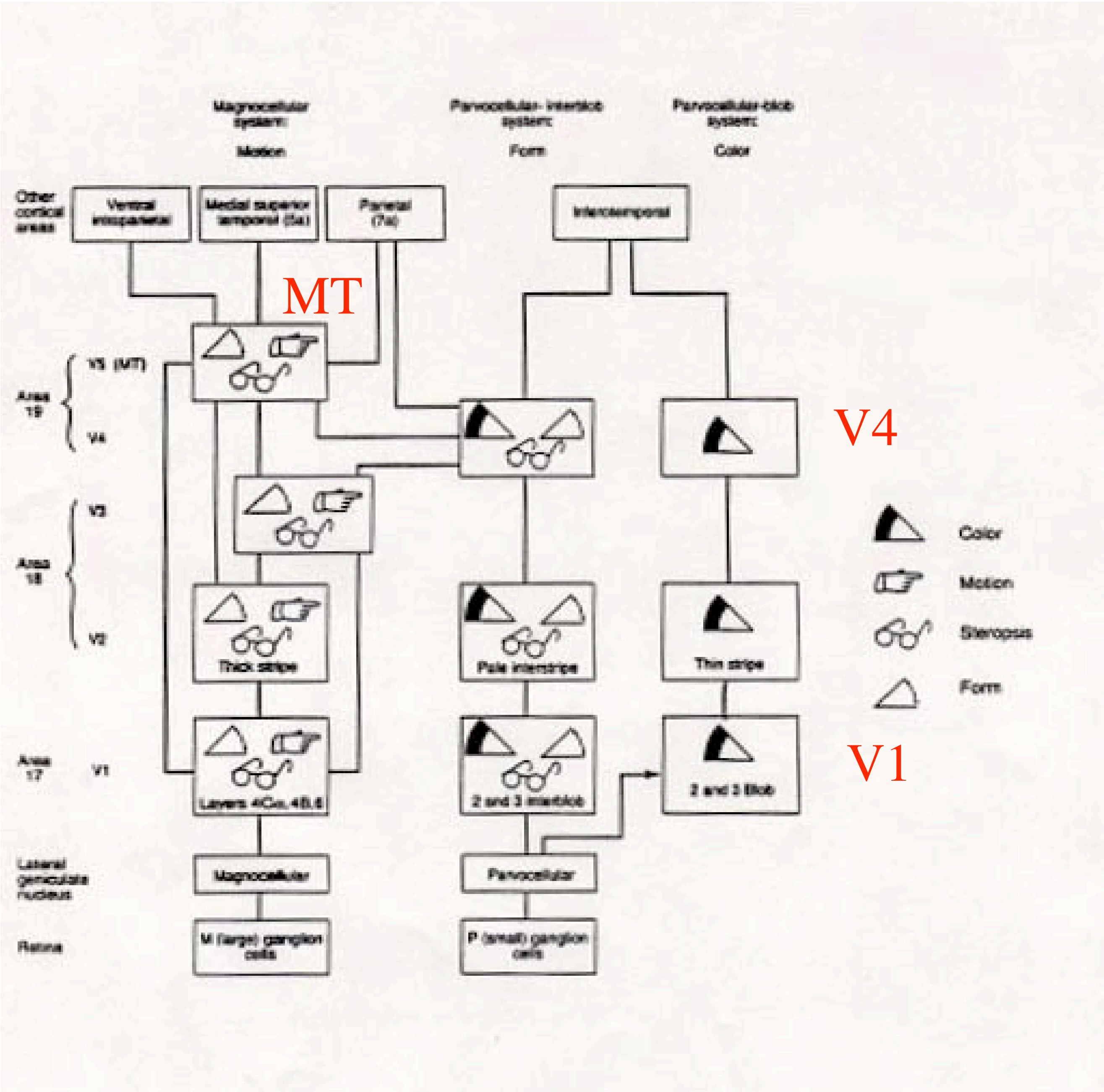
Bi150 (2004)

Vision III: Higher Visual Processing

10/29/04

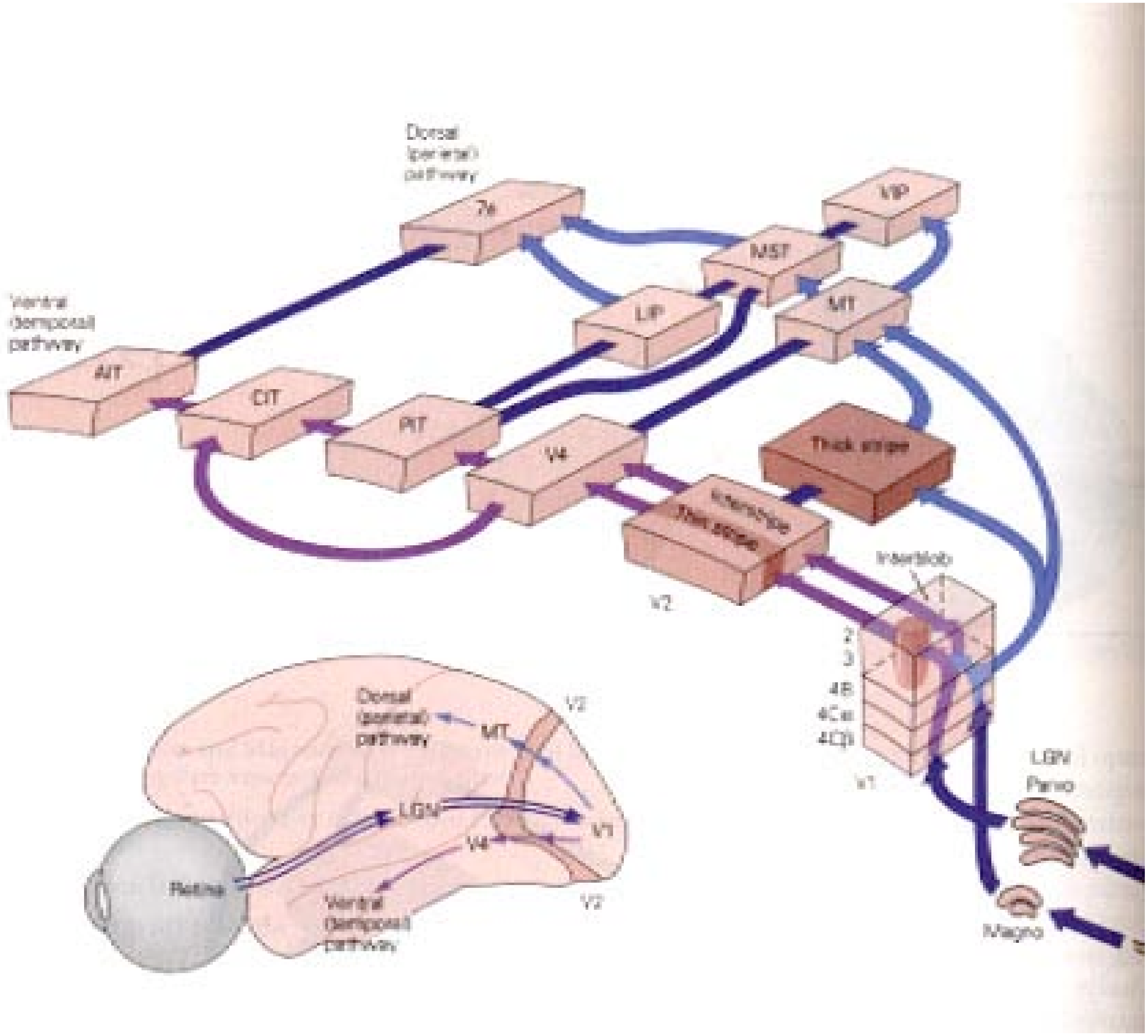
Higher visual areas

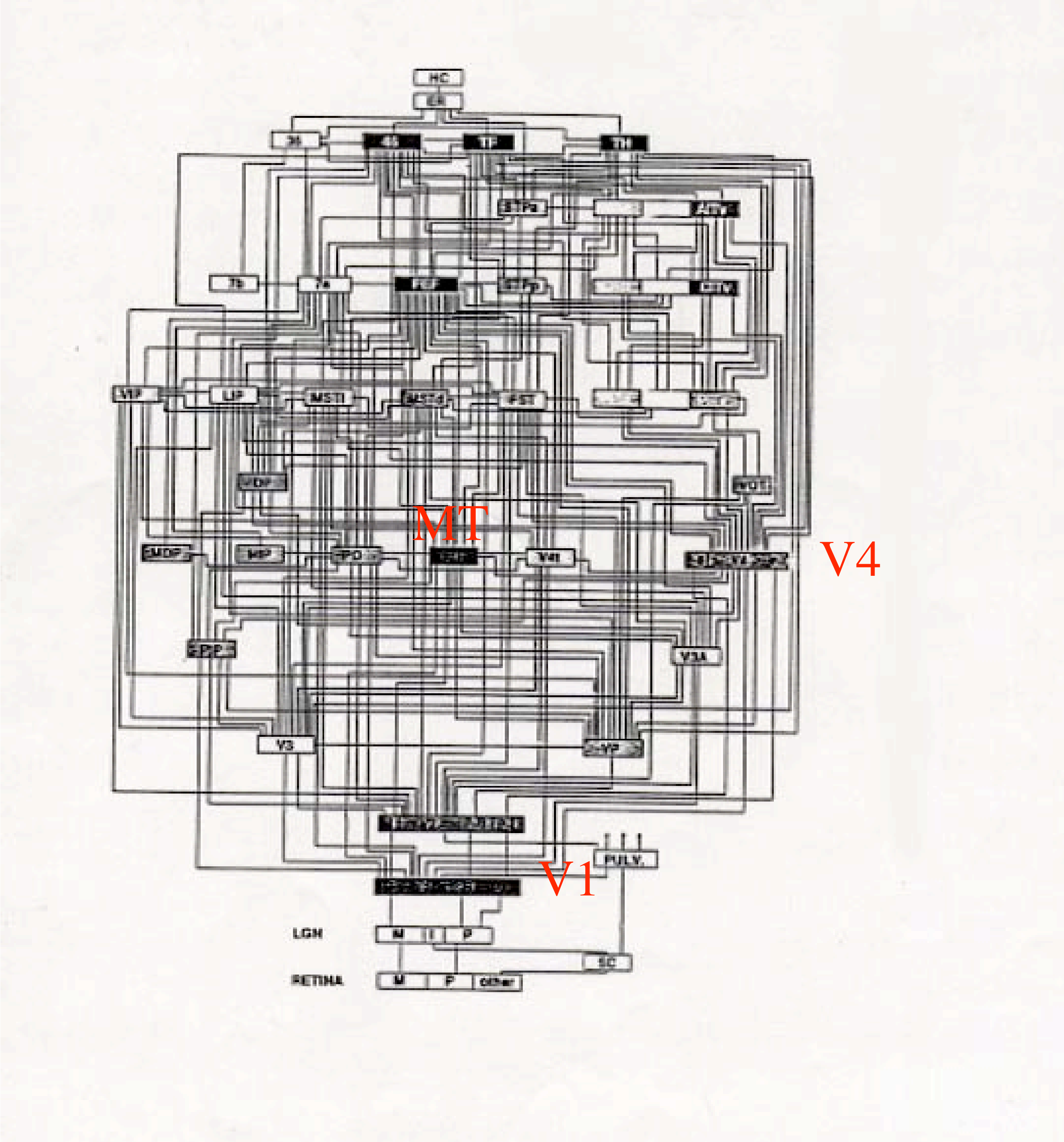
- We saw that V1 contains a complete retinotopic map of visual space.
- As defined by the presence of such maps (partial or complete), there are >20 other visual areas.
- These process many different aspects of the visual image simultaneously.
- The functions of most areas are unknown.



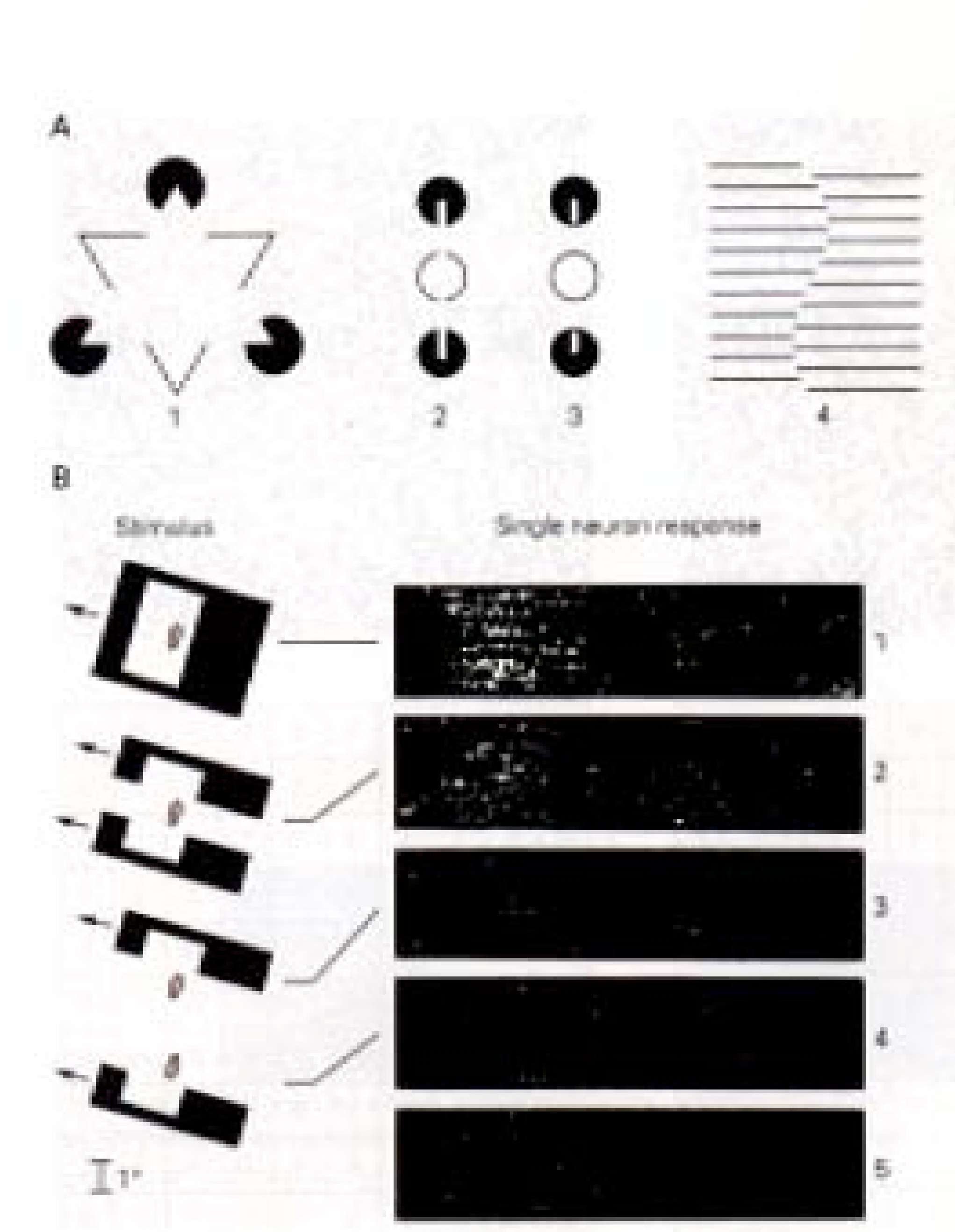
- Processing pathways in cortex may continue the segregation into M and P streams that began in the retina.
- M information goes into the dorsal pathway and is involved in motion processing.
- P information goes into the ventral pathway where color is processed.
- This is an oversimplification.

- Dorsal pathway:
- V1->V2 thick stripe ->MT ->MST ->parietal
- Ventral pathway:
- V1->V2 thin stripe, interstripe -->V4--> infero-temporal





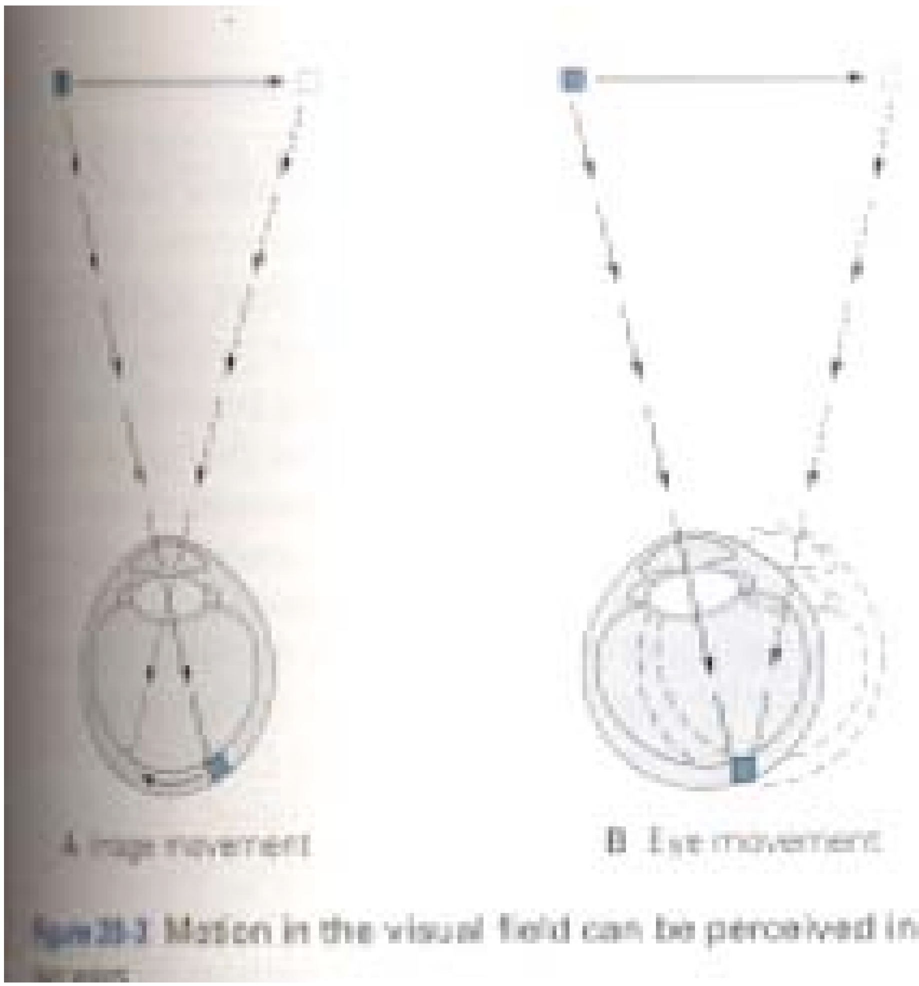
- Mapping actual connections among visual cortices shows that the true picture is much more complicated and does not necessarily fit with parallel processing ideas.



Responses to illusory contours

- Higher-order neurons sometimes have firing patterns that reflect the subjective experience of the individual.
- The neuron in B (dark oval is receptive field) responds differentially to the nonexistent edge in 2 vs 3 and 4, even though the stimulus within its receptive field is exactly the same.

Decoding movement



- The system for decoding movement has to be able to generate the same subjective experience whether an object's image moves on the retina or whether the eye moves to keep the object's image at the same retinal position.

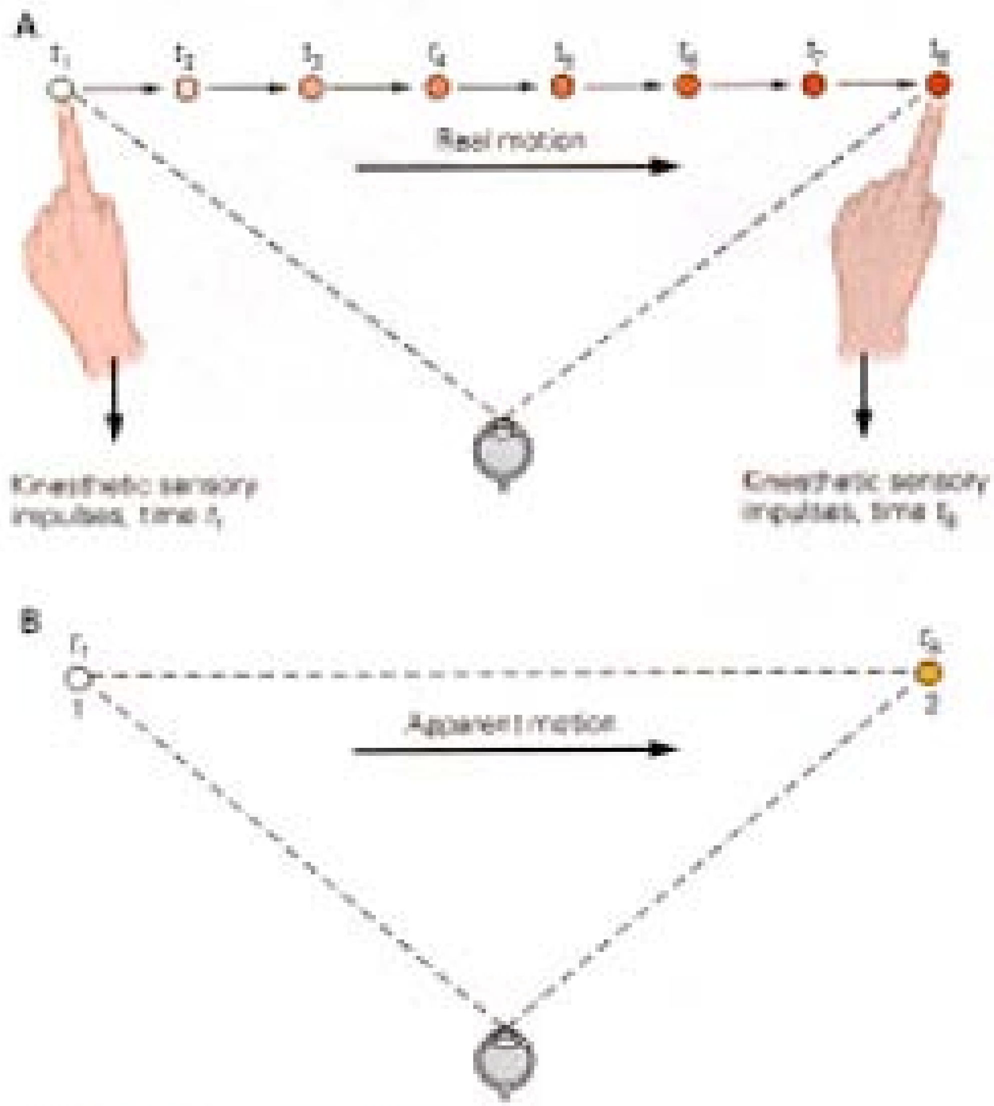
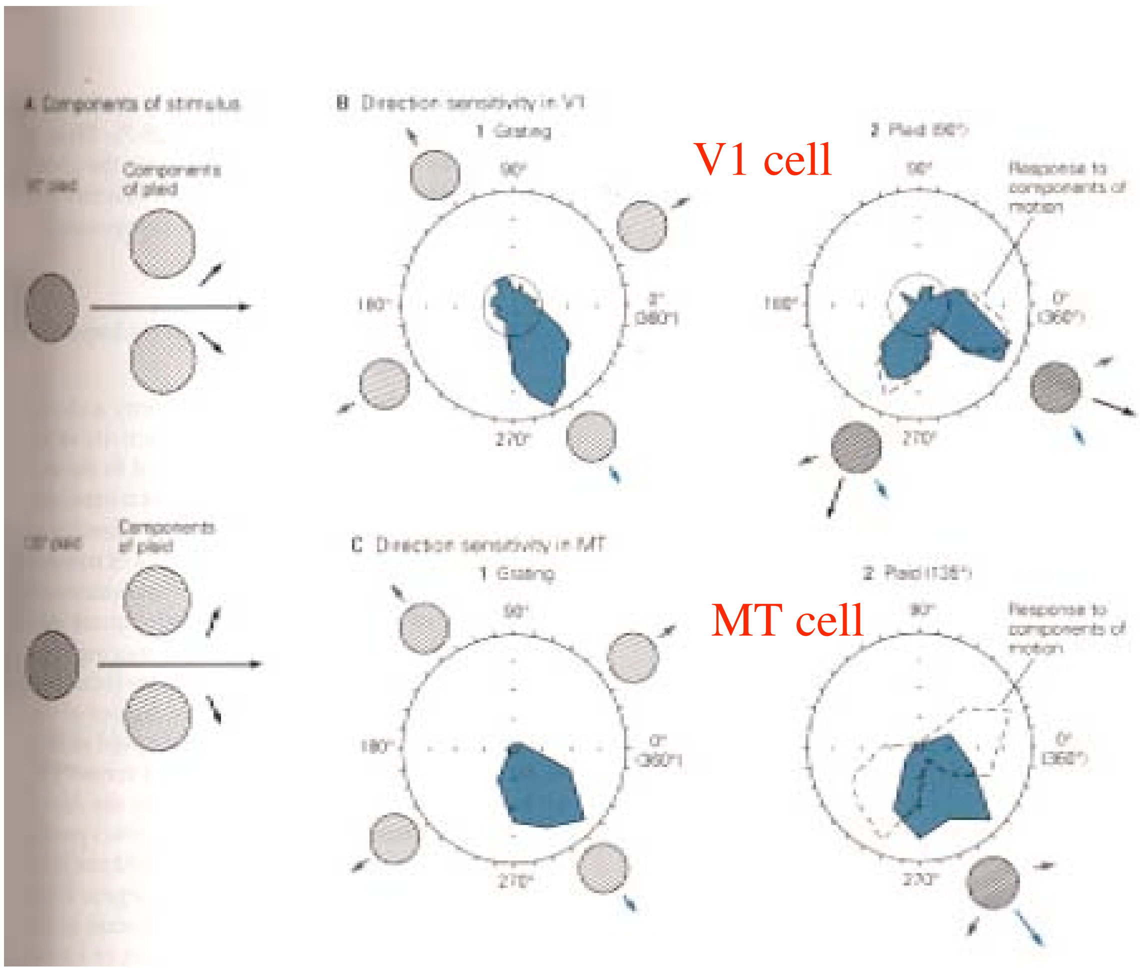


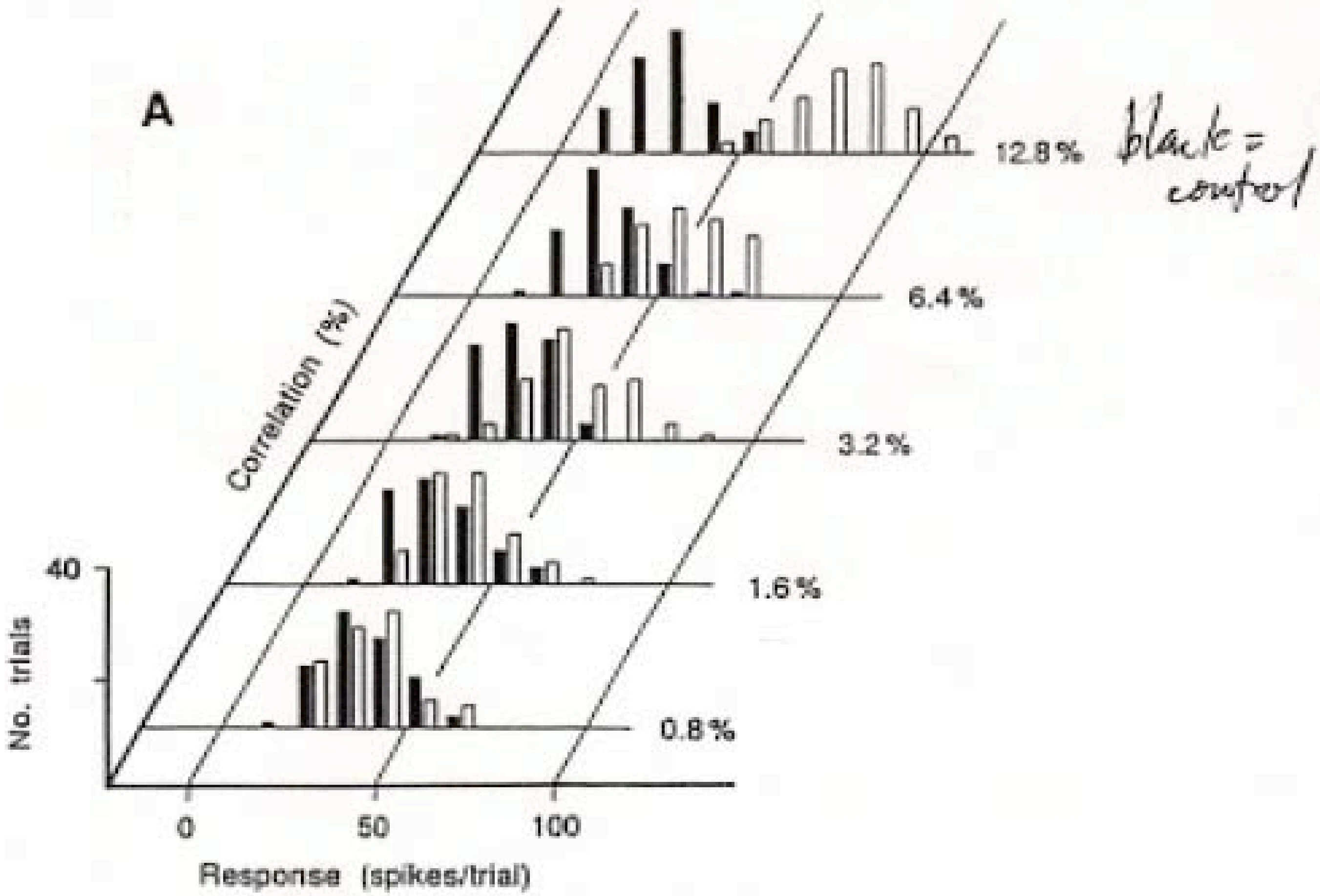
Figure 28-4 The illusion of apparent motion is evidence that the visual system analyzes motion in a separate pathway.

- The motion-processing system generates the illusion of movement when stimuli appear at different retinal positions even though no actual movement took place.
- Thus the brain must be putting the different retinotopically mapped stimuli together to generate perception.

MT neurons respond to global motion of a plaid stimulus

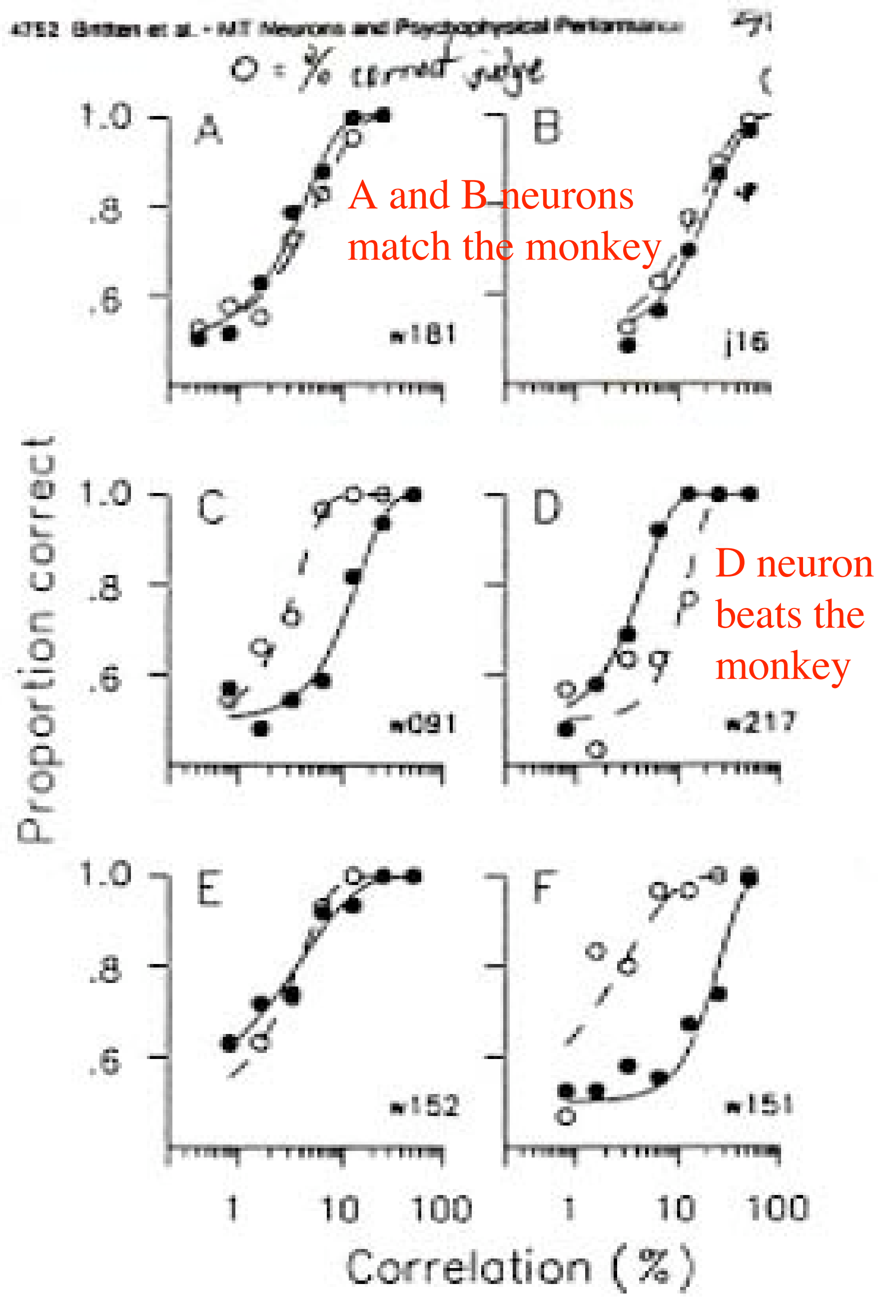


- Moving two gratings together generates an apparent motion of the combined stimulus (plaid) in a different direction.
- Lower-order neurons signal the movement of the individual grating components.
- Higher-order MT neurons respond to the plaid movement, which corresponds to what the observer perceives.

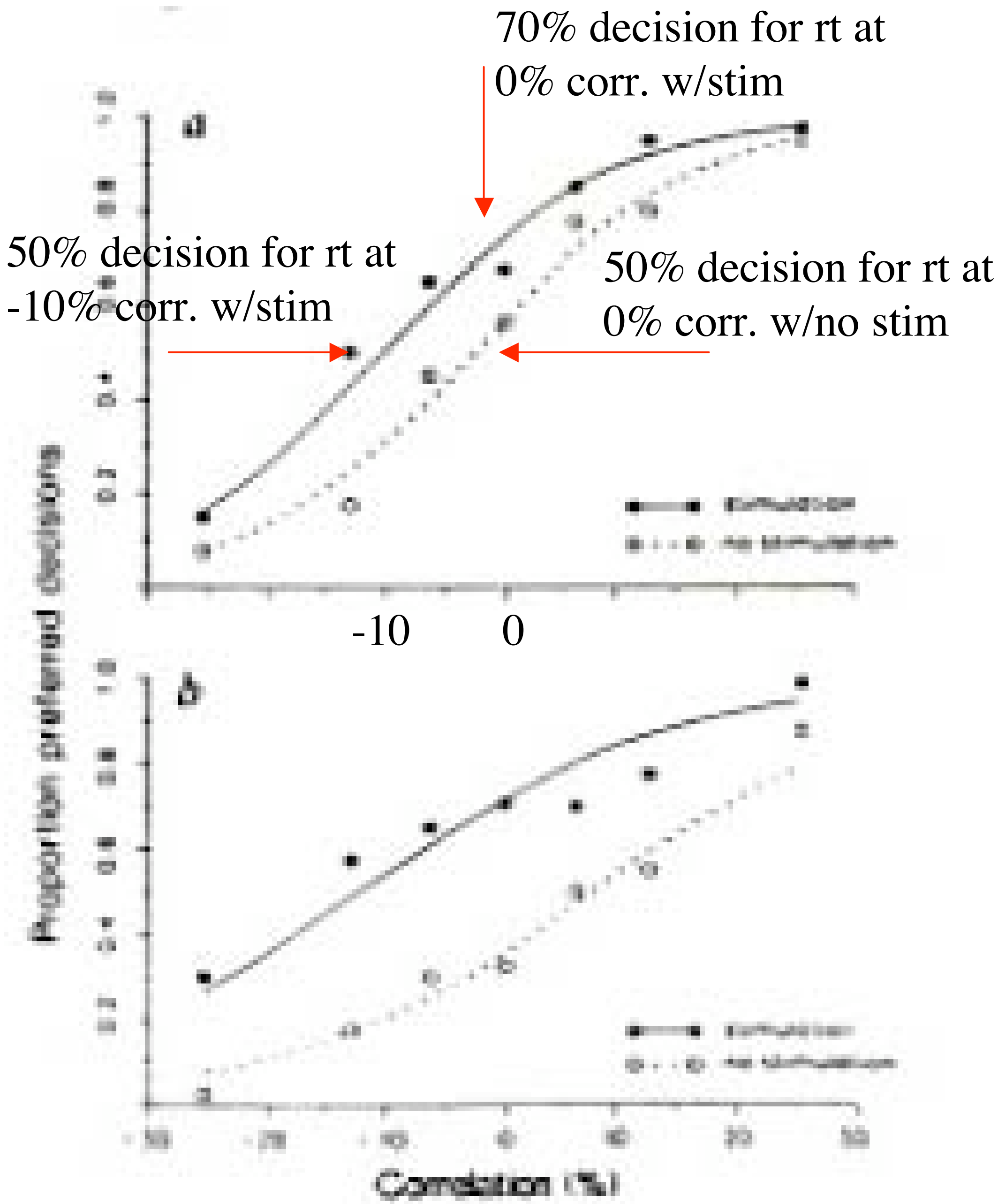


- The sensitivity of MT neuron responses can be measured using moving dot displays.
- MT neurons can readily detect ~2% correlated dot movement.

Comparison of the performance of MT neurons to that of the monkey



- The use of the moving dot display allows a comparison of the monkey’s ability to judge the direction of movement to the ability of the neurons to signal that movement through firing more spikes.
- Some single neurons can perform as well or better than the monkey.
- This raises the issue of why MT neuron columns contain ~100 neurons if one is enough to make a decision.



- Injection of current into an MT column signaling rightward movement increases firing of these cells.
- This biases the monkey’s decision as to whether the dots are moving left or right.
- This shows that MT neuron firing is actually used to encode decisions about the direction of motion of a stimulus.

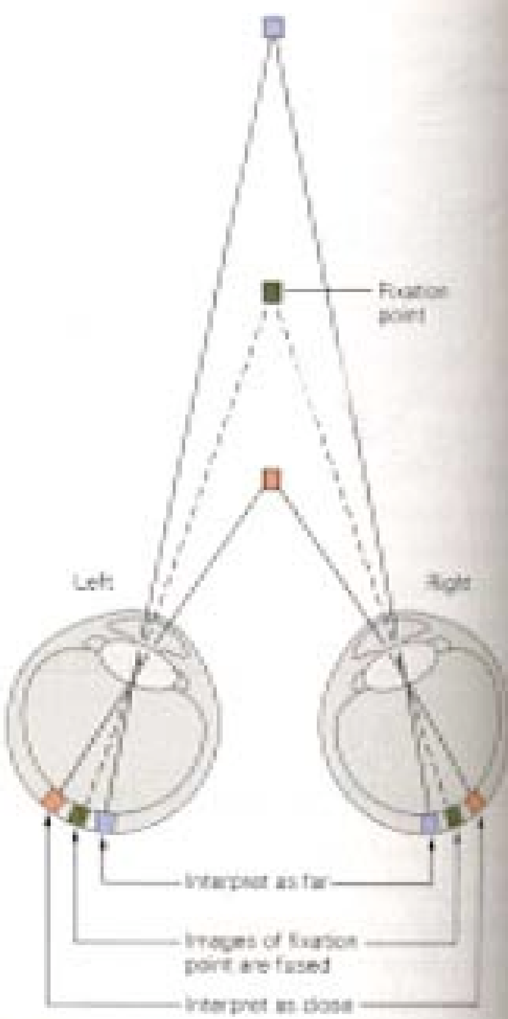
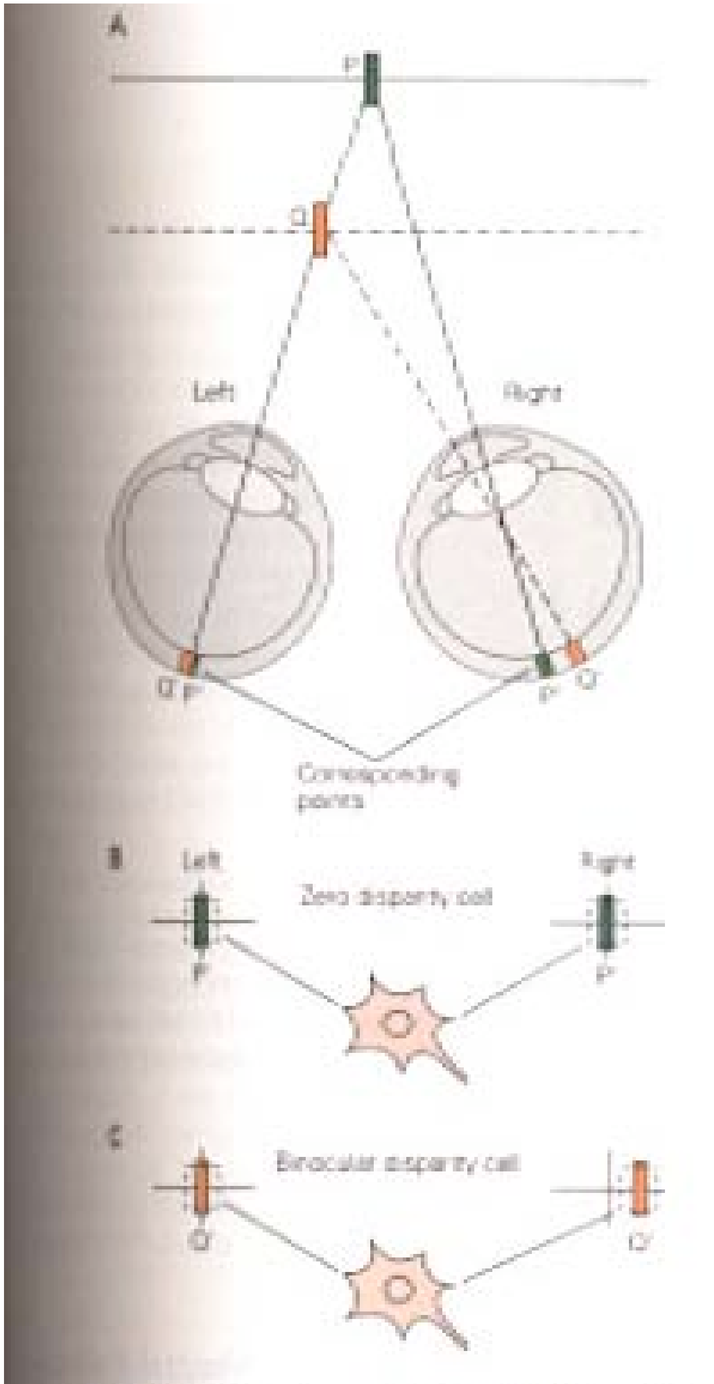


Figure 28-12 When we fix our eyes on a point the [illegible]
gence of the eyes causes that point (the fixation point)
fall on identical portions of each retina. Cues for [illegible]
provided by points just proximal or distal to the fixation p[illegible]
These points produce binocular disparity by stimulating [illegible]
different parts of the retina of each eye. When the lack [illegible]
respondence is in the horizontal direction only and is n[illegible]
greater than about 0.6 mm or 2° of arc, the disparity is pe[illegible]
ceived as a single, solid (three-dimensional) spot.

Stereopsis

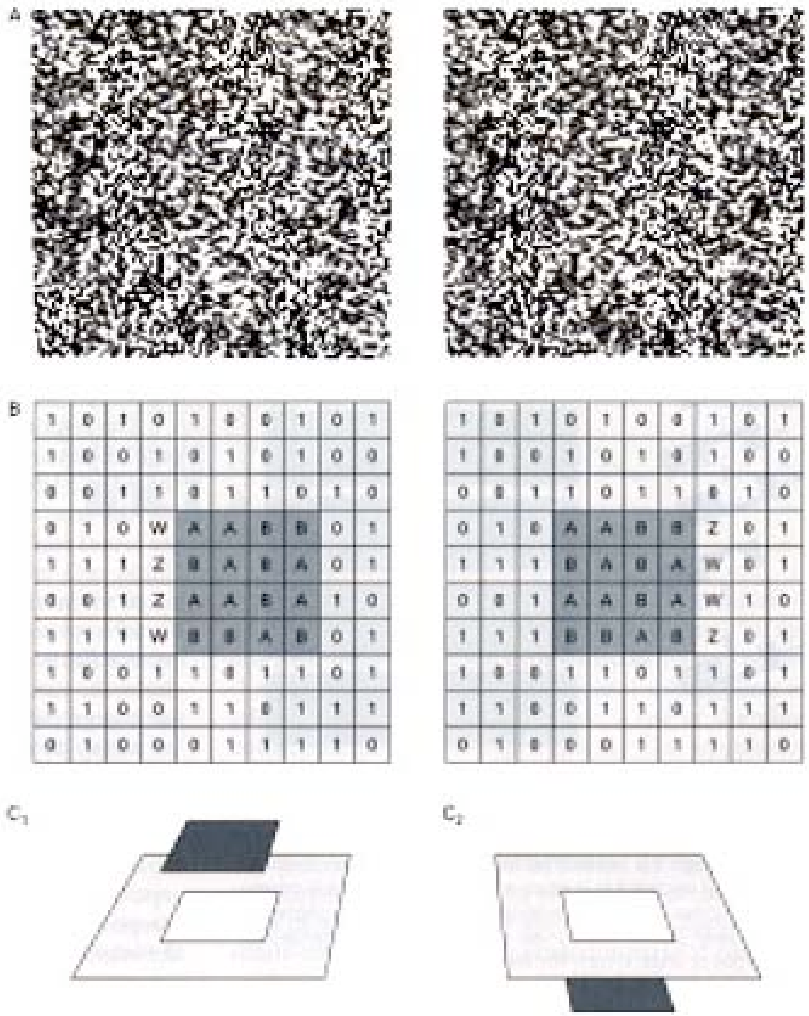
- Perception of near objects in three dimensions occurs because of shifts in the image of near and far parts of the object to different parts of the 2 retinas.



23-13 Neuronal basis of stereoscopic vision.

- Neurons signal disparity by responding optimally to stimulation of different parts of the 2 retinas.
- The neuron shown at top fires best when the bar image falls at exactly the same point on the 2 retinas (zero disparity cell).
- The cell at the bottom (a near cell) fires best when the image of the bar is displaced between the 2 retinas.
- Its firing thus signals that point Q is nearer to the observer.

Stereo vision does not require form recognition

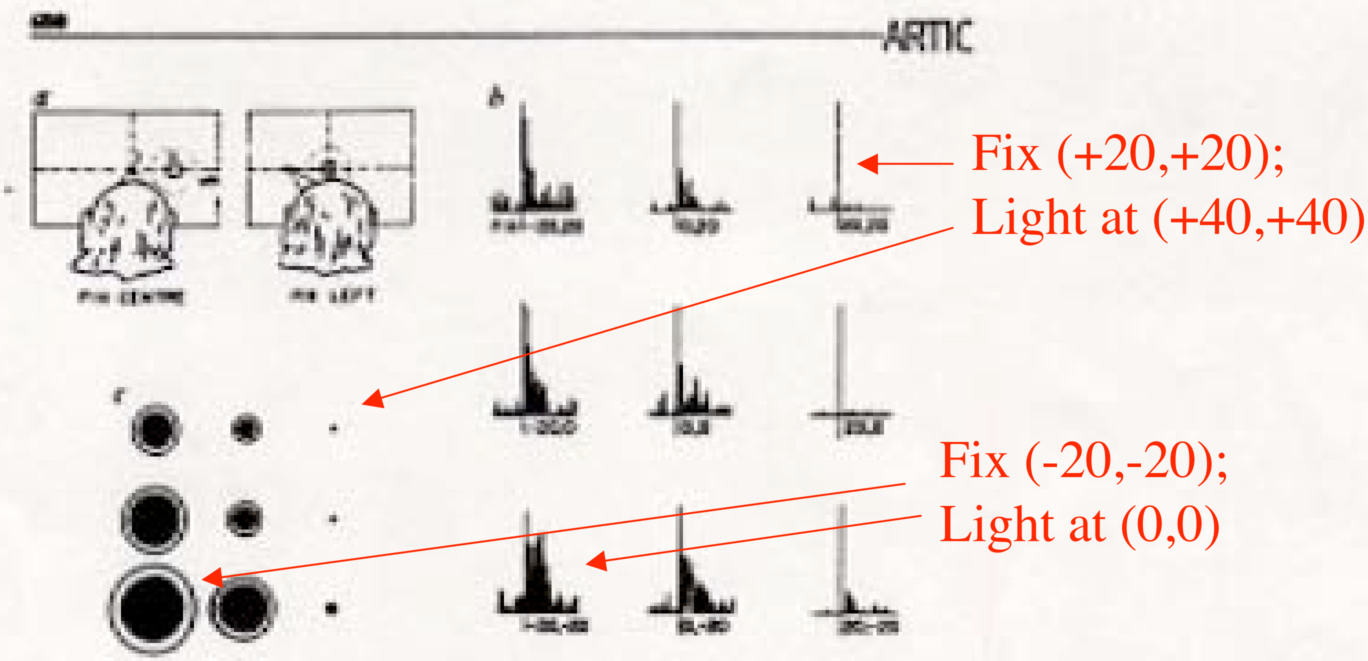


- The ability of the visual system to interpret a random-dot stereogram shows that disparity is calculated at an early stage in visual processing, before perception of form occurs.
- Each dot must stimulate the appropriate set of disparity-sensitive neurons, and their responses are combined to generate the square.

Perception of space

- The neurons we've discussed all have receptive fields mapped onto retinal space.
- However, perception of where objects are requires a transformation of retinal coordinates into body-centered coordinates.
- Transformation of retina-centered into head-centered coordinates is achieved by incorporating eye position into the responses of neurons in posterior parietal cortex.
- A further transformation into body-centered coordinates requires incorporation of head position into neuronal responses.

Gain fields



SPACE PERCEPTION
Neurons in posterior parietal cortex are apparently involved in the transformation from retina-centered coordinates to head and body-centered coordinates. These neurons signal not only position on the retina but also eye and head positions. No neurons are found that signal position of a stimulus in space independently of the position of its image on the retina, but the position of an object relative to the head can be determined by examining the responses of a number of different neurons that have different gain fields.

Perception of form

- Neurons in inferotemporal cortex can respond selectively to complex stimuli such as faces.
- Like people, these neurons seem to be able to generalize between realistic and symbolic representations.

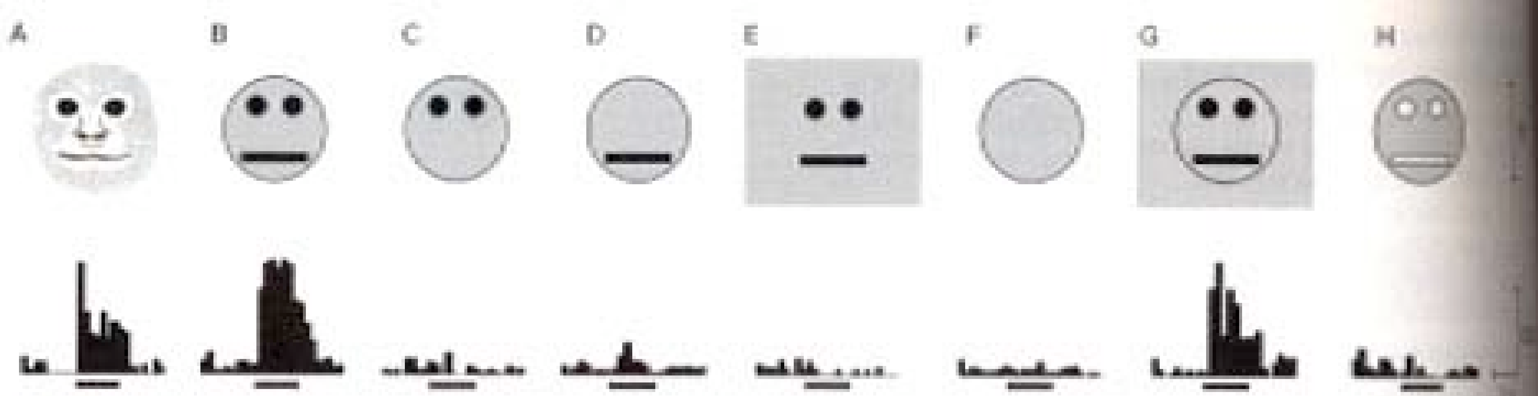
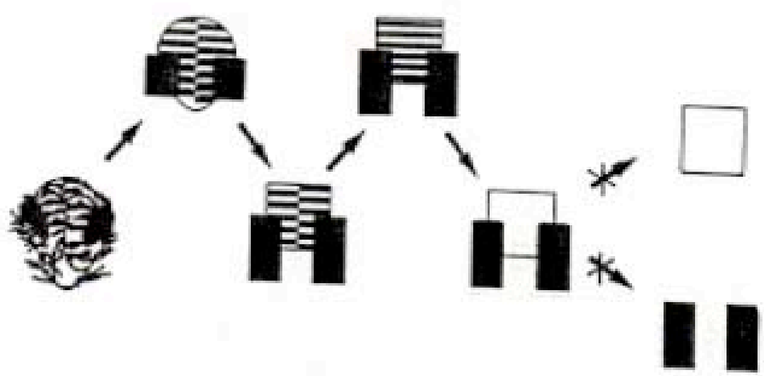


Figure 28-18 Response of a neuron in the inferior temporal cortex to complex stimuli. The cell responds strongly to the face of a toy monkey (A). The critical features producing the response are revealed in a configuration of two black spots and one horizontal black bar arranged on a gray disk (B). The bar, spots, and circular outline together were essential, as can be seen by the cell's responses to images missing one or mo these features (C, D, E, F). The contrast between the and outside of the circular contour was not critical (G). Ho ever, the spots and bar had to be darker than the backg within the outline (H). (I = spikes.) (Modified from K and Tanaka 1984.)

- The response to complex objects (here a plastic tiger head) can be broken down into responses to simpler objects.
- Responses to different classes of objects seem to be arranged in columns.

FACE AND OBJECT RECOGNITION

Neurons in inferior temporal cortex (IT) have the capability of responding to complex objects and to faces. The responses to these objects may also be organized into columns.



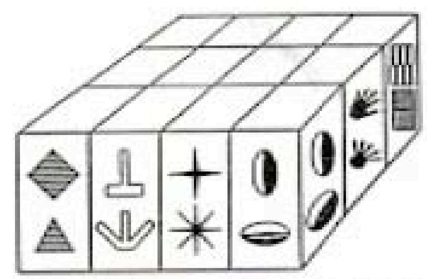
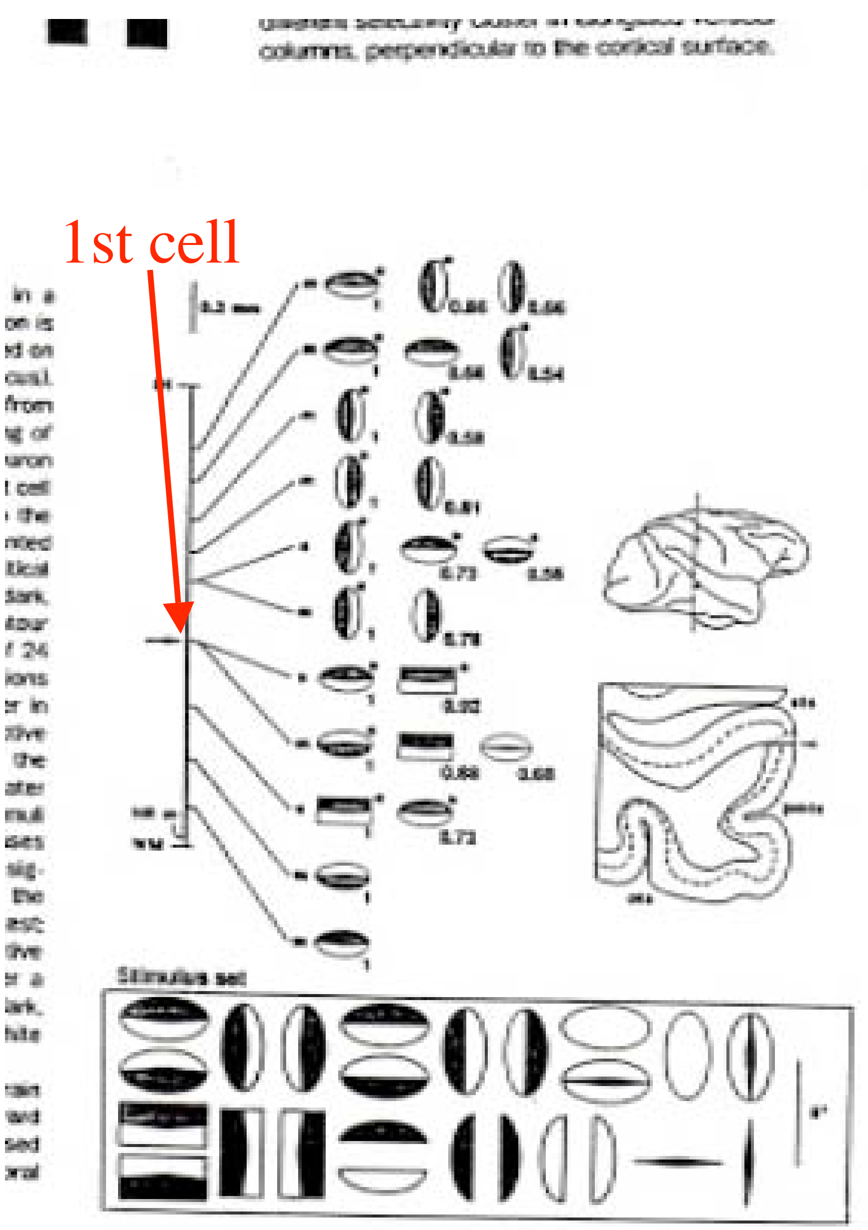


Fig. 3. Schematic diagram of the columnar organization in TE. Cells with similar but slightly different selectivity cluster in elongated vertical columns, perpendicular to the cortical surface.



- In this experiment, a cell was found that responded to a set of plastic lips.
- This response was broken down to an oval with dark on the top.
- Other neurons stacked vertically along this column exhibited optimal responses to related stimuli (vertical light/dark ovals, light/dark ovals with light on top, light/dark rectangles, etc.)