THE EYE
THE PHYSIOLOGY OF HUMAN PERCEPTION

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The scientific study of the eye is believed to have originated with the Greek physician Herophilus, who lived from about 335 to 280 BCE. Indeed, from his work came the words that we use today to describe the various parts of the eye, including the words retina and cornea. In Herophilus’ day, scientists believed that we could see because beams of light came out of our eyes and fixed on objects. In the centuries since, doctors and anatomists have discovered that vision relies on just the opposite effect. Human eyes are actually light collectors. Light rays travel from objects around us and stimulate the light-sensitive cells in our eyes. This book takes a look at these amazing organs and how they function to allow us to see the world.

Anyone staring into another person’s eye would notice that its exterior is mostly white. This part of the human eye, the sclera, is made up of fibrous tissue and provides a tough protective coating around the whole eyeball. The most noticeable part of any eye is the coloured iris and the dark pupil that it surrounds. The iris, which works much like the aperture of a camera, expands in darkness to let more light into the pupil and contracts in bright light to keep the light-sensitive cells from being overwhelmed. The colour of the iris comes from melanin, a substance that protects the eye from absorbing strong light. In the centre of the iris is the pupil, which allows light and other visual information into the interior of the eye. The iris and pupil are protected by a transparent, domelike cover called the cornea.

Light enters the interior of the eye by passing through a crystalline lens, which bulges or flattens, depending on how far away an image is, and then through a semisolid gel-filled chamber called the vitreous body. The vitreous body gives the eye shape and flexibility. Finally, the light reaches the retina, a membrane made up of layers of cells,
which receive visual information and transmit this information to the brain.

The eyes would not be able to receive this information if they did not move. How they move is a complicated process. Eyeballs are set into protected parts of the skull called eye sockets. Between the sockets and the eyeballs are layers of fat and six thin muscles that gently tug the eyeball in one direction or another. Most of the actual movements of the eyes are carried out without awareness. For example, when a person sees bright light at the edge of the field of vision, he or she is immediately drawn to look at it. This response is called the fixation reflex. Scientists have also learned that the eyes move a number of times within a single second. These tiny movements help keep the eyes focused on a world that is constantly in motion and stimulate the retina to take in fresh visual information even with stationary objects.

Eyes are delicate and precise organs that are vulnerable to problems. There are, however, a number of mechanisms in place to protect the eyes. Eyebrows and eyelashes keep out dust, sweat, and other irritants. Eyelids lubricate the surface of the eyeball and protect against the introduction of foreign bodies into the eye. Lacrimal glands at the outside upper corner of each eye create a steady supply of tears to keep the eyeballs moist. Tears—produced by irritation, yawning, and crying—also contain bacteria-killing enzymes that destroy infections. To keep the eyes moist, we blink, often involuntarily.

The retina in the back of the eye has an especially valuable role to play in vision. Light-sensitive cells in the retina, known as rods and cones because of their distinctive shapes, enable us to see. For example, cones are highly sensitive to colour, and thus they are responsible for daylight (photopic) colour vision and for fine visual discrimination. Most of them are concentrated around a
small dimple in a part of the retina called the fovea, or macula lutea.

In the darkness of night, the light-sensing rods are far more helpful than the cone cells. Rods are responsible for motion detection and for night (scotopic) vision. After 30 minutes in the dark, the human eye can become up to 10,000 times more sensitive to light. Night vision is also different from day vision because the cones are much less active, resulting in reduced detection of colour.

As cones and rods react to stimuli, they excite nerve-cell bodies called ganglions. Ganglion cells send this raw information to the brain, which then translates it into a visual image. Scientists have learned much about vision through studying the electrophysiology of the retina. Many studies have focused primarily on what happens when the eyes are electrically stimulated. By placing an electrode on the eye, scientists can create electroretinograms, which show the electrical impulses that enable the eyes to communicate with the brain. These types of studies have helped scientists to identify and understand new information concerning the electrical pathways of the rods and cones. Such studies have also greatly expanded scientists’ understanding of how people perceive colour. Colour blindness, inherited forms of which commonly affect males, occurs because the colour-sensitive cones in a person’s retinas are missing or weak. Because in many cases only certain cones are affected, colour-blind persons usually can see at least some colour. For instance, a person whose red cones are missing or do not work cannot distinguish between red and green.

When light projects an image onto the retina in the back of the eye, the image is upside down, reversed (with respect to left and right), and two-dimensional. The optic nerve sends this image to the back of the brain, to an area called the occipital lobe. Fortunately, the brain knows how
to translate this image into one that is right side up and non-reversed. Also, the image appears three-dimensional because the separation of the two eyes enables each eye to see an object from a slightly different angle. The brain takes the two retinas’ information and fuses it into a single three-dimensional image through a process called stereoscopic focus. How the eyes work together and coordinate two sets of images is a complex topic, one that is explored in this volume.

In the 20th and early 21st centuries, a significant amount of information about the human eye was gleaned from studies of eye disease. Malfunction of the eyes and of the visual process has helped scientists to understand the basic structures of the eye and how each structure contributes to vision.

Diseases and other eye problems can take place within different parts of the eye. Some of the ailments of the outer eye include sty, an inflammation of the eyelid, and trachoma, a bacterial disease that is prevalent in poverty-stricken areas of the world. The eyelashes of trachoma victims turn inward and brush against the corneas. This constant irritation can scar the cornea. Inner eye diseases include problems such as cataracts. In persons with cataracts, the lenses of the eyes lose their transparency and appear to have a milky cover. Cataracts can be caused by birth defects, wounds, exposure to X-rays, drugs, or old age. In many cases, cataracts can be corrected by surgery.

There are a variety of conditions that can affect the retina. For example, the retina can become detached from the underlying layer of supporting cells called the retinal pigment epithelium. Retinal detachment can cause “floaters”—deposits in the eye that produce visual spots or shadows. Sometimes retinal detachment is caused by trauma, but more often it is caused by aging and changes
of the gel in the vitreous body. Macular degeneration is a blinding disorder that is characterized by the gradual deterioration of the retina, particularly the fovea. Persons with macular degeneration sometimes have blind spots in the centre of the visual field before they lose their sight entirely. Premature babies are sometimes treated with oxygen in order to help them survive their first days of life. This excess oxygen, however, can cause the infants’ retinal blood vessels to develop abnormally, giving rise to a condition known as retinopathy of prematurity, which can lead to blindness.

Accidents are another important cause of blindness. Mishaps with household chemicals or even looking at the sun too long can destroy vision. In addition, there are a number of abnormalities, including nearsightedness (seeing only close objects clearly), farsightedness (seeing only distant objects clearly), and astigmatism (in which all objects are blurry), that can result in impaired vision.

Since the 1200s, physicians have been able to correct ordinary vision problems like nearsightedness and farsightedness. Reading glasses were first used in Europe and China, but they remained expensive and rare. In the 1780s, Benjamin Franklin became frustrated by repeatedly having to take off his reading glasses and put on a different pair of glasses when he needed to see at a distance. As a result, Franklin inserted distance lenses in the top half of his eyeglass frames and reading lenses in the bottom half, thereby creating the first bifocals.

But it was German scientist Hermann von Helmholtz who developed the modern field of ophthalmology. He did it by inventing the ophthalmoscope, which allows doctors to see inside the eye. Thanks to the pioneering efforts of Helmholtz and others, there are now three different types of eye specialists: ophthalmologists, medical doctors who
focus on eye problems and perform surgery; optometrists, who give eye exams and prescribe corrective lenses; and opticians, who fit, supply, and adjust eyewear for patients.

Painter and inventor Leonardo da Vinci came up with the idea of contact lenses in 1508. But it wasn’t until 1887 that the first contacts were actually produced. These glass lenses were so large and uncomfortable that they could be worn only for an hour at a time. The first practical contact lenses did not come along until 1938. But these rigid plastic contacts remained uncomfortable for most people. Finally, in the 1970s, scientists introduced “soft” contacts made of flexible plastic.

Starting in the 1990s, people began turning to eye surgery to permanently correct nearsightedness, farsightedness, and astigmatism. LASIK (laser-assisted in situ keratomileusis) surgery has become popular. In this procedure, doctors cut a tiny flap across the clear cornea and fold it back so that a laser can then reshape the tissue underneath. In the mid-2000s, roughly 1.4 million people a year underwent this type of surgery.

By studying the human eye, medical experts have learned not only about the eye itself but also about the way the brain functions as we look out onto the world. As science moves forward, researchers are discovering new ways to treat and cure eye diseases and disorders, giving many persons affected by such conditions the gift of vision. This book will allow readers to see the human eye in a new way.