HUMAN VISUAL SYSTEM AND IMAGE FORMATION

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Annotation. This article discusses the structure and functions of the human visual system and the process of image formation in the eye. It explains the roles of the iris, pupil, lens, retina, rods, and cones in vision. The paper also examines binocular vision, color perception, color blindness, and common eye defects such as myopia, hyperopia, and presbyopia. Furthermore, the similarities between the human eye and camera systems are highlighted. The study emphasizes the importance of understanding image formation mechanisms for applications in Digital Image Processing (DIP), computer vision, and medical imaging technologies

Keywords: Human Visual System, Image Formation, Retina, Lens, Color Vision, Eye Defects, Digital Image Processing (DIP), Computer Vision

The eyes provide what many would regard as the most important of all our senses — sight. Take a look around you now. If your eyes are working normally, they just transmitted focused colour images of several objects located different distances away to your brain and with virtually no effort!

The eye: The structure of the eye allows it to limit or maximise the amount of light entering it, focus the light to form an image and then transmit the image to the brain. These primary functions are carried out by:

- the **iris** and **pupil**: these close down to limit light when it is bright and dilate (open up) to maximise the light entering the eye in the dark;
- the **cornea** and **lens**: these bend the rays of light entering the eye so that the light focuses on the retina;
- the **retina**: this is where the image should form. Specialised cells in the retina then transmit the image to the brain.

Figure 1. The amount of light entering the eye is controlled by the colored iris which opens and closes

The rest of the eye is there basically to keep it in shape (vitreous humour, aqueous humour and sclerotic layer), to stop stray light from entering or reflecting around the eye (the choroid) and to change the shape of the lens to allow it to focus (suspensory ligaments and ciliary muscles).

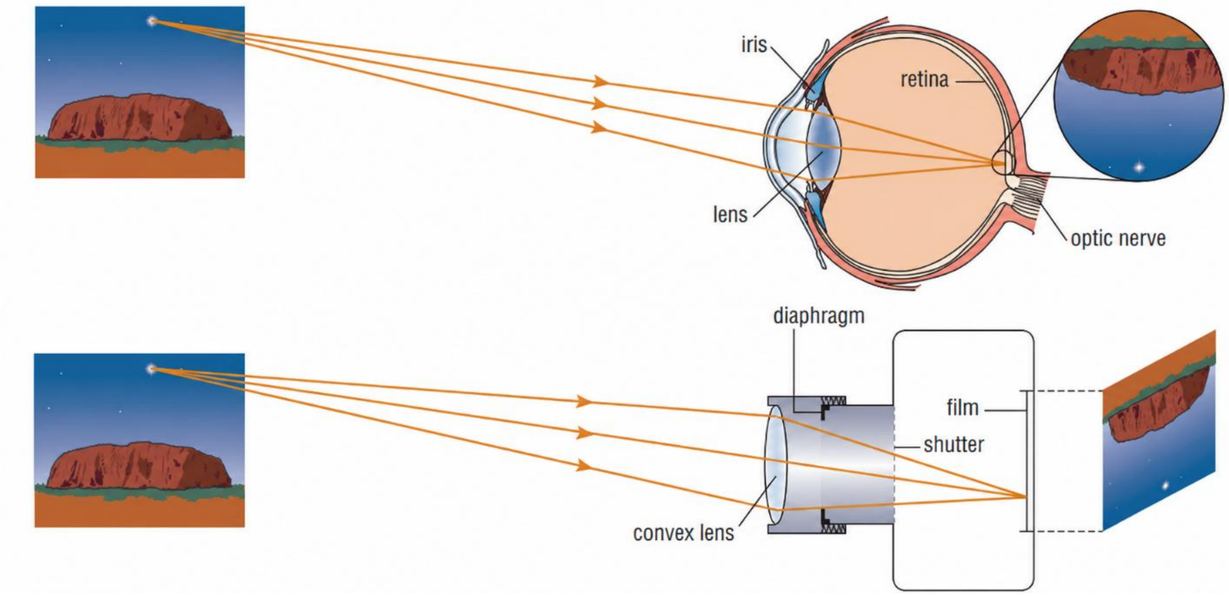

Figure 2. The eye focuses images in the retina. Although the image is upside down, the brain processes it so that we perceive it the correct way up. The operation of the eye acts very much like an old-fashioned film-loaded camera

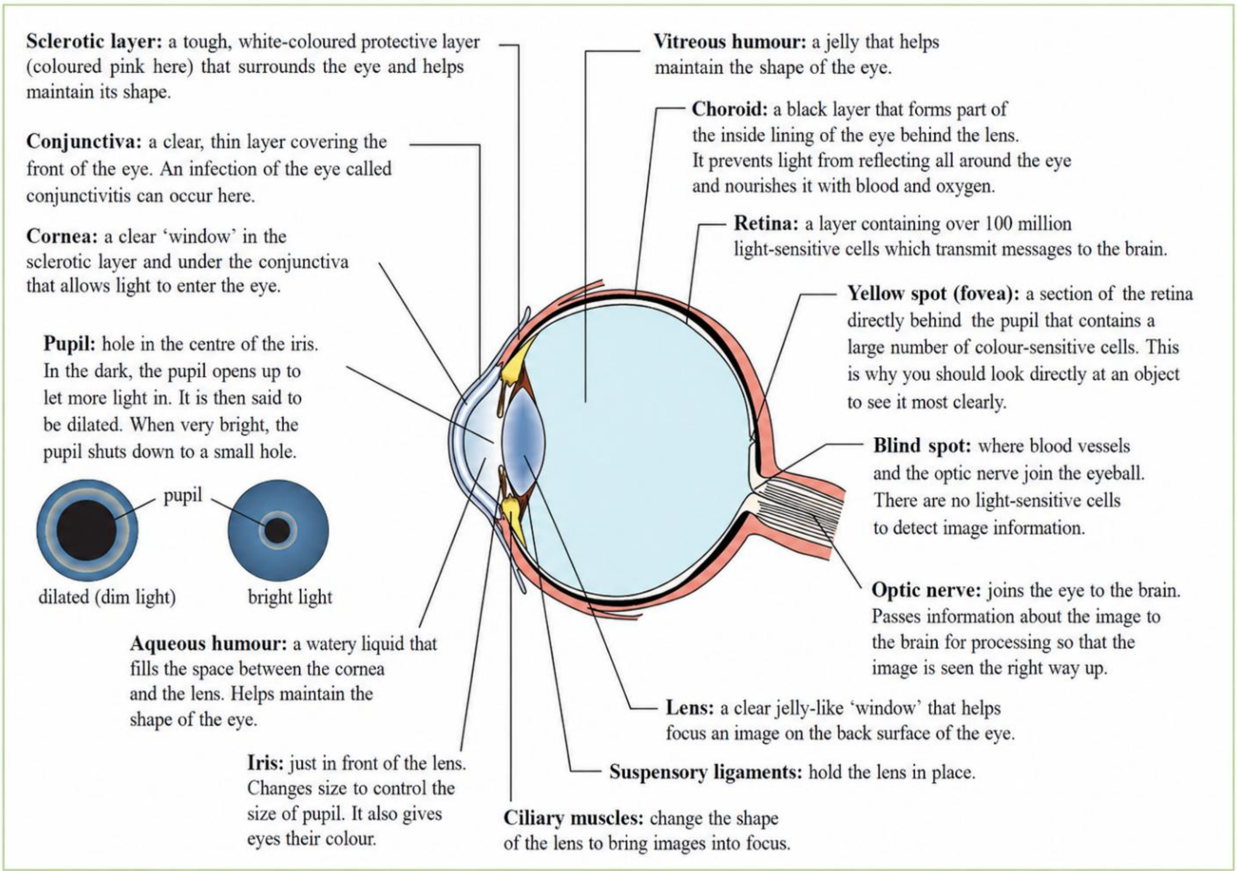

Figure 3 The human eye

Eye protection. A number of features help protect your eyes:

- eyebrows and eyelashes help keep dust out;
- tear ducts produce tears to flush out any foreign particles;

- eyes are set back in depressions in our skulls called **orbits**. This gives them some protection from being knocked.

Why two eyes? wo eyes allow you to judge distances more accurately since each eye sees a slightly different view. The brain combines the two images to create a three-dimensional view that gives us more information about how far away an object is. This is known as **binocular vision**.

Colour vision. The retina contains special cells called **rods** and **cones**. Rods are more sensitive than cones, but respond only to light and dark, helping us to detect shapes. Cones need more light to be activated and come in three types which detect the colours red, blue and green. Only the rods are activated at night or in the dark and so you see everything in shades of grey without much colour.

If red light falls on the retina, 'red' cones are activated. With purple light, both red and blue cones are activated. Both rods and cones send messages to the brain to help you see.

Some people lack some types of cone cells and cannot easily differentiate between some colours, most notably red and green. This condition is known as red/green **colour blindness**. It is an inherited disease and affects about 1 in 15 males and 1 in 1000 females.

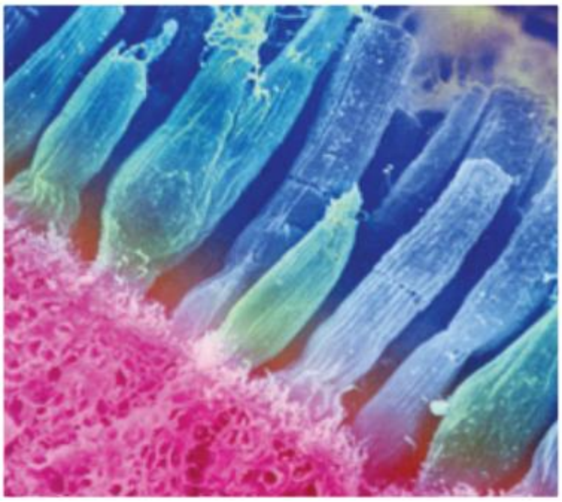

Figure 4. A scanning electron microscope photograph of rods and cones

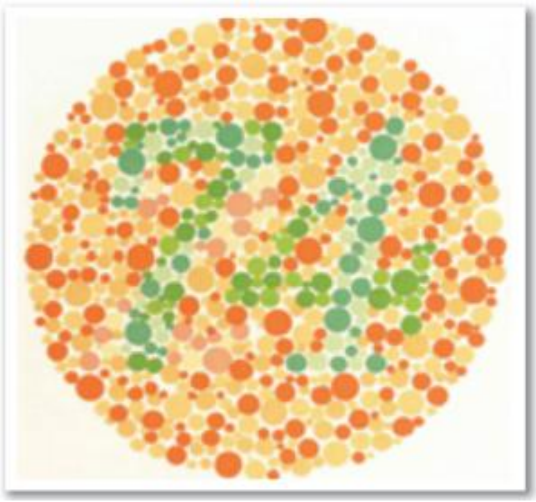

Figure 5. A colour blindness test. What do you see?

What colours can't you see? Lots of colours cannot be seen by humans. Infra-red (IR) and ultraviolet (UV) are two colours, for example, that are impossible for us to see. We feel IR, however, as heat and UV is known to damage our skin. Special cameras can detect IR and make it possible to detect sources of heat (such as people lost in the bush). Likewise, some dyes, fabrics and detergents can convert 'invisible' UV into a strange violet-white glow that can be seen.

Eye defects. The job of the lens is to bend light so that an image is formed on the retina. It does this by using the ciliary muscles to change its shape. When these muscles relax, they pull on the suspensory ligaments and stretch the lens, making it thinner so it bends light less. When the ciliary muscles contract, they pull less and allow the lens to fatten up. Fatter lenses bend light more, which is what's required when looking at close objects. The ability of your eyes to change lens shape and focus at different distances is called **accommodation.**

In some people, the lens becomes less elastic and is unable to become thin enough or fat enough to focus images at exactly the right position in the eye. This can result in one of three conditions:

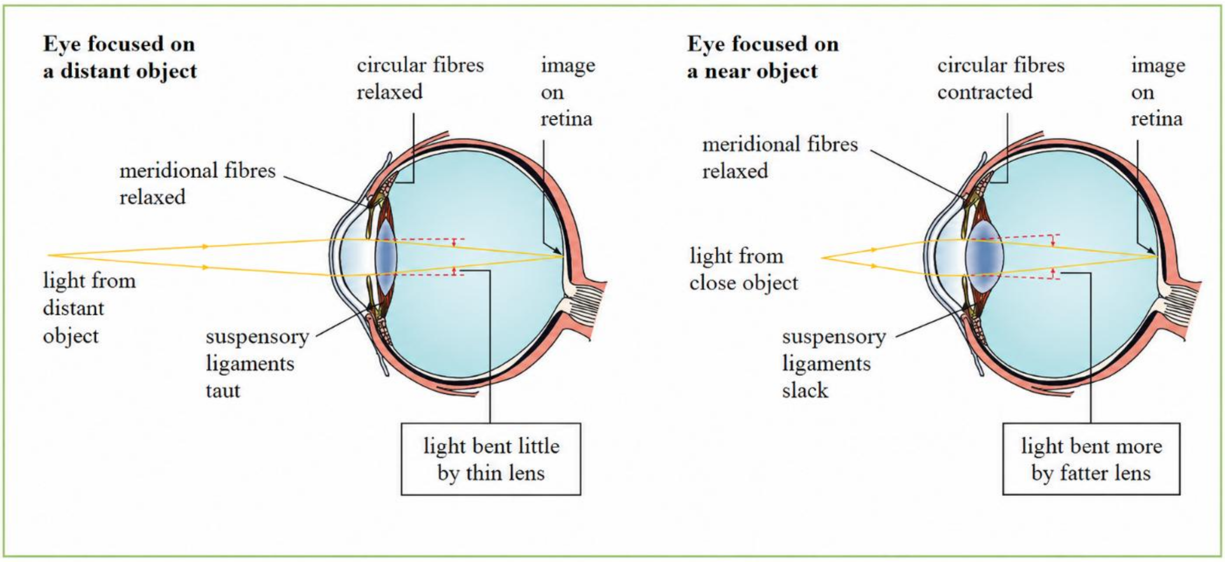

Figure 6. This is how the eye focuses on close and distant objects: the ciliary muscles in each eye stretch and relax the lens making it thinner and thicker. This changes the amount of bending of light that occurs as it passes through the lens.

- short-sightedness—people can focus on objects a short distance away, but not on distant objects. This condition is known as **myopia**.

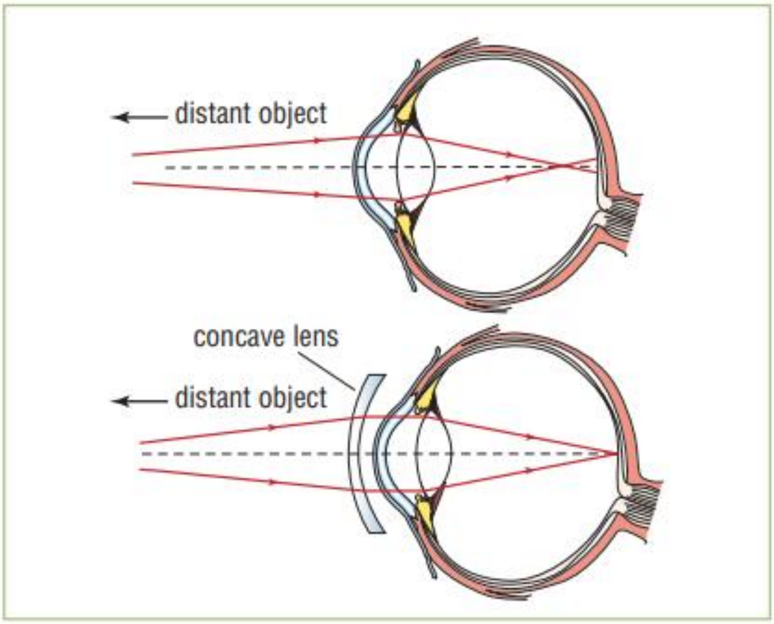

Figure 7. Short-sightedness (myopia) can be corrected by wearing concave lenses that move the focus point of the image back onto the retina.

- long-sightedness—people can see long distances away, but cannot focus on close-up objects. Another name for long-sightedness is **hyperopia.**

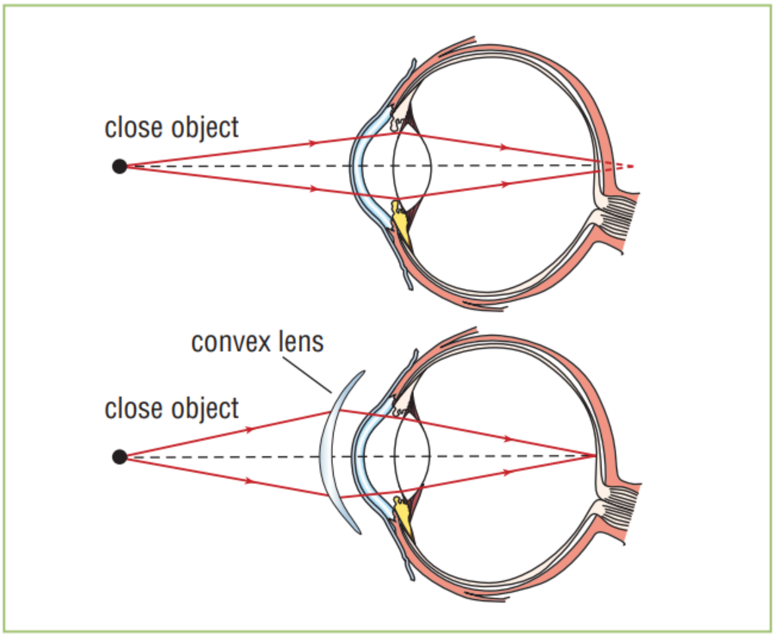

Figure 8. Long-sightedness or hyperopia, can be corrected by wearing convex lenses which bend light more so the focus point of the image is brought forward onto the retina

- **presbyopia**—as people age, they often lose the ability to focus at short distances, particularly when reading. Some people have trouble focusing at both short and long distances, and may use bifocal lenses, which have two types of lens in one (e.g. convex at the bottom for reading, and concave at the top for distance vision).

Figure 9. Contact lenses can be used to correct impaired eyesight

As well as spectacles, contact lenses can be used to correct vision. Soft plastic lenses are available which are more comfortable than hard glass lenses, but they are not suitable for everyone. Wearers of contact lenses must ensure that their eyes still receive enough oxygen. Modern plastic contact lenses are gas permeable, allowing some oxygen to pass through to the cornea. The eye may react to a lack of oxygen by growing additional blood vessels to supply more oxygen via the bloodstream, but the extra vessels can cause irritation and other problems.

Conclusion. The human visual system is a highly sophisticated biological imaging system capable of capturing, focusing, and interpreting visual information. Understanding how images are formed on the retina and processed by the brain provides a strong foundation for Digital Image Processing (DIP). Many DIP techniques, such as image enhancement, edge detection, color analysis, image restoration, and object recognition, are inspired by the mechanisms of human vision. The comparison between the eye and a camera demonstrates how optical principles are applied in both biological and digital systems. Therefore, studying the human visual system contributes significantly to the development of advanced image processing, computer vision, artificial intelligence, and medical imaging applications.

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