigmatism is caused by the cornea having major irregularities including unevenness or scars (see Figure 3). In cases like this it is easier to correct the defect with contact lenses. The tear film between the eye and the contact lens helps to smooth out the irregularities in the cornea.



(a) This diagram shows a cross section of an eye with irregular astigmatism, i.e. the cornea has several curvatures.



(b) This diagram shows how a contact lens can compensate for the irregular curvatures of the astigmatic eye. It demonstrates that the "optical system" is extended by the tear film that is developed between the cornea and contact lens. The contact lens corrects the visual defect directly on the eye so the scattered rays can be focused.

Fig. 3 Irregular astigmatism and its correction

Task Sheet 2

This sheet guides you through a second investigation. The work you do here will be similar to the work carried out by the Project Rainbow team at the University of Reading. You can work in groups of three to carry out the investigation.

Why do you need to carry out the research?

The Project Rainbow team had to devise a method for measuring how bright a colour was. This was so that they could work out what combination of colours in a colour scheme for the inside of buildings allowed visually impaired people to see things more clearly. Colour combinations, where one colour stands out strongly from the other make it easier for visually impaired people to see their environment. From their investigations, the team have been able to produce colour charts, where each colour is given a number based on how bright it is. The further apart the colour numbers, the greater the contrast. Designers can choose contrasting colours based on the figures in the colour charts - as long as the combination looks pleasant to the eye!

What do you need to know so that you can carry out the research?

Sunlight is known as white light. It is a mixture of all the colours of the spectrum. A white object looks white in white light because it reflects all the colours in the spectrum. An object which appears black in white light absorbs all the colours of the spectrum: it does not reflect any of them. A green object absorbs most of the colours of the spectrum except green light. This is reflected, and so the object appears green: only the green light from the spectrum reflects off the object into your eye.

Carrying out the research

- *Your group will have to devise and carry out a fair test to measure colour brightness.*

You will have to think about:

- *what coloured material is available to test*
- *what apparatus is available to measure colour brightness*
- *how you will collect your data*
- *how the test will be made fair (what else, other than colour, might affect the brightness you can measure?)*
- *how to record the results*
- *the way you will report your findings*

Produce a table showing numerical values for different colours. You will have to come up with a method to decide how large a difference in brightness is enough to provide good contrast for visually impaired people. Will you have to carry out any more tests to find this out?

Reviewing your work and telling people what you have found out

- *Write a report of your findings.*
- *Compare your work with other groups - did you come to the same conclusions about what colour combinations could be suggested to designers?*

Follow-up work might involve surveying your school or college to see if it is a good environment for visually handicapped people. Apart from colour contrasts, what other factors might be important?