2.1.5 The functioning of the retina

The retina is where the processing of the retinal image begins. Recordings of electrical output from single ganglion cells have shown a number of important characteristics. The first is that the electrical discharge is a series of voltage spikes of equal amplitude. Variations in the amount of light falling on the photoreceptors supplying signals to the ganglion cell through the network of collector cells, produce changes in the frequency with which these voltage spikes occur but not in their amplitude. The second is that there is a level of electrical discharge present even when there is no light falling on the photoreceptors, called the spontaneous discharge. The third is that illuminating photoreceptors with a spot of light, can produce either an increase or a decrease in the frequency of electrical discharges, relative to the level of frequency of discharges present when light is absent.

Further studies of the pattern of electrical discharges from a single ganglion cell have revealed two other important aspects of the operation of the retina. The first is the existence of receptive fields. A receptive field is the area of the retina that determines the output from a single ganglion cell. A receptive field always represents the activity of a number of photoreceptors, and often reflects input from different cone types as well as from rods. The sizes of receptive fields vary systematically with retinal location. Receptive fields around the fovea are very small. As eccentricity from the fovea increases, so does receptive field size.

Within each receptive field there is a specific structure. Receptive fields consist of a central circular area and a surrounding annular area. These two areas have opposing effects on the ganglion cell's electrical discharge. Either the central area increases and the annular surround decreases the rate of electrical discharge, or, in other receptive fields, the reverse occurs. These types of receptive fields are known as on-centre/off-surround and off-centre/on-surround fields, respectively. If either of these two types of retinal receptive fields is illuminated uniformly, the two types of effect on electrical discharge cancel each other, a process called lateral inhibition. However, if the illumination is not uniform across the two parts of the receptive field, a net effect on the ganglion cell discharge is evident. This pattern of response makes the retinal fields well suited to detect boundaries in the retinal image.

While every retinal ganglion cell has a receptive field, not every ganglion cell is the same. In fact, there are two types of ganglion cell, called magnocellular (M) cells and parvocellular (P) cells. There are a number of important differences between the M-cells and P-cells. First, the axons of the M-cells are thicker than the axons of the P-cells, indicating that signals are transmitted more rapidly from the M-cells than from the P-cells. Second there are many more P-cells than M-cells and they are distributed differently across the retina. The P-cells dominate in the fovea and parafovea and the M-cells dominate in the periphery. Third, for a given eccentricity, the P-cells have smaller receptive fields than the M-cells. Fourth, the M-cells and P-cells are sensitive to different aspects of the retinal image. The M-cells are more sensitive to rapidly varying stimuli and to small differences in illumination but are insensitive to differences in colour. The P-cells are more sensitive to small areas of light and to colour.

This brief description shows that the retina extracts information on boundaries in the retinal image and then extracts specific aspects of the stimulus within the boundaries, such as colour. These aspects are then transmitted up the optic nerve, formed from the axons of the retinal ganglion cells, along different channels.