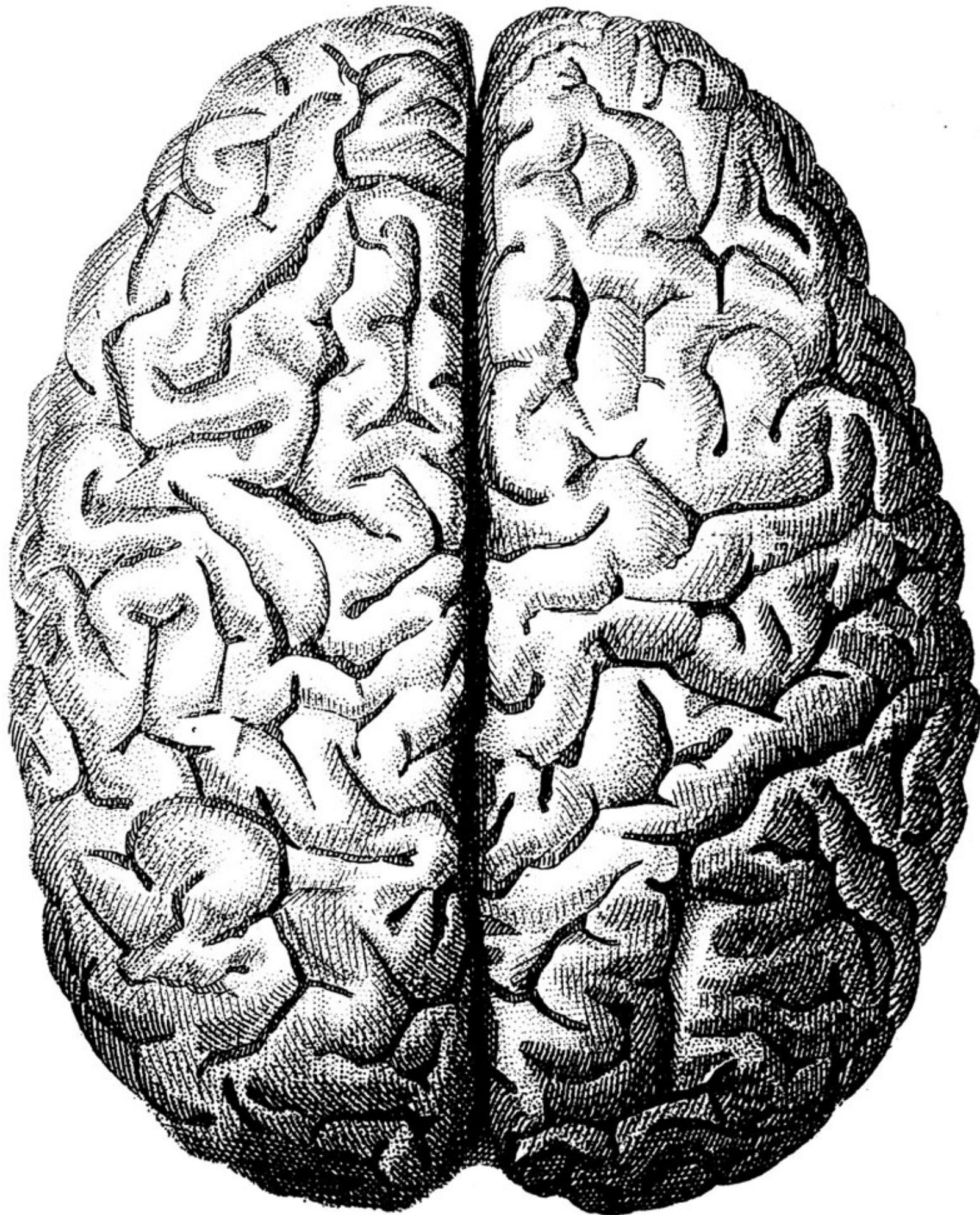
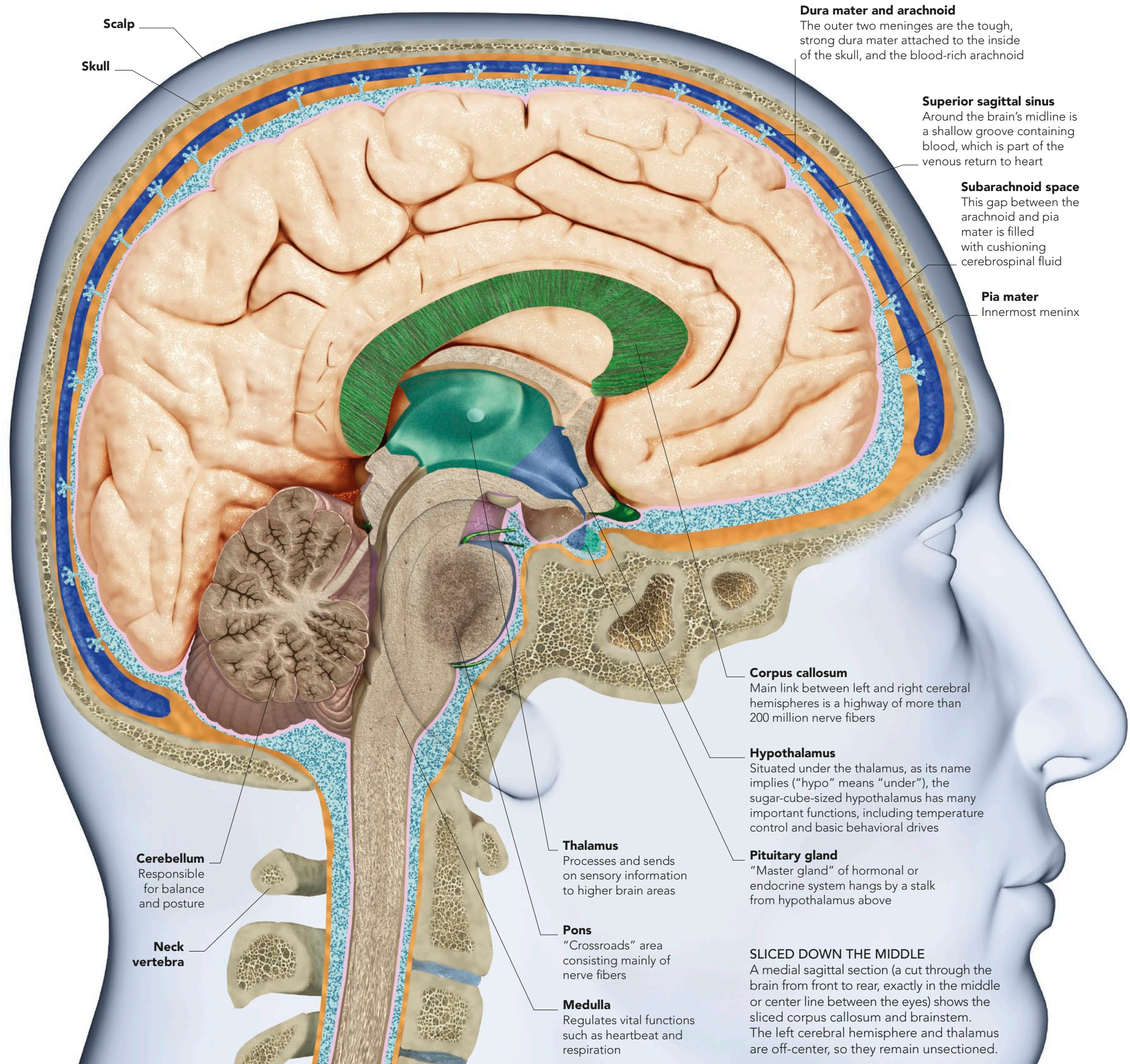


Perceptual Neuro Science

Mental Iconicity • G. Greenberg • 3.24.26

Neuroanatomy





cortex

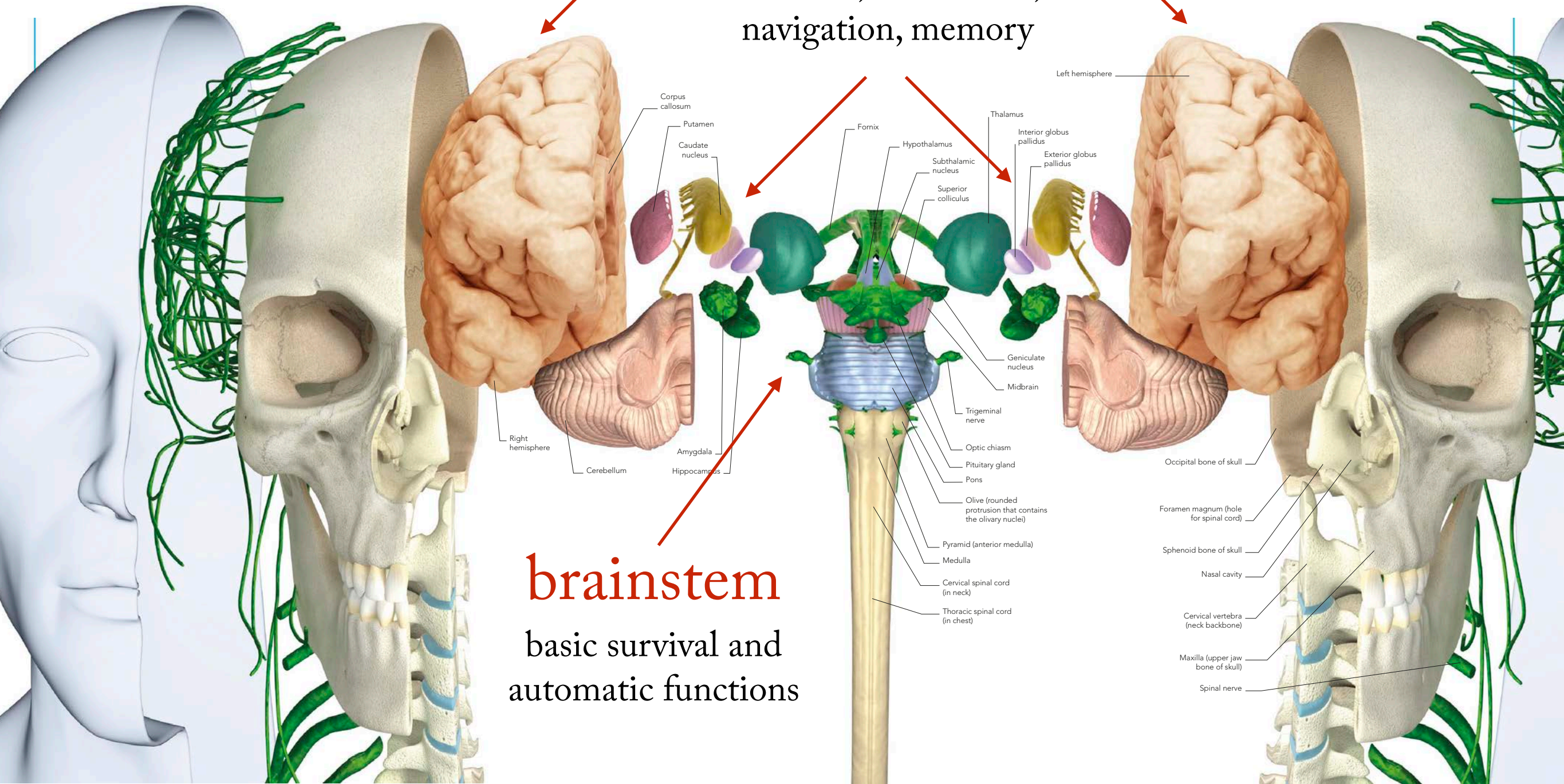
conscious perception,
decision making, control,
language and thought

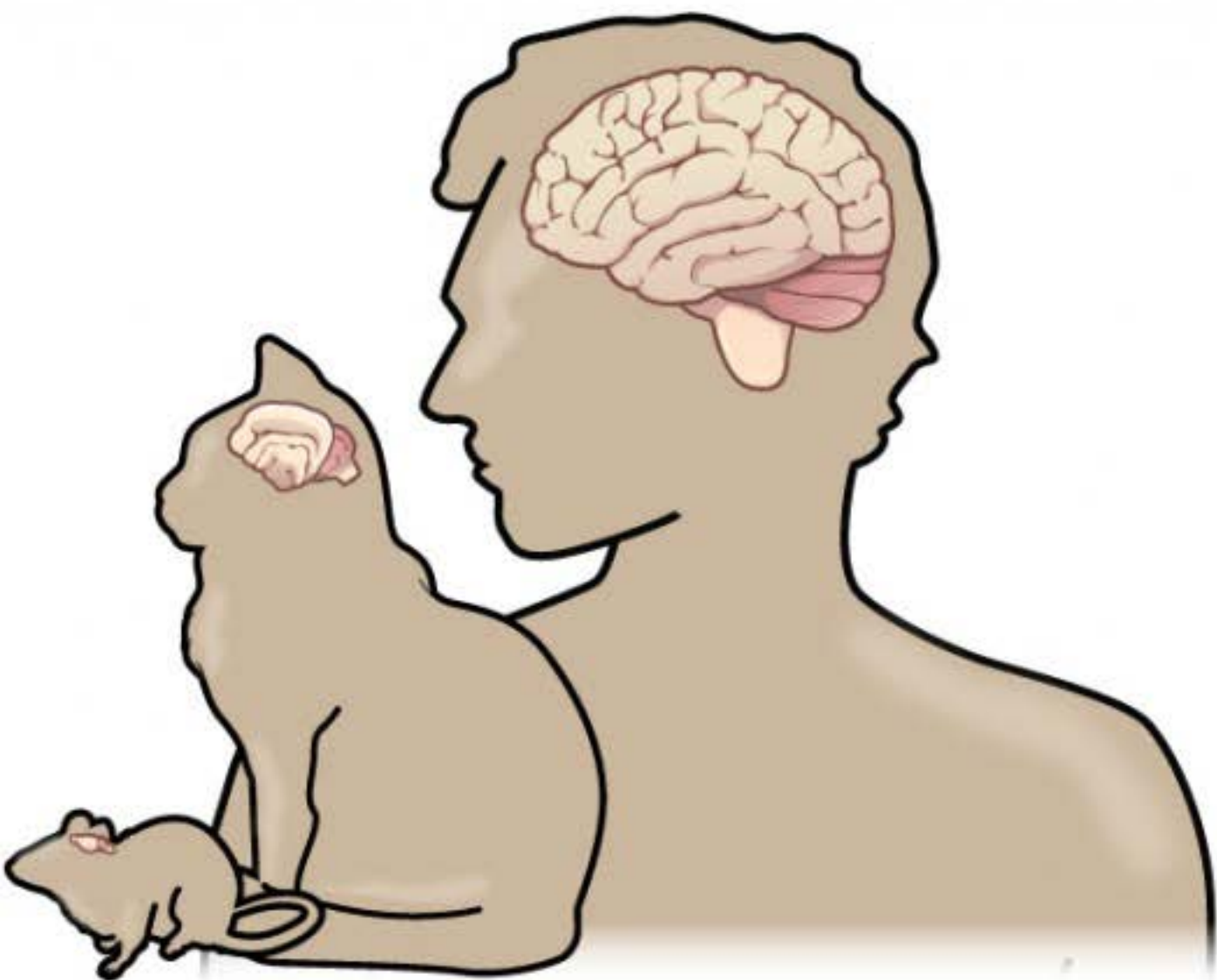
midbrain

emotion, motivation,
navigation, memory

brainstem

basic survival and
automatic functions





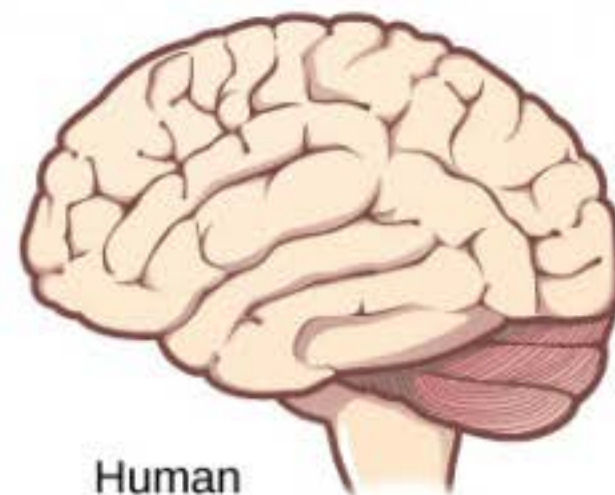
Rat



Cat



Chimpanzee



Human



Dolphin



Frontal lobe

Executive functions, thinking, planning, organising and problem solving, emotions and behavioural control, personality

Motor cortex

Movement

Sensory cortex

Sensations

Parietal lobe

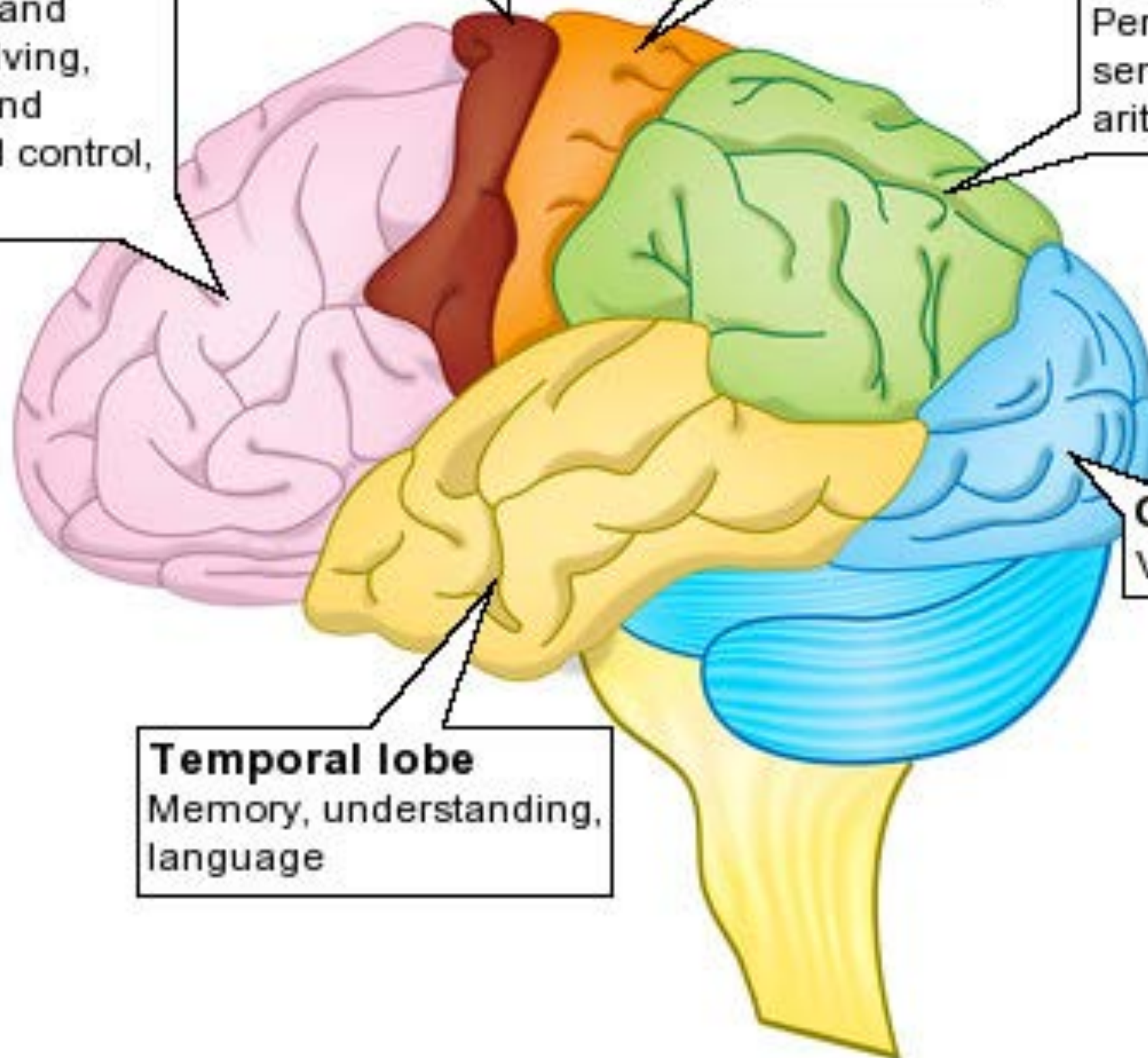
Perception, making sense of the world, arithmetic, spelling

Occipital lobe

Vision

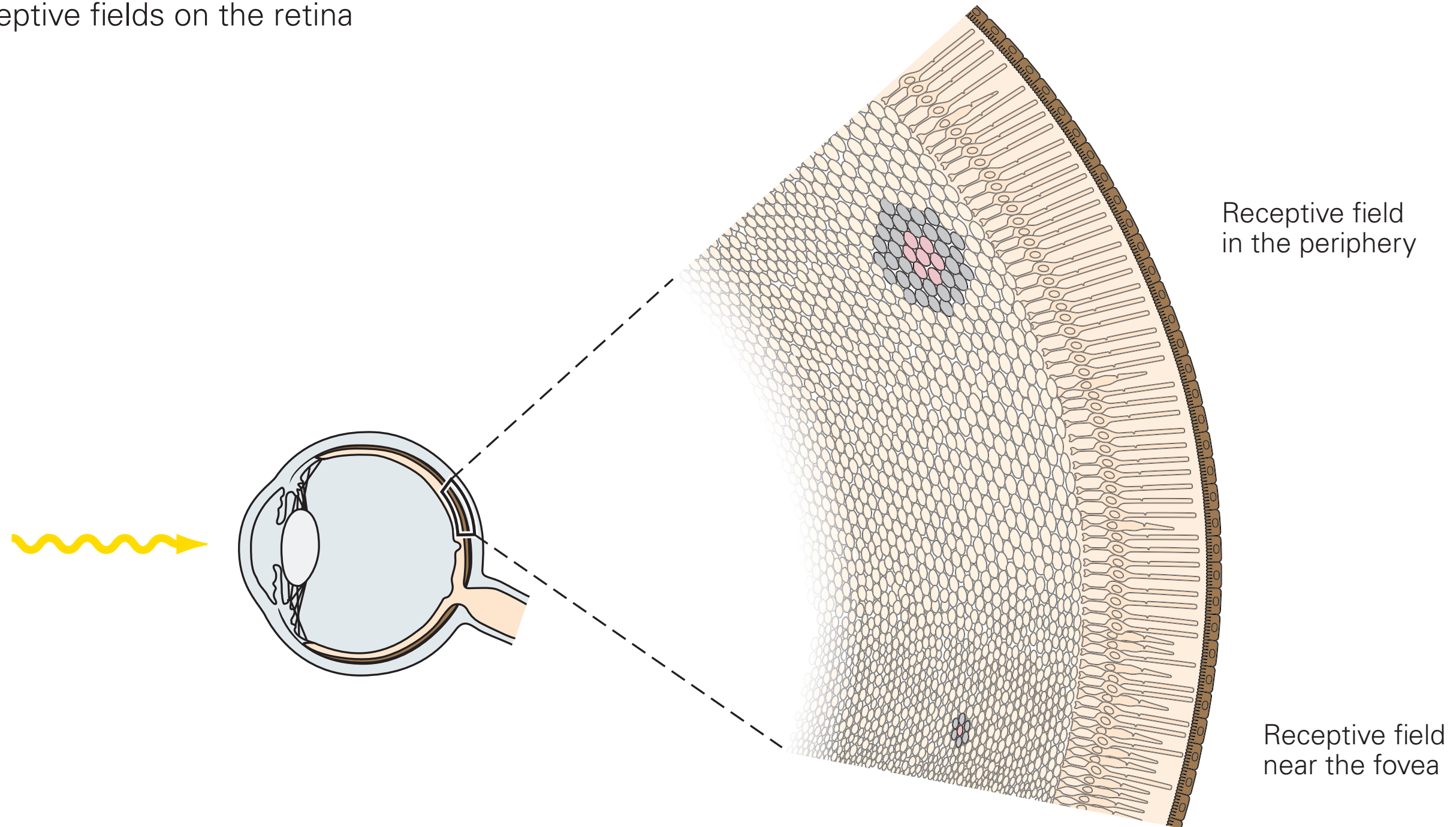
Temporal lobe

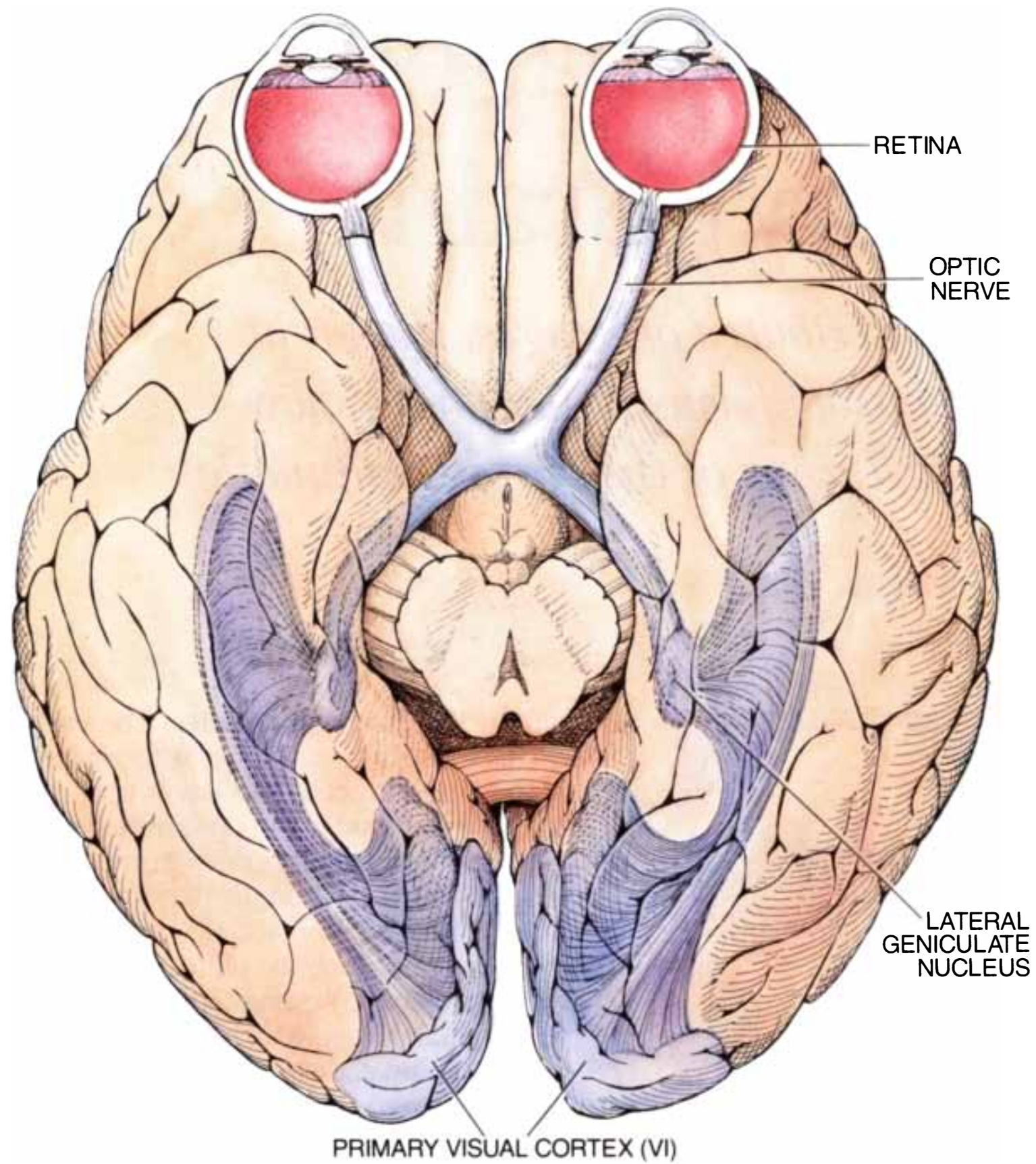
Memory, understanding, language

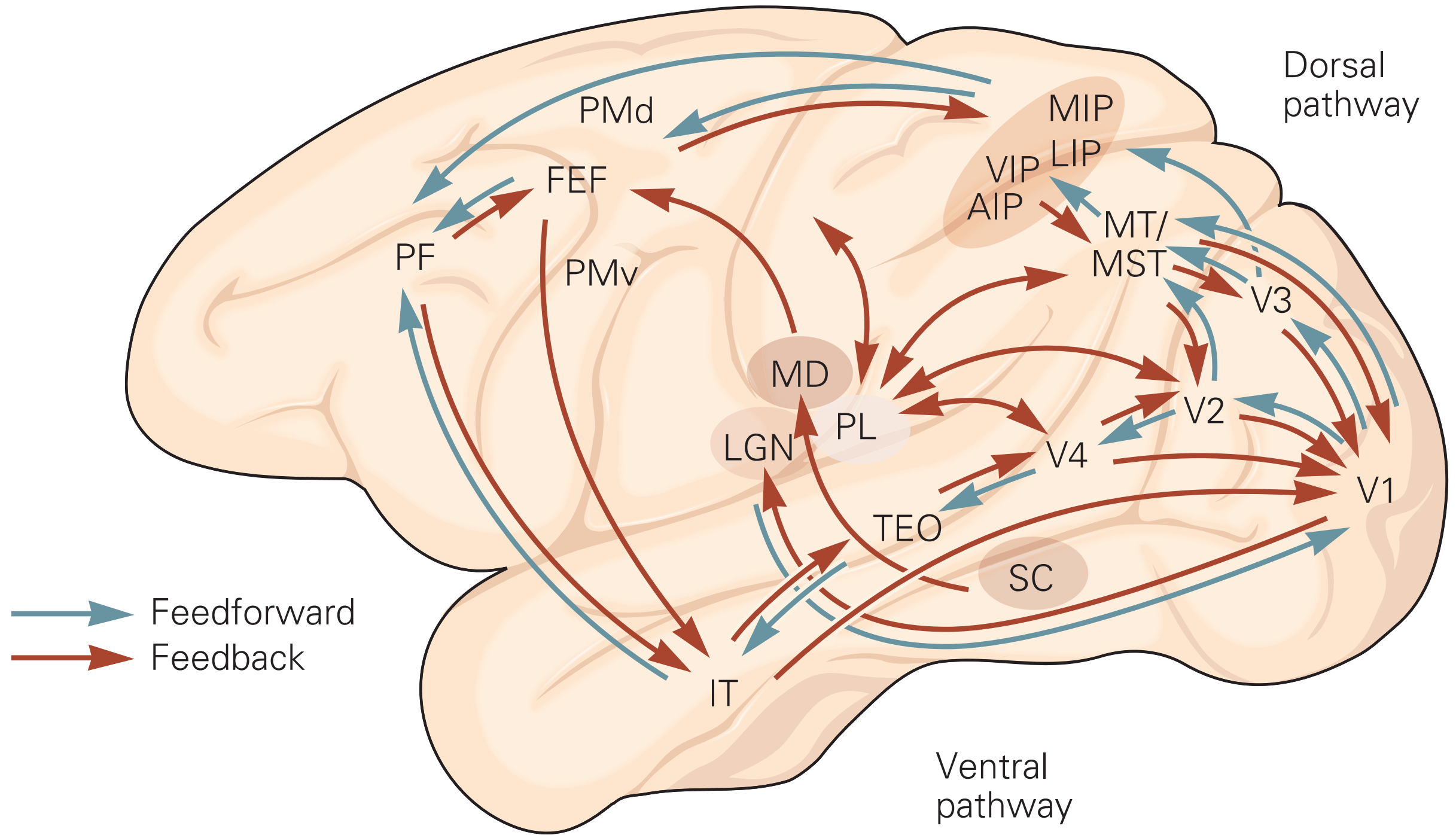


Vision

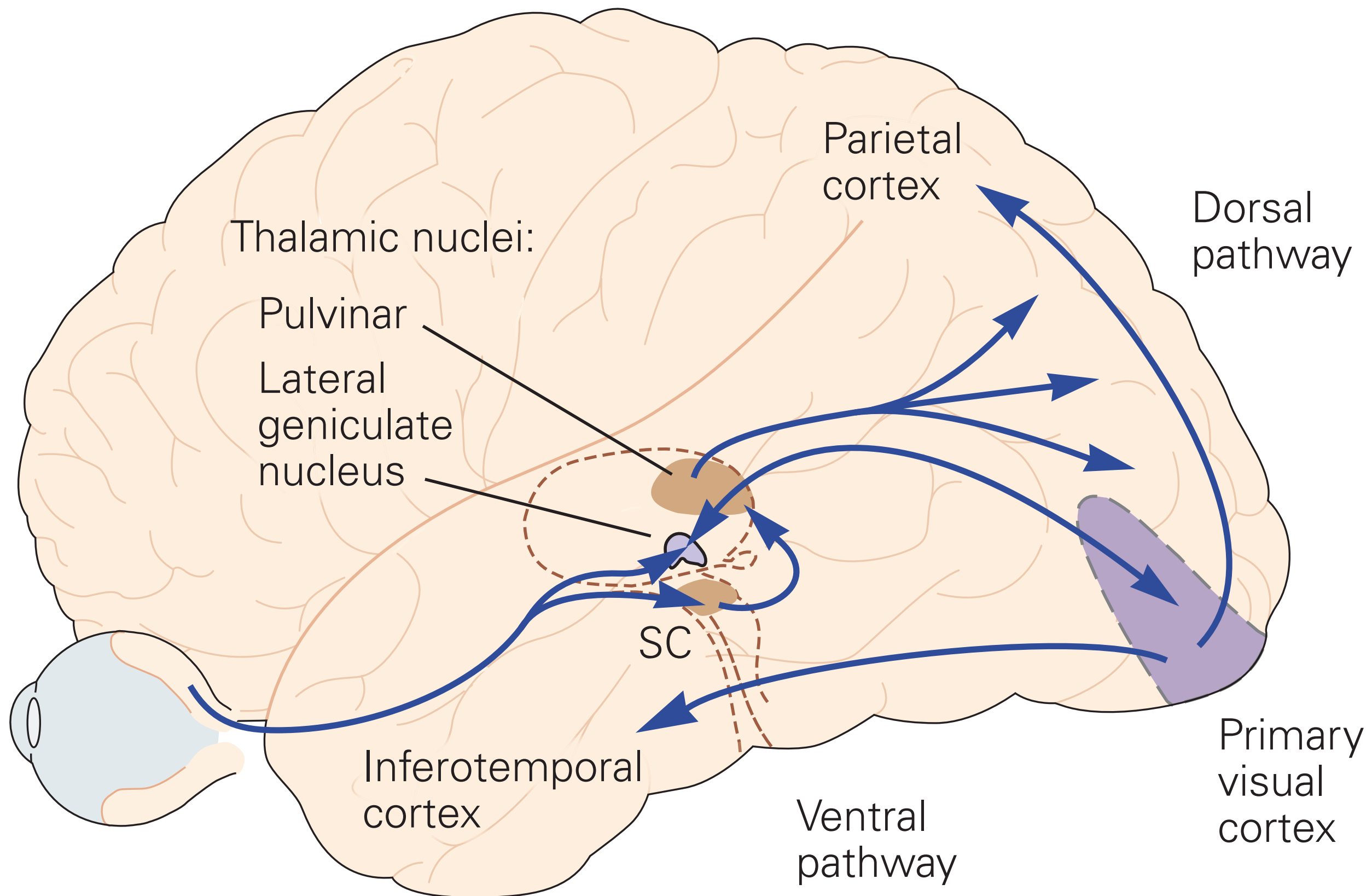
A Receptive fields on the retina



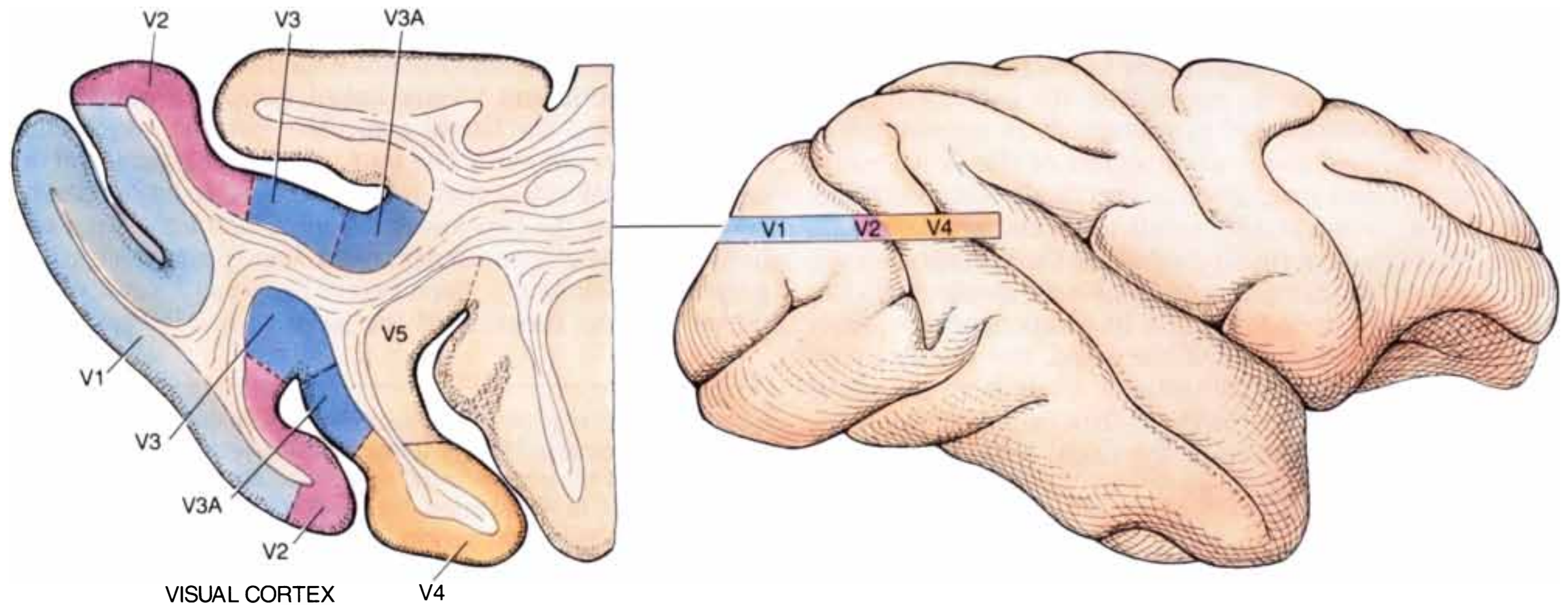




A Visual processing



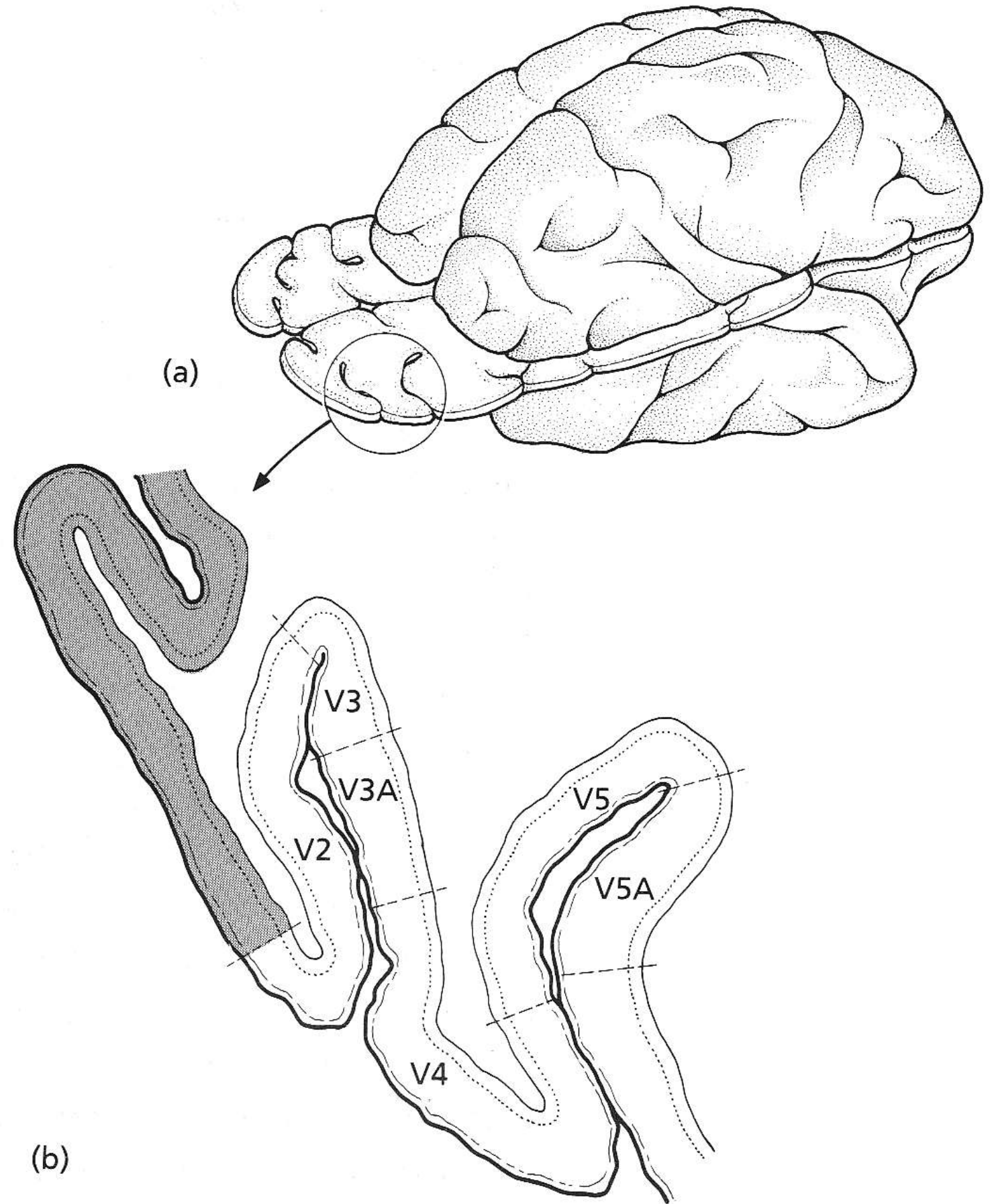
MACAQUE MONKEY BRAIN

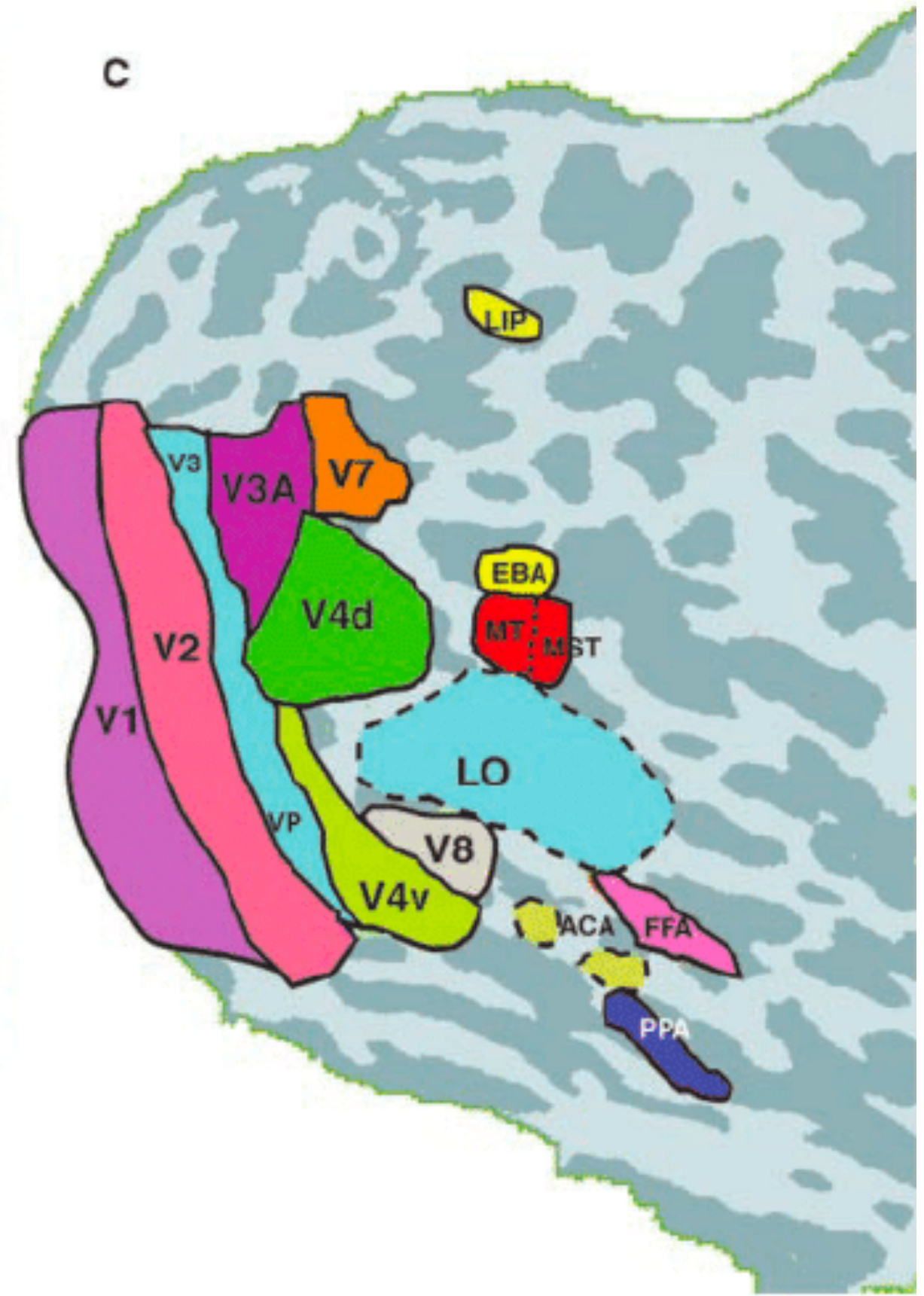


VISUAL CORTEX of the macaque monkey has been studied in detail. A cross section through the brain (*left*) at the level indi-

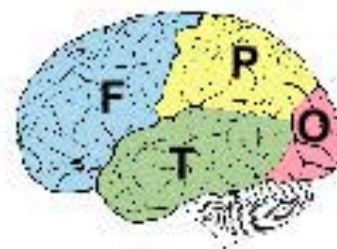
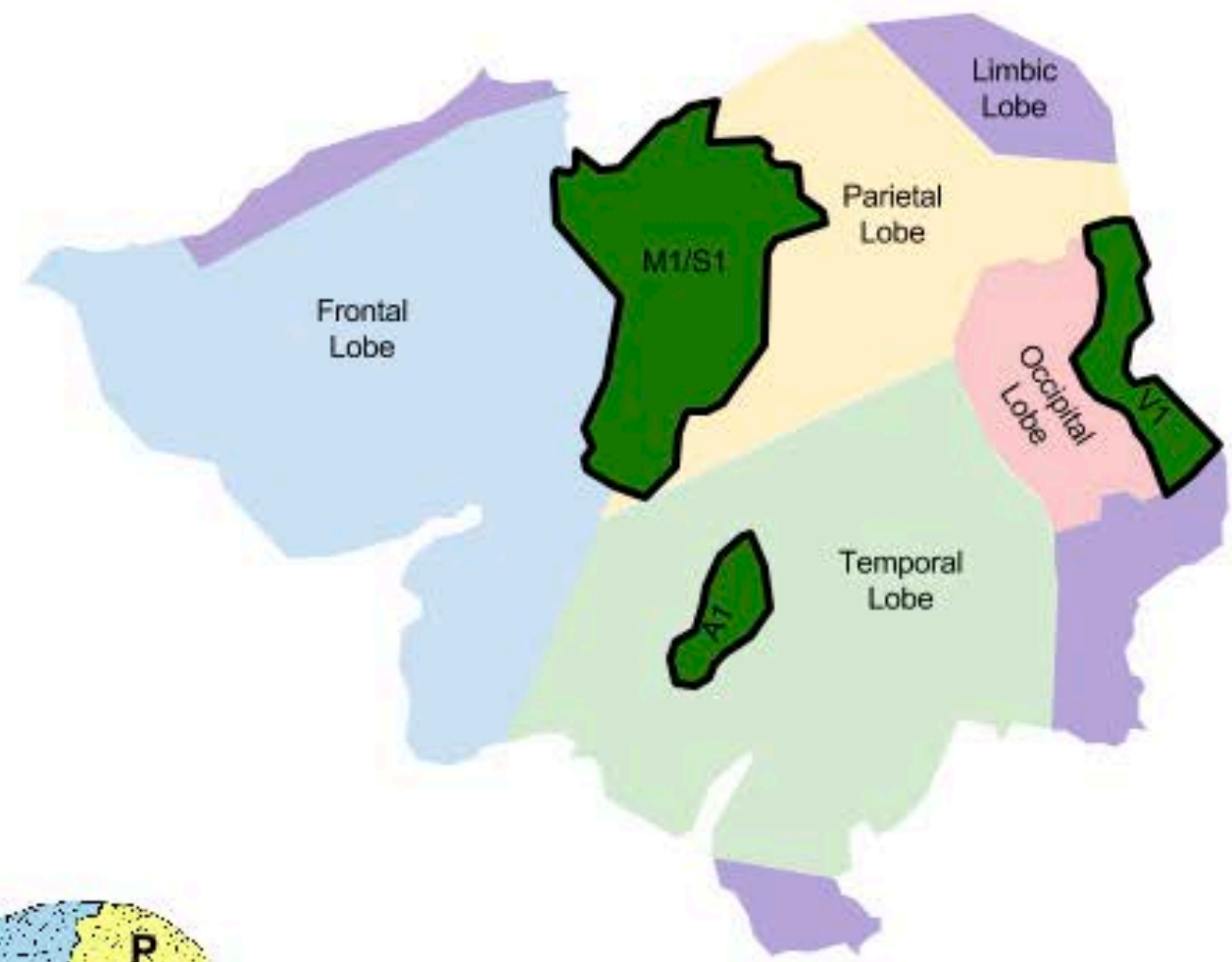
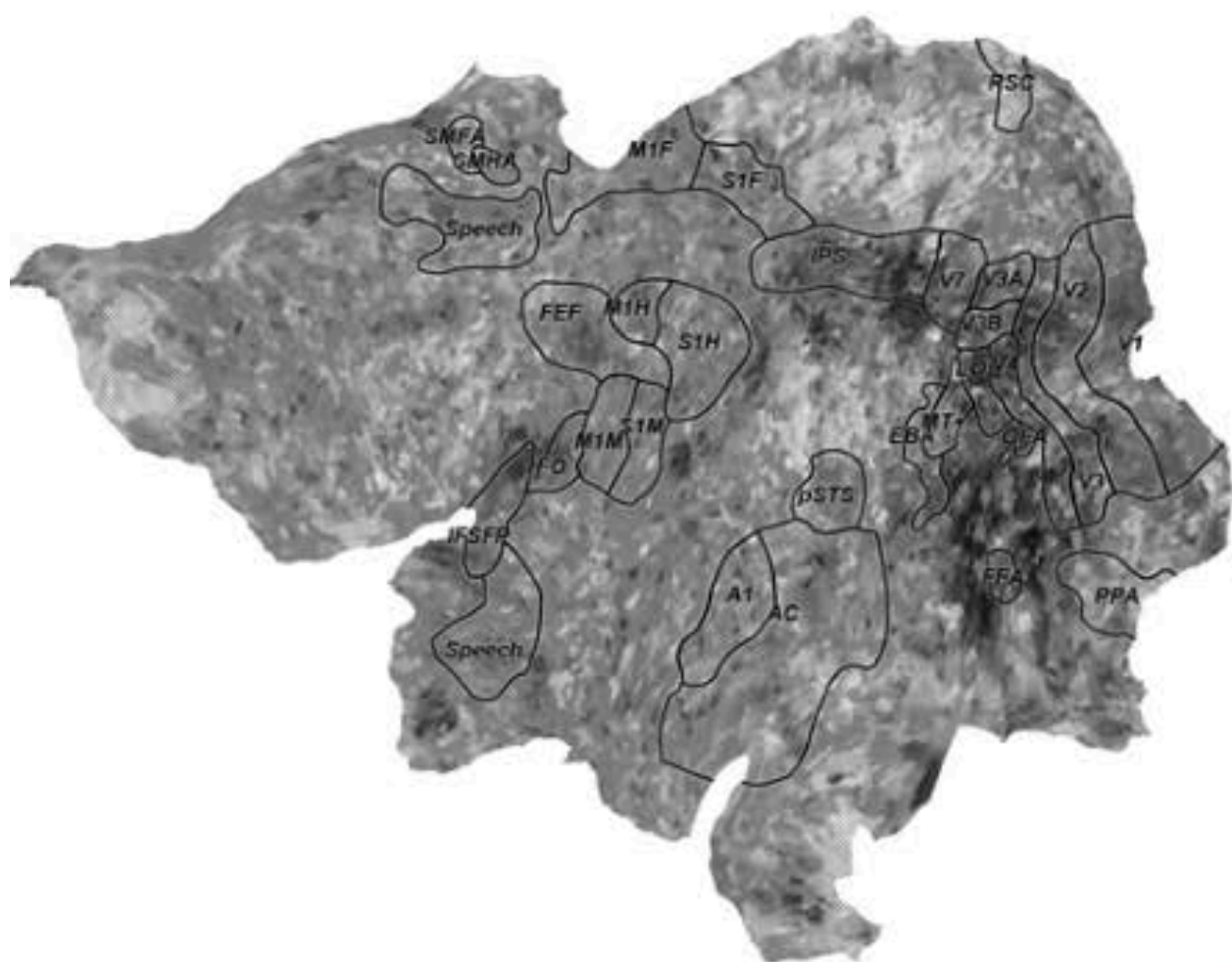
cated (*right*) shows part of the primary visual cortex (V1) and some of the other visual areas in the prestriate cortex (V2-V5).

Fig. 11.1 The visual cortex of the macaque monkey is very extensive and much of it is buried in sulci. Its extent is best appreciated when the brain is cut horizontally (a). In the section shown in (b), the primary visual cortex at the back is shown in grey. Lying in front of the primary visual cortex are several visual areas, each one of which undertakes a different task.

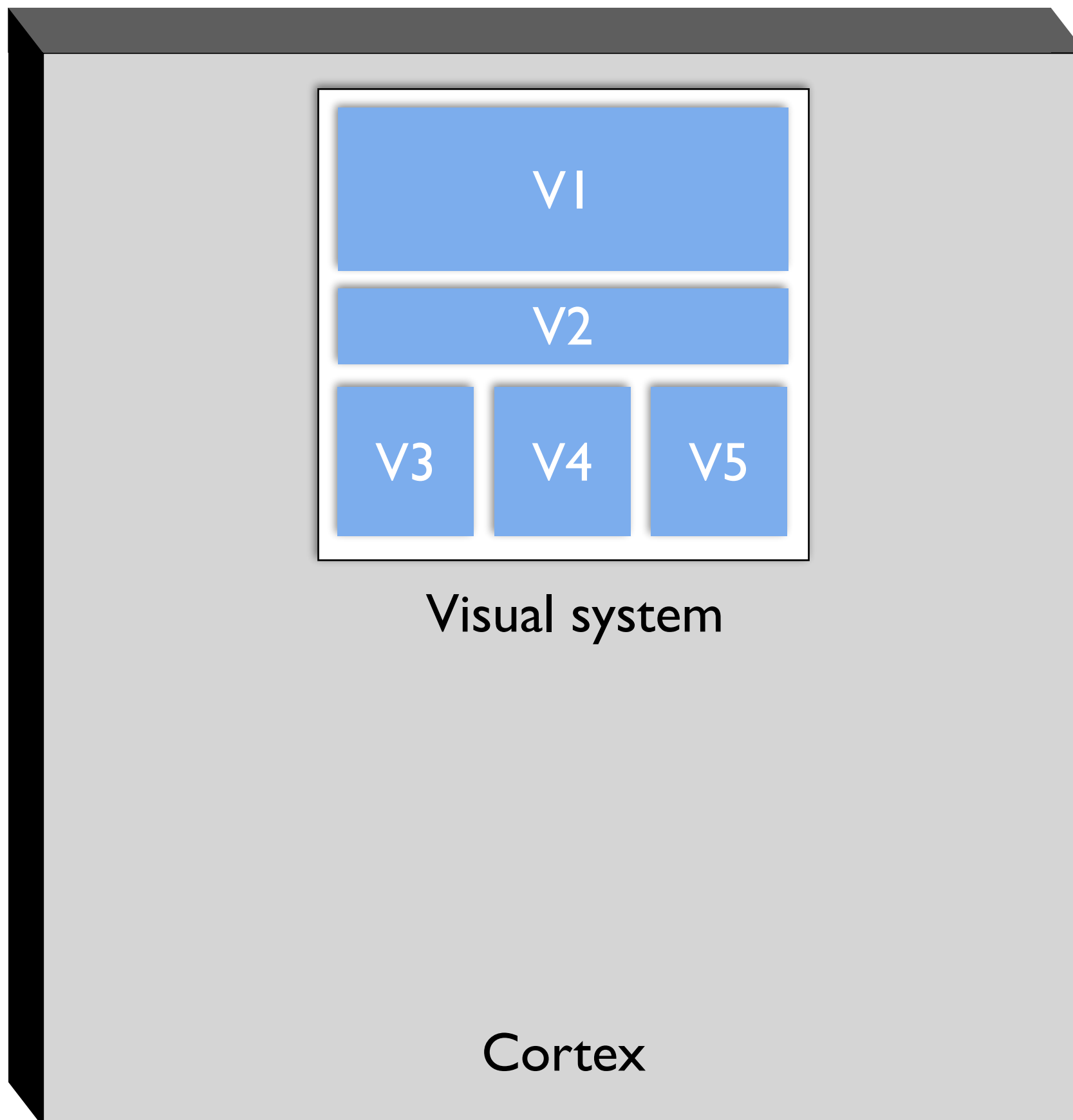


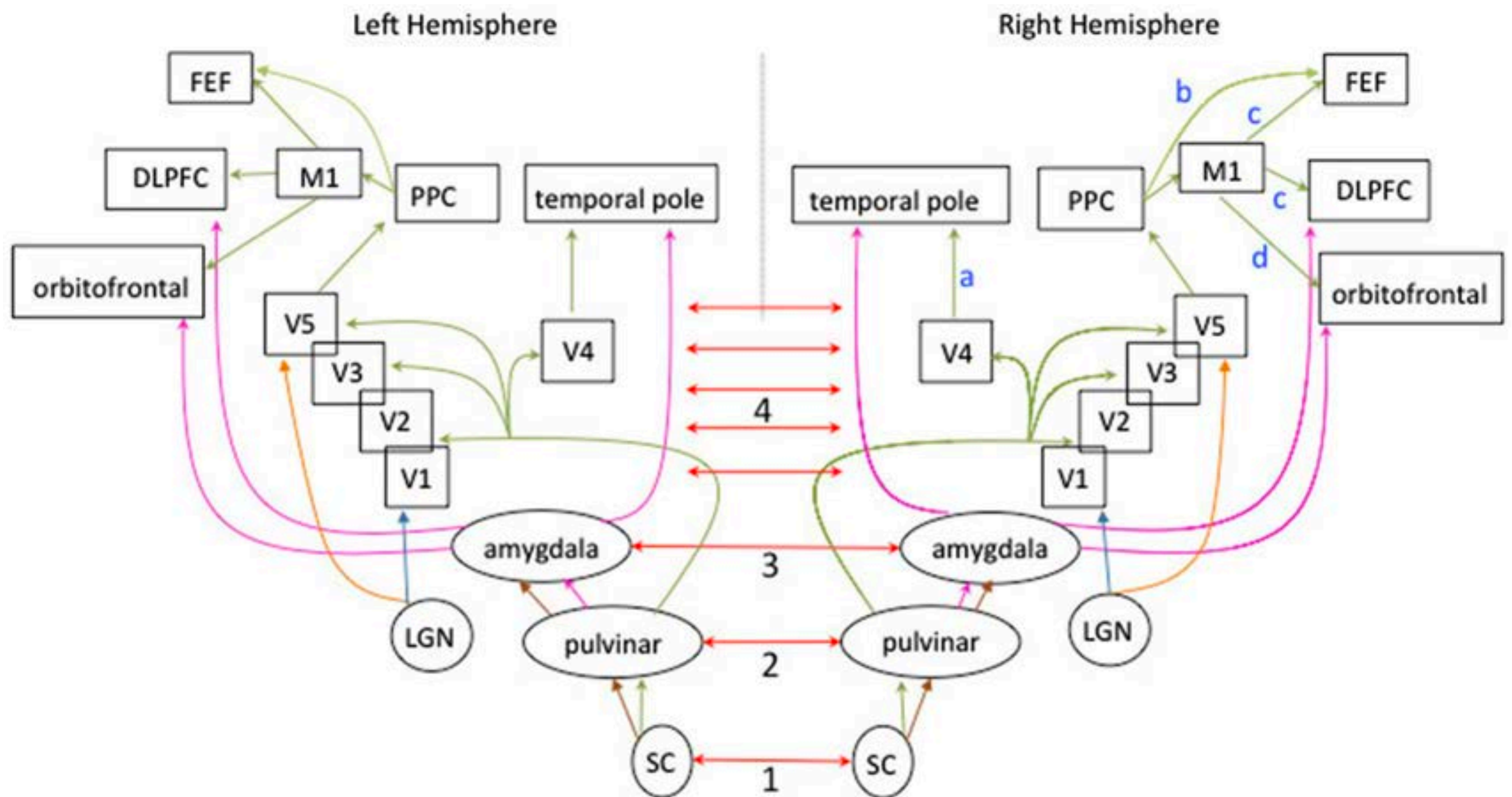


C shows areas in human visual cortex, as described in the text. Consensus is highest in lower-tier (generally, left-most) areas; such areas tend to be evolutionarily more conserved, and the retinotopy is more easily resolved. “Neuroimaging Weighs In: Humans Meet Macaques in “Primate” Visual Cortex”



Flat map of the human brain

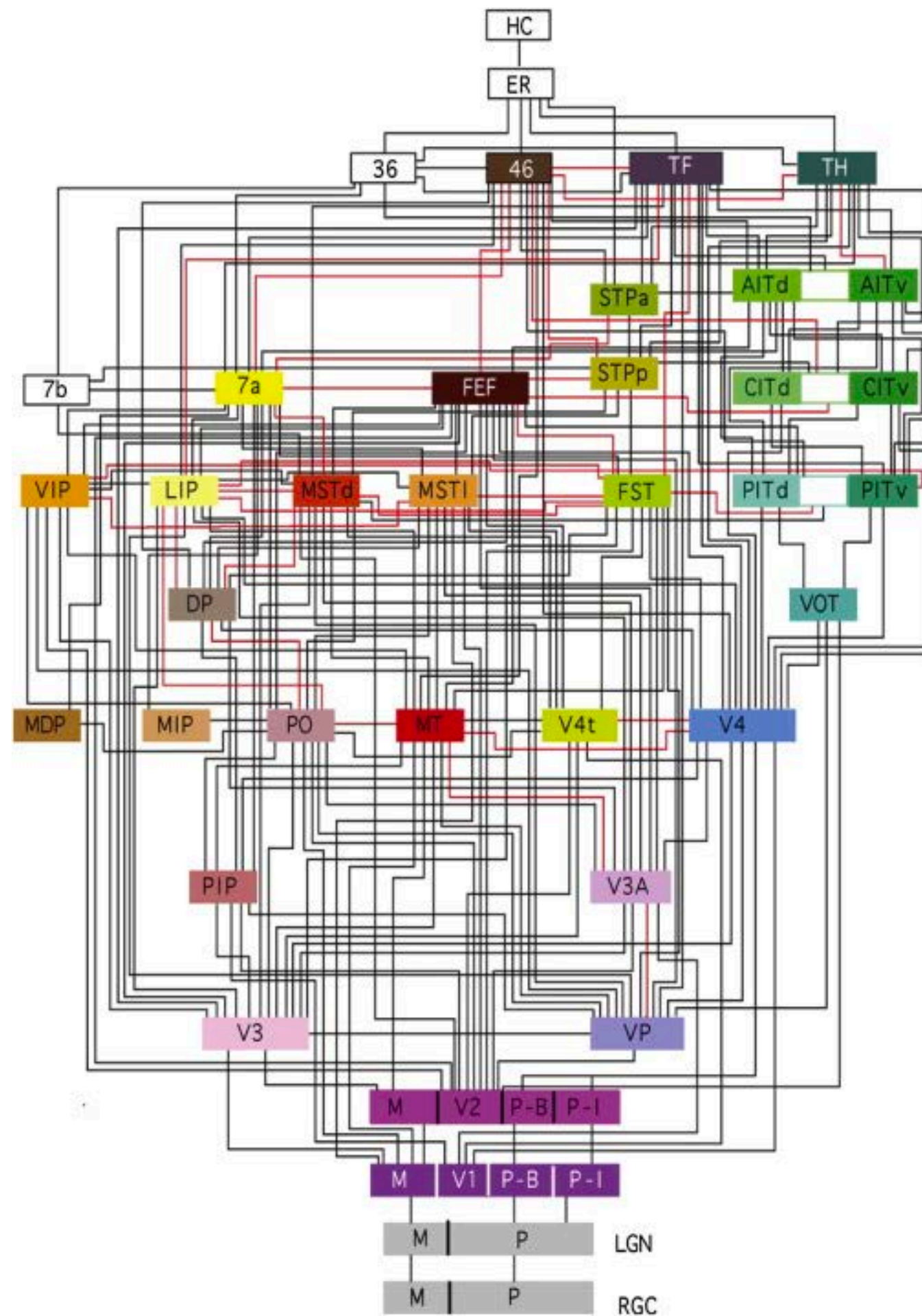


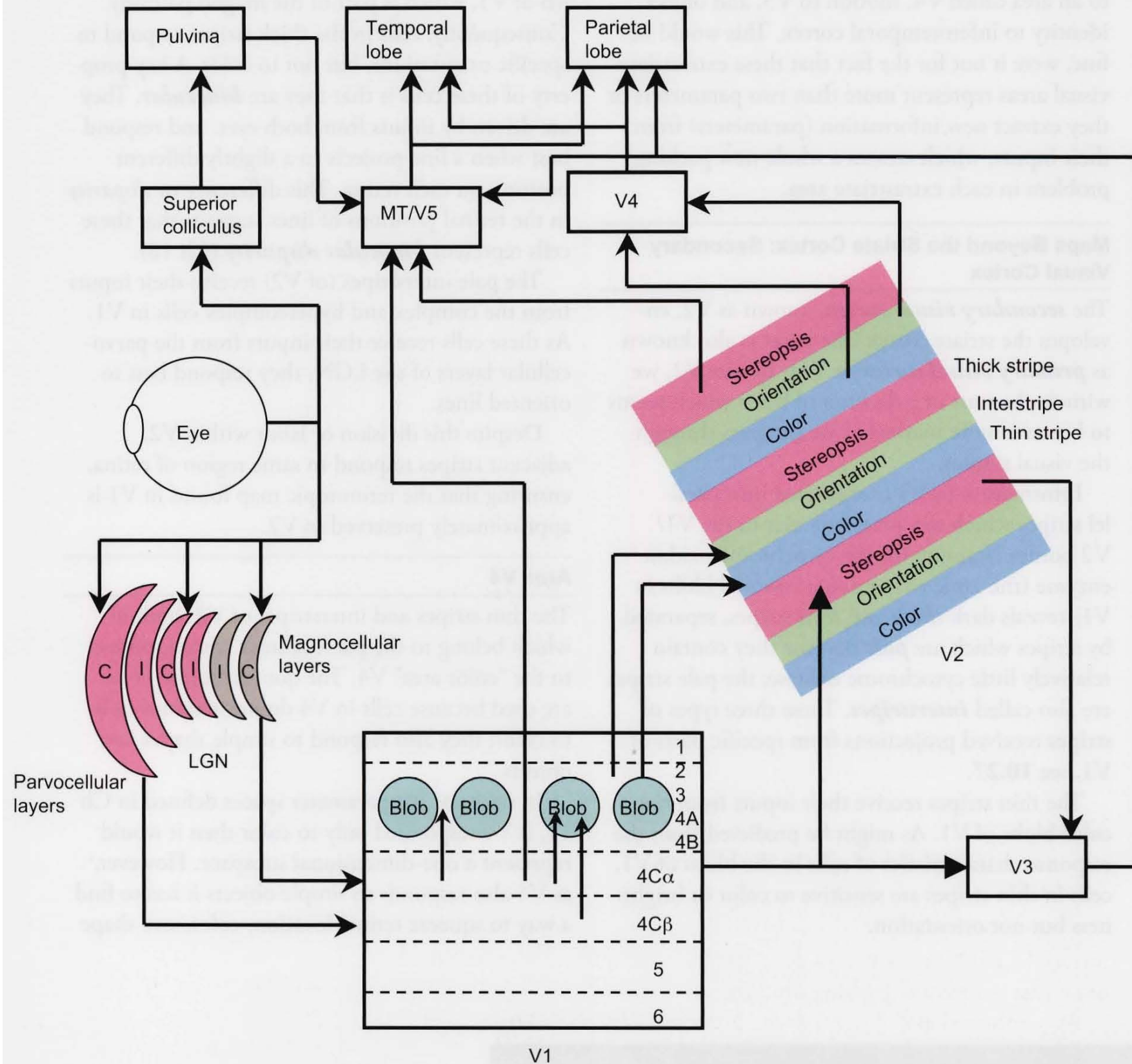


- Colliculo-pulvinar pathway
- Pulvino-amygdalar pathway
- Colliculo-pulvino-amygdalar pathway
- Geniculo-extrastriate pathway
- Geniculo-striate pathway

- Interhemispheric connections
- 1: intercollicular commissure
- 2: massa intermedia
- 3: anterior commissure
- 4: splenium of the corpus callosum

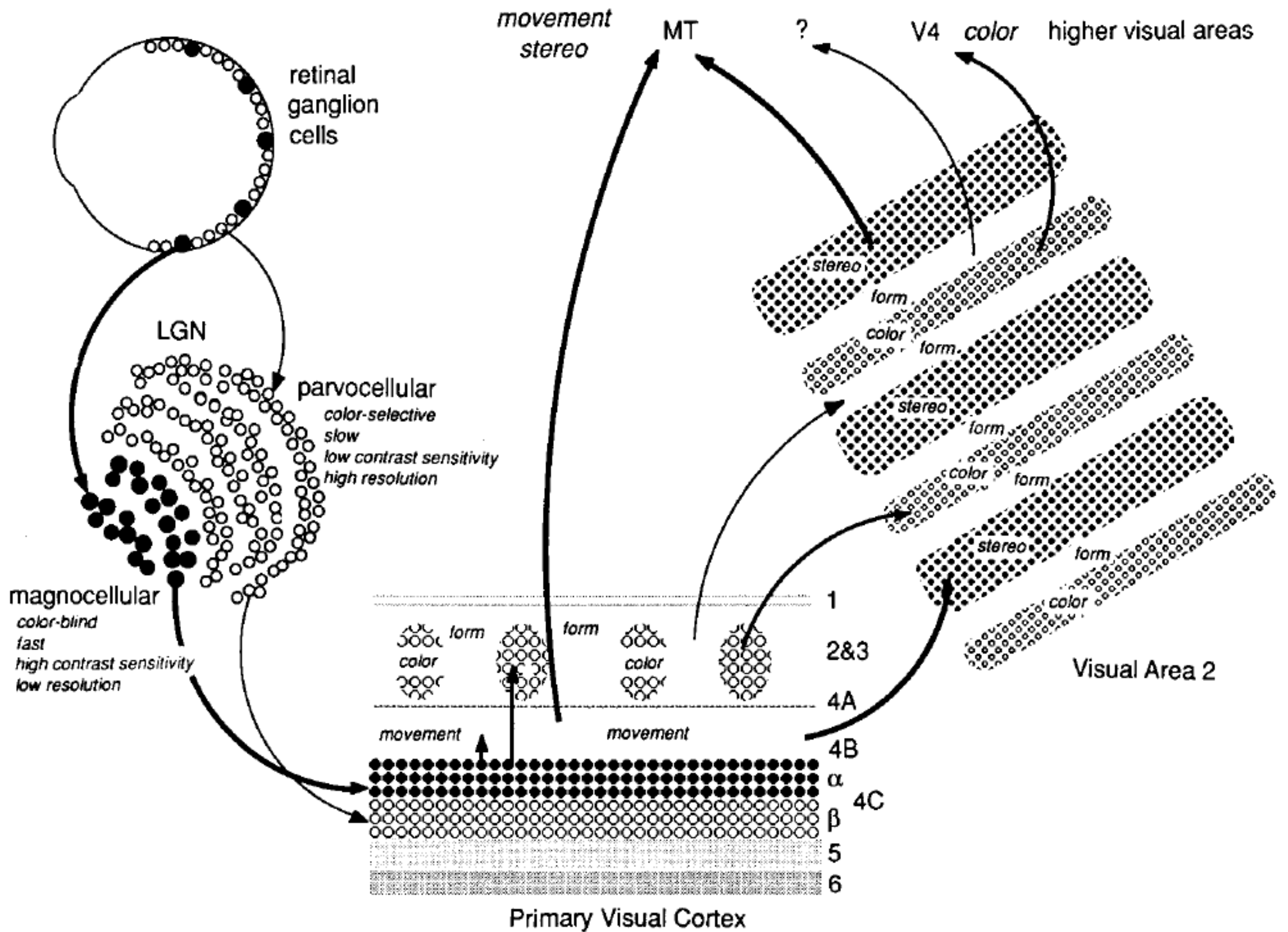
- Intrahemispheric connections
- a: ILF
- b: SLF
- c: FSL
- d: FIL





10.27 Unpacking the striate cortex

Information from different ganglion cells in each eye projects to specific layers of the LGN (C=contralateral, I=ipsilateral, see 9.9). These then project to V1, which projects to discrete stripes of V2, which innervate V3–V5, areas specialized for processing different types of information.



Dorsal and Ventral Pathways

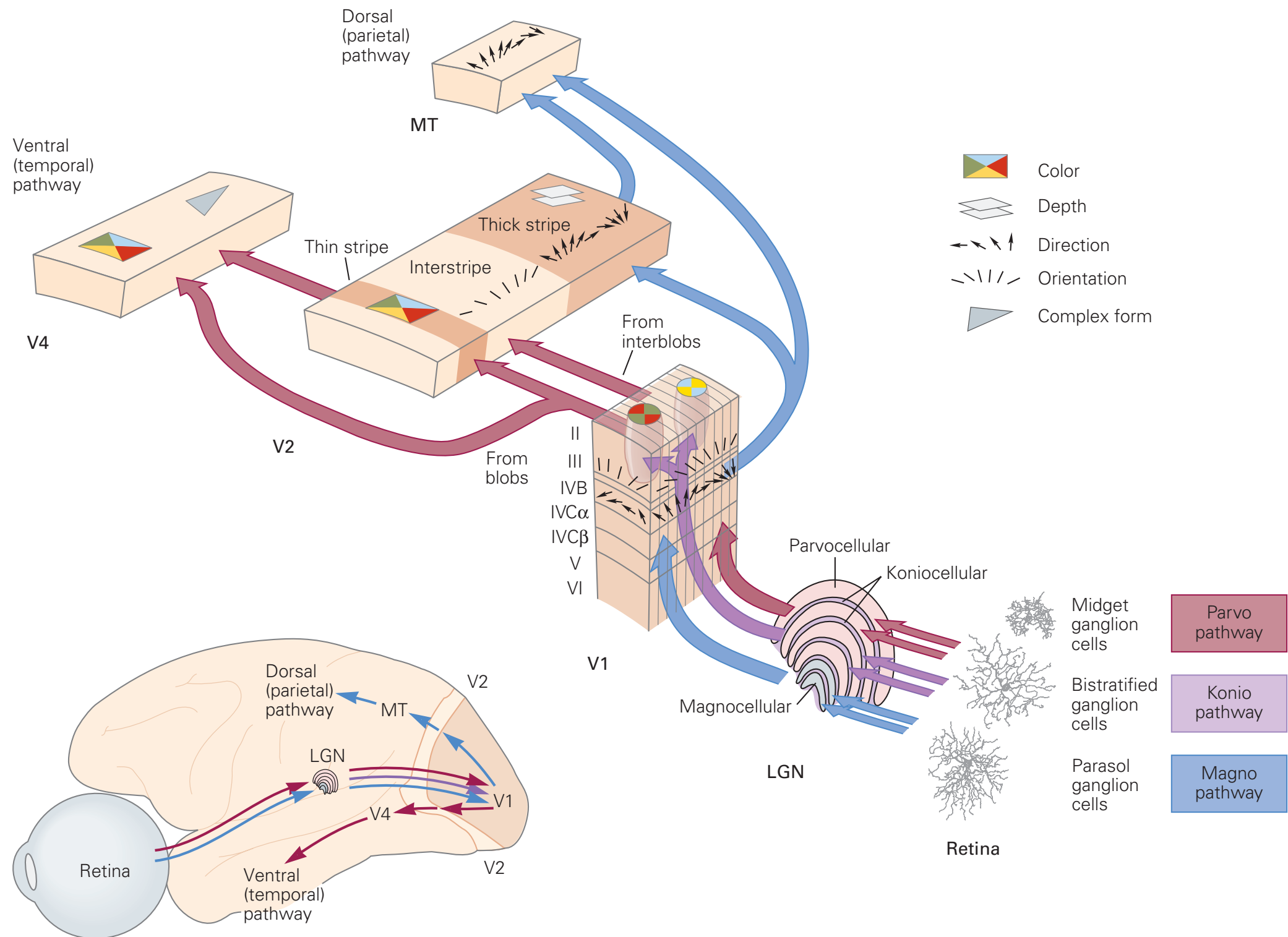
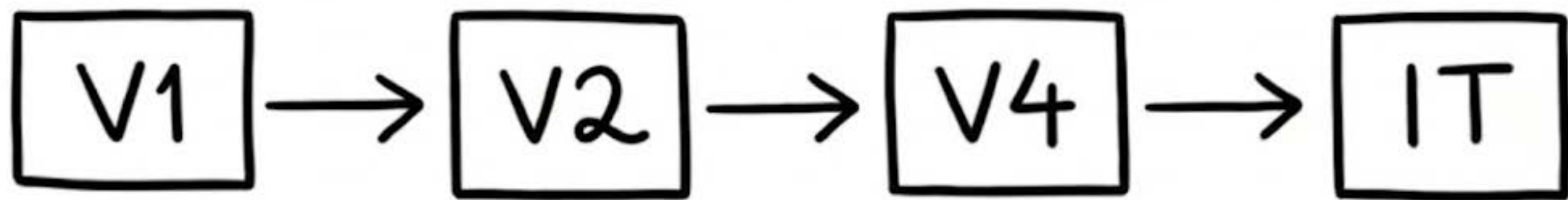
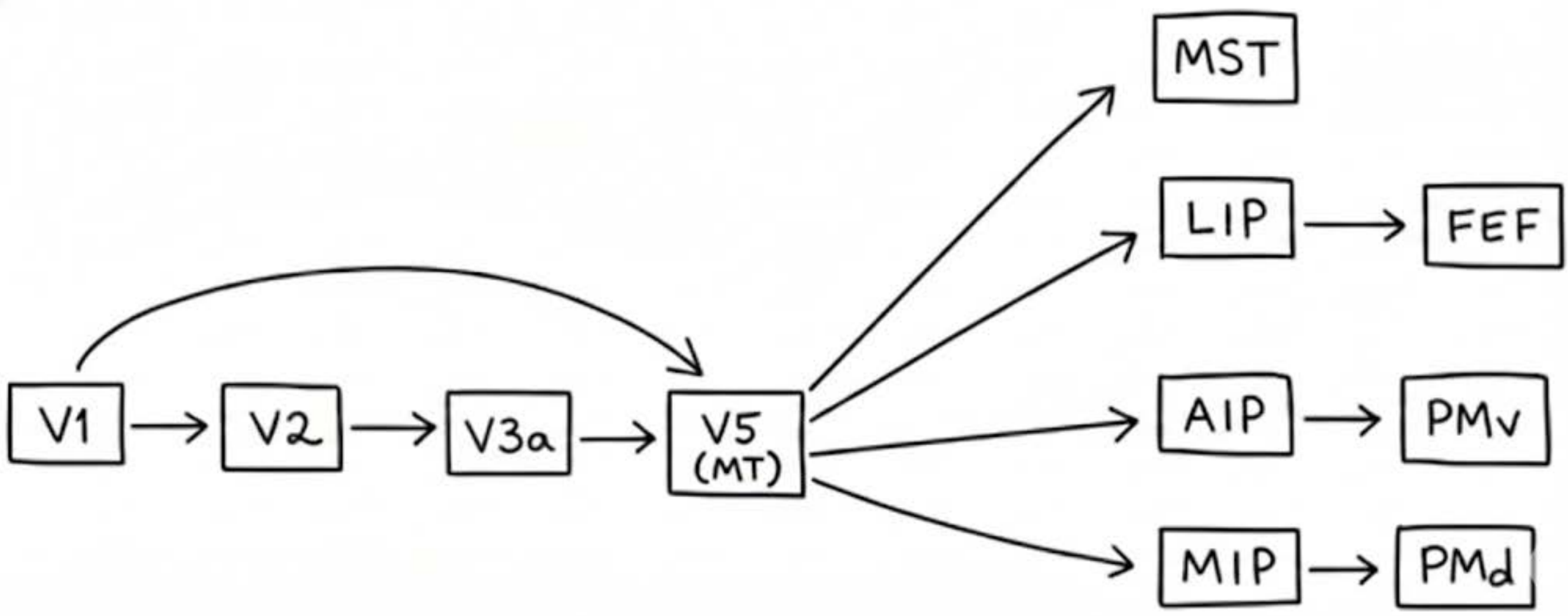


Figure 21–14 Parallel processing in visual pathways. The ventral stream is primarily concerned with object identification, carrying information about form and color. The dorsal pathway is dedicated to visually guided movement, with cells selective for direction of movement. These pathways are not strictly

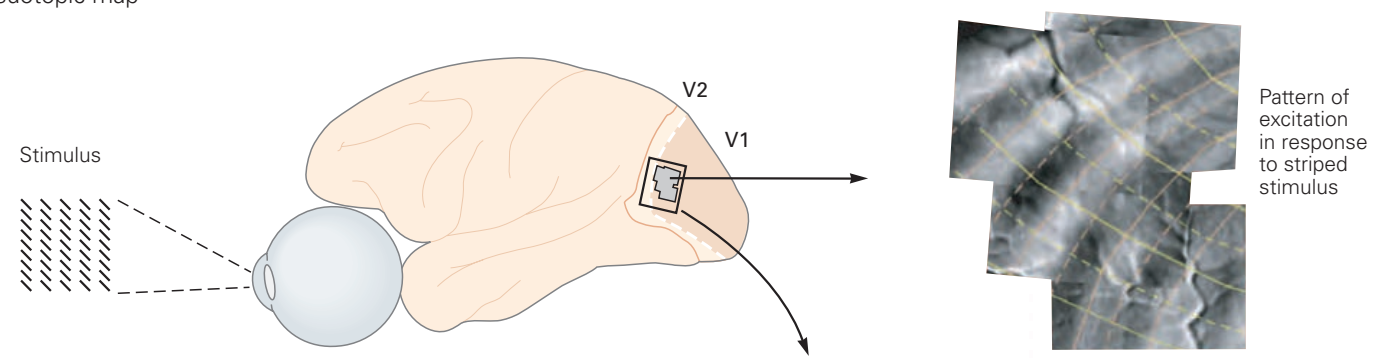
segregated, however, and there is substantial interconnection between them even in the primary visual cortex. (Abbreviations: **LGN**, lateral geniculate nucleus; **MT**, middle temporal area.) (Retinal ganglion cell images courtesy of Dennis Dacey, reproduced with permission.)



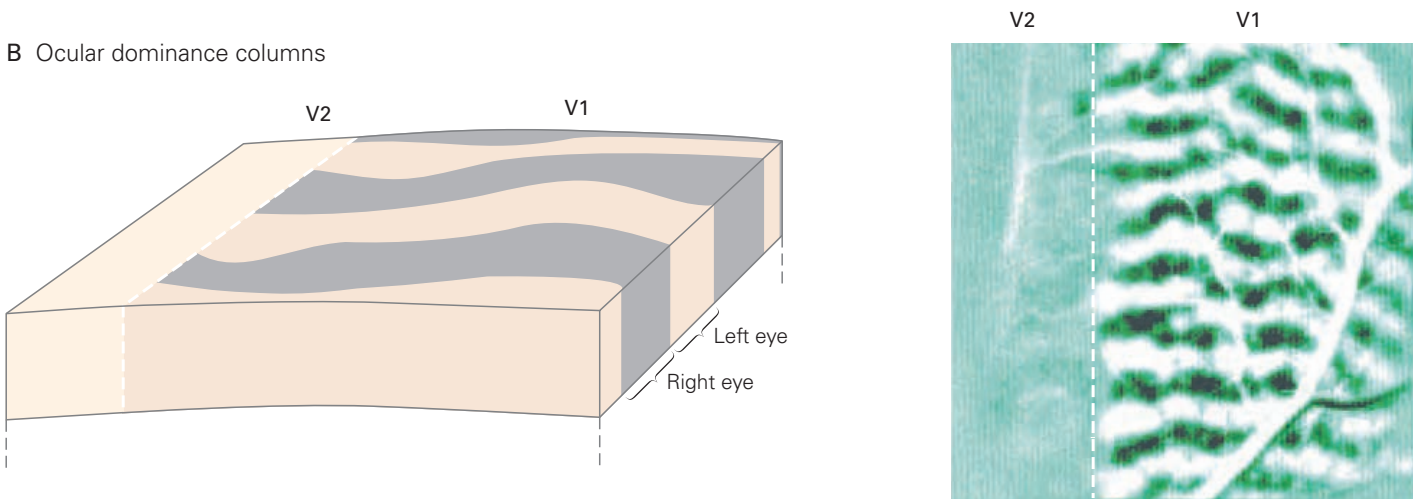


V1 Maps

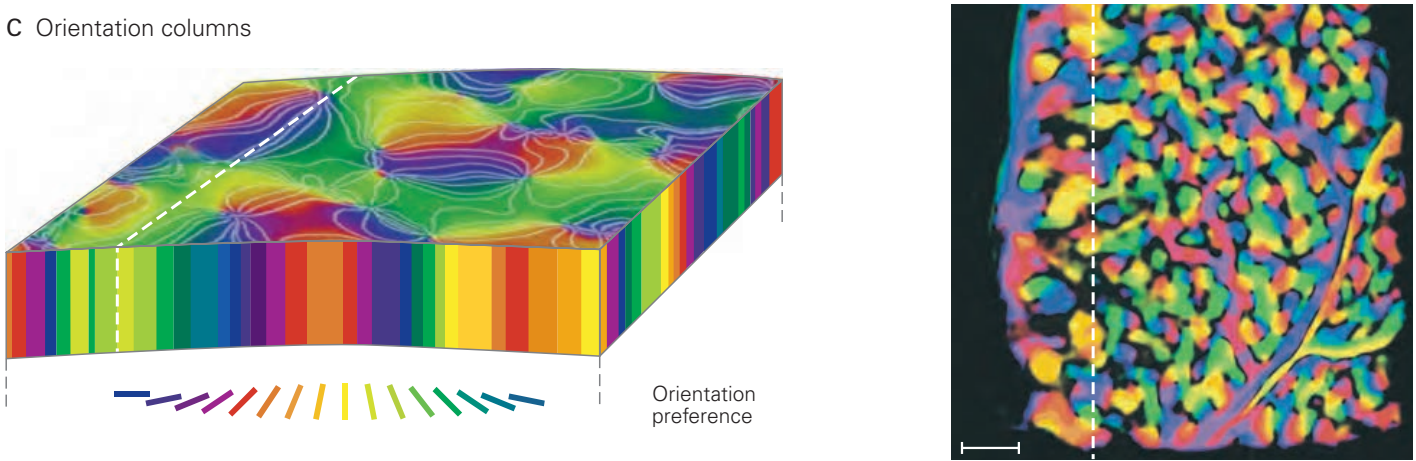
A Visuotopic map



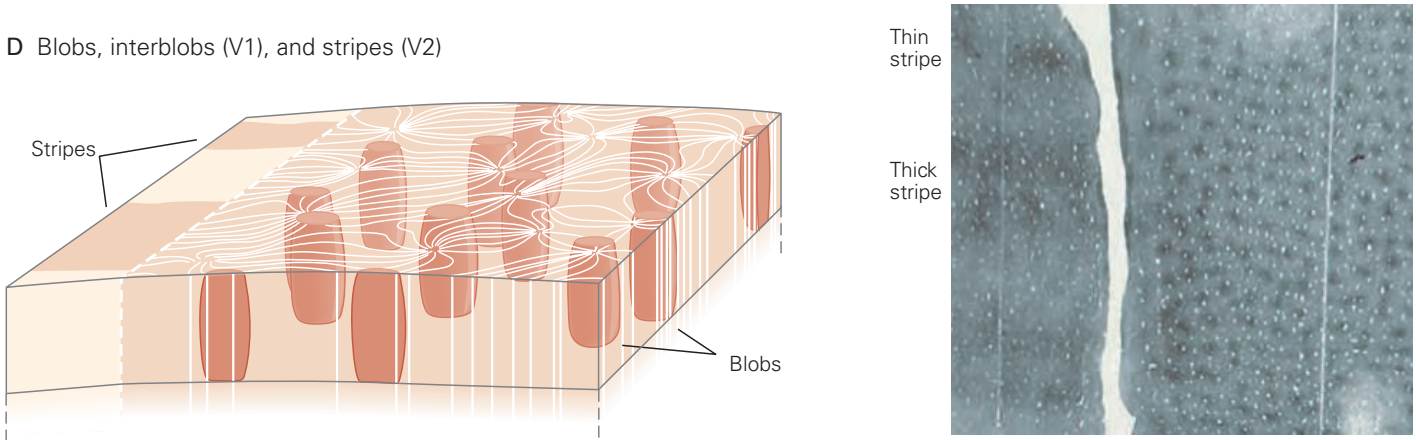
B Ocular dominance columns



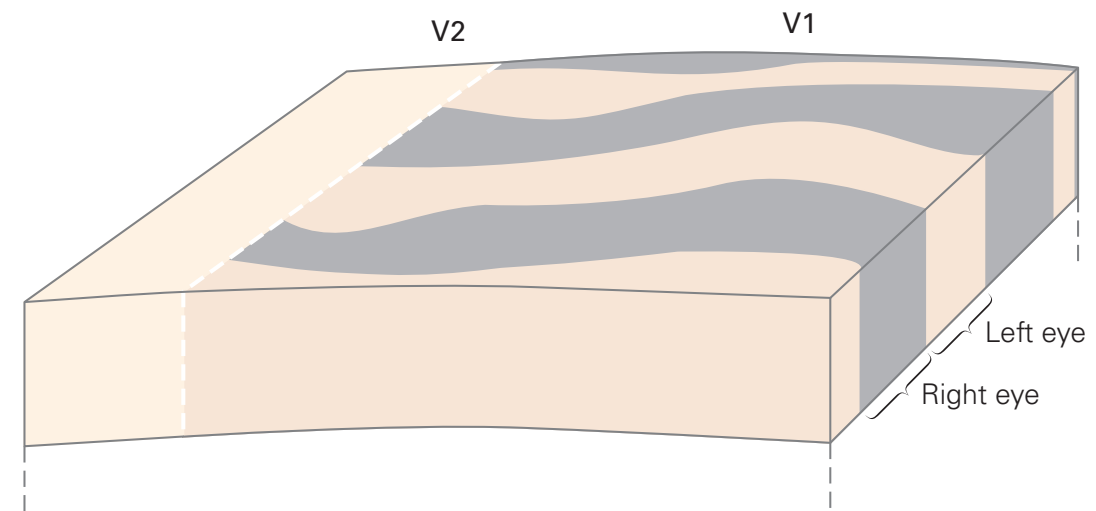
C Orientation columns



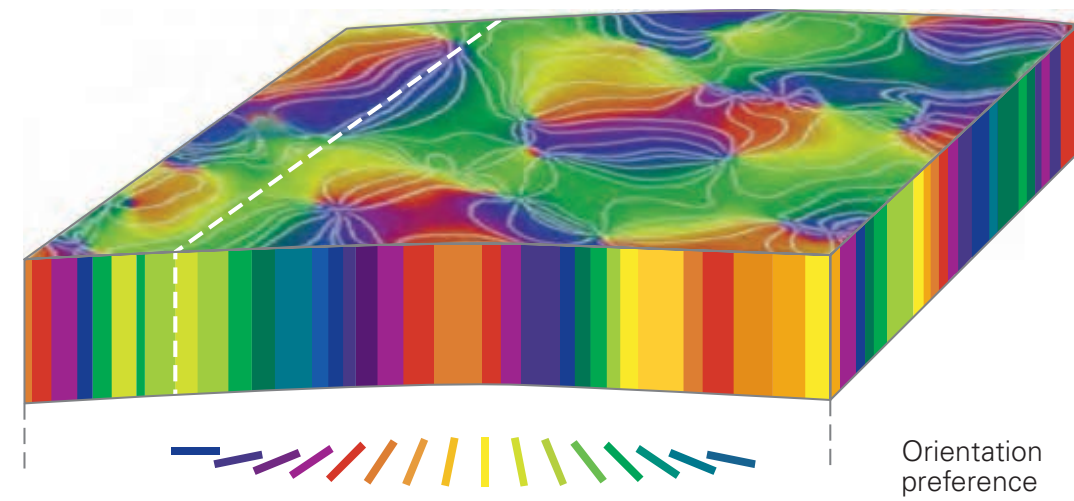
D Blobs, interblobs (V1), and stripes (V2)



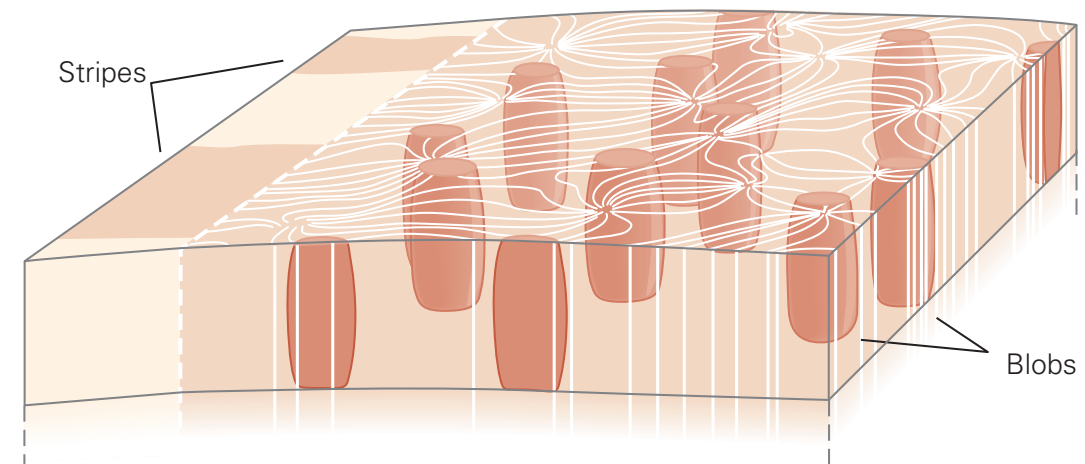
B Ocular dominance columns



C Orientation columns



D Blobs, interblobs (V1), and stripes (V2)



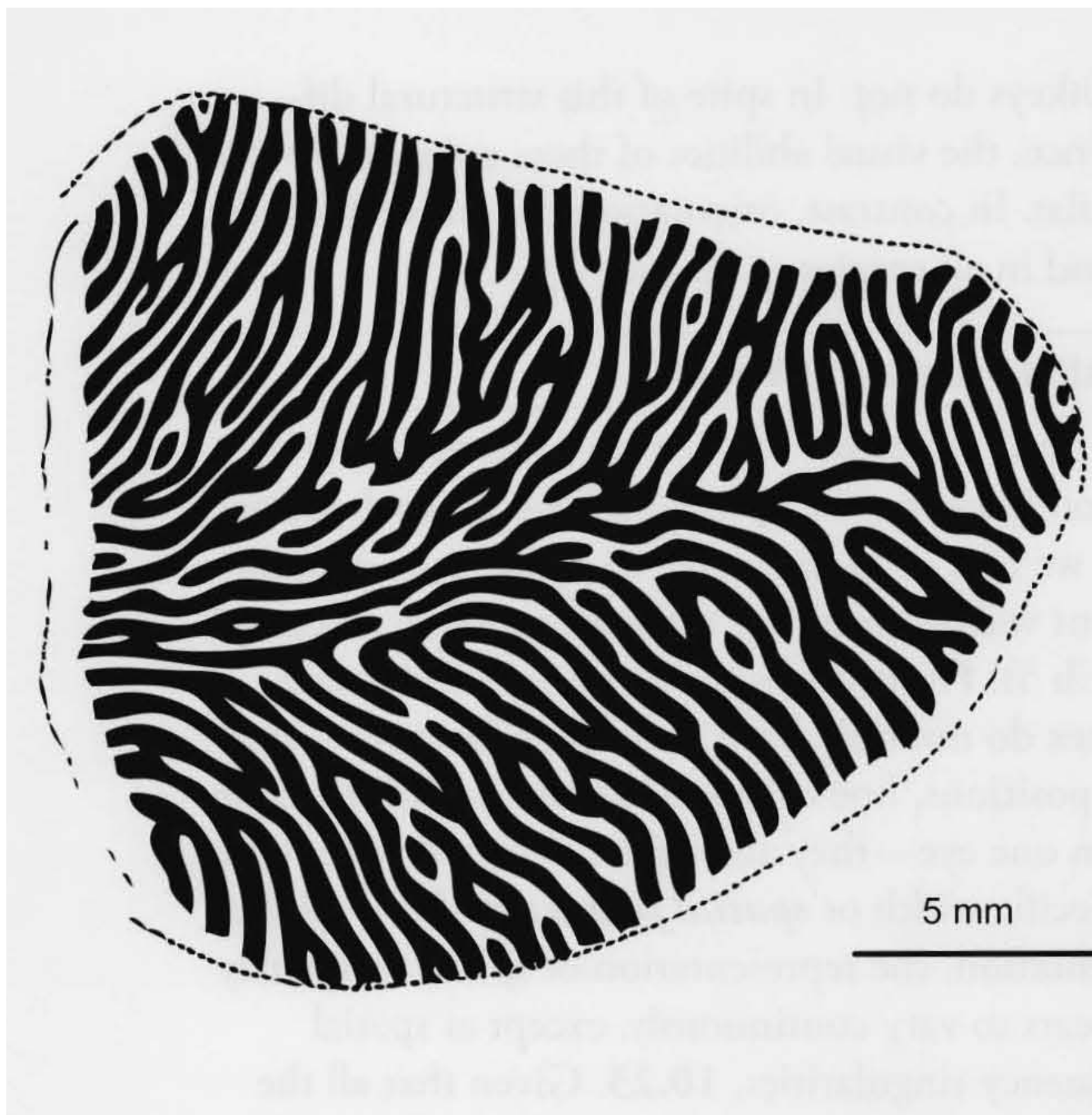
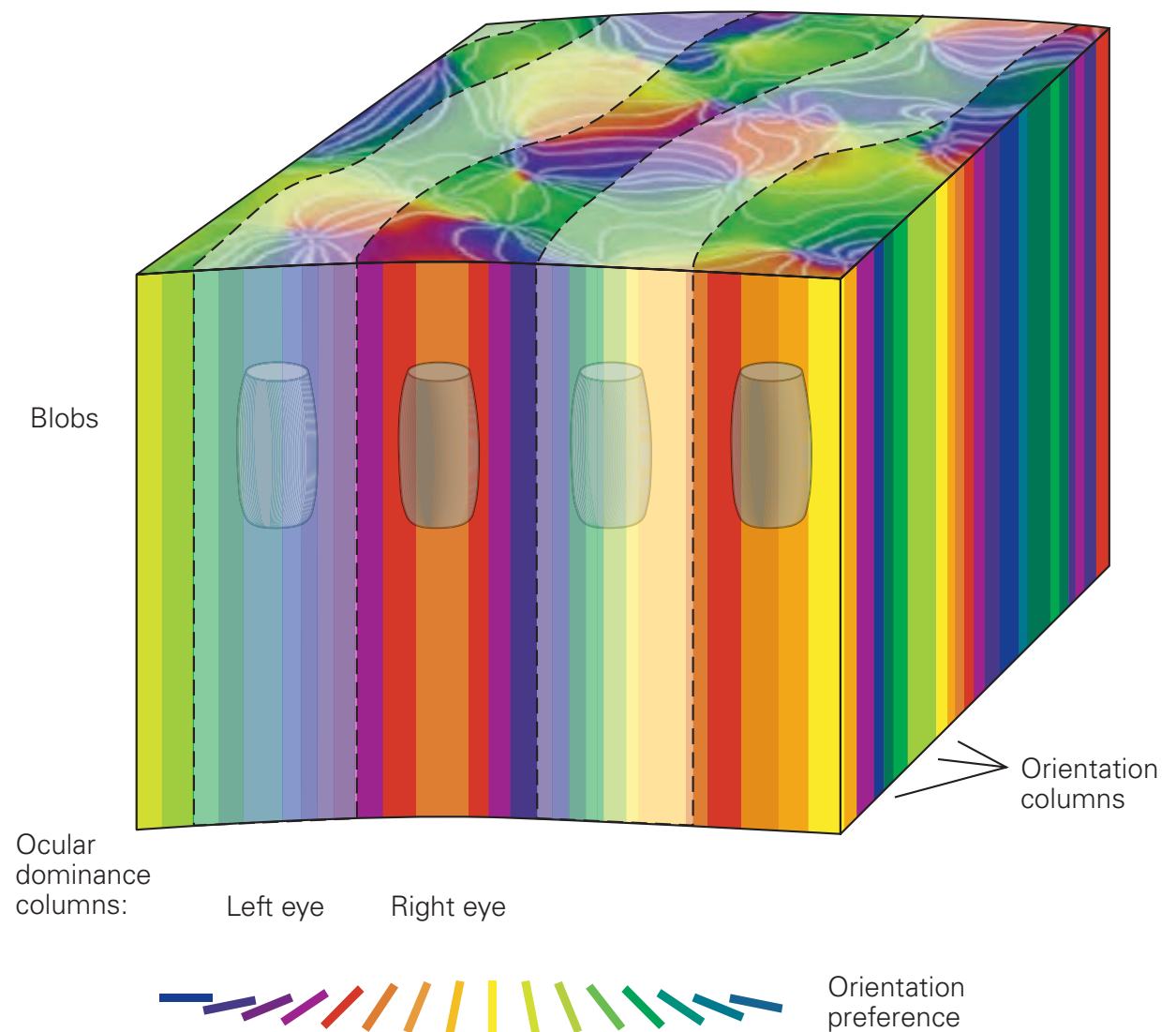
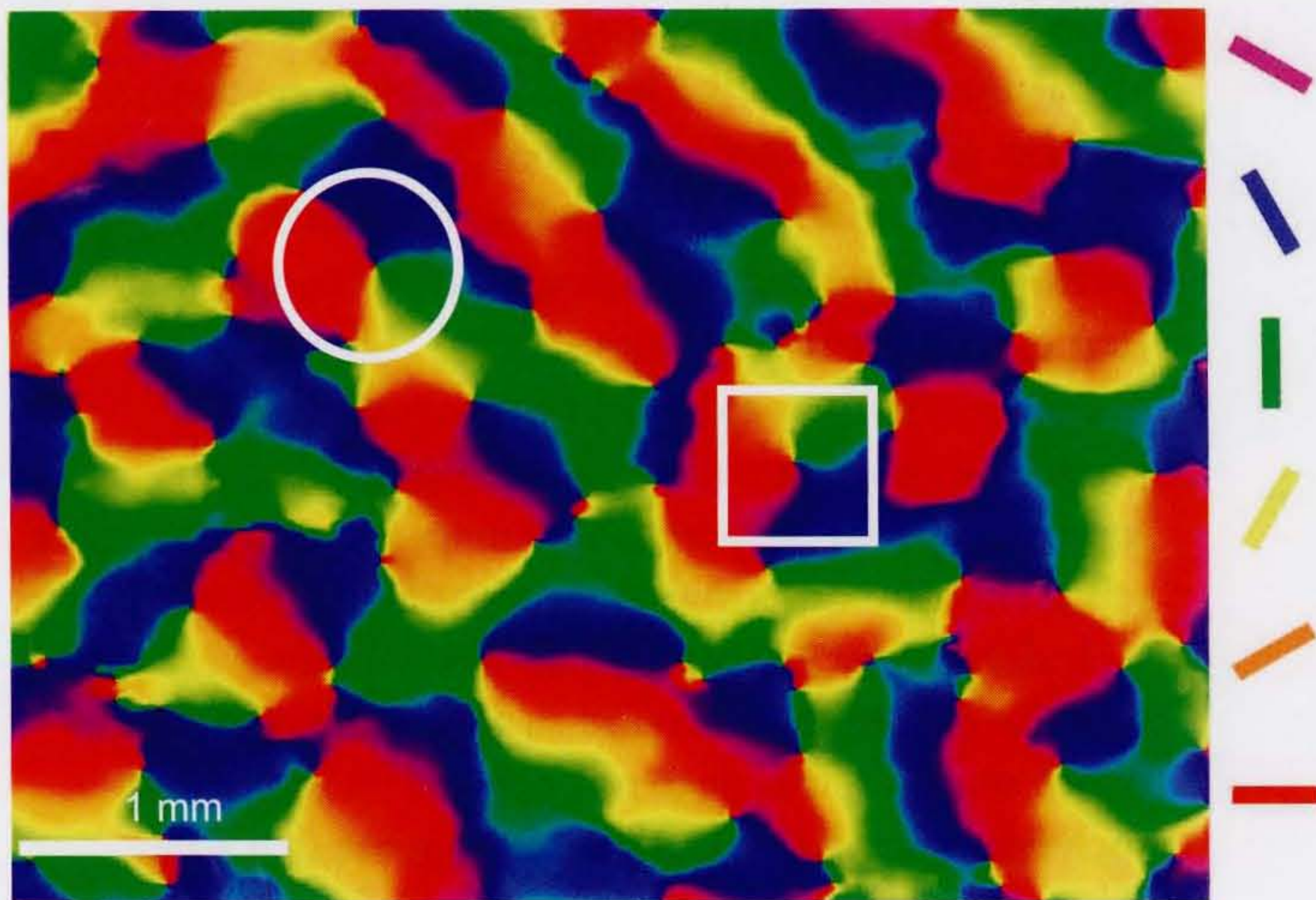


Figure 21–13 A cortical computational module.

A chunk of cortical tissue roughly 1 mm square contains an orientation hypercolumn (a full cycle of orientation columns), one cycle of left- and right-eye ocular-dominance columns, and blobs and interblobs. This module would presumably contain all of the functional and anatomical cell types of primary visual cortex, which would be repeated hundreds of times to cover the visual field. (Adapted from Hubel 1988.)



a



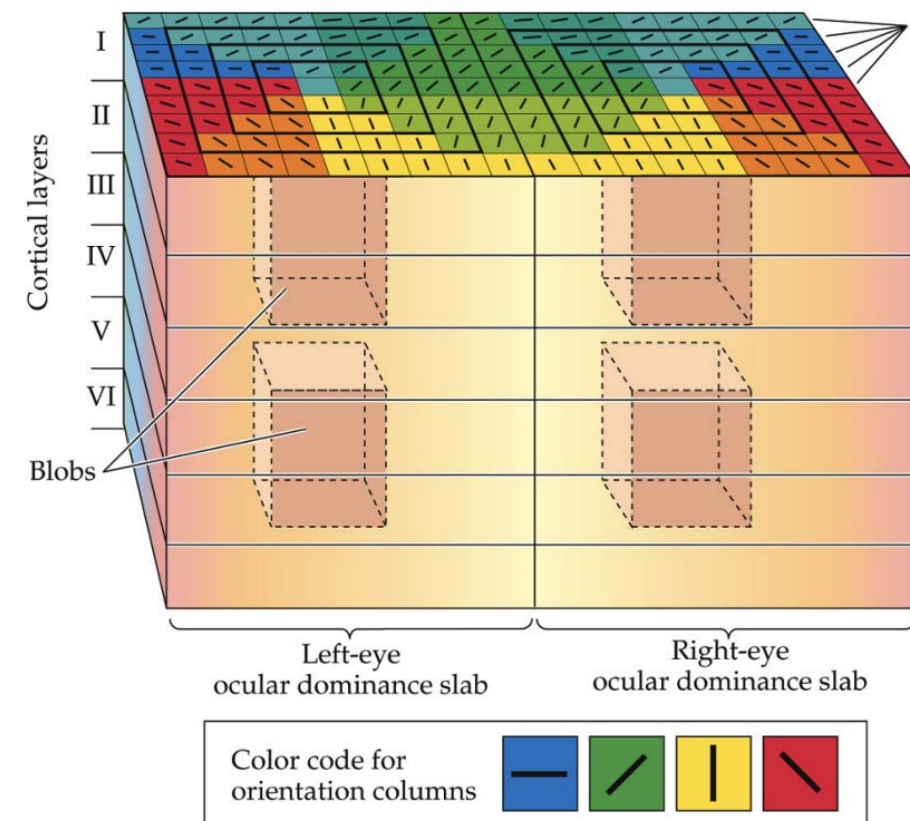
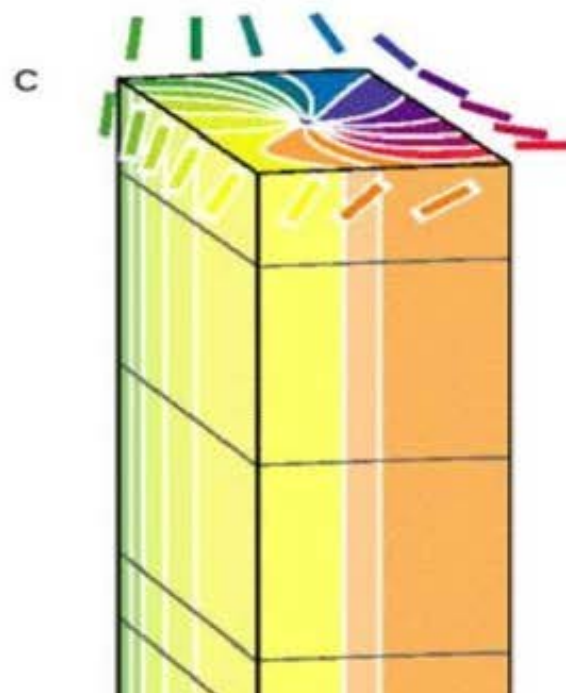
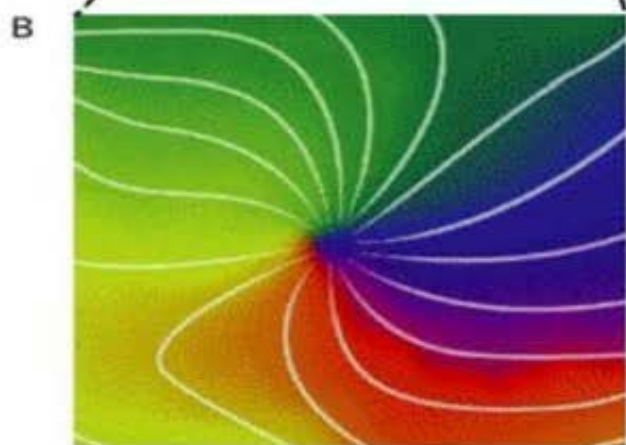
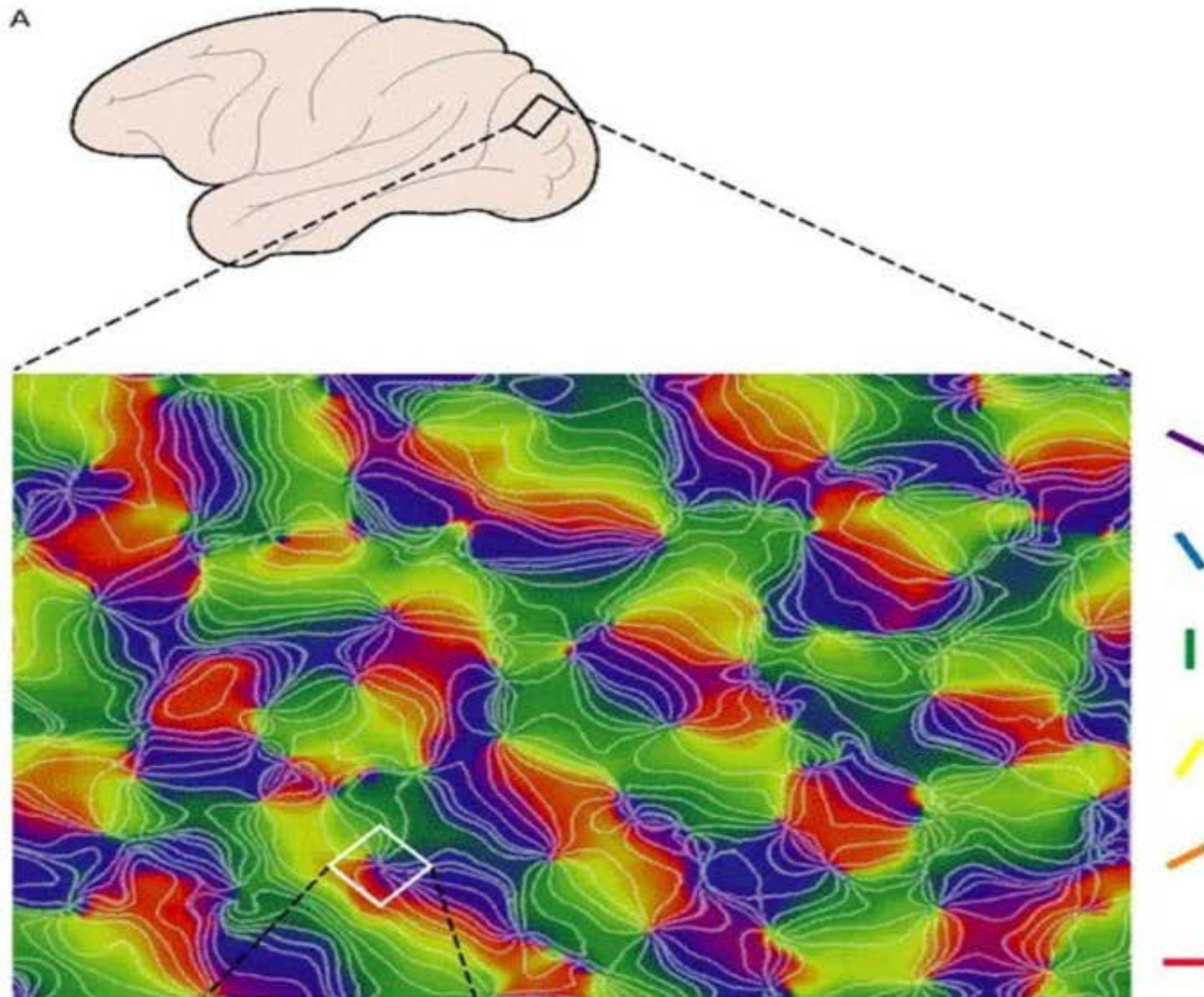


Fig. 9.3 The cells of the inner layer of the retina (whose fibres project to the brain), and the cells of the lateral geniculate nucleus, do not respond to light as such. Rather they respond to a difference in the intensity of light between one part of their receptive fields and another part. Thus, stimulating such cells with diffuse light (a) is ineffective in eliciting a response; flashing a light in the centre of the receptive fields yields an ON response (b); while in the surround a response is obtained only when the light is switched OFF (c). The cell is therefore said to have an antagonistic 'centre-surround', or a concentric, receptive field.

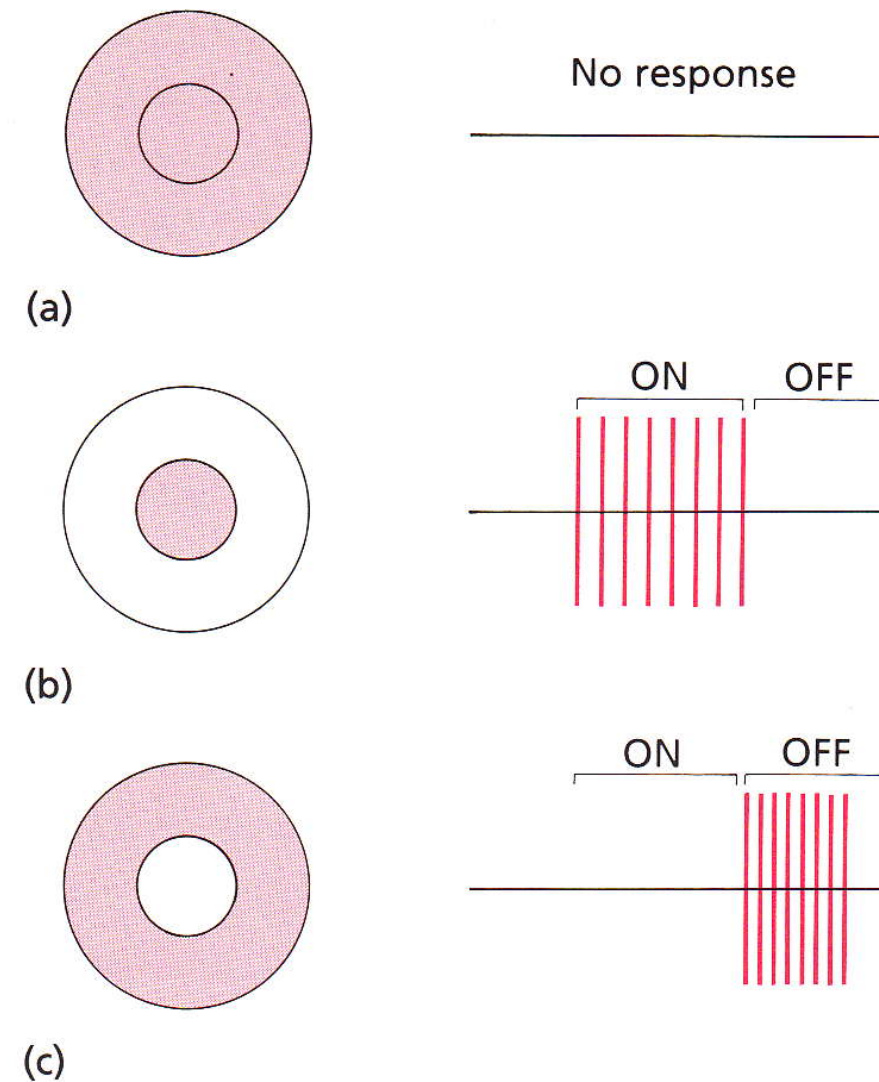
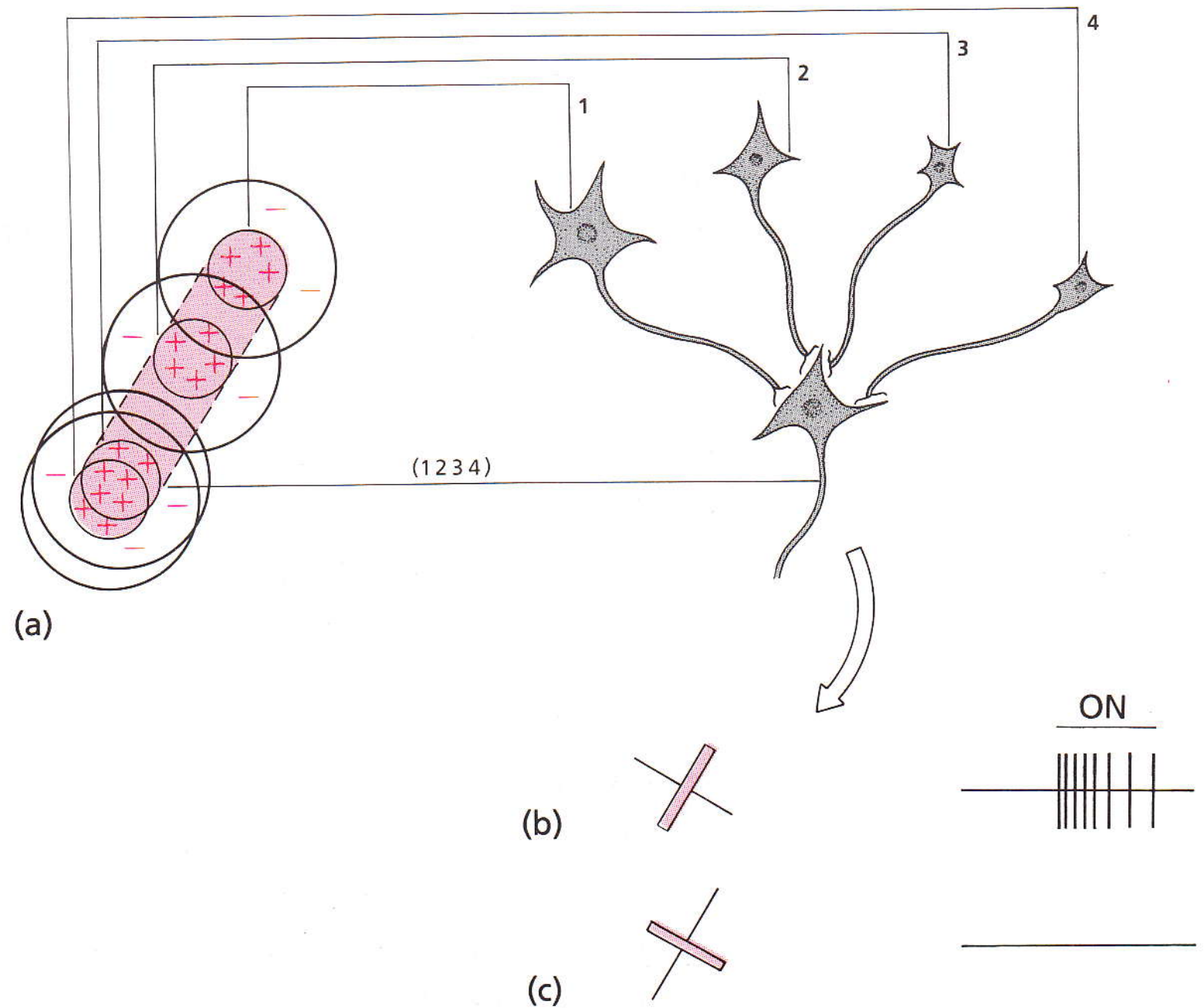
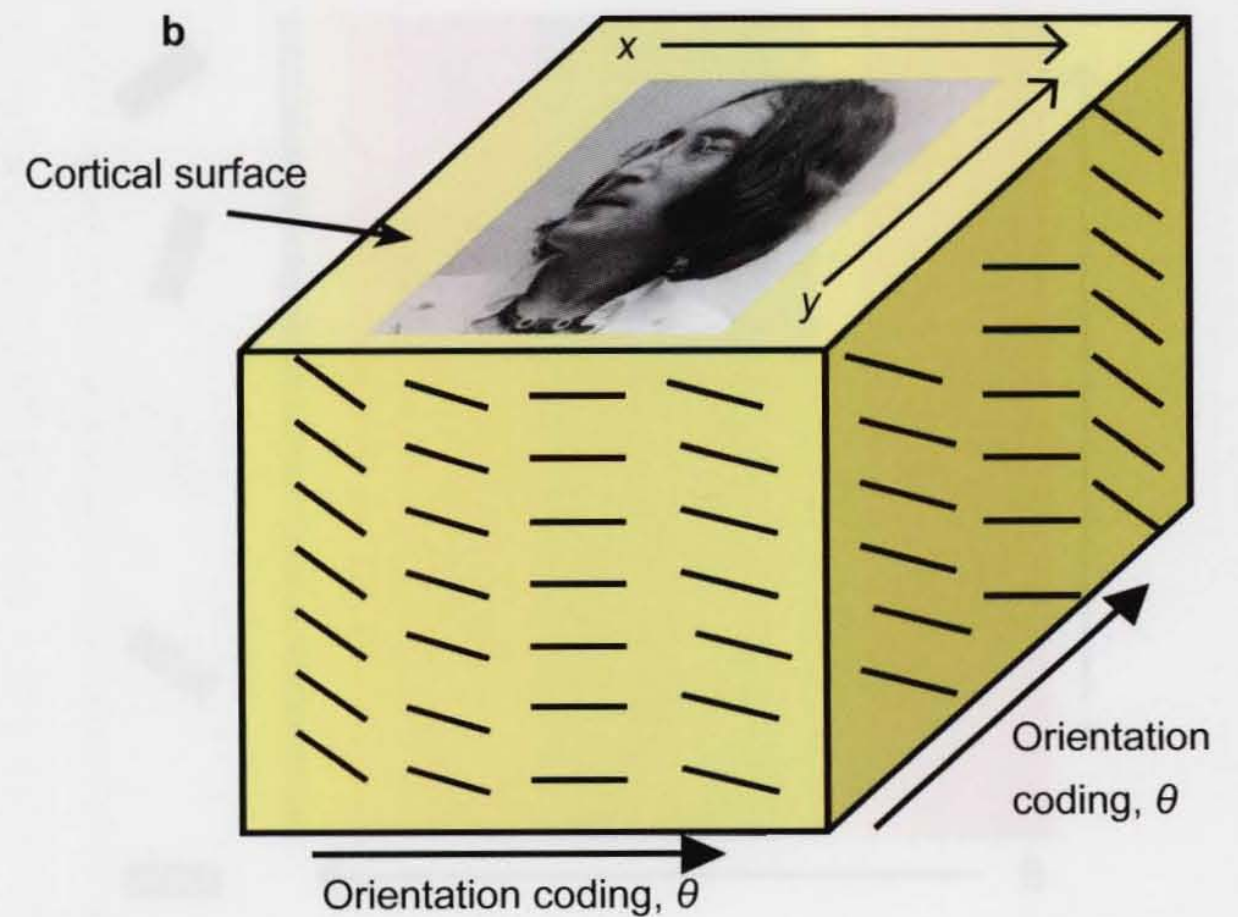
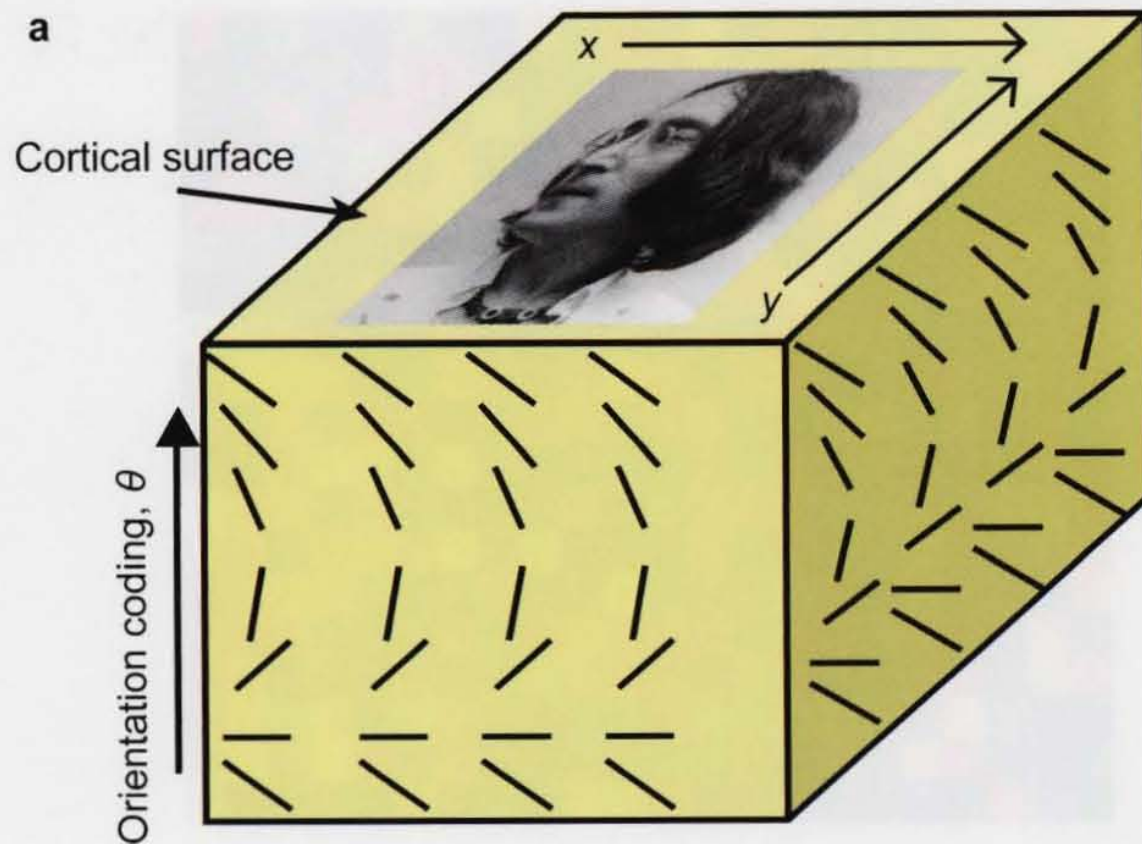


Fig. 9.2 A simple orientation selective cell behaves as if it receives input from several centre-surround antagonistic cells of the lateral geniculate nucleus (a). Flashing a line with an orientation that stimulates more of the excitatory centres (+) will stimulate the cell (b). Changing the orientation so that more of the inhibitory (−) surrounds are stimulated will diminish the cell's response. An orthogonal orientation to the one shown in (a) will yield no response from the cell (c), since it will invade both excitatory and inhibitory regions, which will therefore cancel out. (Redrawn from Hubel, D.H. & Wiesel, T.N. (1962). *J. Physiol. (Lond.)* **160**, 106–154).





10.13 Two possible ways of mapping x, y position in the retinal image along with orientation, θ

The scheme shown in **b** is the one found in the striate cortex.

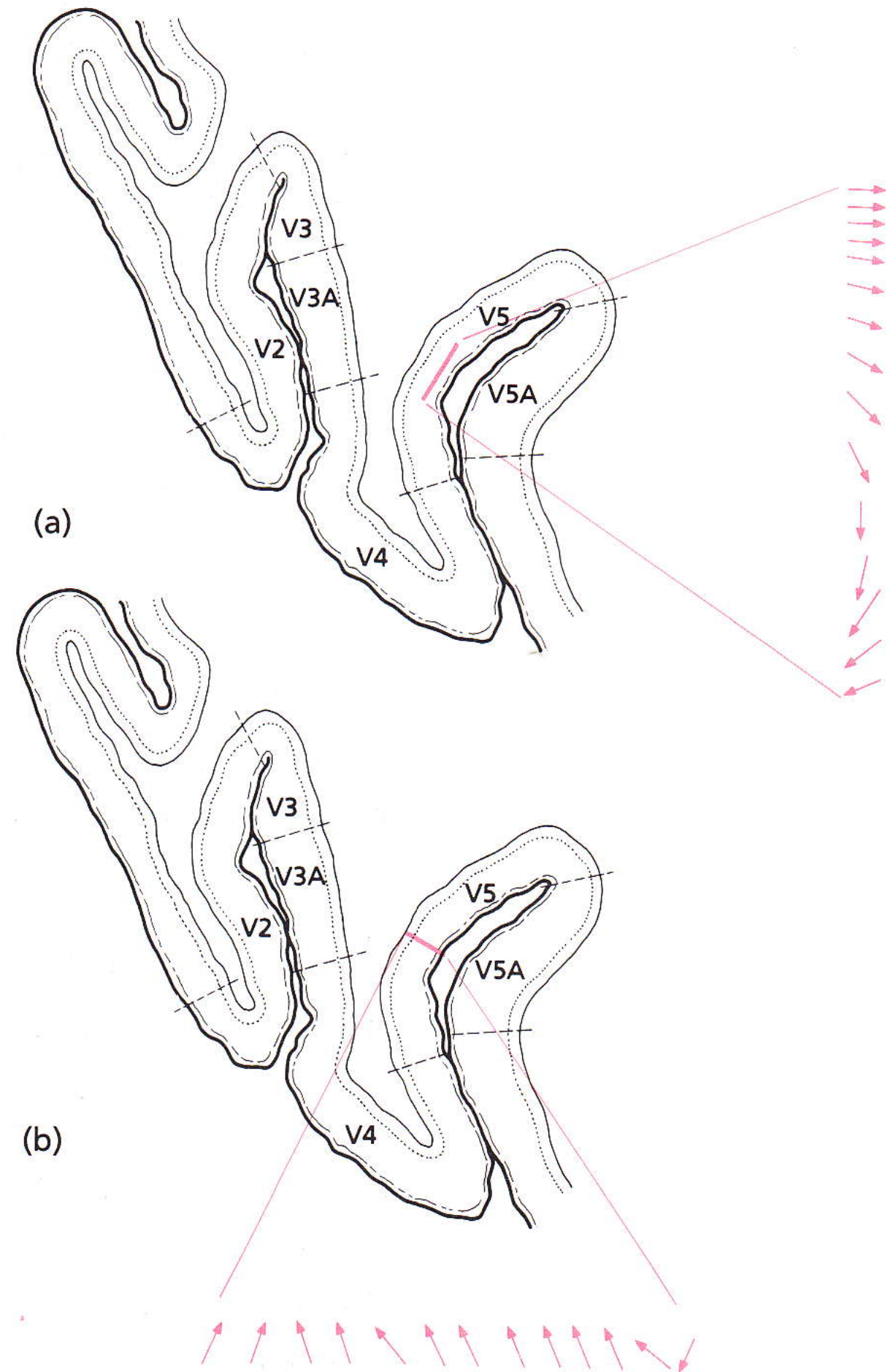
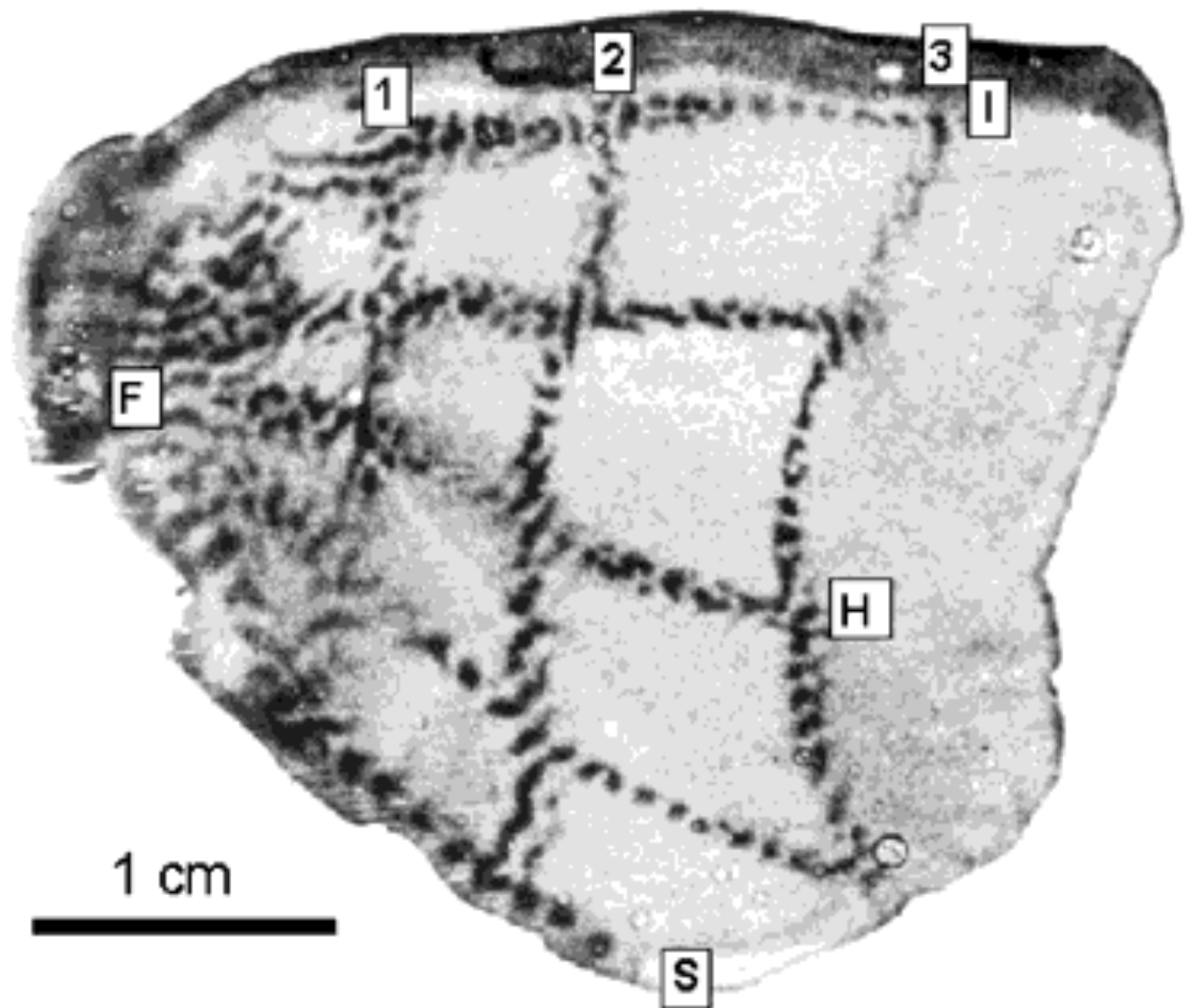
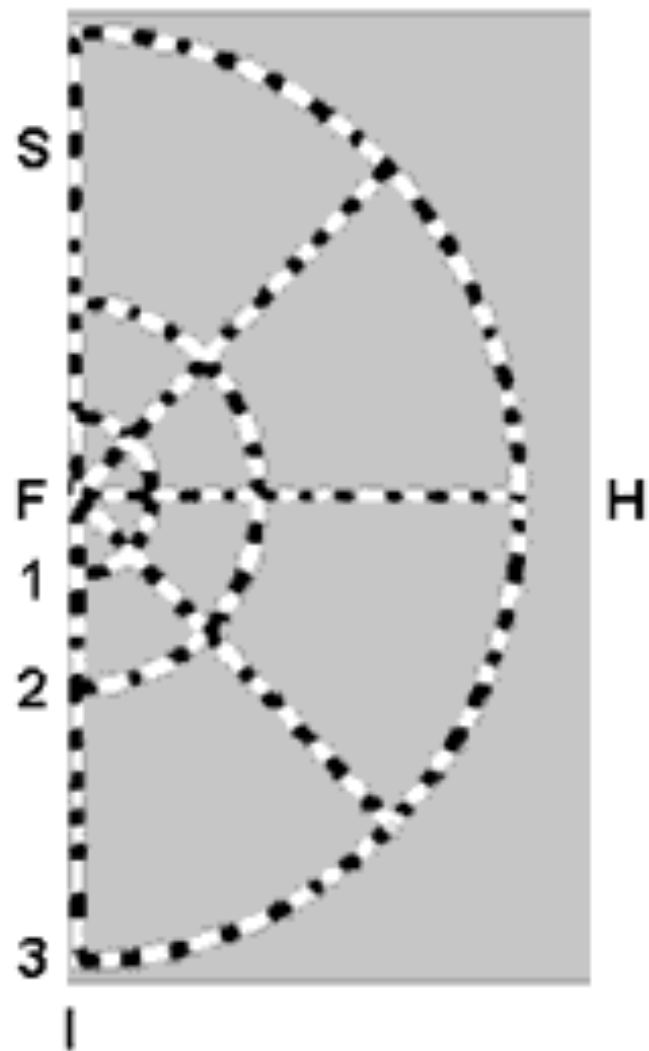
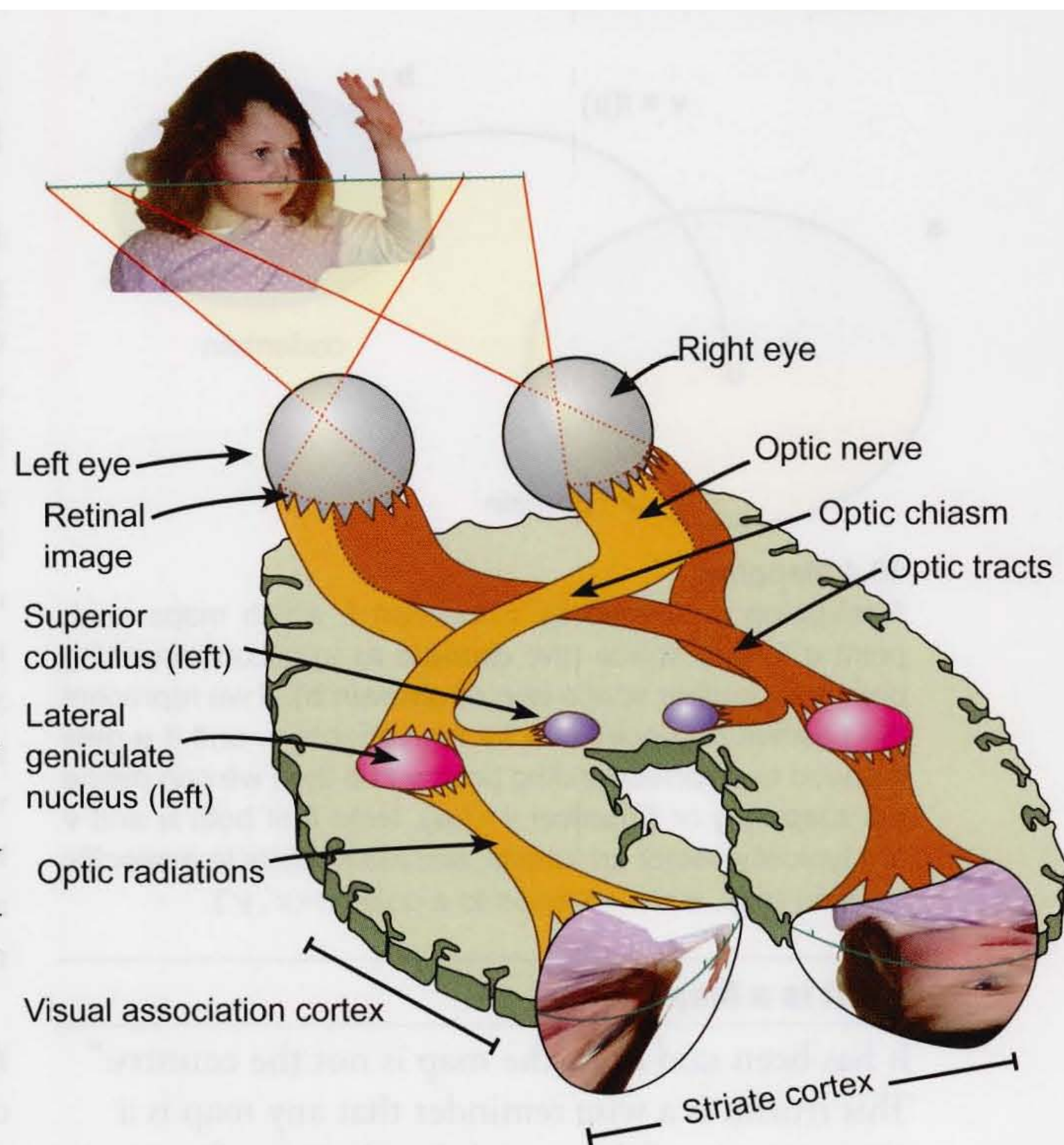


Fig. 14.3 (a) The directional preferences of successive cells, separated from each other by small distances, in area V5 encountered during a long electrode penetration made obliquely to the cortical surface of area V5. Note the orderly change in the successive directions of motion. (b) The directional preferences of successive cells in area V5, but this time encountered in a long penetration made at right angles to the cortical surface.

Retinotopy

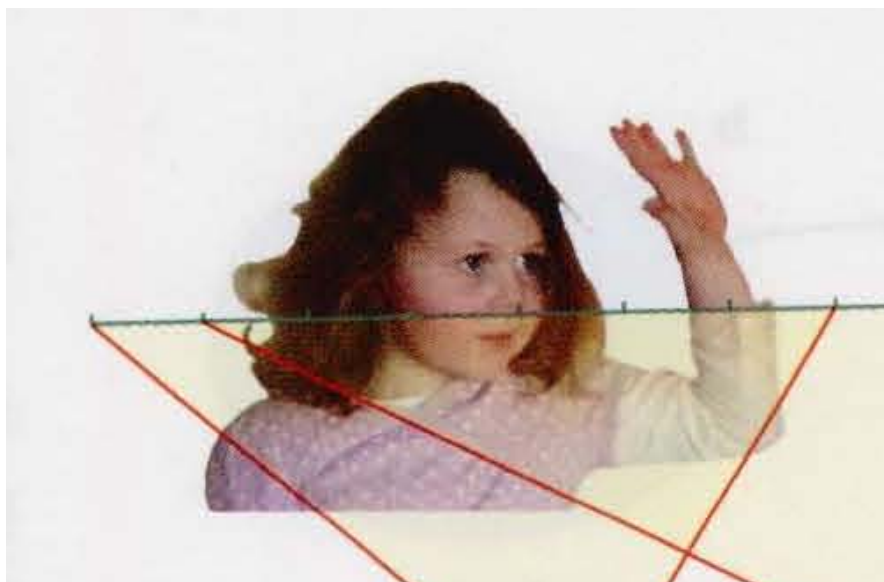
Imaging Retinotopy



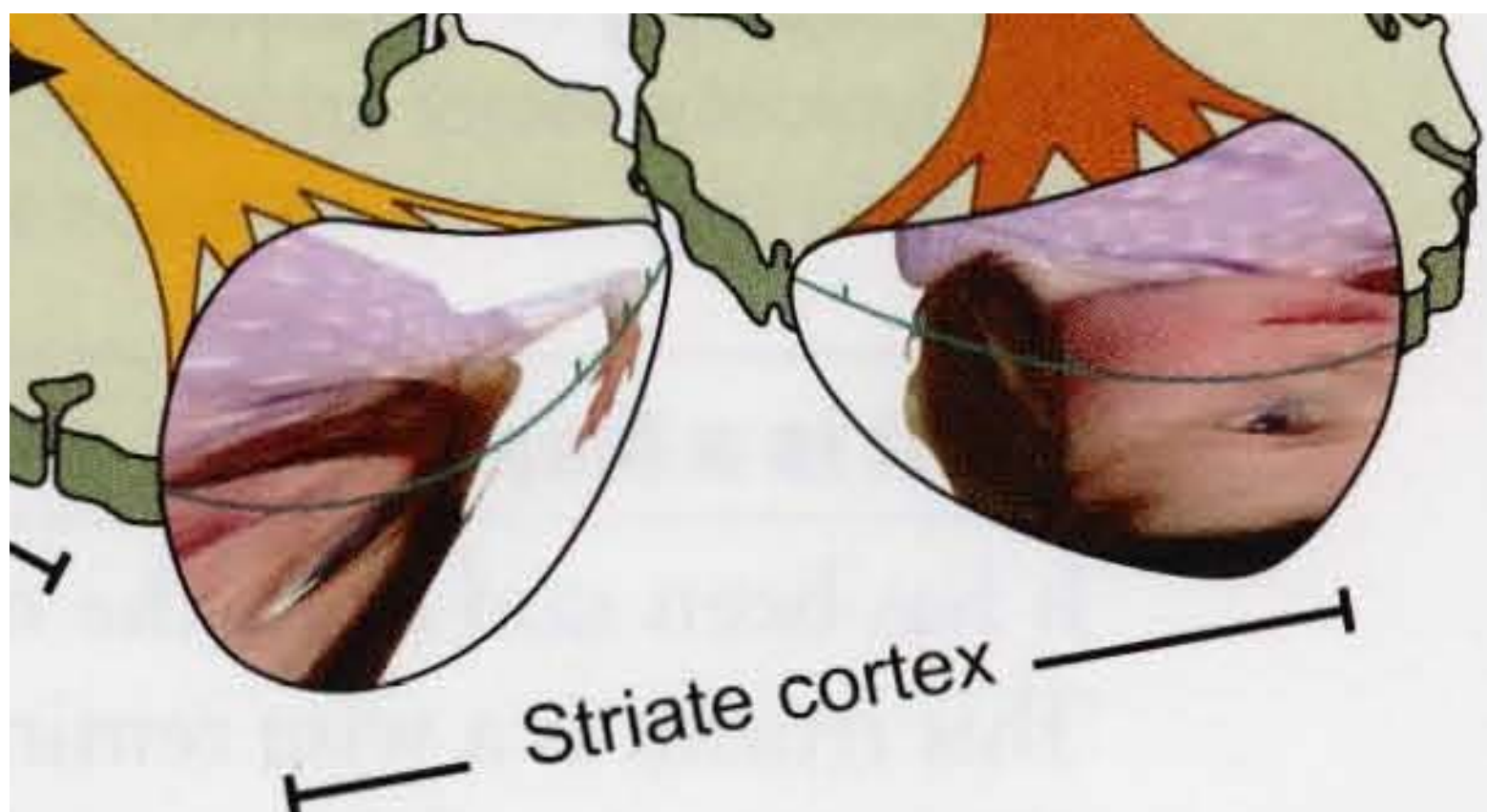


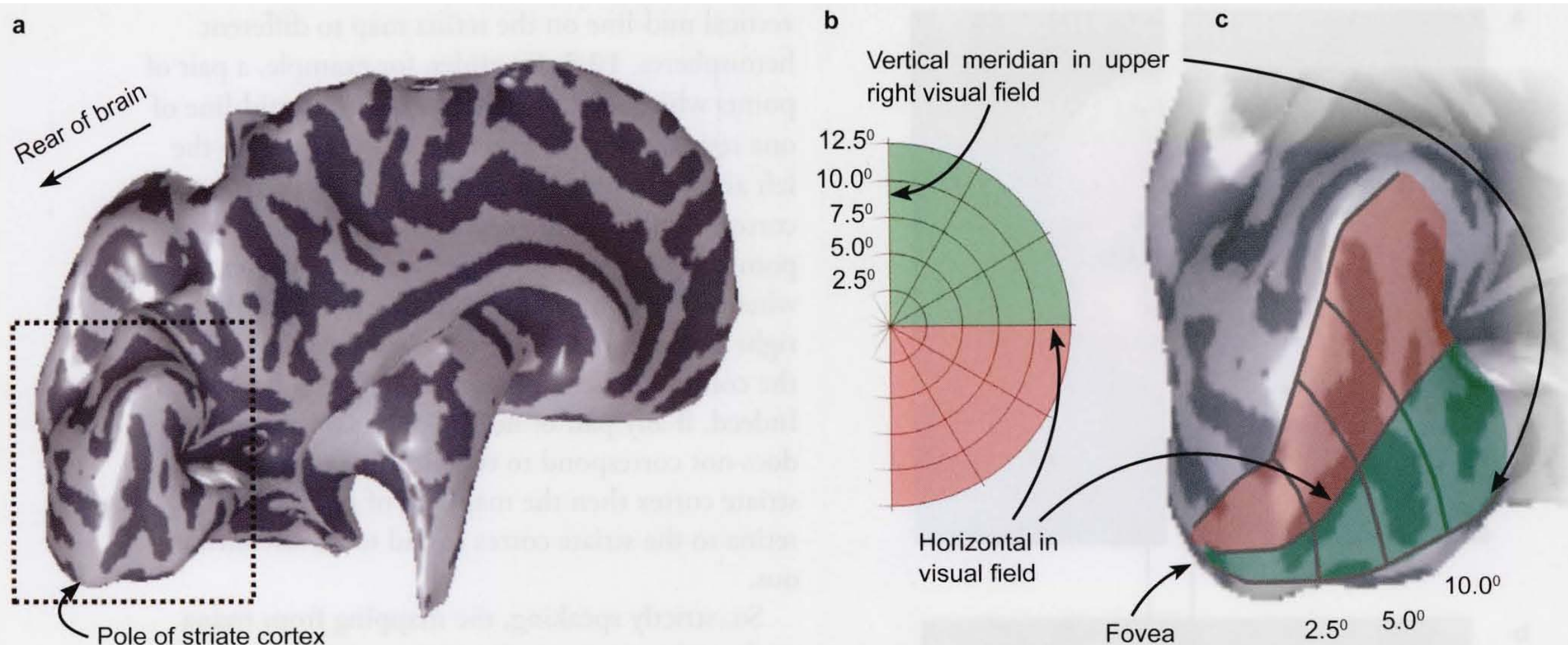
10.3 Schematic projection of a scene into the two retinas and from them into the brain

For more details see 1.6 and 1.7 (pp. 5–6).



1. **Division of visual hemifields**
2. **Up-down inversion**
3. **Complete and continuous**
4. **Cortical magnification**
5. **Radical discontinuity at the median**
 “the cut in the cortical representation places the regions of the scene on either side of the cut farthest apart in the brain!”



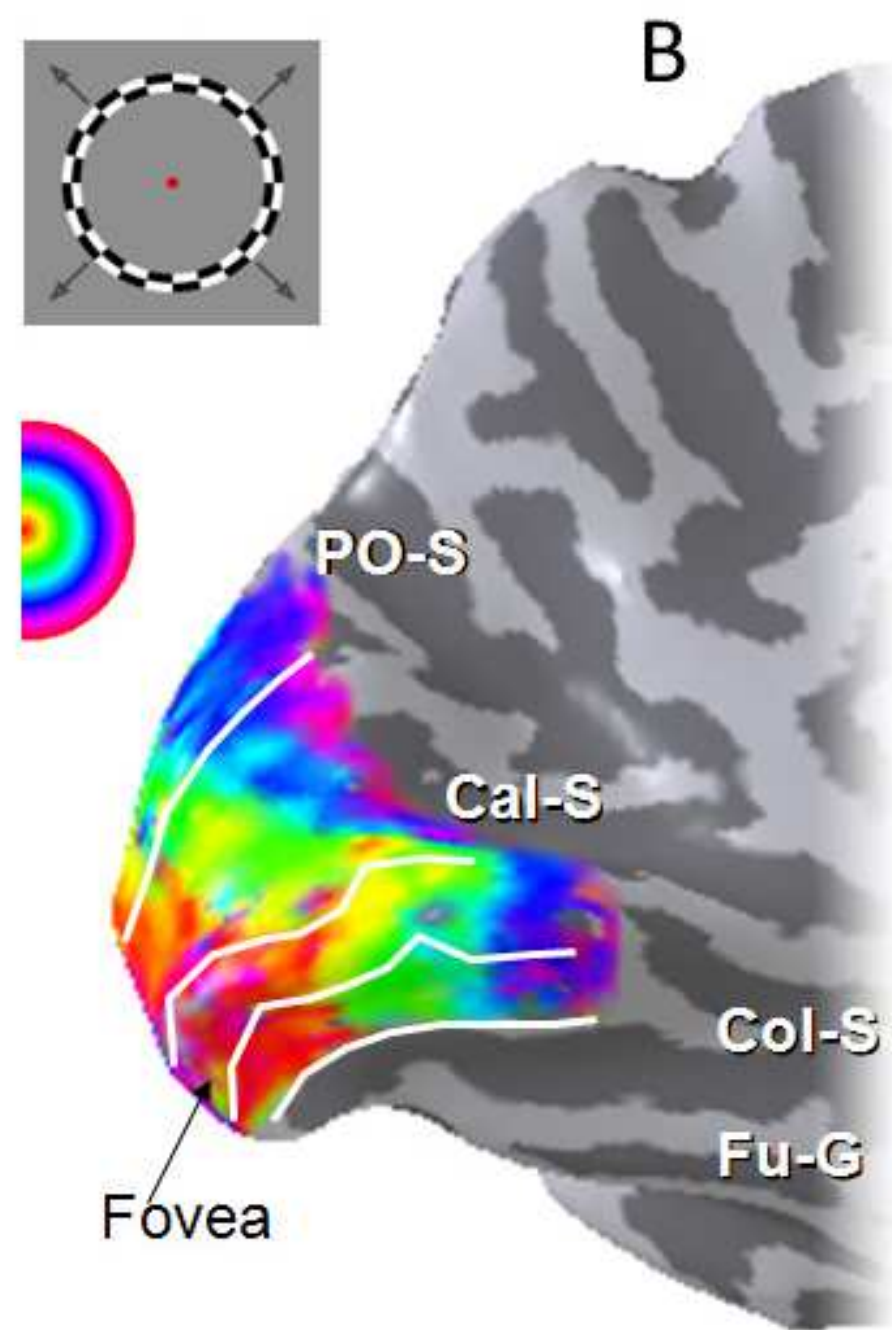
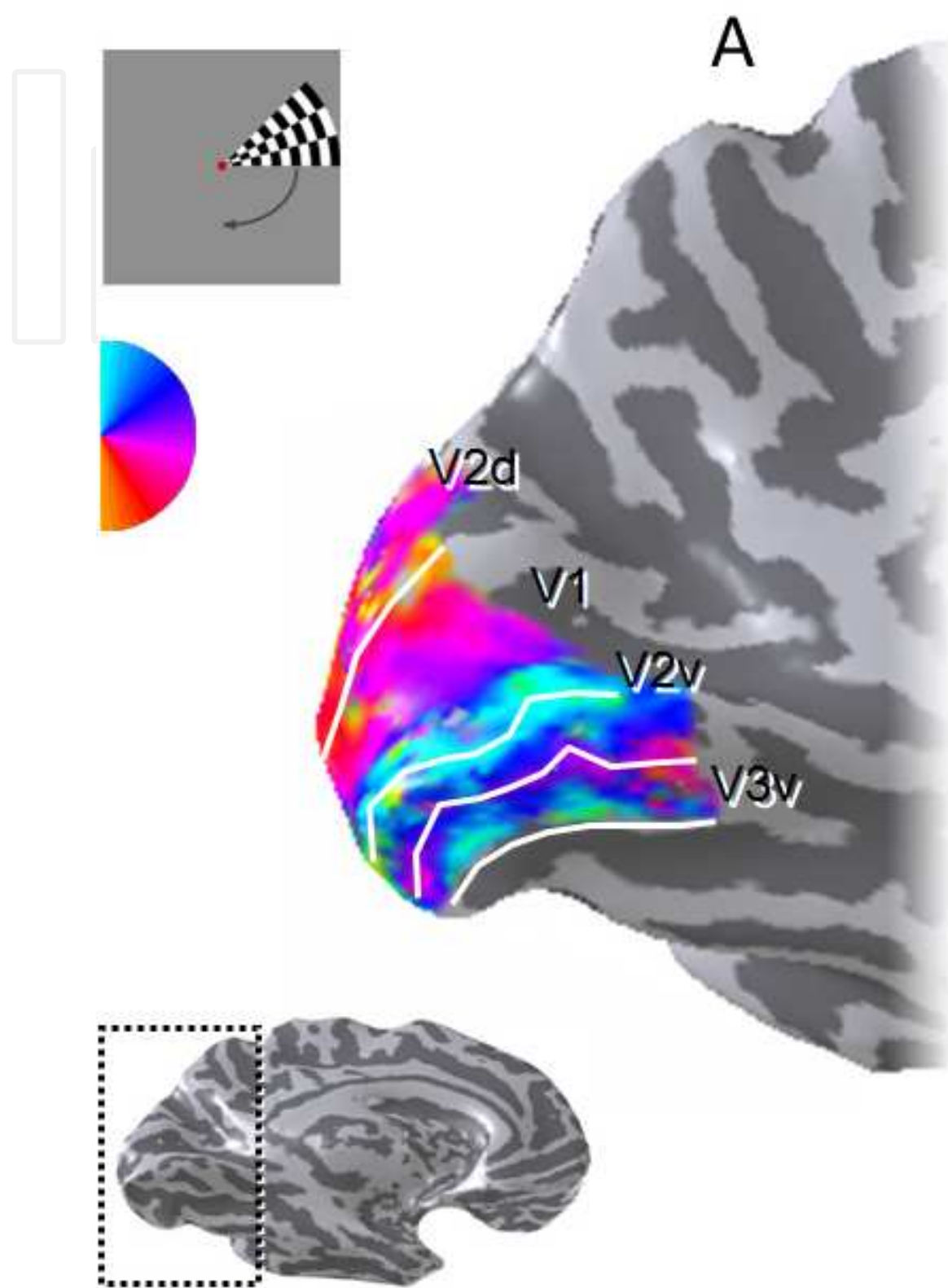


10.7 Mapping visual field to cortex

a View of inner (medial) surface of the left hemisphere, with the rectangle framing the visual areas at the back of the brain.

b Right visual hemi-field. The right half of the visual field (which projects to the left side of the retinas of both eyes) is mapped to the striate cortex, **c**, of the left hemisphere. The fovea of both eyes corresponds to the center of the visual field, where the radial lines converge to a point.

c Magnified version of the rectangle in **a**. The lower (pink) half of the visual hemi-field corresponds to the upper part of the calcarine sulcus, and the upper (green) half of the visual hemi-field corresponds to the lower part of calcarine sulcus. The visual field corresponding to the fovea projects to the pole of the striate cortex. The center of the visual field in **b** gets mapped to a disproportionately large area in the striate cortex. This mapping effectively magnifies the region of the visual field which projects to the fovea, and "shrinks" regions which project to periphery of the retina. It is helpful to the understanding of this figure to compare it to the schematic projection in **10.3**. Courtesy Tony Morland.



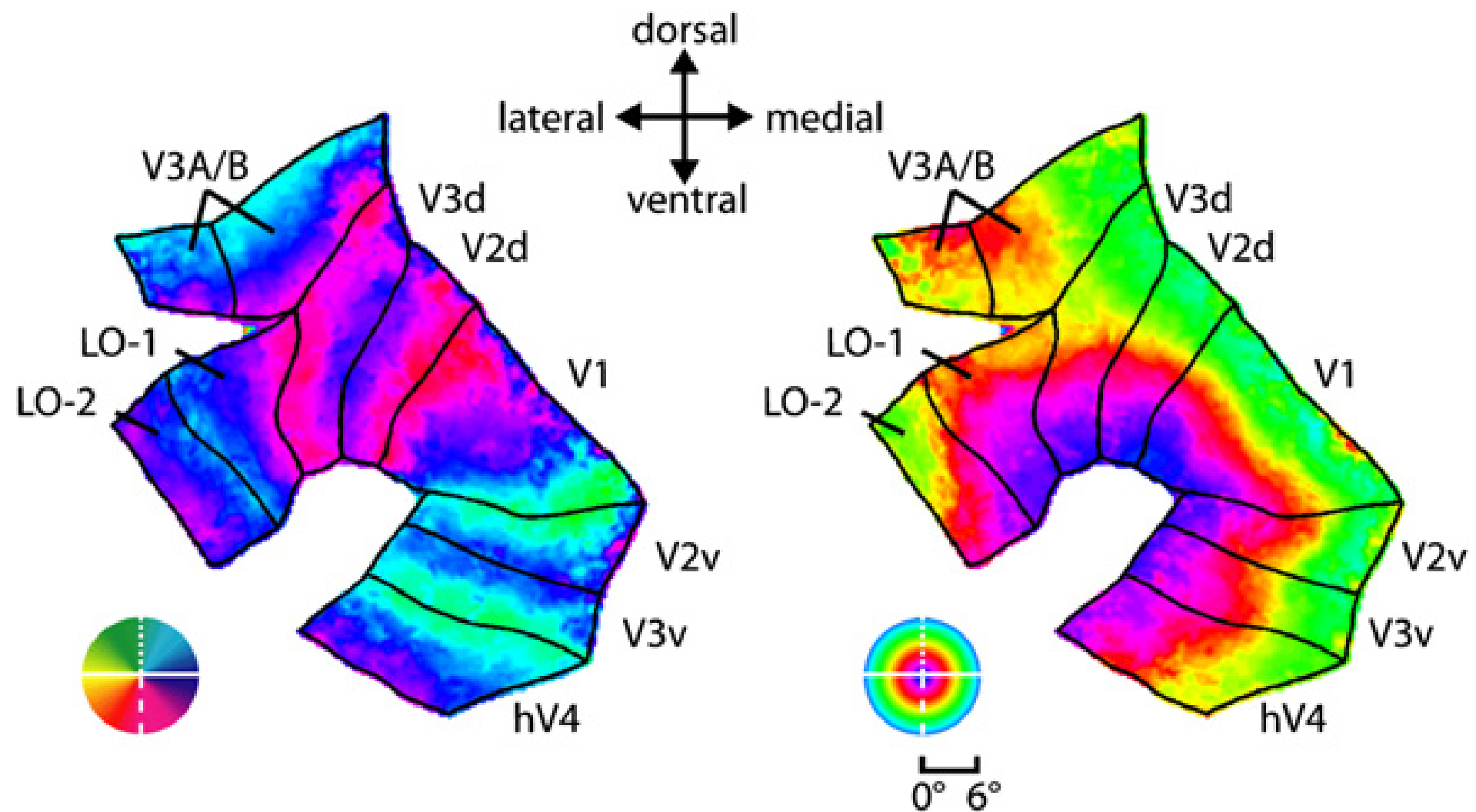
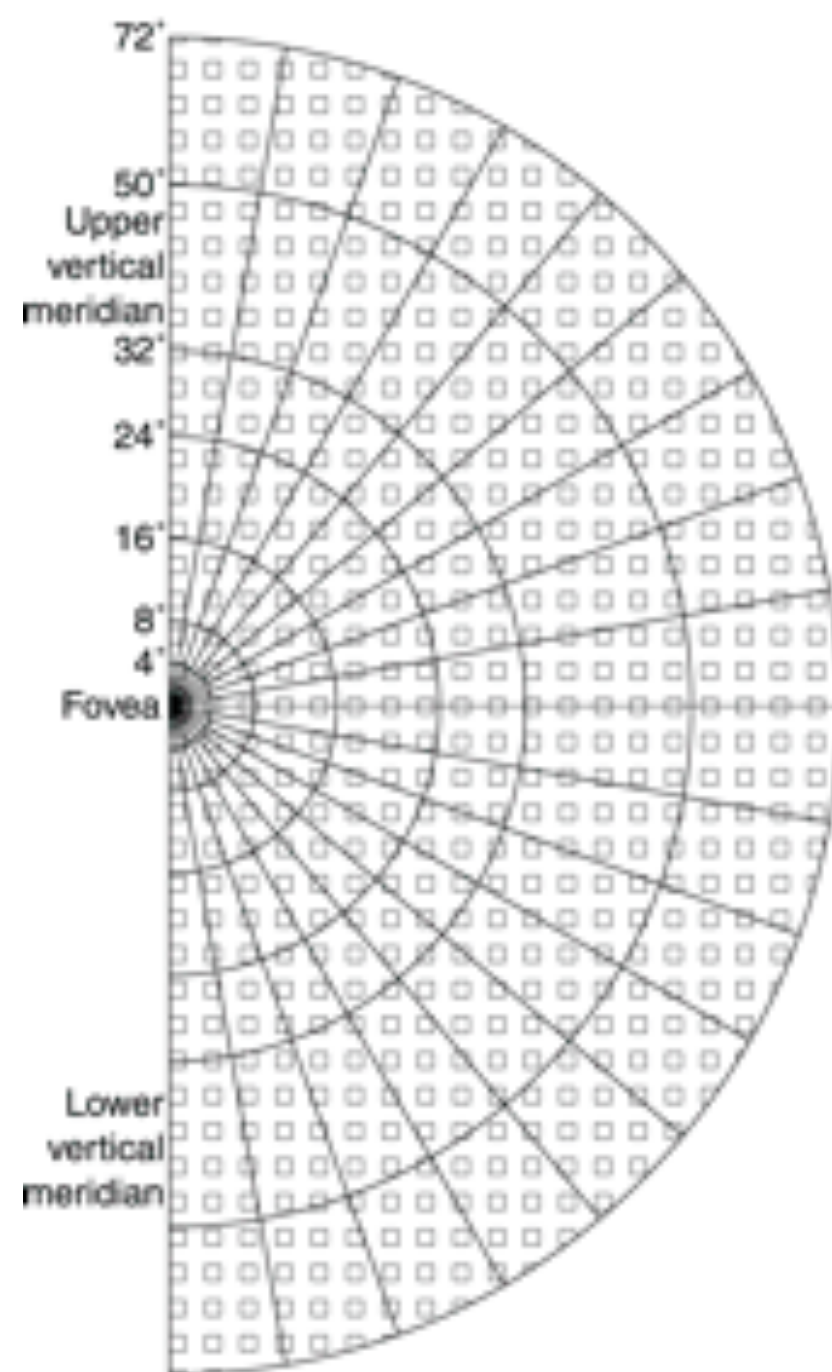


Figure 6. Visual Field Maps Illustrated on a Computationally Flattened Cortical Representation

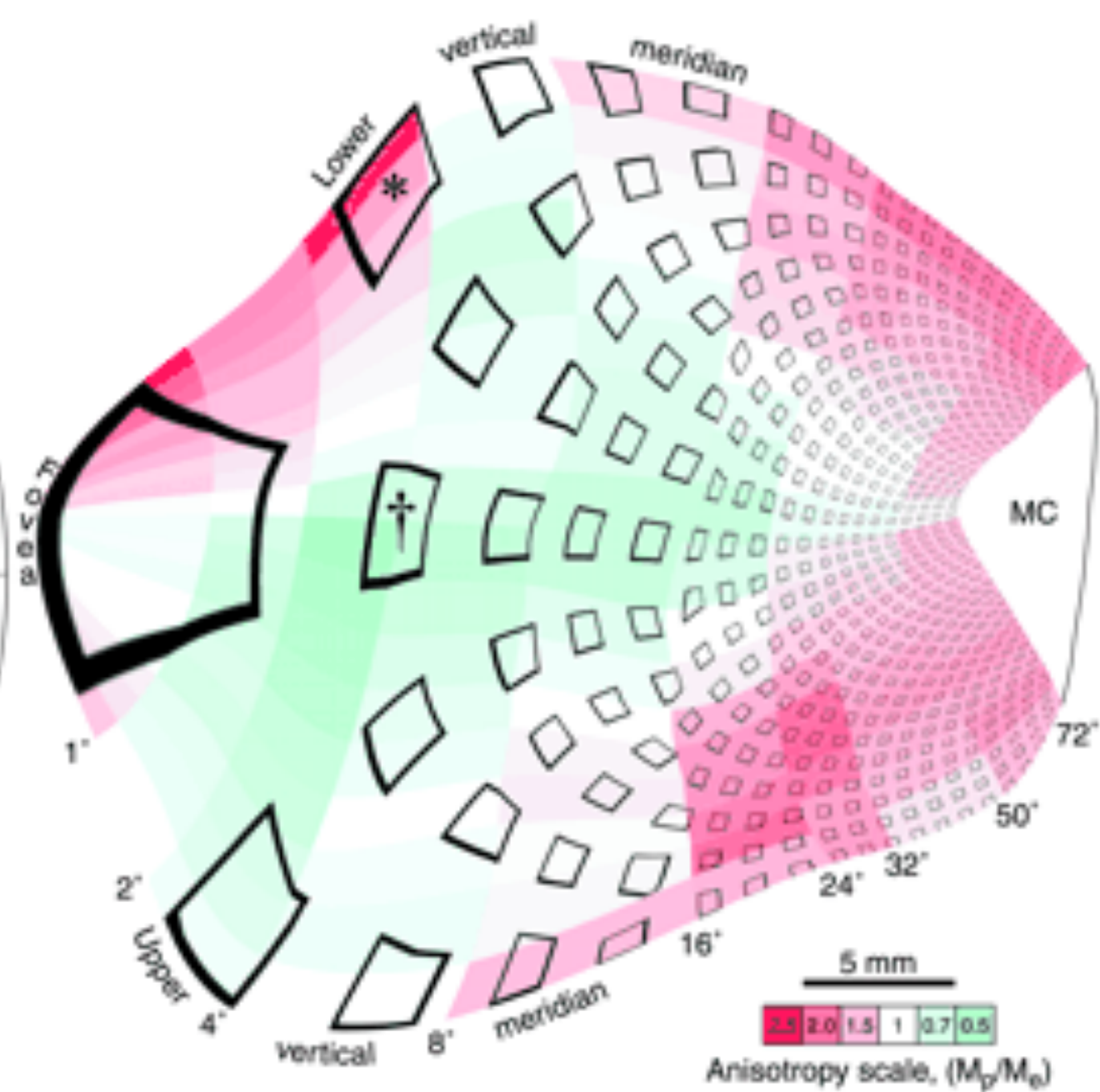
Adapted from Figure 1 in [Larsson and Heeger \(2006\)](#). A flattened representation of cortex illustrates the spatial relationship between maps near the occipital pole in the left hemisphere. The maps show the angular (left) and eccentricity (right) maps averaged across 15 hemispheres. In the left column, color indicates polar angle (inset legend). In the right column, color indicates eccentricity between 0° and 6° (inset legend).

Cortical Magnification

A) Right visual hemifield



B) Left visual cortex



Many Retinotopies

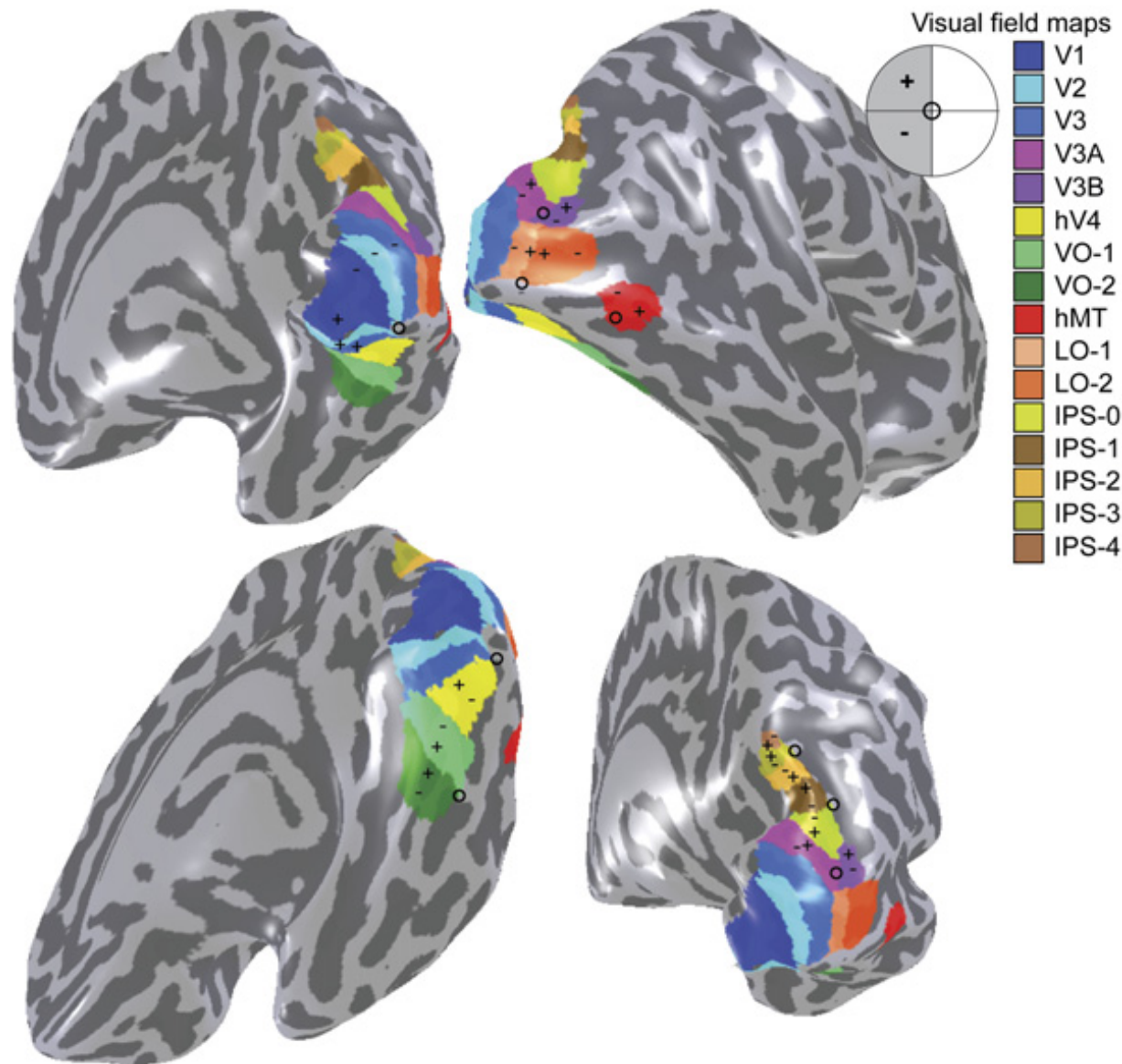


Figure 2. Visual Field Maps in Human Visual Cortex

The positions of sixteen maps are shown on an inflated rendering of the cortical surface of a right hemisphere. Although this organization is generally accepted, certain aspects are still debated. Most of the visual field maps are based on measurements of one subject (V1/2/3, hV4, VO-1/2, LO-1/2, IPS-0); others are added based on descriptions in the literature (IPS-1/2/3/4, hMT). Fovea and upper/lower visual fields are indicated by the “o”, “+”, and “–” symbols, respectively. The posterior visual maps in and around calcarine are labeled V for visual and a number, e.g., V1, V2, V3, V3A, following the naming of homologs in macaque monkey. To be conservative about potential homology between these maps and maps in nonhuman primates, we use a conservative labeling scheme. Maps in lateral occipital are numbered as LO-x, maps in ventral occipital are numbered as VO-x, and maps in the intraparietal sulcus are numbered IPS-x.

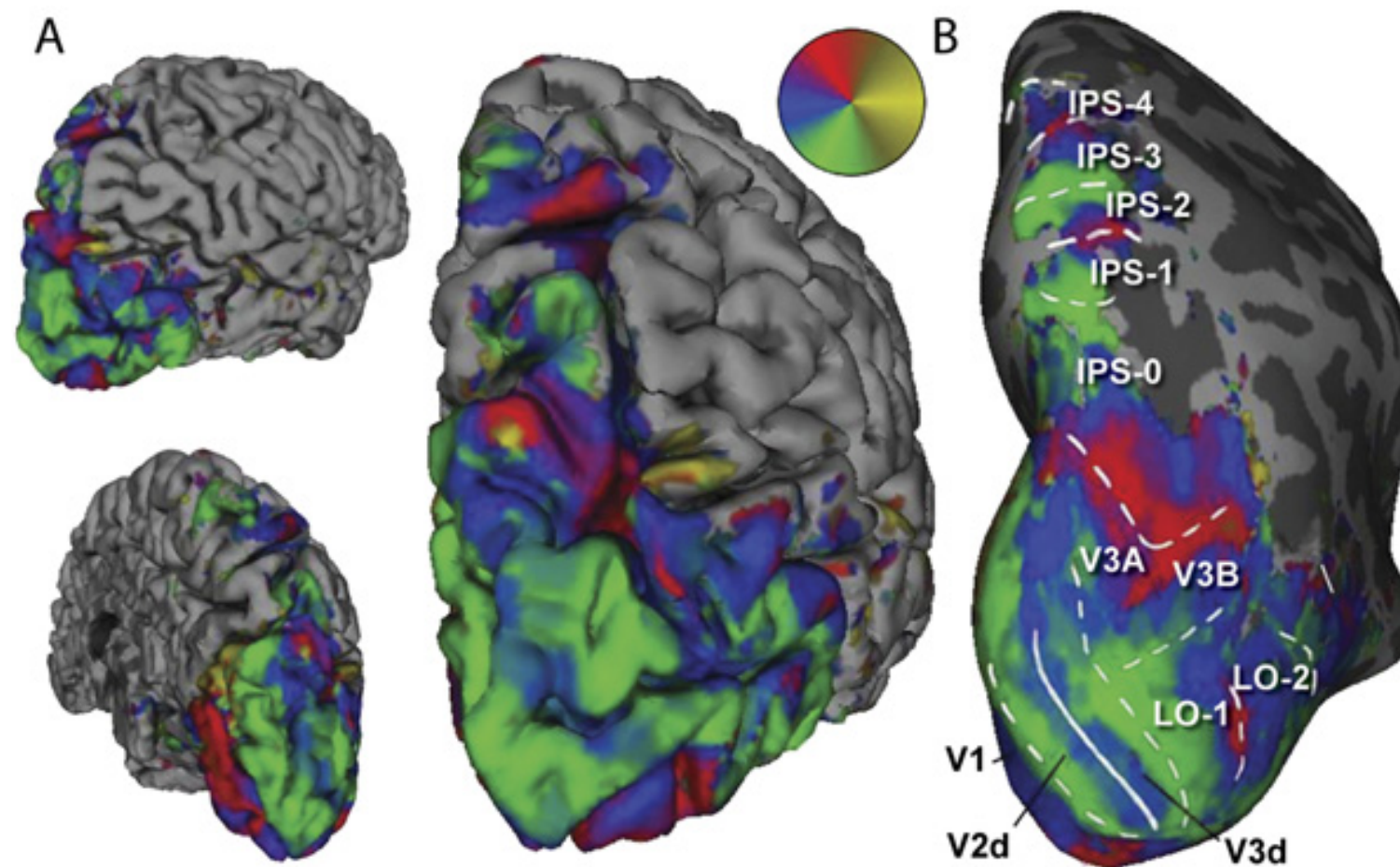


Figure 5. Visual Field Maps on the Dorsal and Lateral Surface of the Human Brain

Adapted from Figure 1 in [Swisher et al. \(2007\)](#) Angular mapping with a rotating wedge stimulus produces modulation of the BOLD signal in a substantial portion of posterior cerebral cortex. The images show the right hemisphere of a single subject. (A) The reconstructed pial surface is shown from posterior lateral (top left), posterior medial (bottom left), and posterior dorsal (right) views. In these views, the cortex is folded as in the normal anatomical state. (B) The value of inflation for visualization is illustrated; notice that the data within the sulci that are occluded in the previous images become visible, and it is much easier to appreciate the reversals in the angular representation that are an important indicator of the boundary between visual field maps (solid and dashed lines). The stimuli covered the central 12 degrees radius.

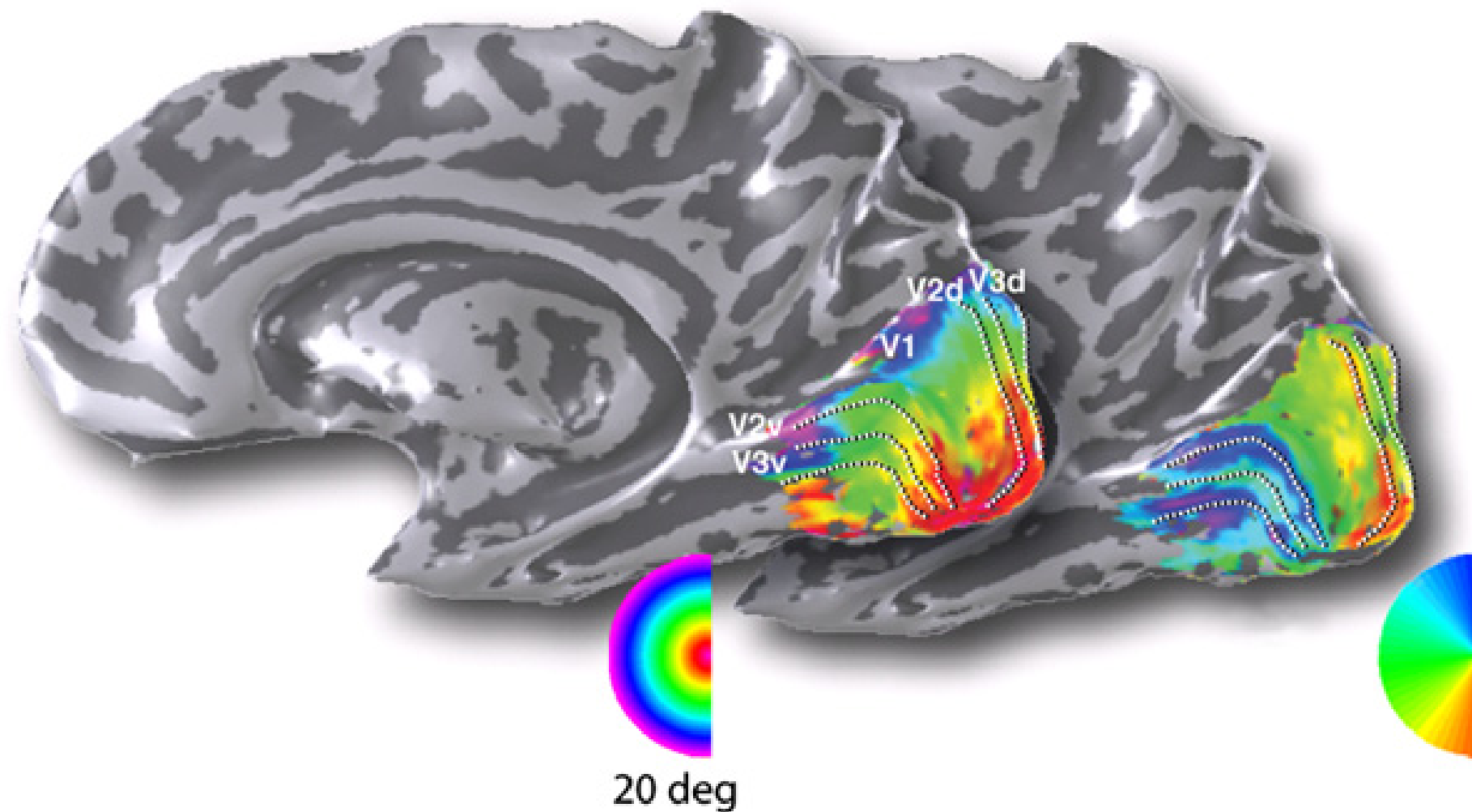
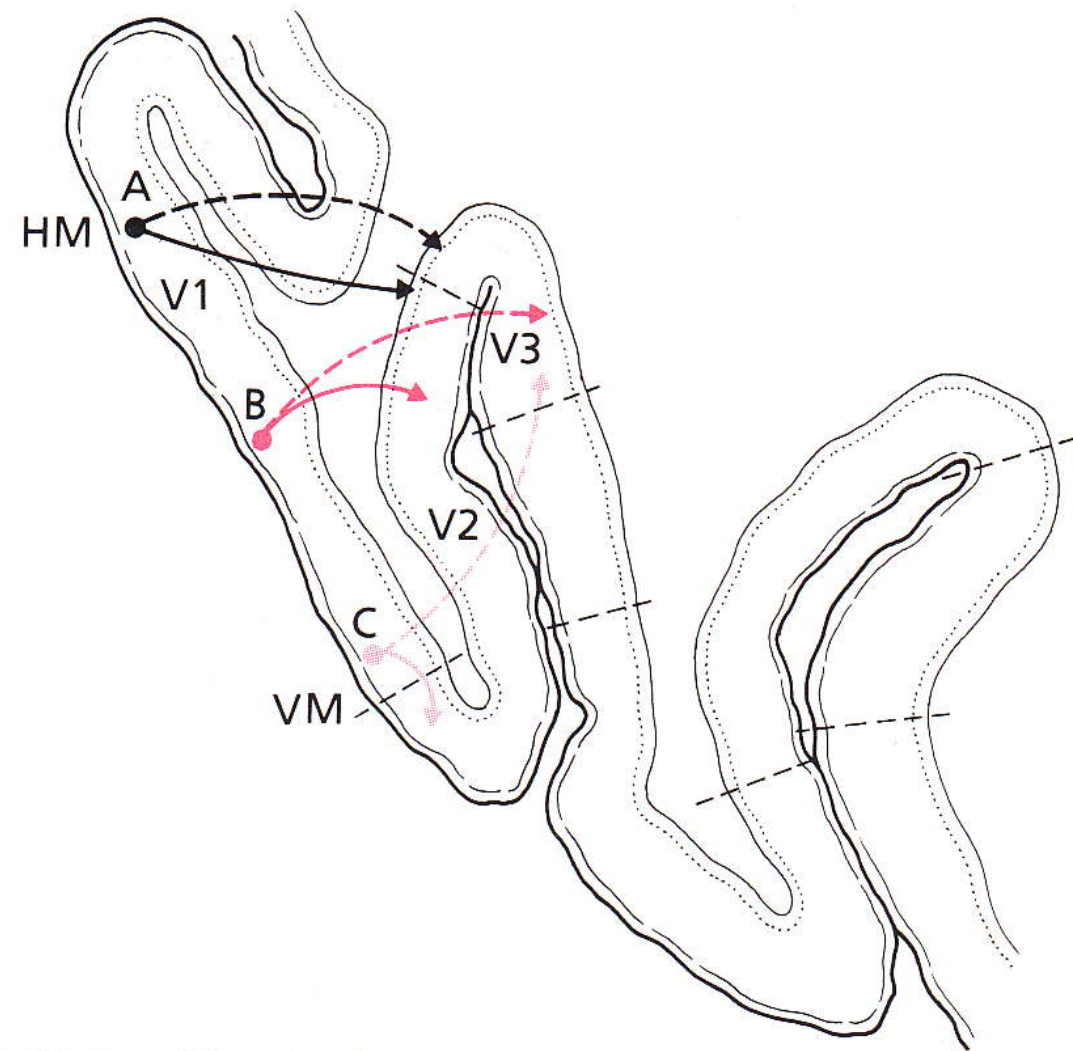


Figure 4. V1, V2, and V3 Visual Field Maps

Visual field maps are measured in the right hemisphere of a single subject using expanding ring and rotating wedge stimuli. The color overlay indicates the eccentricity (left) or angle (right) that produces the most powerful response at each cortical location. The stimuli covered the central 20 degrees radius. For clarity, only responses near the medial occipital cortex are shown. The stimulus-driven responses shown in this paper are substantially above statistical threshold ($p < 0.001$, uncorrected). Other details as in [Figure 3](#).



Left visual hemisphere

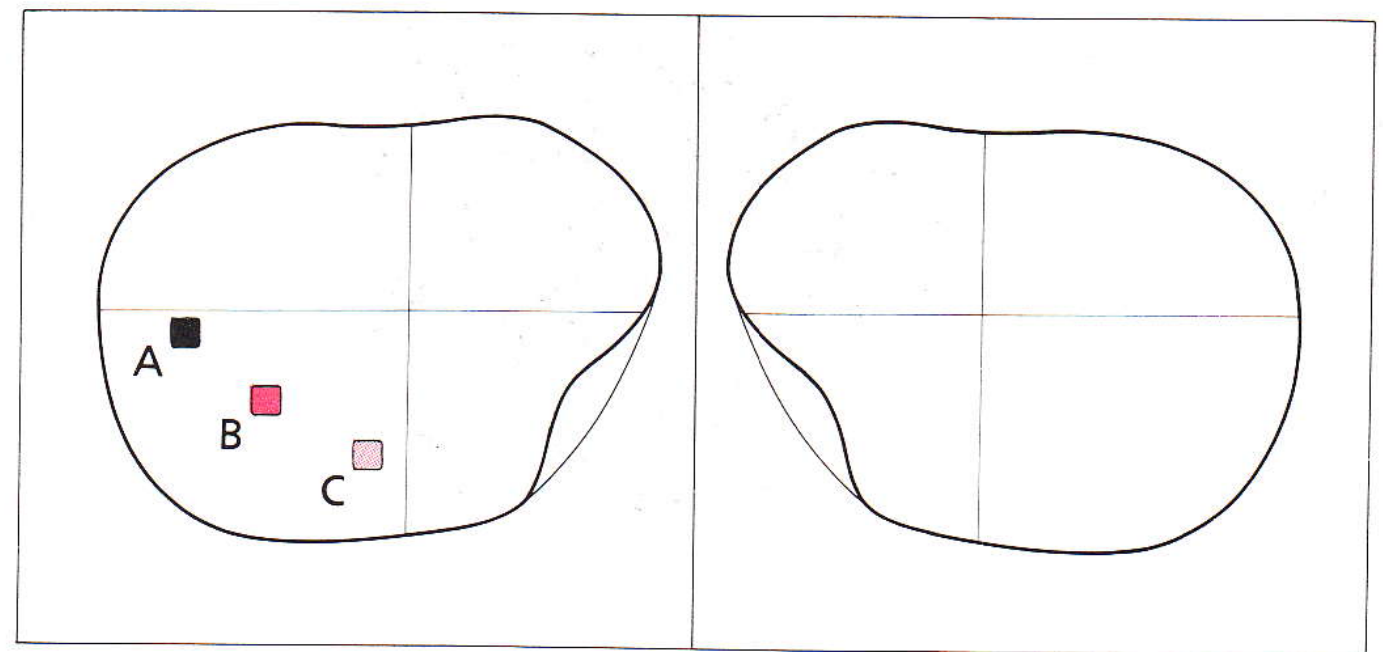


Fig. 12.5 The systematic connections between area V1 and areas V2 and V3, shown schematically. The retina is topographically represented in area V1, with the horizontal (HM) and vertical (VM) meridian representations occupying distinct zones. The systematic, point-to-point, connections between area V1 and areas V2 and V3 means that the retina (and hence the visual field, below) is also topographically represented in the latter areas.

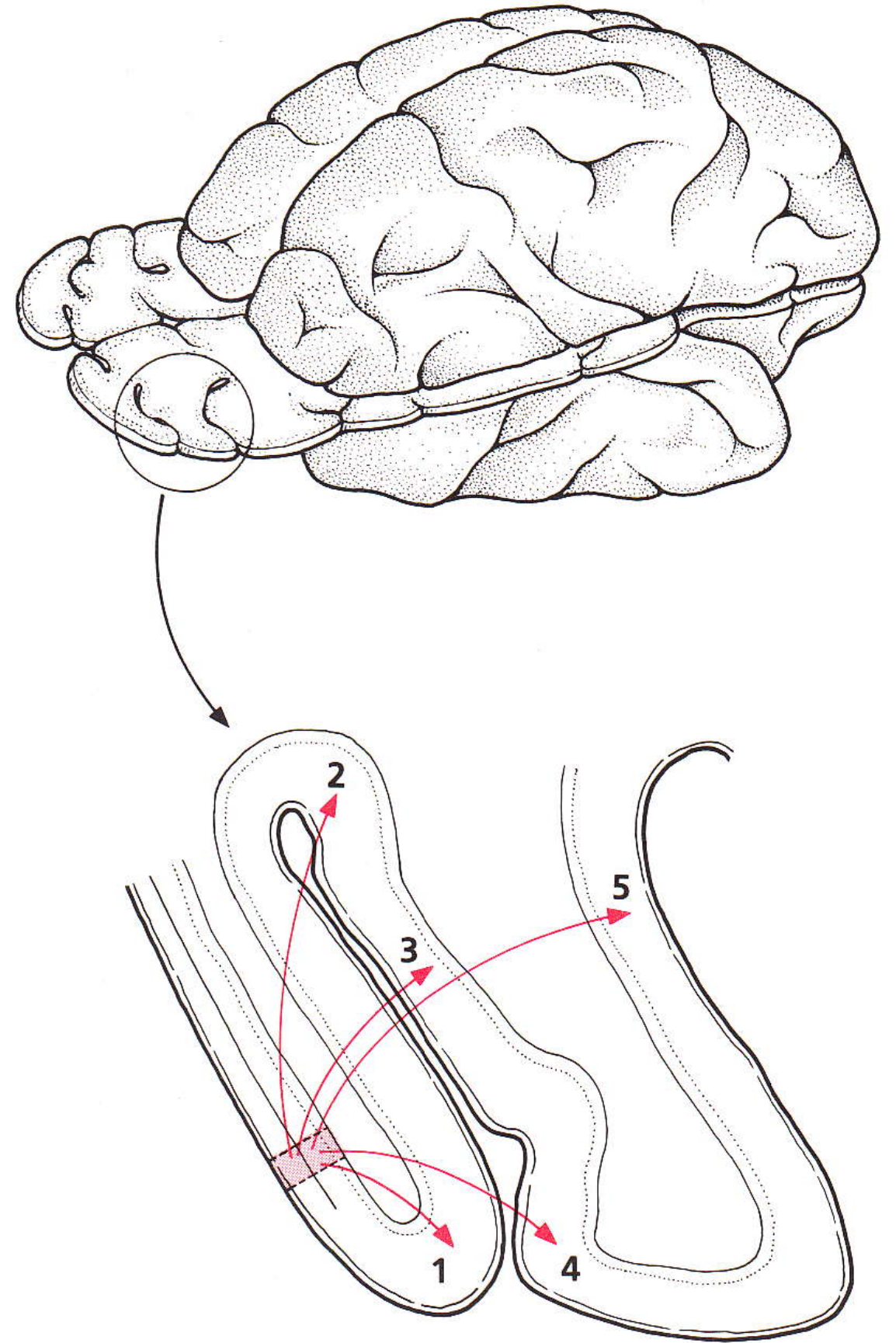
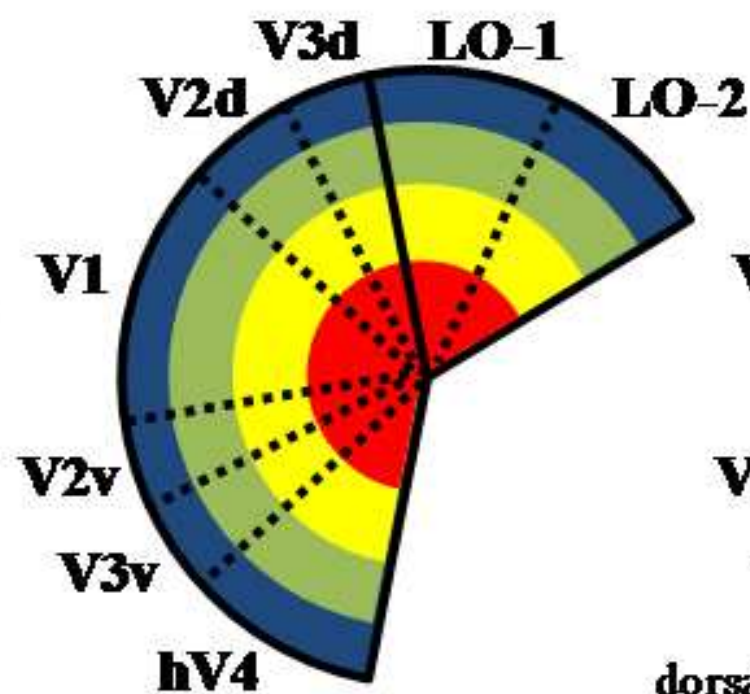
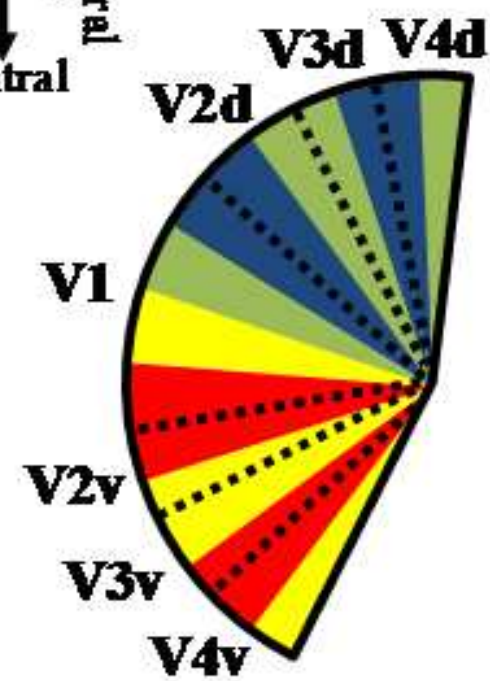
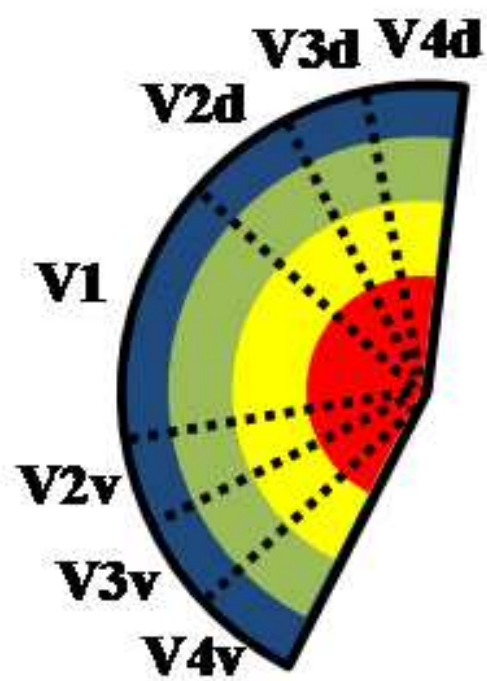
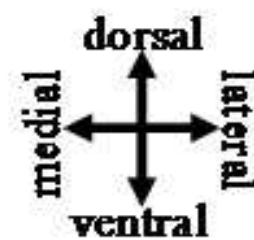
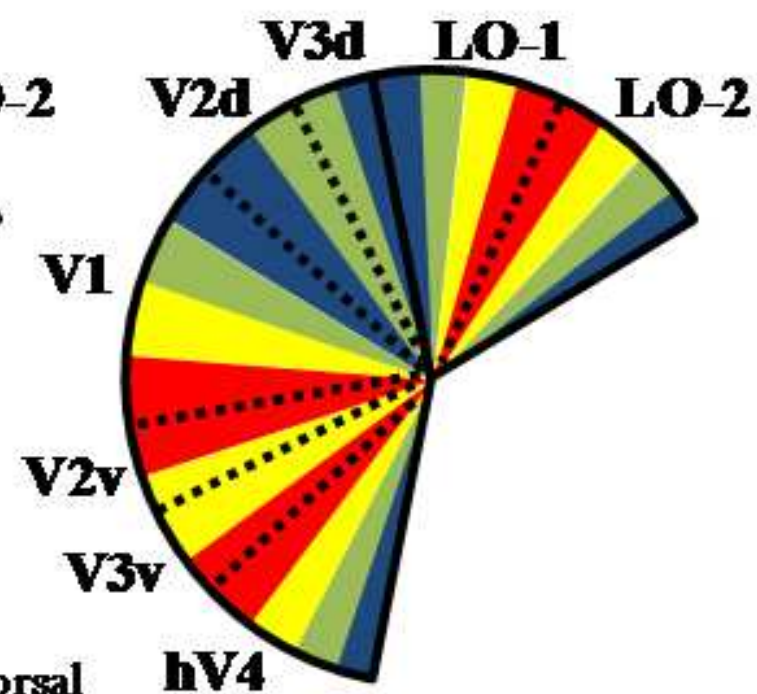


Fig. 13.1 The parallel anatomical outputs from a given small region of the primary visual cortex (area V1), which receives an input from a corresponding part of the retina and thus has all the visual information registered by that part of the retina represented in it. (Redrawn from Zeki, S. (1975). *Cold Spring Harb. Symp. Quant. Biol.* **40**, 591–600.)

A**B****C**

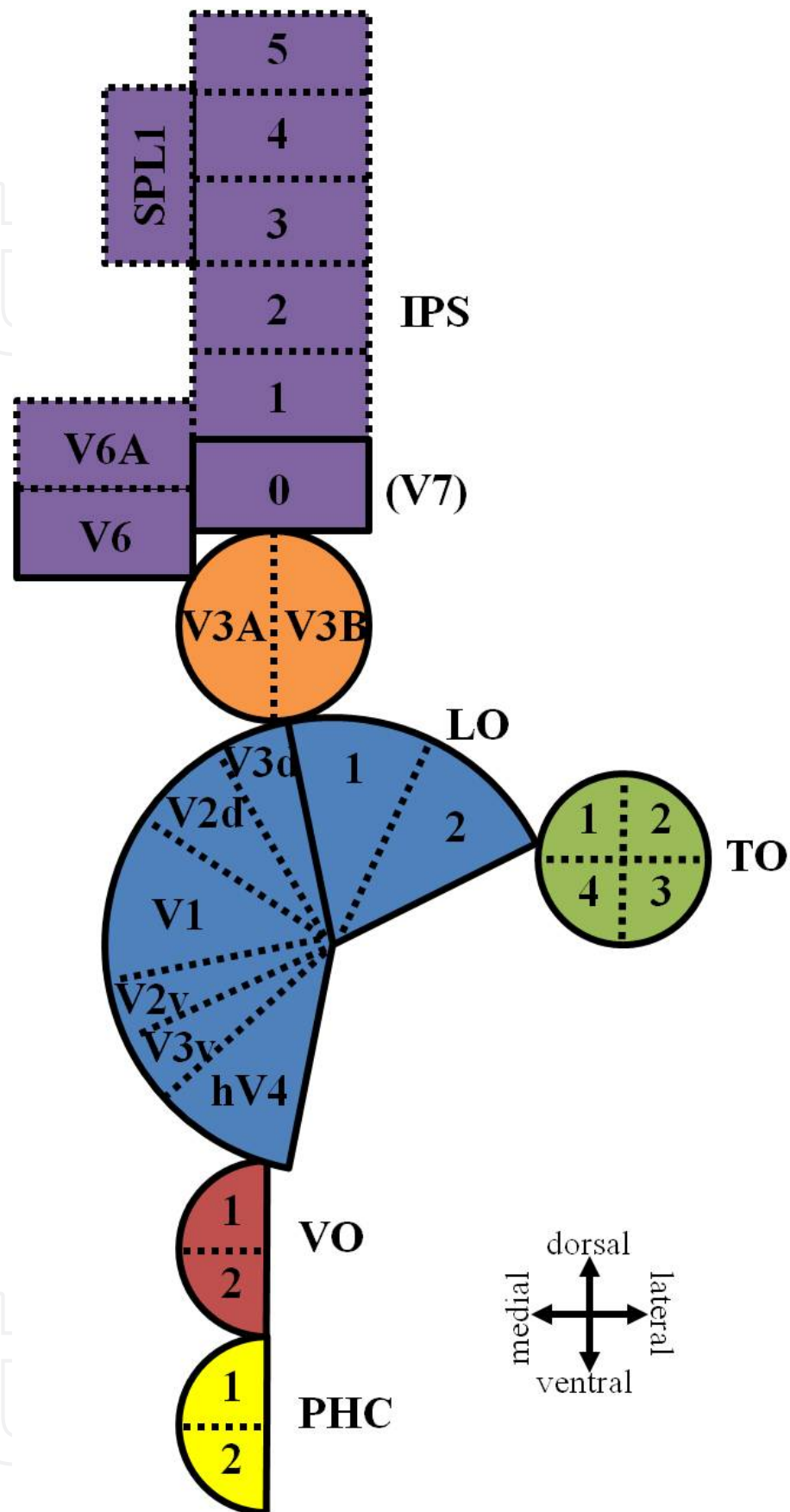
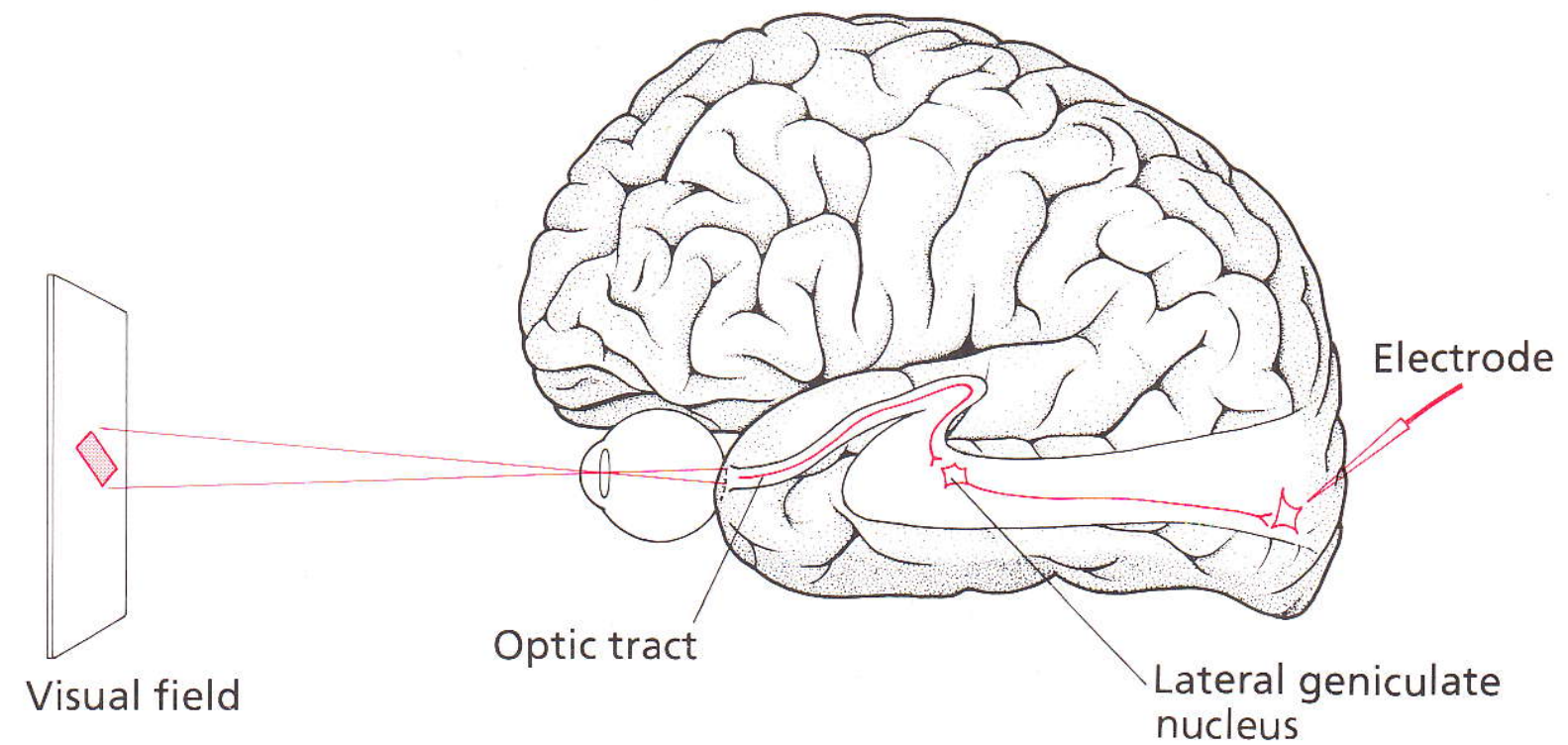


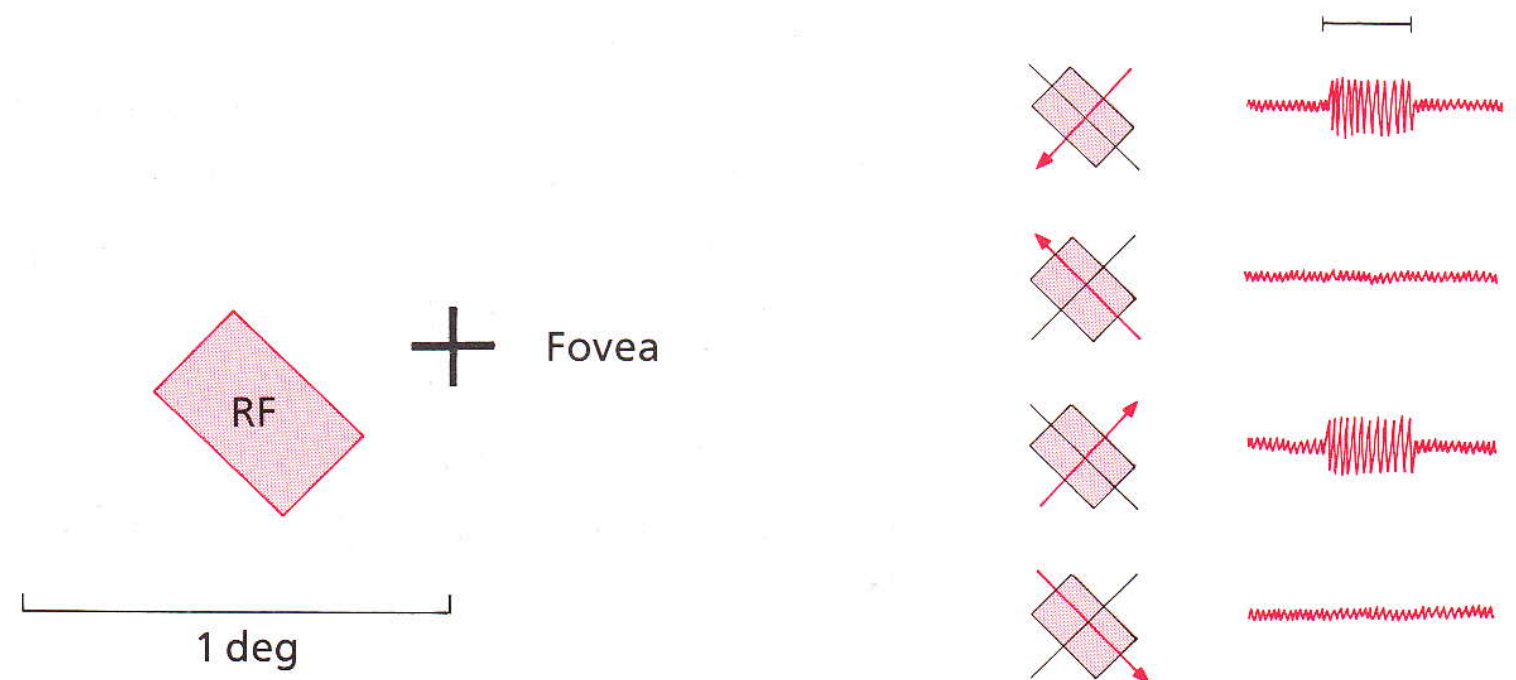
Figure 11. The Current State of Contiguous Visual Field Maps in Occipital, Parietal, and Temporal Lobes of Human Cortex. The figure depicts a cartoon overview of hemifield representations of visual field maps (VFMs) in a single right hemisphere if the cortical sheet of that hemisphere were removed from its usual position and laid flat. The center of the blue region is centered on the occipital pole, while the purple region is in parietal cortex, the red and yellow regions are on the ventral surface of the occipital and temporal lobes, and the green region is on the lateral surface of the temporal lobe. Each color except purple represents a likely or confirmed 'clover leaf' cluster of VFMs. Solid black lines indicate the borders between 'clover leaf' clusters and dotted lines indicate the borders between hemifield representations within clusters. In the purple region, the organization is much less clear, particularly for maps outlined in dotted rather than solid black lines (IPS-1, IPS-2, IPS-3, IPS-4, IPS-5, SPL1, and V6A). See main text for more details.

Hierarchy

Fig. 9.1 The receptive field of a cell is that part of the field of view which, when stimulated, yields a reaction from the cell, measured as a change in its electrical discharge. (a) An electrode is placed in the vicinity of a cell in the visual cortex and the receptive field (RF) of the cell is plotted on a screen (in red). Once the receptive field is defined, its characteristics can be studied in greater detail. In this instance (b) the cell is found to be orientation selective, responding to an obliquely oriented line and being unresponsive to the orthogonal orientation.

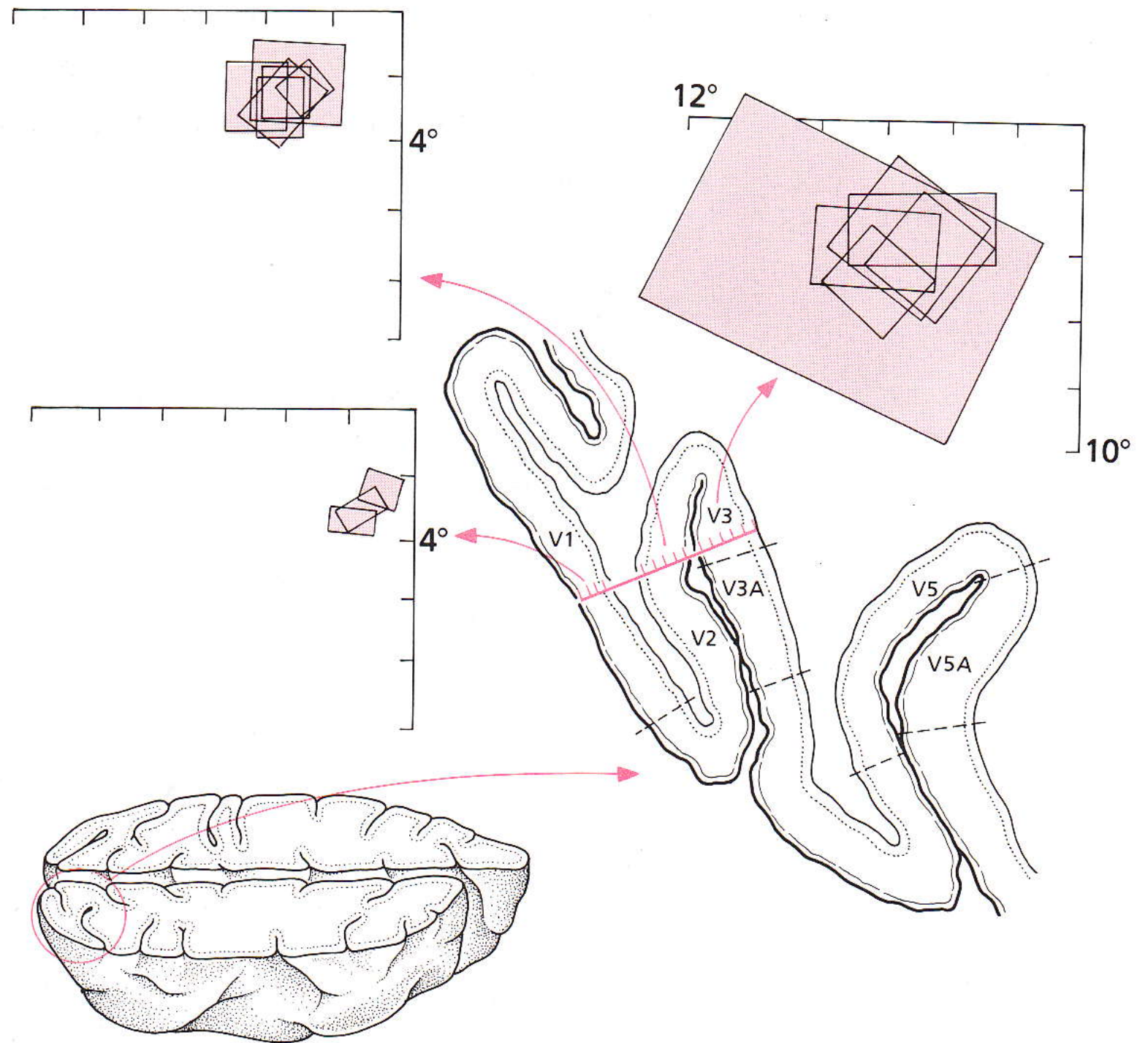


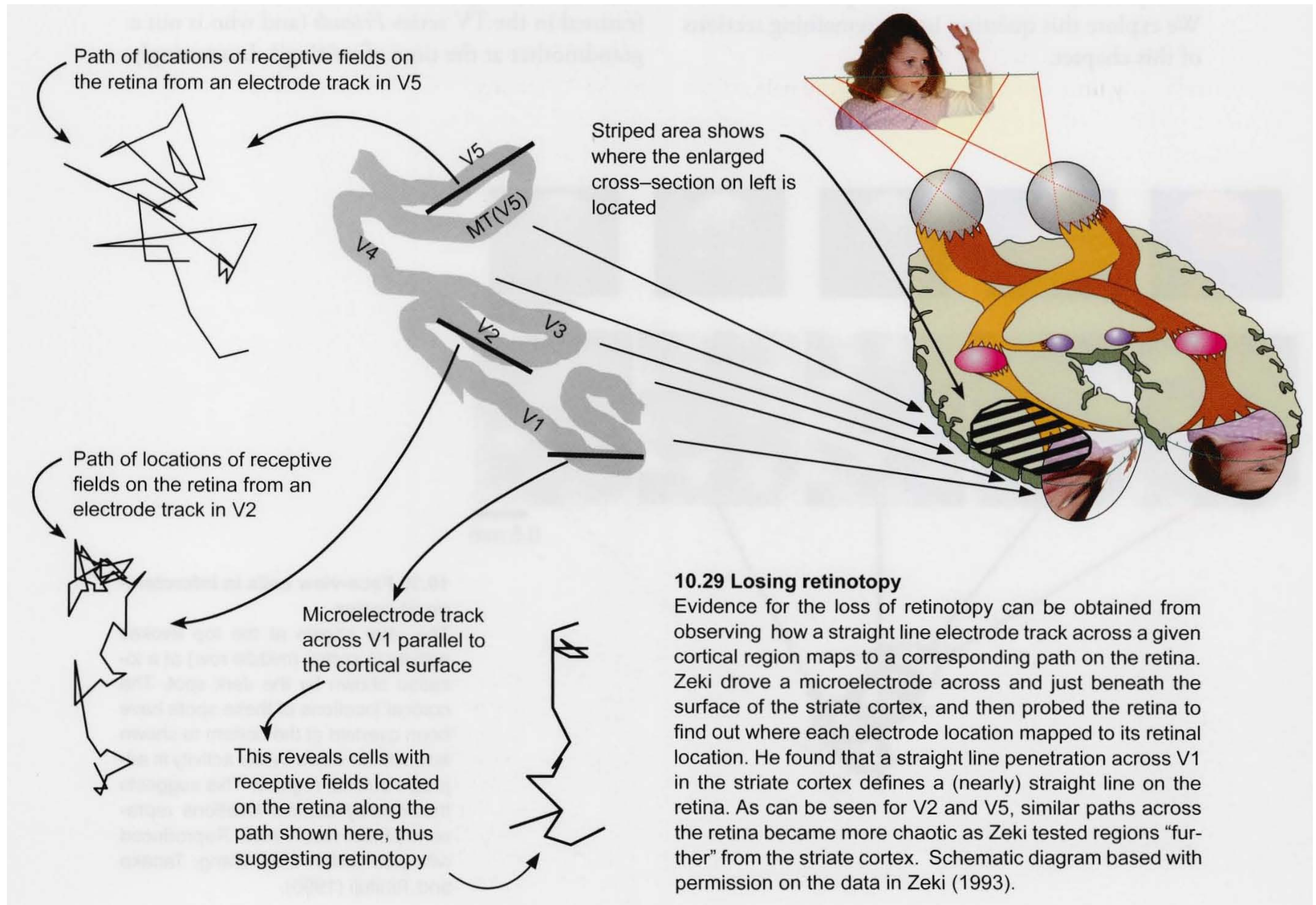
(a)



(b)

Fig. 11.3 The change in receptive field size of cells in three visual areas of monkey cortex. Receptive fields are smallest in area V1 and larger in area V3, with those in area V2 having intermediate sizes. Cells in the parietal and temporal visual areas (not shown) have even larger receptive fields.





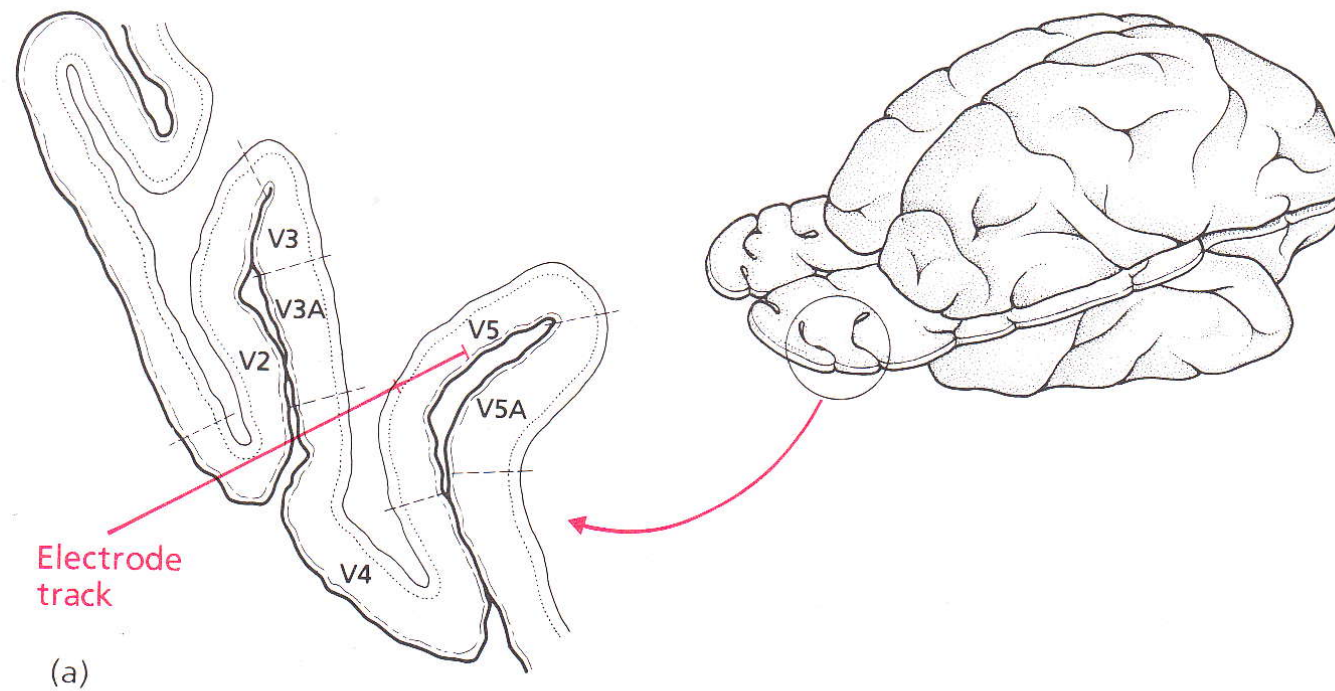
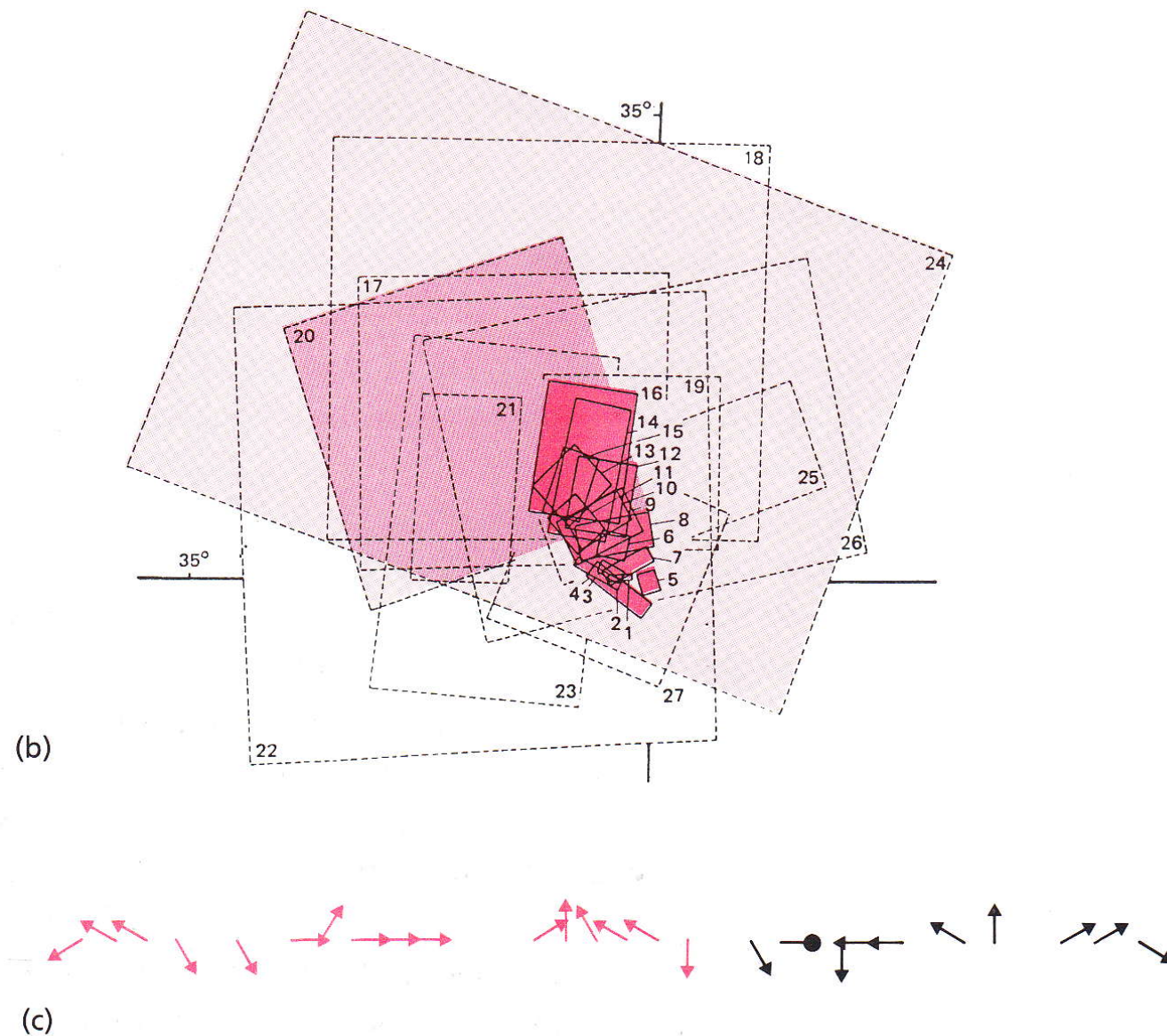


Fig. 17.7 A hint of a remarkable organization within area V5 of monkey visual cortex. Of the successive cells studied in a long oblique penetration through area V5 (a), the first sixteen (dark red) had relatively small receptive fields and their field centres were displaced from each other in an orderly way (b). By contrast the next group of cells, encountered in the same penetration, had large receptive fields and their centres were displaced from each other in an apparently chaotic way. (c) The directional preferences of all cells encountered in the penetration. The black dot indicates that the cell was motion, but not directionally, selective.



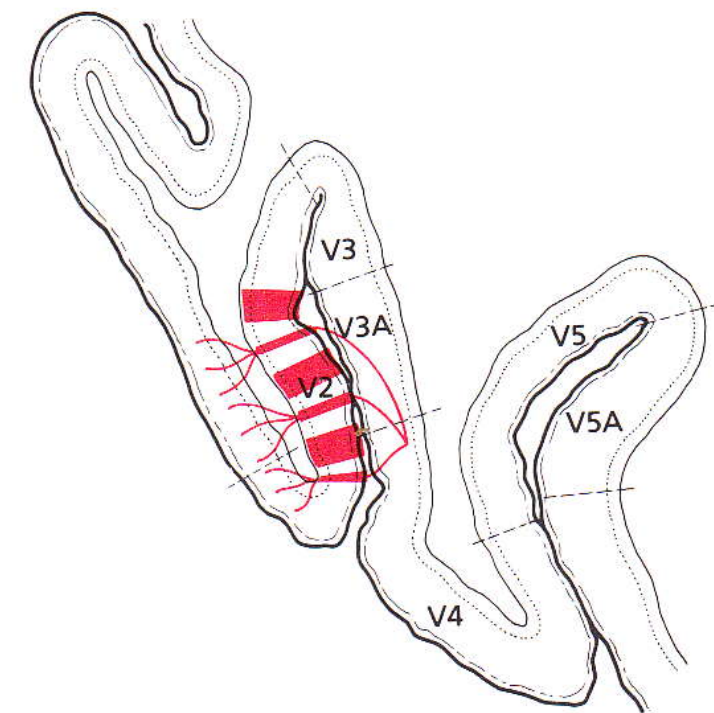
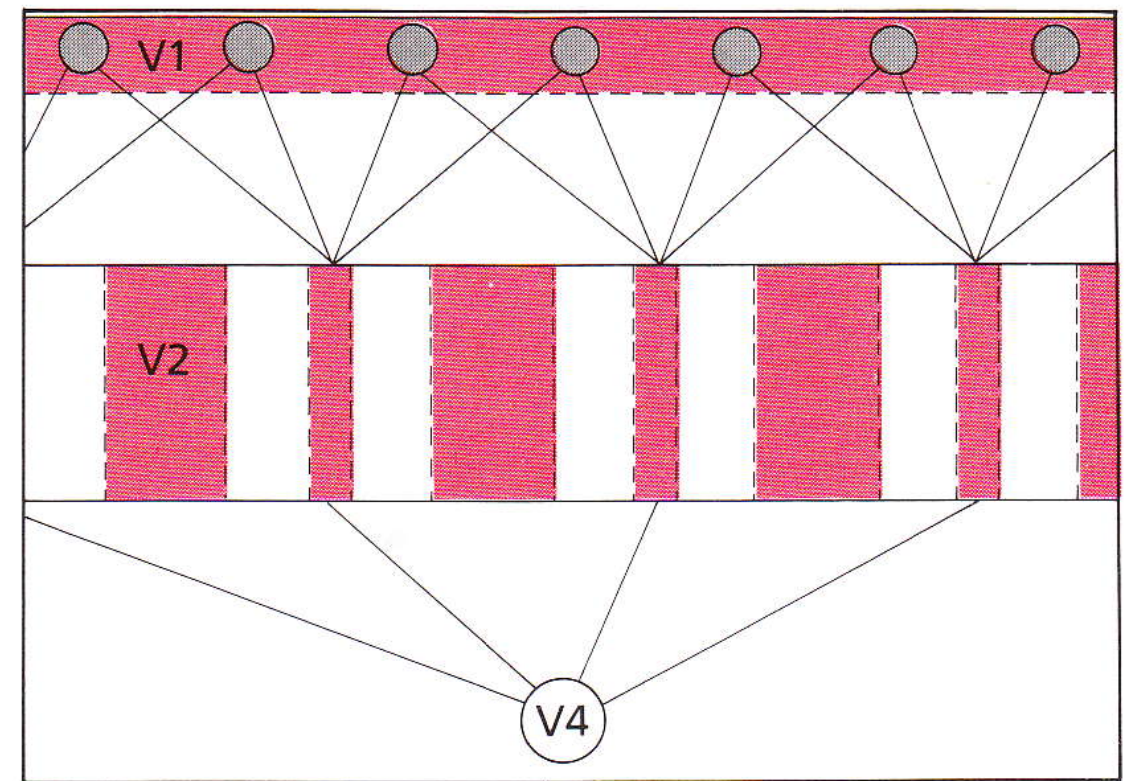
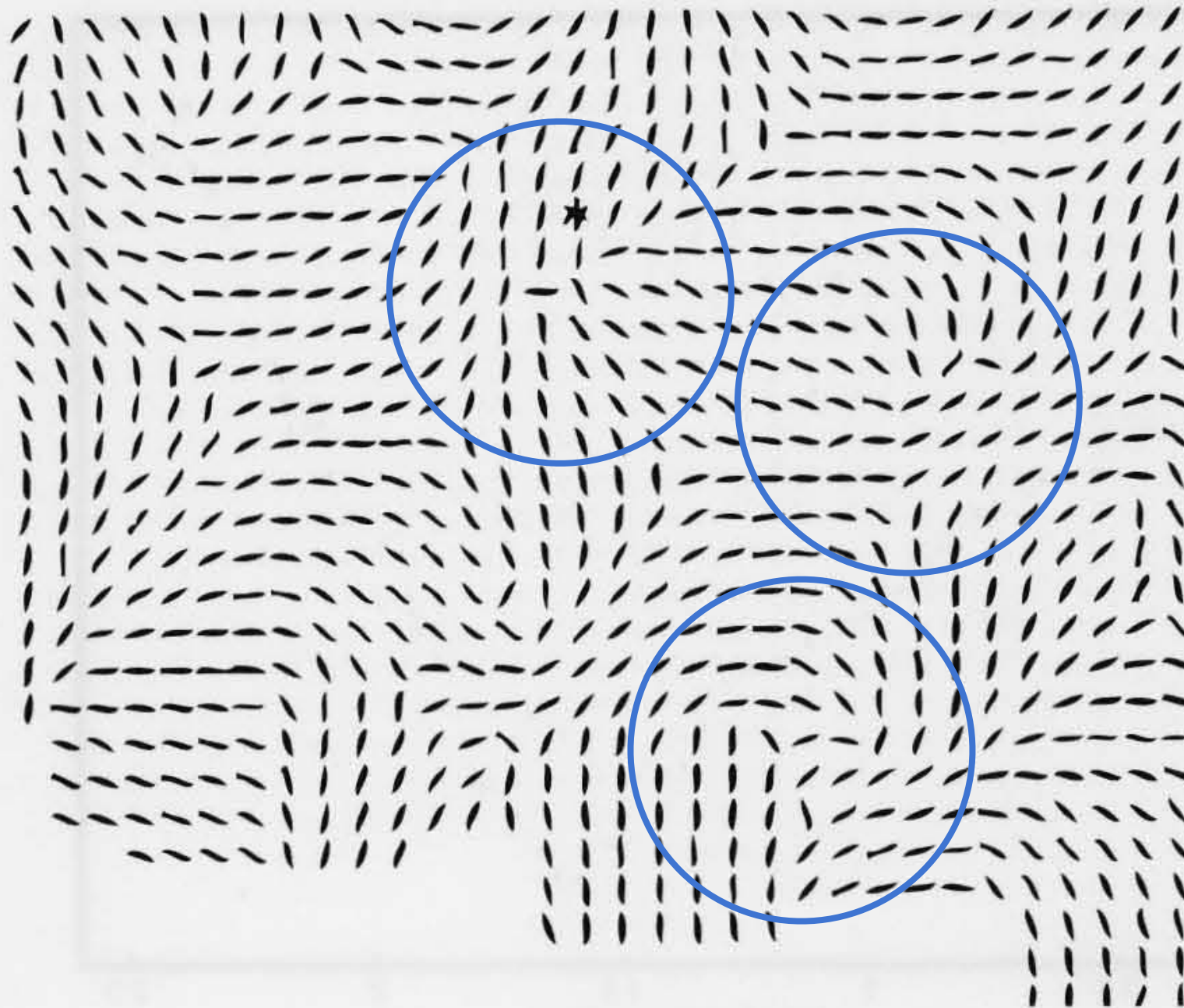
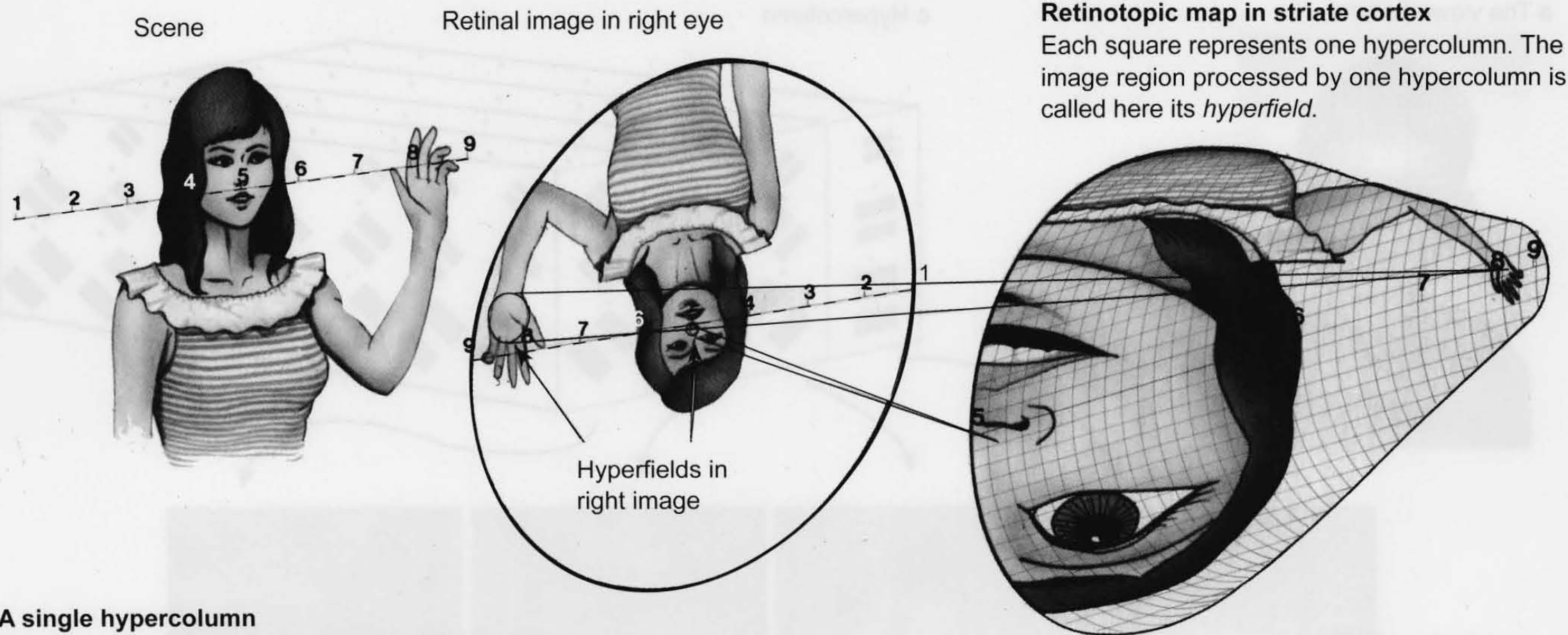


Fig. 29.2 The connections from the blobs of V1 to the thin stripes of V2 to area V4, shown schematically above and on a section through the relevant areas below.



10.10 Orientation map in visual cortex (V2)

Surface of part of the V2 viewed from above. Here, the orientation of lines drawn on the cortical surface indicates the orientation to which that cortical region is most sensitive. Courtesy Swindale, Matsubara and Cynader (1987).



A single hypercolumn

Part of a single hypercolumn dealing with a patch of the retinotopic map indicated by the arrow. Each hypercolumn includes one set of orientation columns that analyzes a region in the left eye's image and another set that does the same for the matching region in the right eye's image.

9.23 Hypercolumn hypothesis

Each hypercolumn is a processing sub-unit, made up of the full range of cell types found in the striate cortex, dealing with a patch of retina called, by us, its hyperfield. Within the hypercolumn, each column has cells with the same preferred orientation and these columns are arranged in slabs also sharing the same orientation. This arrangement is sometimes called the *ice cube model* of the striate cortex. Only a small sample of cells are shown here.

