processing power, as several billion neurons in V1 and V2 are devoted to analyzing the signals from only 2 million nerve fibers coming from the optic nerves of two eyes. This makes possible the massively parallel simultaneous processing of the entire visual field for incoming signals for color, motion, texture, and the elements of form. It is here that the elementary vocabularies of both vision and data display are defined.

By the time it gets to the LGN, the signal has already been decomposed by the concentric receptive fields discussed in the previous chapter that convert the signal into red–green, yellow–blue, and dark–light differences. These signals are then passed on to V1 where slightly more complex patterns are processed.

Figure 5.2 is derived from Livingston and Hubel's diagram (1988) that summarizes both the neural architecture and the features processed in V1 and V2. A key concept in understanding this diagram is the tuned receptive field. In Chapter 3, we saw how single cell recordings of cells in the retina and the LGN reveal cells with distinctive concentric receptive fields. Such cells are said to be tuned to a particular pattern of a white spot surrounded by black or a black spot surrounded by white. In general, a tuned filter is a device that responds strongly to a certain kind of pattern and responds much less, or not at all, to other patterns. In the primary visual cortex, some cells respond only to elongated blobs with a particular position and orientation, others respond most strongly to blobs of a particular position moving in a particular direction at a particular velocity, and still others respond selectively to color.

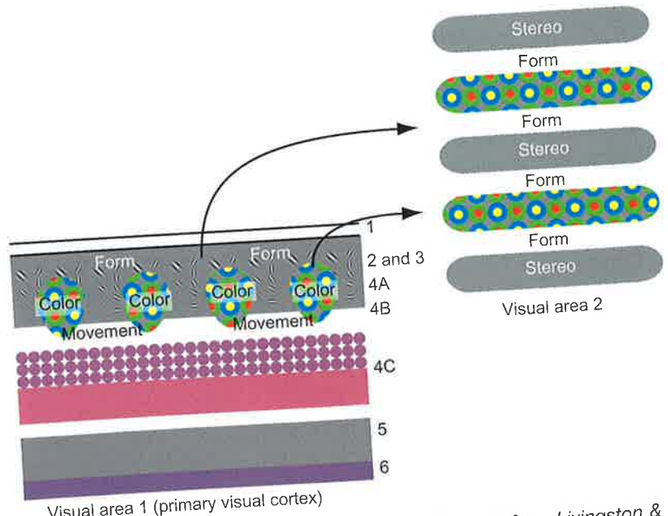

Figure 5.2 Architecture of the primary visual cortex. (*Redrawn from Livingston & Hubel (1988).*)

There are cells in V1 and V2 that are differentially tuned to each of the following properties:

- Orientation and size (with luminance) via the Gabor processor described later in this chapter
- Color (two types of signals) via the opponent processing channel mechanisms discussed in Chapter 4
- Elements of local stereoscopic depth
- Elements of local motion

In V1 and V2 and many other regions of the brain, neurons are arranged in the form of a spatial map of the retina, meaning that adjacency relationships are preserved. A feature that is close to another feature in the image on the retina is processed by nearby neurons in V1. These maps are highly distorted, however, because the fovea is given far more space in the cortex than regions in the periphery of vision. In cortical regions devoted to the fovea, receptive fields are much smaller. It is a system in which, for each point in visual space, neurons are tuned for many different orientations, many different kinds of color information, many different directions and velocities of motion, and many different stereoscopic depths.

Notice that here we have been talking about V1 as containing a single map of the visual field, but in fact it contains a set of semi-independent feature maps, all spatially co-registered.

The Elements of Form

It is useful to think of the things that are extracted by early stage visual processing as the elements of form and pattern perception. Phonemes are the smallest elements in speech recognition, the components from which meaningful words are made. In a similar way, we can think of orientation detectors, color detectors, and so on as the elements from which meaningful perceptual objects are constructed.

An important point that can be derived from Figure 5.3 is that color and the elements of form (orientation and size) are processed separately and therefore are easy to visually separate. It is also the case that moving patterns are visually separate from static patterns. These different properties are said to have different *channels*, meaning that information expressed in one channel, the color of a symbol, does not interfere with information expressed in another, the orientation of a symbol. There are three basic high-level channels that match the areas shown in Figure 5.2—namely, color, form, and motion. We can use this fact to establish a basic principle of display design.

[G5.2] Use different visual channels to display aspects of data so that they are visually distinct.