# Retinotopy & Phase Mapping

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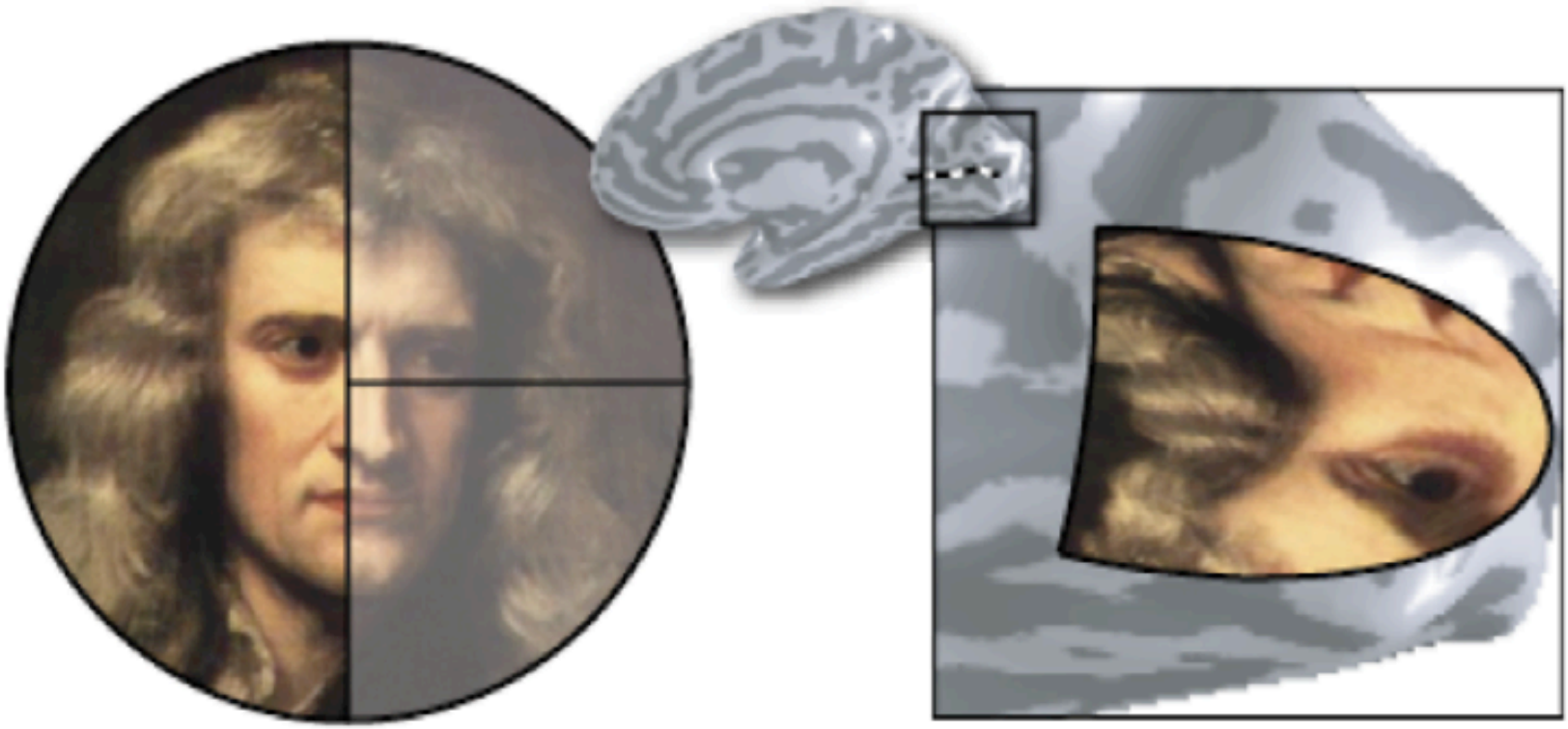
B. A. Wandell, et al. ‘Visual Field Maps in Human Cortex’, Neuron, 56(2):366-383, 2007

# Retinotopy



- Visual Cortex organised in visual field maps:
- Nearby neurons have receptive fields at nearby locations in the image
- Receptive fields of neurons is a region of space in which the presence of a stimulus will alter the firing of that neuron. (identified in auditory, somatosensory and visual system)
- Retinotopy descibes the spatial organisation of the neuronal responses to visual stimuli

# Human Visual Cortex


- Human cortex spans a surface area on the order of 1000cm$^2$
- 2-4mm in thickness
- 50000 neurons per cubic millimeter => 25 billion neurons in both cortical hemispheres
- Much of the posterior human brain responds to visual stimulation
- Human visual cortex: Entire occipital lobe and extends significantly into the temporal and parietal lobes (20% of cortex) => 5 billion neurons
- Essential for vision: Calcarine sulcus, located on the medial aspect of the occipital lobe

# Discovery of Visual Field Maps

- Observed strong correlations between visual field deficits and the location of lesions within human visual cortex (V1)
- V1 in each hemisphere encodes one half of visual space
- Cortical magnification: The central fovea is represented over a larger fraction of cortical surface than a comparable extern of the peripheral visual field
- Animal research: uncovered multiple maps
- Useful for many generations of clinicians

# Motivations for Measuring Human Visual Fields

- Clinical Applications
- Differences between primate species
- Differences between human and non-human primates
- Relationship between maps and perceptual function
- Relationship between maps and behavior (stimulation of MT influences behavioural decisions about motion)
- Cortical organisation of visual function
- Quantitative measures of these maps are used for analyses of visual system pathology (plasticity-baseline measurements)
- Anatomical correspondence does not imply functional correspondence

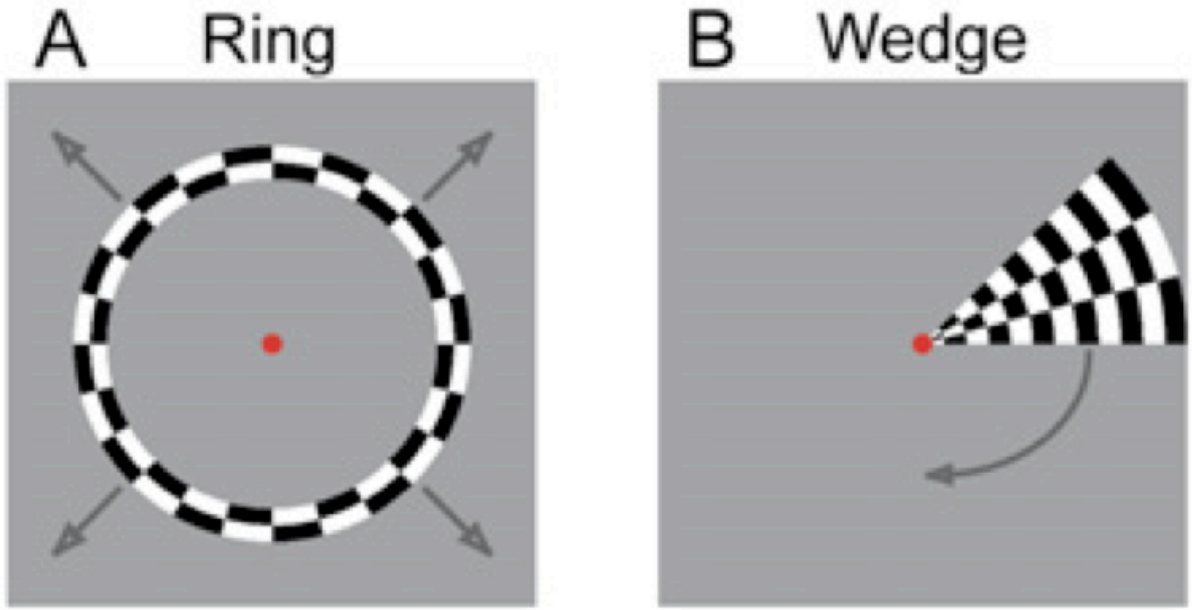
# Visual Field Maps versus Visual Areas

- Visual Areas:
  - Architecture
  - Connectivity
  - Visual Topography
  - Functional characteristics
- These criteria may conflict
- Architecture and connectivity are not easily accessible in-vivo
- Small differences in experimental design and interpretation may lead to differences in area definition

- Visual Field Maps:
- Relatively straightforward
- Each visual field map contains no more than a single representation for each point in the visual field
- A visual field map should represent a substantial portion of the visual field
- A visual field map should generally be contiguous
- The basic features of a visual field map should be consistent across subjects

# Measuring Visual Field Maps

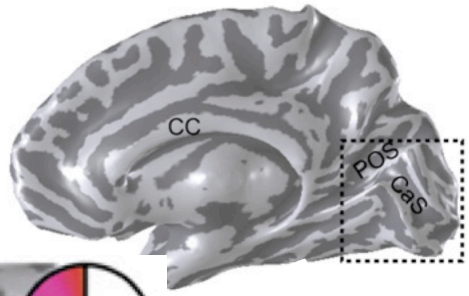
## Travelling-Wave Method/
## Phase Encoded Retinotopic Mapping

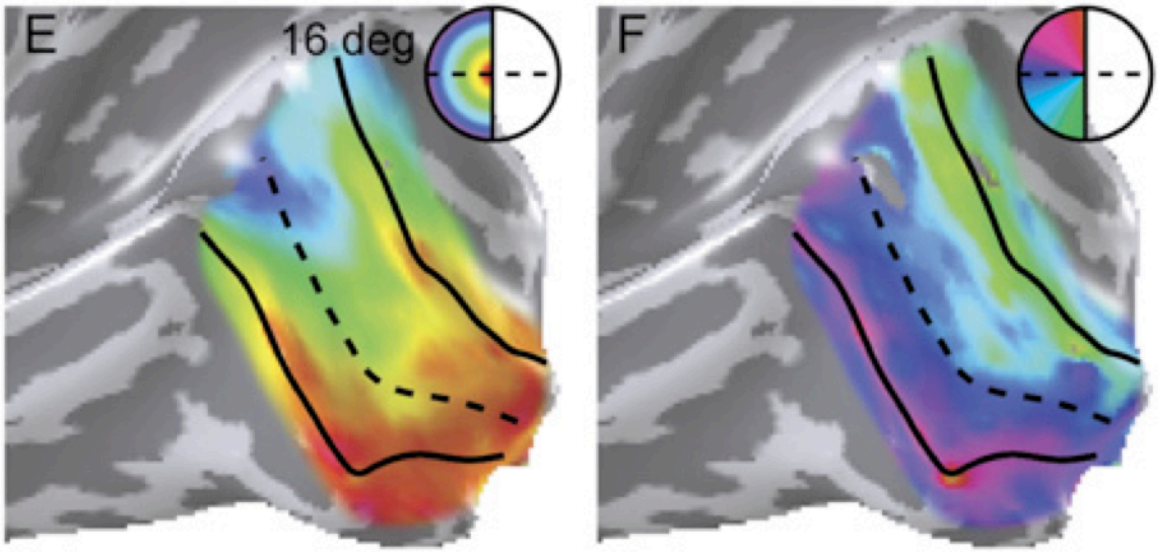



**Effective Eccentricity**

**Effective Angle**

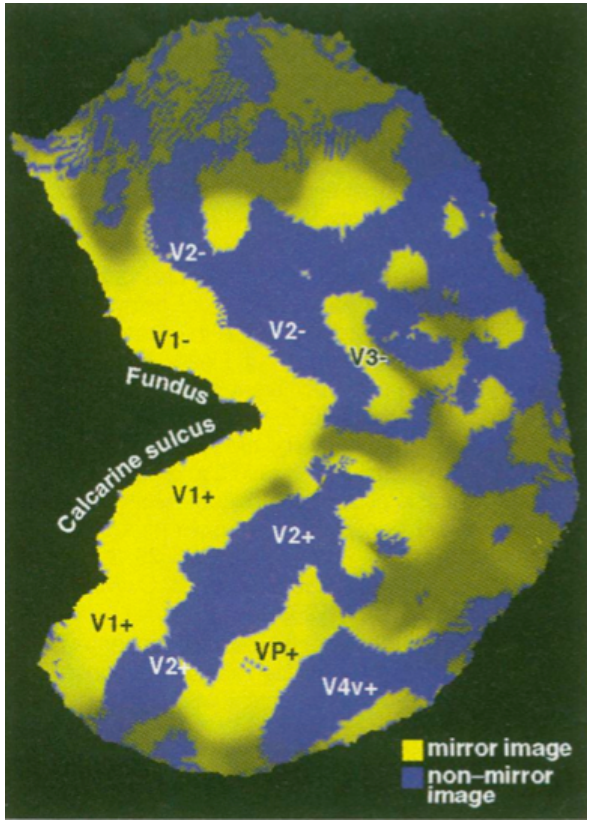
# Phase-encoded Retinotopic Mapping



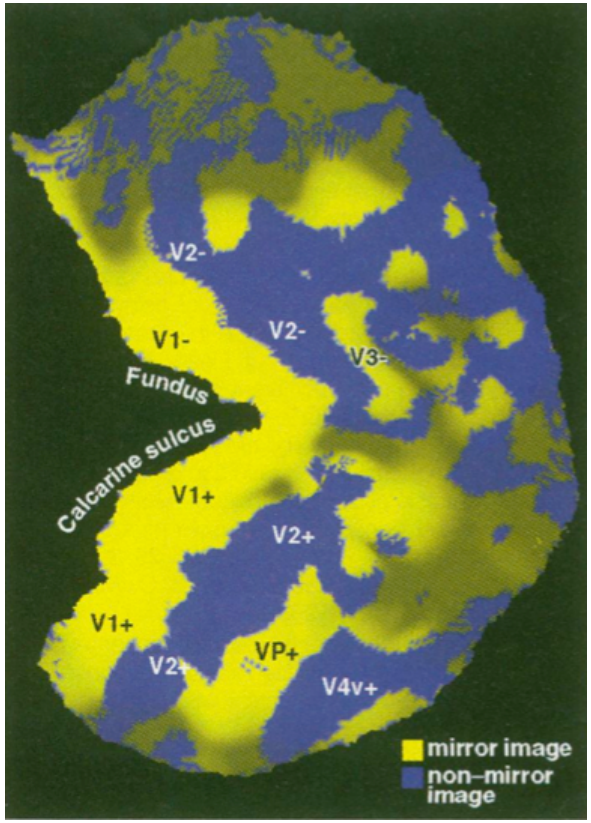

- Differential measurement; for each cortical location, the most effective stimulus is estimated by comparing the responses to a set of stimuli
- Presents an orderly series of visual field locations from which the most effective location can be interpolated using simple mathematical methods
- The entire visual field layout is estimated
- The visual field map description is not limited by the choice of certain critical visual field locations (horizontal and vertical meridians)
- Effective for measuring field maps with neurons that have small receptive fields that are mainly confined to one hemifield, such as V1

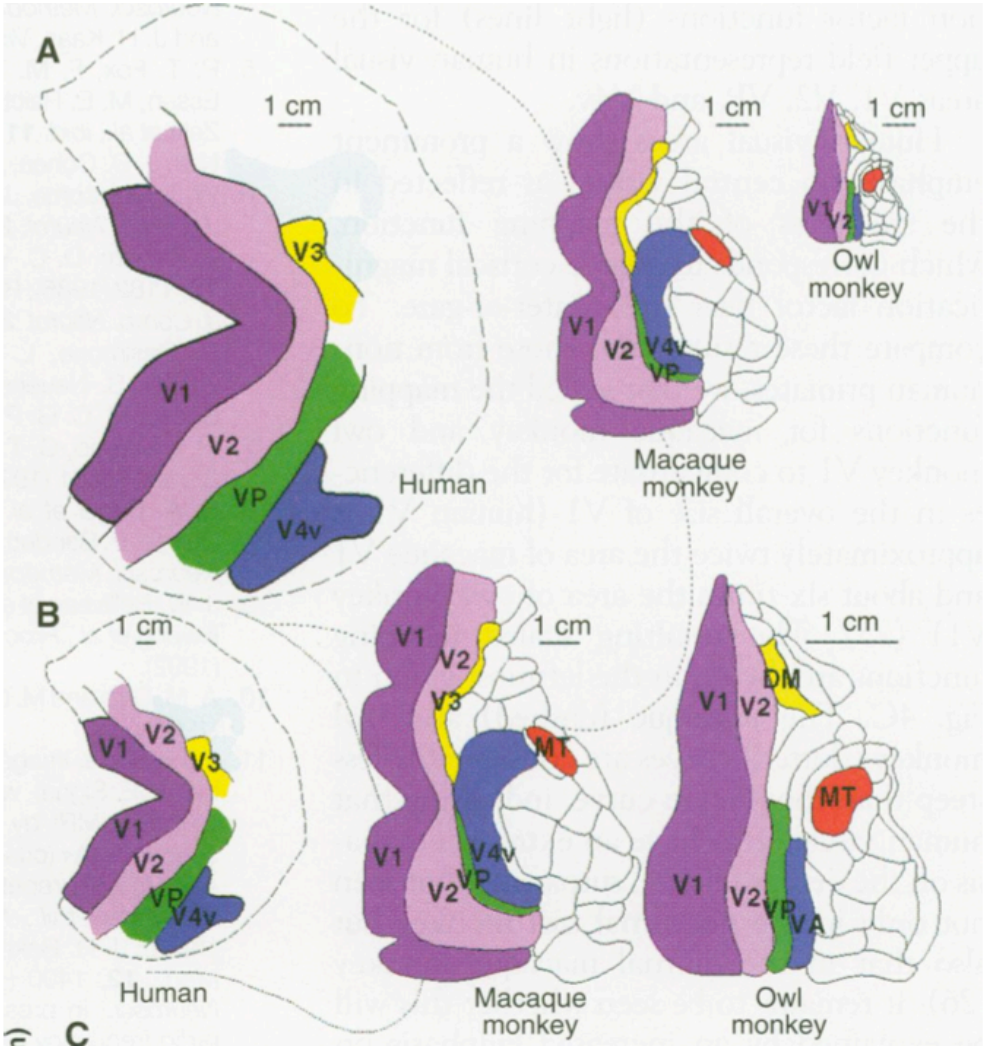
# Visual Field Maps in Humans and Animals




M. I. Sereno, et al. 'Borders of Multiple Visual Areas in Humans Revealed by Functional Magnetic Resonance Imaging', Science, 268 (5212):889-893, 1995

# Visual Field Maps in Humans and Animals

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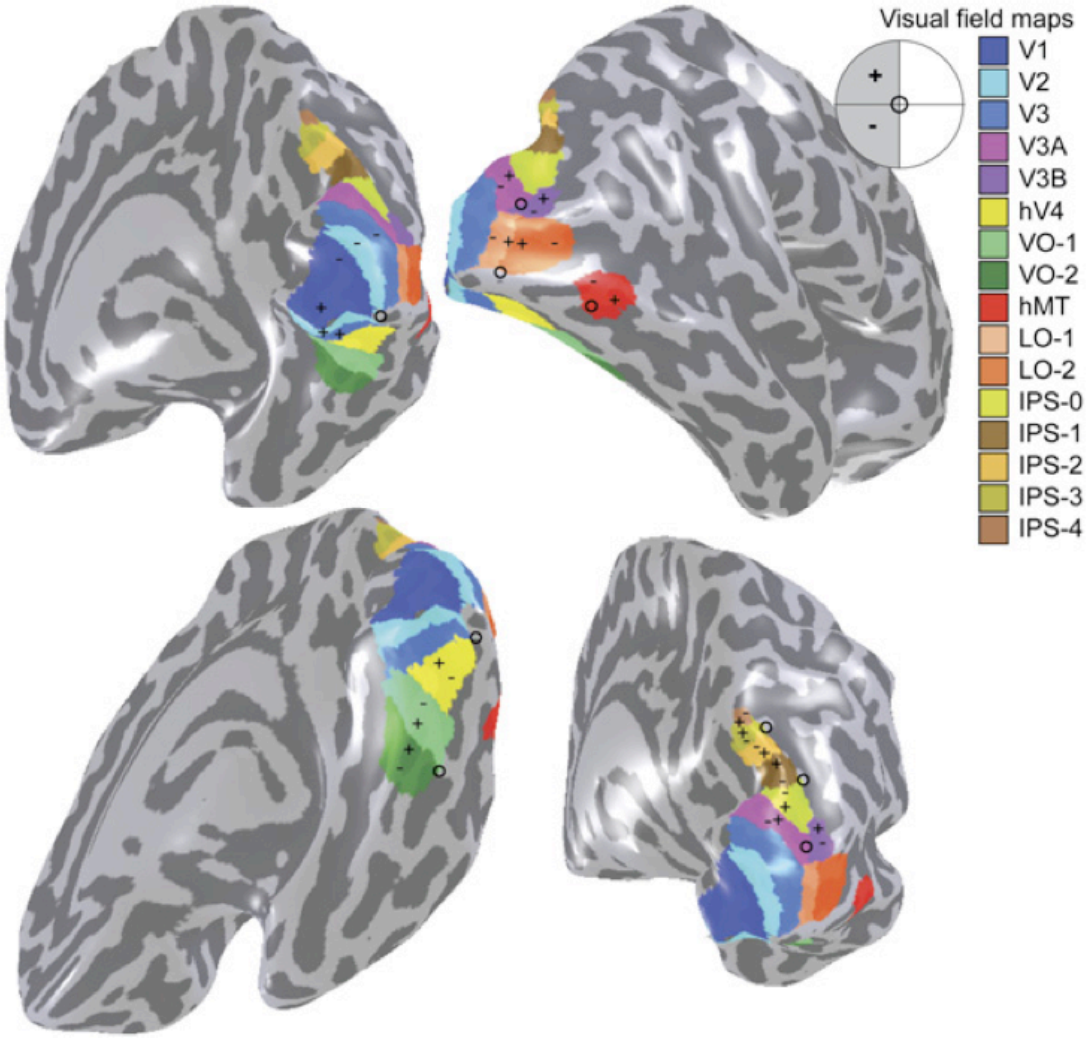
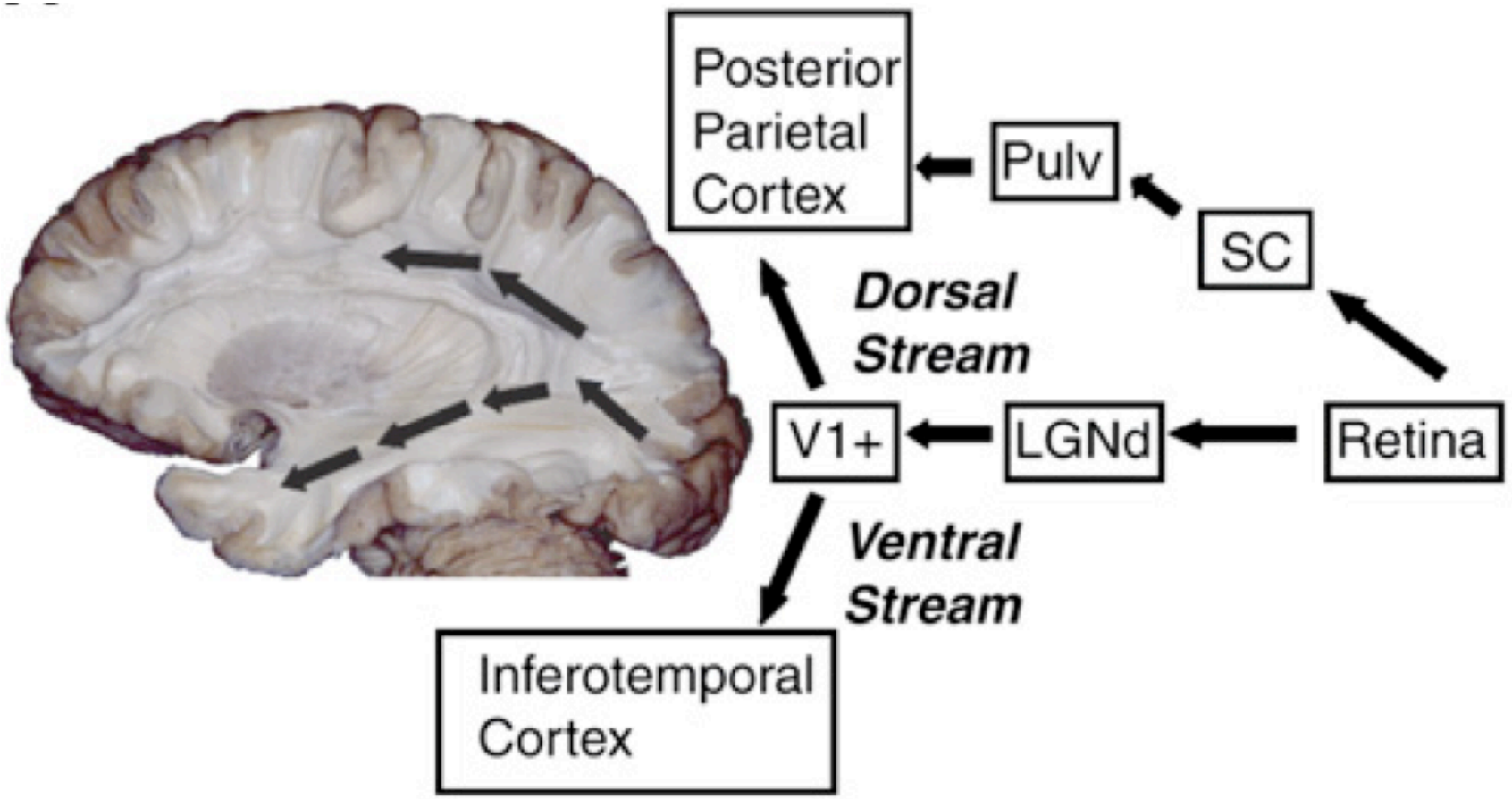
# Visual Field Maps in Human Visual Cortex



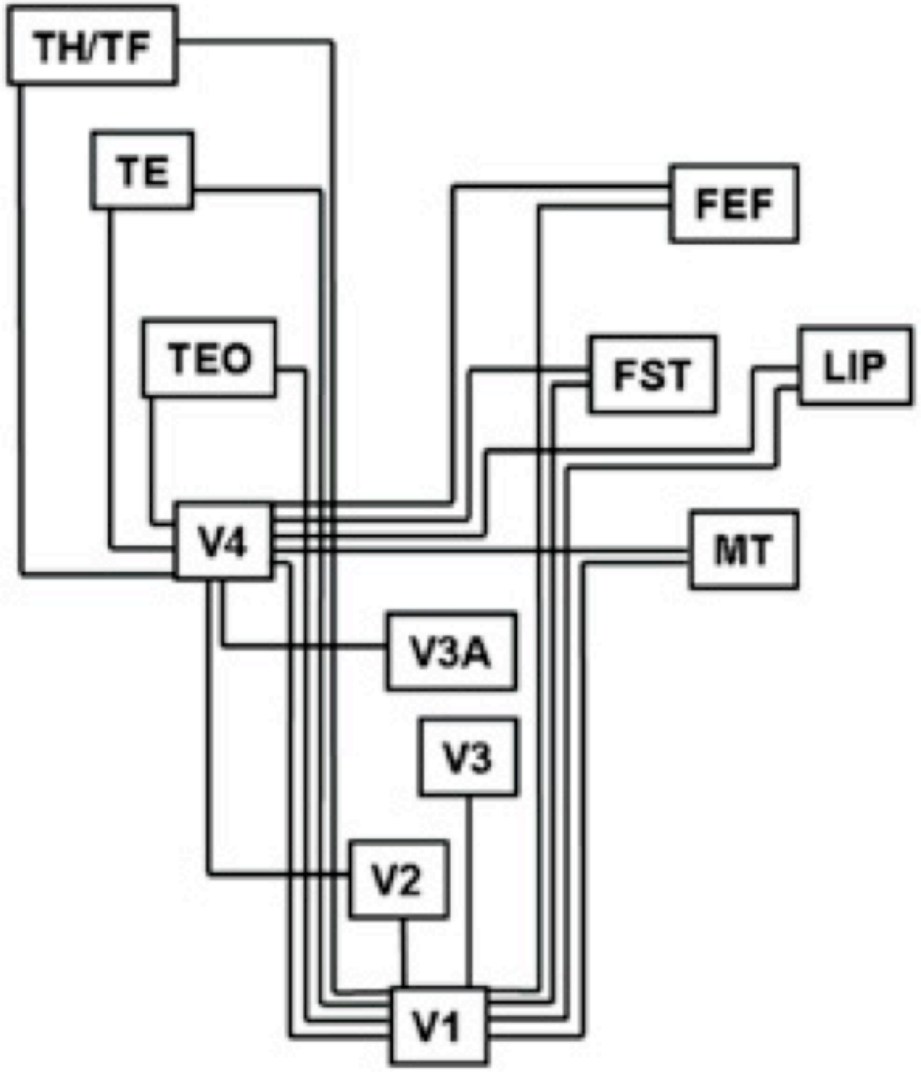
# Limitations of the Phase-encoded Mapping

- Fails when measuring maps with large receptive fields
- Stimulus is poorly designed to measure neuronal populations whose receptive fields are centered on the fovea
- Eccentricity fields are nonlinearly distorted, particularly when cortical response regions overlap with the fovea
- Angular responses near the vertical midline are difficult to measure due to technical limitations
- Adjacent fields do not always have the opposite field sign (V3A and LO-1 has similar signs)

# Organisation of Visual Field Maps



# Anatomical Organisation of Visual Field Maps




- Anatomical method
- Hierarchical graph
- Visual areas in macaque
- Connection are classified:
  - Ascending
  - Lateral
  - Descending
- Substantial uncertainties