6) The Visual System

In vertebrates:

- the eye detects colour and light
- but the brain assembles the information and perceives the image

Although light detection in the eye is the first stage in vision, remember that it is actually the brain that "sees." The brain processes complex images in several stages, first analysing simple features, and then computing more complex features.

The toad visual system has 3 levels of analysis:

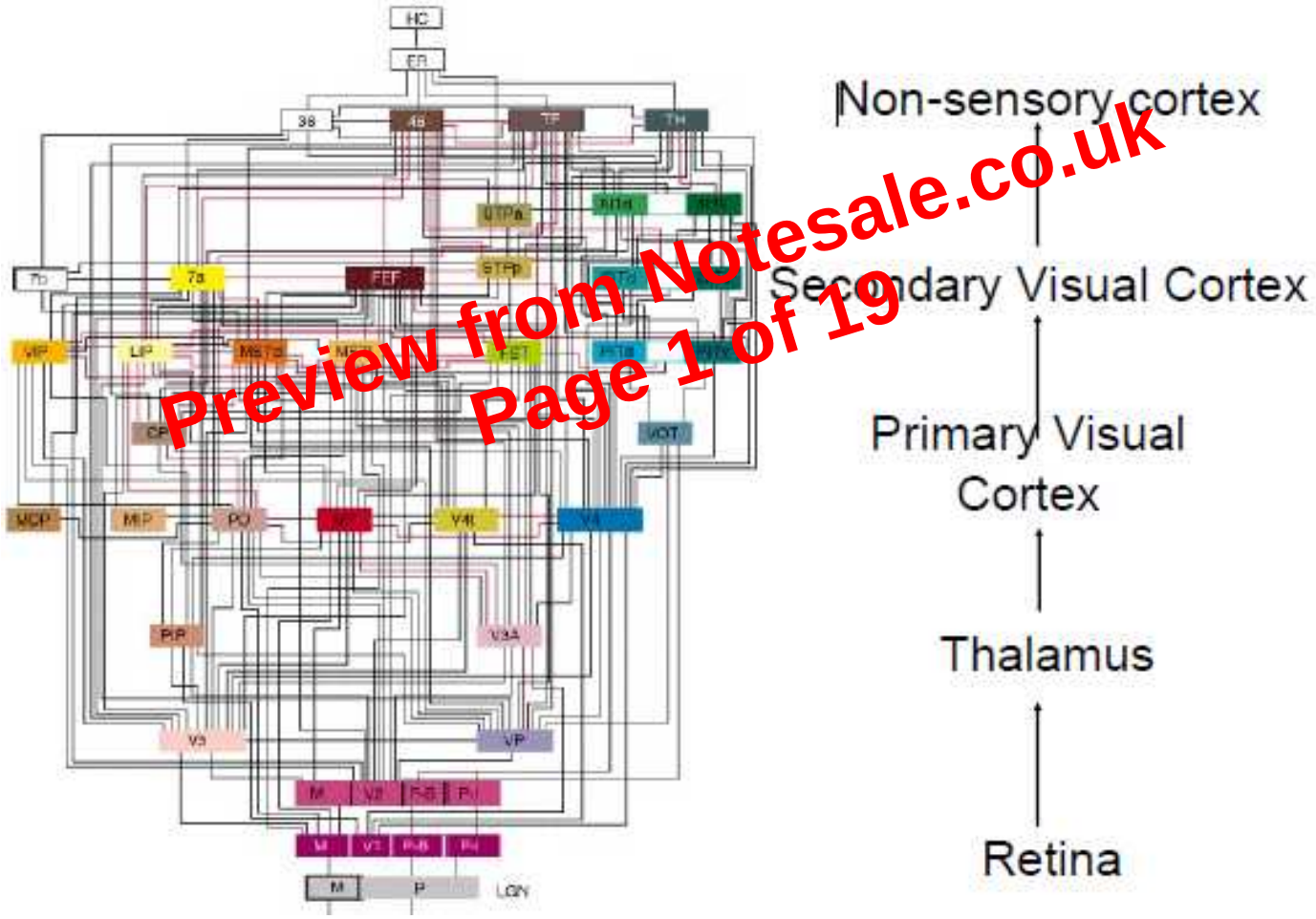
- Retina (1st level)
- Pretectal thalamus (2nd level)
- Tectum (3rd level)

The human visual system also has 3 main levels:

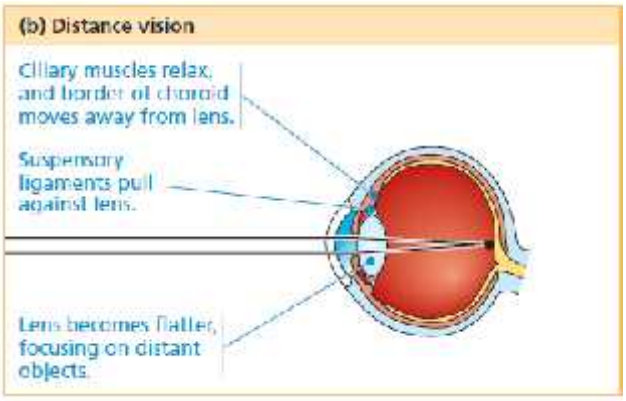
- Retina
- Thalamus
- Cortex

A circuit level description of the visual system

This shows how complex our visual system is.



- When you view a **distant object**, your lens is flattened.



By turning your head and pointing your eyes in a particular direction, your brain also determines what lies in your field of vision.

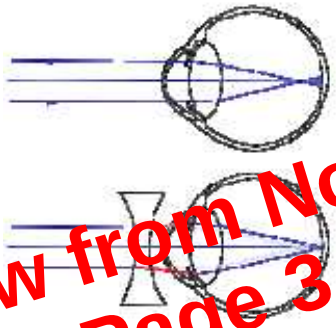
Although our peripheral vision allows us to see objects over a nearly 180° range, the distribution of photoreceptors across the eye limits both what we see and how well we see it. Overall, the human retina contains about 125 million rods and about 6 million cones.

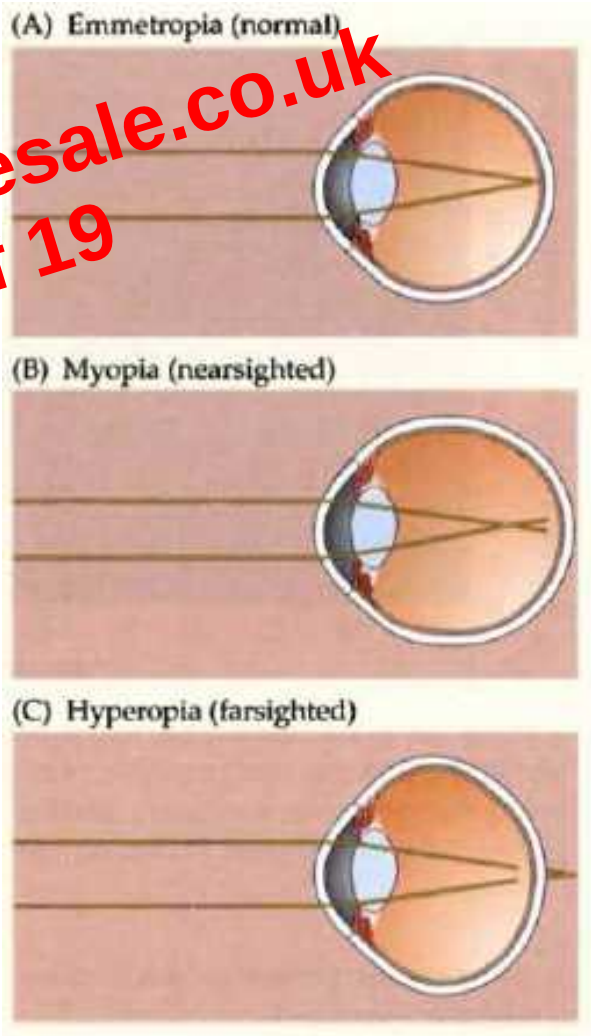
At the **fovea, the centre of the visual field,** there are no rods (the more sensitive light receptors) but a very high density of cones— about 150,000 cones per square millimetre. The ratio of rods to cones increases with distance from the fovea, with the peripheral regions having only rods.

- In daylight, you achieve your sharpest vision by looking directly at an object, such that light shines on the tightly packed cones in your fovea.
- At night, looking directly at a dimly lit object is ineffective, since the rods—the more sensitive light receptors—are found outside the fovea. Thus, for example, you see a dim star best by focusing on a point just to one side of it.

Refractive Errors

Myopia (short sighted) is a condition of the eye where the light that comes in, does not directly focus on the retina but in front of it. This gives a blurry image. It can be caused by the corneal surface being too curved, or by the eyeball being too long. In either case, with the lens as flat as it can be, the image of distant objects focuses in front of, rather than on, the retina.



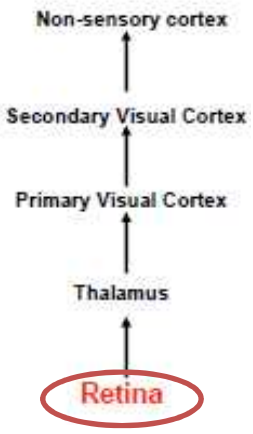


Hyperopia (long sighted) occurs in people who are unable to focus on near objects. They are said to be farsighted, or hyperopic. It can be caused by the eyeball being too short or the refracting system too weak.

The Retina: Rods and Cones

Processing of visual info begins in the retina. The human retina contains two types of photoreceptors: rods and cones

- **Rods** are more sensitive to light but do not distinguish colours; they enable us to see at night, but only in black and white.
- **Cones** provide colour vision, but, being less sensitive, contribute very little to night vision. There are three types of cones. Red, blue and green. These cones have these 3 pigments called photopsins that detect light of different wavelengths.



In humans, cones are concentrated in the **fovea**, the centre of the visual field, and rods are more concentrated around the periphery of the retina.

Types of Receptors in Retina

Figure 10.4 Structure of the retina. (A) Section of the retina showing overall arrangement of retinal layers. (B) Diagram of the basic circuitry of the retina. A three-neuron chain—photoreceptor, bipolar cell, and ganglion cell—provides the most direct route for transmitting visual information to the brain. Horizontal cells and amacrine cells mediate lateral interactions in the outer and inner plexiform layers, respectively. The terms *inner* and *outer* designate relative distances from the center of the eye (inner, near the center of the eye; outer, away from the center, or toward the pigment epithelium).

Information flows through layers of neurons in the retina.
There are five basic classes of neurons in the retina:

- photoreceptors
  - Rods
  - Cones
- bipolar cells
- ganglion cells
- horizontal cells
- amacrine cells

The human retina is organized into layers of neurons that receive visual information and process it before sending it to the brain. Closest to the lens (and thus to light input) is a layer of **ganglion cells**, a central layer contains three neuronal types, **bipolar cells, horizontal cells, and amacrine cells**; and at the "rear" of the retina lie the **photoreceptors** (rods and cones). The layers of cells between the photoreceptors and the ganglion cells process information about the visual field. Even though ganglion cells are closest to the light input, the photoreceptors absorb the light and then the info is processed to the ganglion cells.

A three-neuron chain - **photoreceptor cell to bipolar cell to ganglion cell** - is the most direct pathway of information flow from photoreceptors to the optic nerve. Absorption of light by the photopigment in the outer segment of the photoreceptors initiates a cascade of events that changes the membrane potential of the receptor, and therefore the amount of neurotransmitter released by the photoreceptor terminals (phototransduction).