from *Biophysical Psychology* (1988), by D. P. Kimble,
Holt, Rinehart, Winston (New York), pp 151-153.

Spatial Frequency Analyzers: An Alternative Model

The Hubel and Wiesel feature detection model is not the only way of characterizing the response of visual cortical neurons. In recent years an alternative model has been put forward. Two of the leading proponents of the spatial frequency model are Fergus Campbell (Campbell, 1974) and Russell DeValois (DeValois and DeValois, 1980). Consider the visual pattern in Figure 5.19. This figure is a grating composed of parallel lines. All visual stimuli can be considered to be composed of some number of light–dark alternations that occur within some specified distance across the visual field. Visual space is measured in degrees of arc. There are 180 degrees from one side of the visual field to the other, that is, from the far left-hand side of what you can see when looking straight ahead to the far right-hand side.

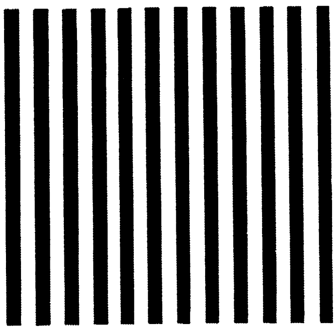

Figure 5.19 A grating stimulus illustrating the concept of spatial frequency.
The frequency of any particular stimulus is determined by the number of light–dark alternations in each degree of visual angle. This in turn depends on the distance between the stimulus and the observer.

A stimulus such as that shown in Figure 5.19 can be characterized in terms of its *spatial frequency*—the number of light–dark alternations in each degree of the visual field.

Human observers vary in their ability to perceive different spatial frequencies, depending not only on the actual frequency but also on the degree of contrast between the light and dark regions, and other factors. Most subjects seem to be most sensitive (can detect lowest levels of contrast) when the spatial frequencies of a grating stimulus are between one and five cycles per degree. Visual acuity can be evaluated as the upper limit of the spatial frequency that an individual can detect. This is usually about 48 cycles per degree (Campbell and Robson, 1968). Rhesus monkeys show almost identical responses to human observers when tested in similar ways (DeValois et al., 1974).

Individual cells in the visual cortex, the same cells that can be classified as simple or complex when tested with Hubel and Wiesel type stimuli, can also be classified as frequency analyzers when tested with grating stimuli. This is true for cats (Maffei and Fiorentini, 1973) and monkeys (DeValois and DeValois, 1980). Figure 5.20 shows the results of such an experiment. Thus evidence exists to support both the feature detection model and the spatial frequency model. It is somewhat premature to tell which of these approaches will prove most useful in the future development of theories of vision.

Evidence from perceptual demonstrations also exists for separate channels in the human visual system. These channels are usually thought to be separate pathways in the visual system, each channel performing some different analysis on visual input. Look at Figure 5.21. If you follow the directions in the figure caption, you should perceive changes in the test stimulus on the left after staring (i.e., adapting some of your spatial frequency channels) to the pattern on the right. Demonstrations of this sort suggest that the frequency analyzer model is relevant to understanding the results of some perceptual experiments with human subjects.

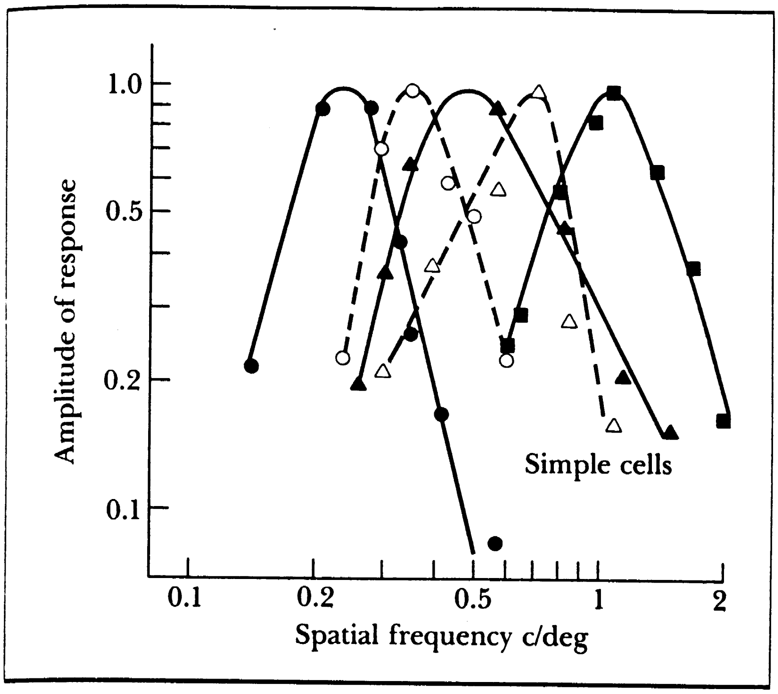

Figure 5.20 Response of simple cells in the cat visual cortex to different spatial frequencies.
Stimuli used were similar to that shown in Figure 5.19 (Maffei and Fiorentini, 1973).

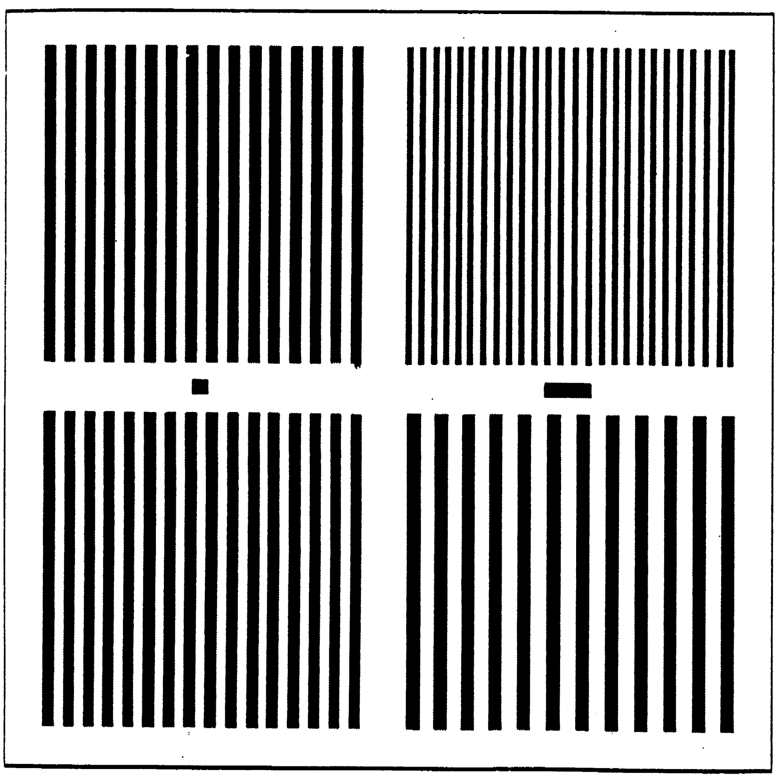

Figure 5.21
Place the book on a desk or table and view this figure from about 2m. First look at the small square in the middle of the left-hand side. The upper and lower gratings should appear to be the same. Now shift your gaze to the right-hand side and look back and forth at the small rectangle for at least one minute. Now again shift your gaze back to the left-hand side and fixate on the small square. Note the change in the appearance of the gratings on the left-hand side. These effects are thought to be due to adaptation of spatial frequency channels in your visual system (Blakemore and Sutton, 1969).