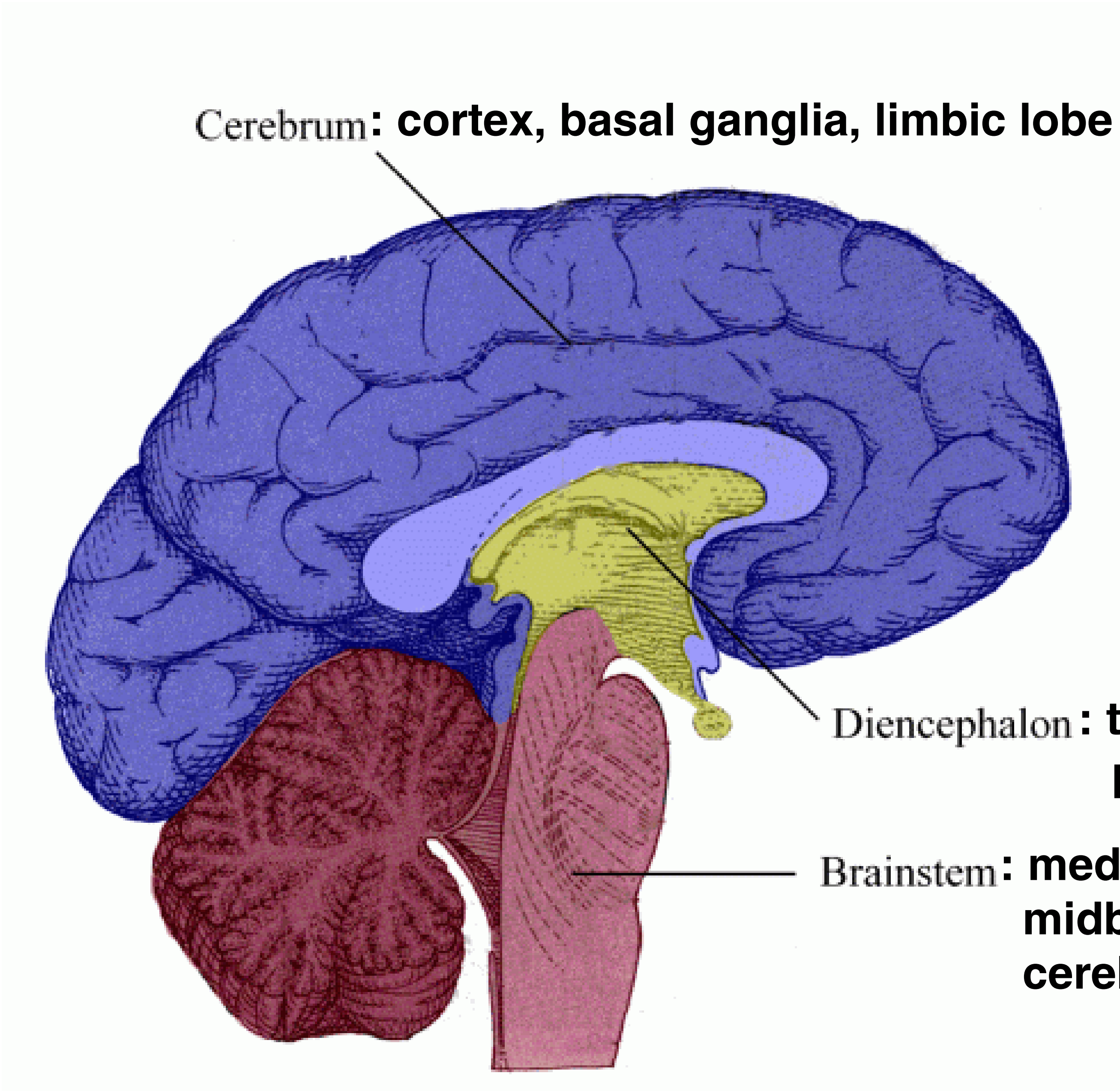
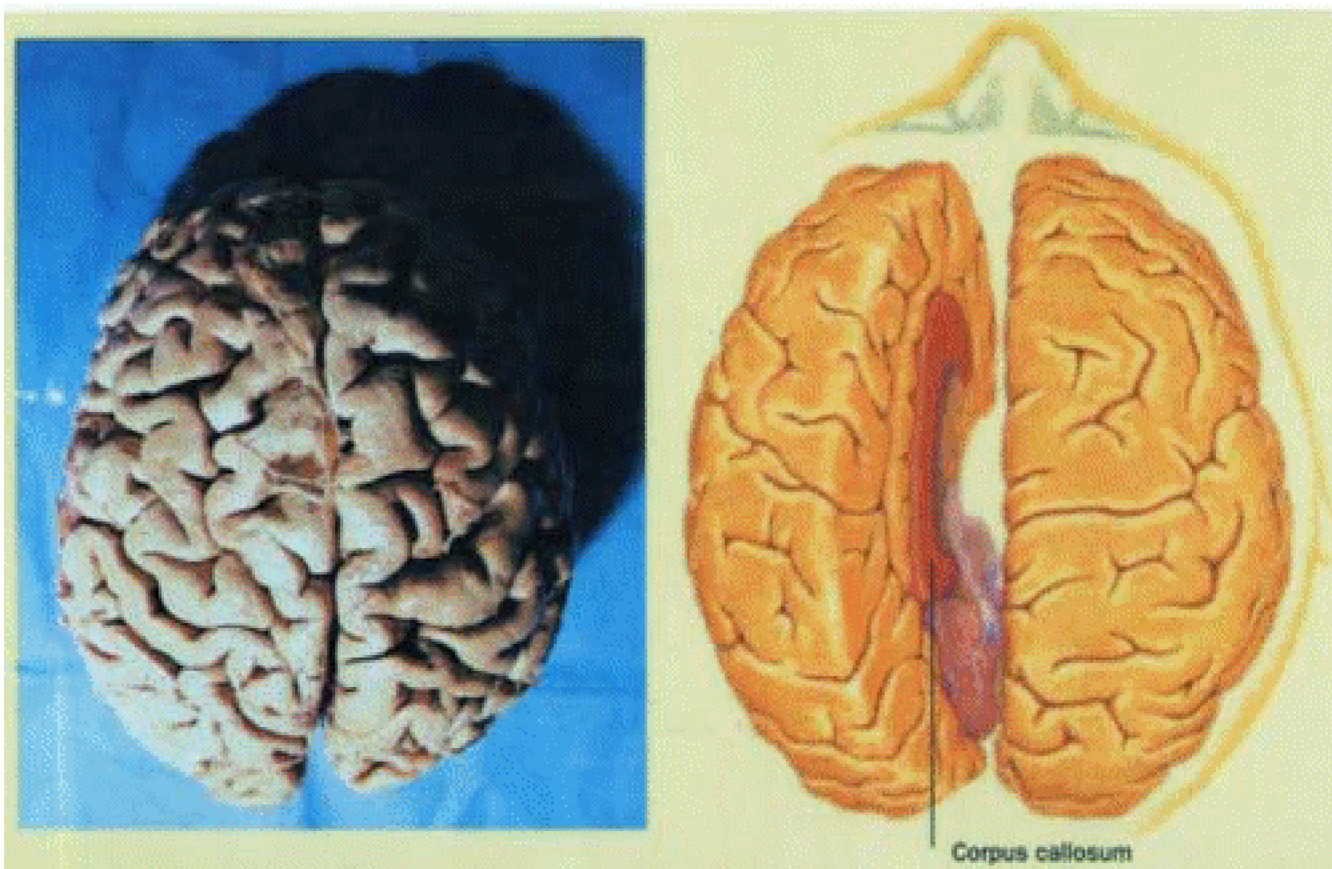
Neuroscience Tutorial

Brain Organization

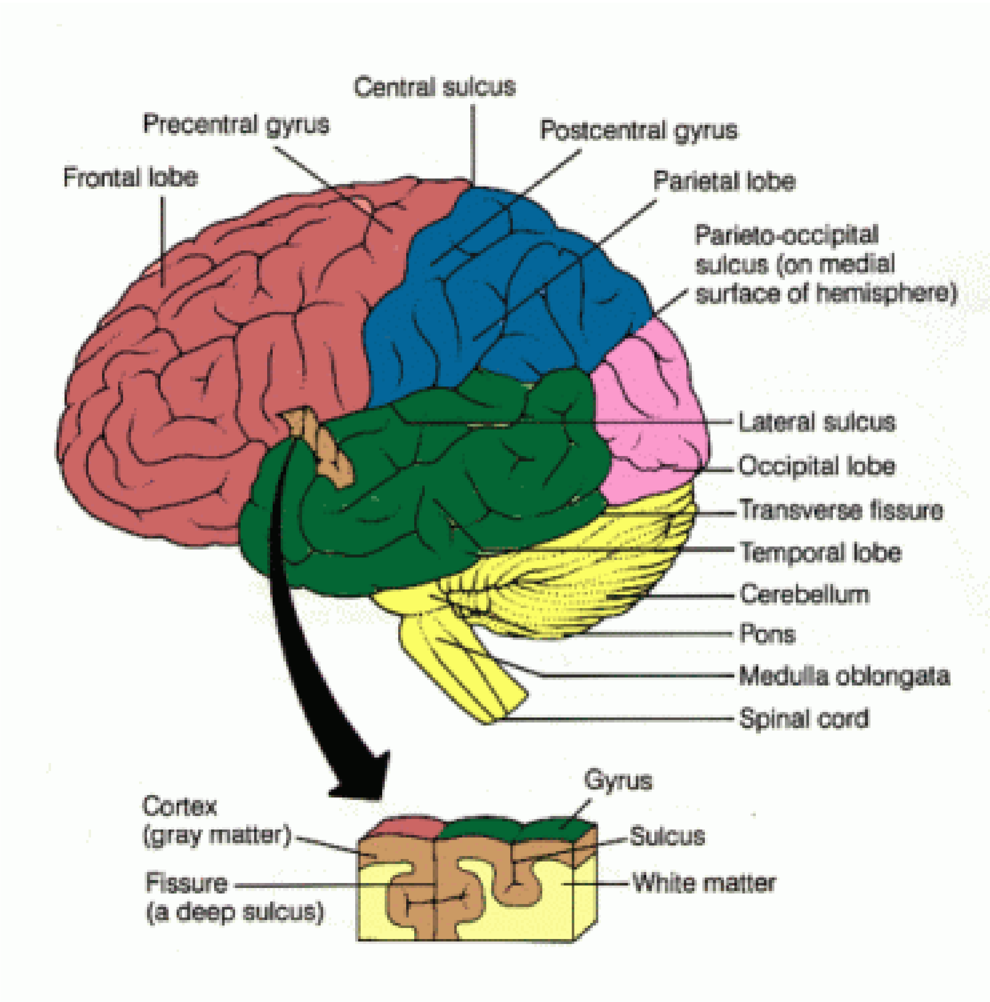


Cortical Organization

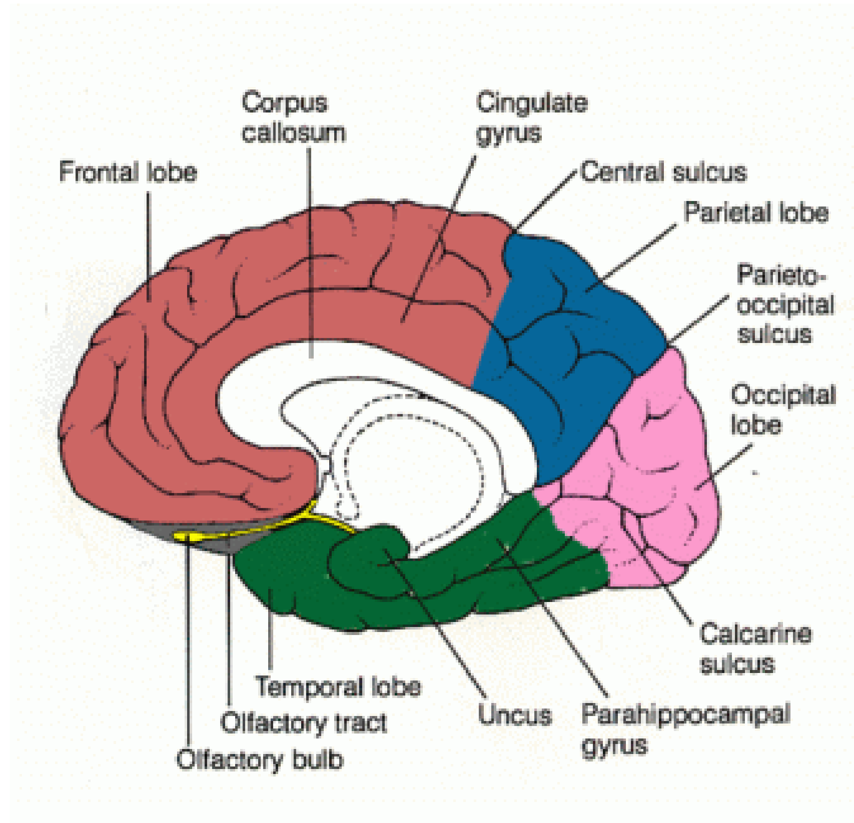


Cortical Organization

lateral view



medial view



Brain Terminology

anterior	toward the front
posterior	toward the back
medial	toward the middle (midline)
lateral	toward the side
dorsal	toward the top
ventral	toward the bottom
superior	above
inferior	below

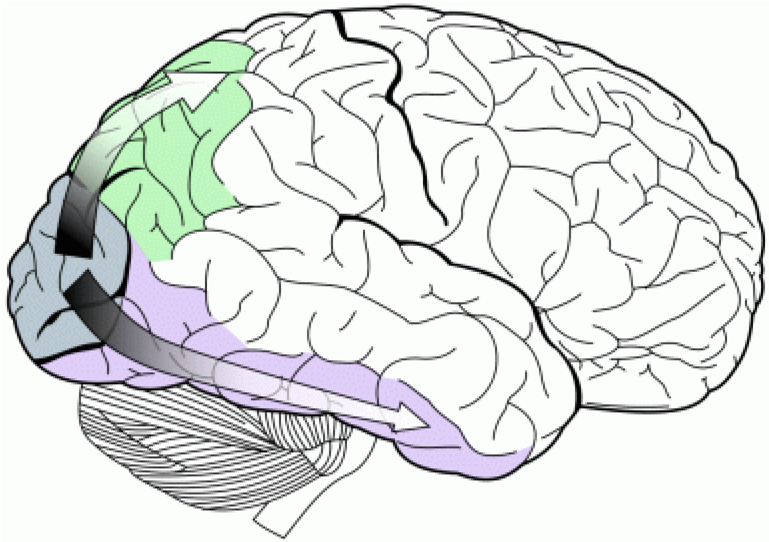
Visual System

~30% of brain devoted to vision

~8% touch

~3% hearing

Visual System Organization



Dorsal stream

“where” pathway: parietal cortex (V5, MT, LIP)

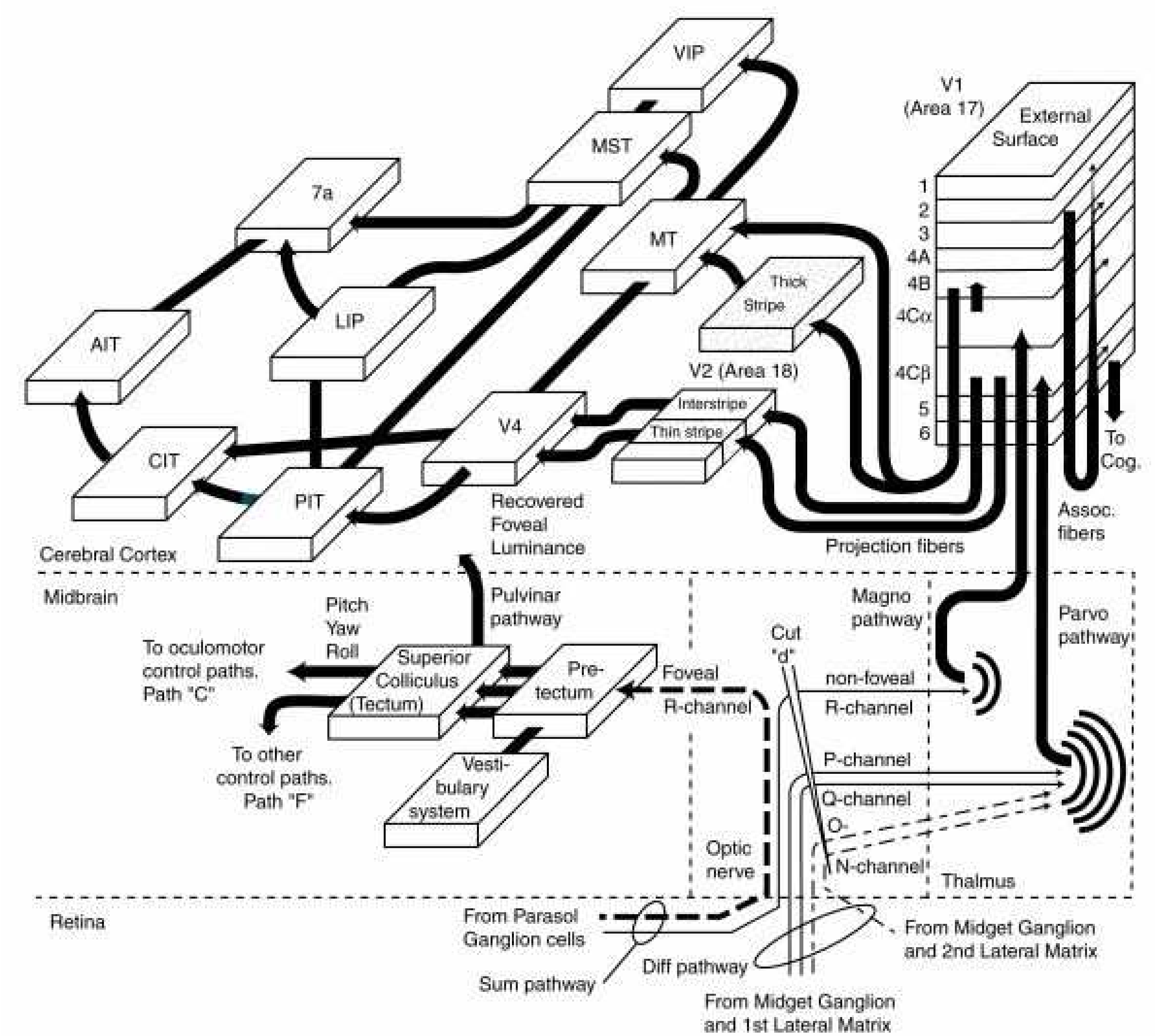
location of objects, attention, motion

Ventral stream

“what” pathway: temporal cortex (V4, IT)

color and shape perception, object identification

Hierarchical Organization of Visual Cortex

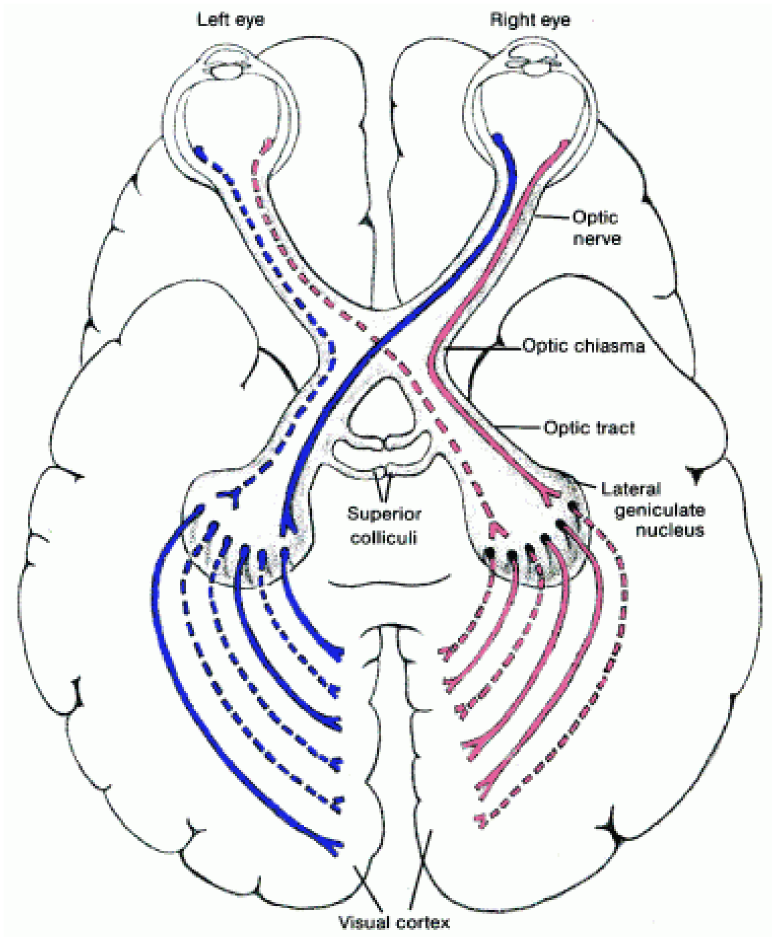


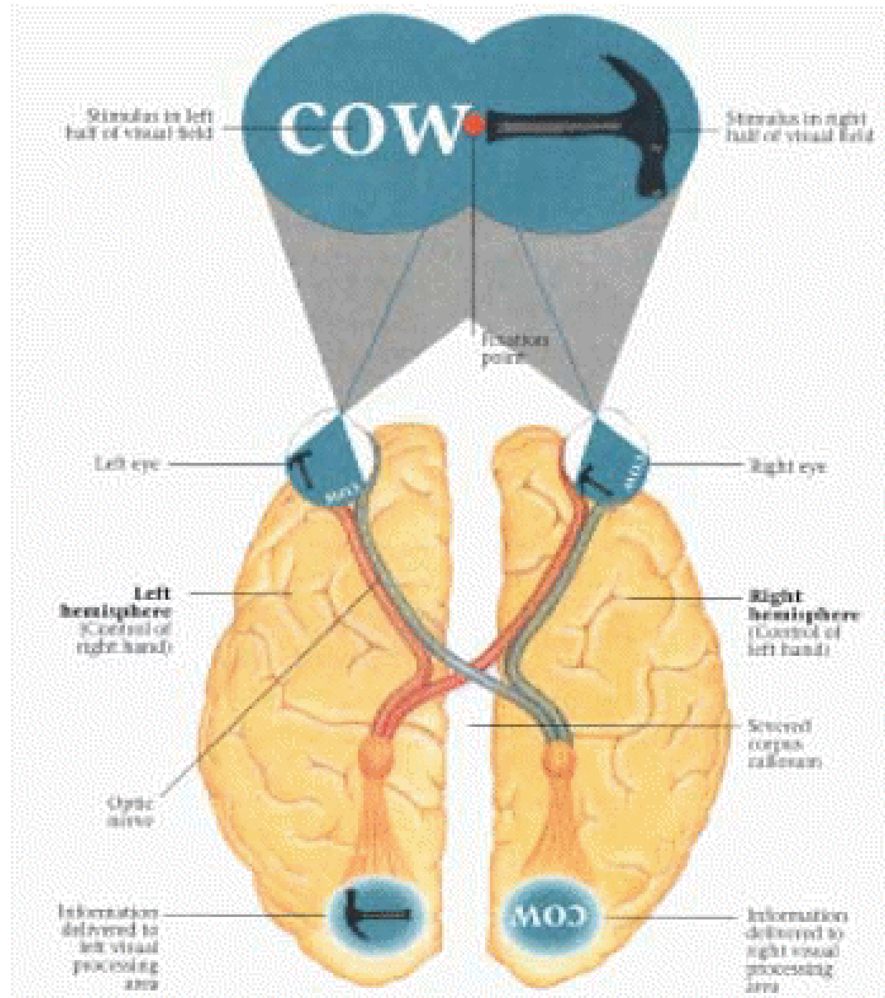
Pathways are reciprocal (feedforward + feedback)

“Bottom up” vs. “Top down”

Stages of Visual Processing

Lateral Geniculate Nucleus





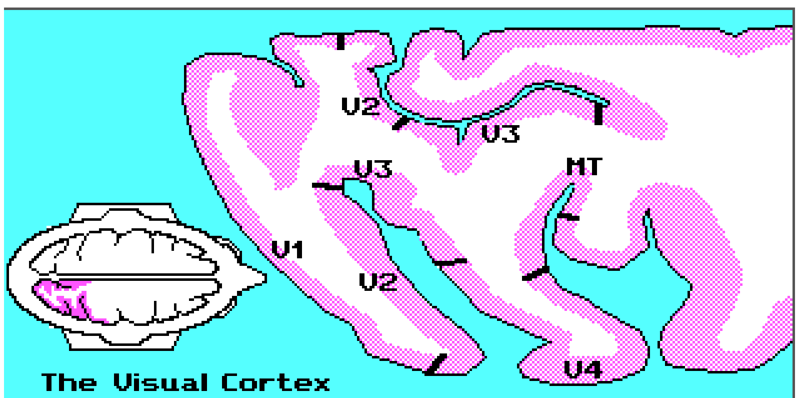
90% of projections to V1, 10% to superior colliculus -> pulvinar -> extrastriate

small, center-surround receptive fields

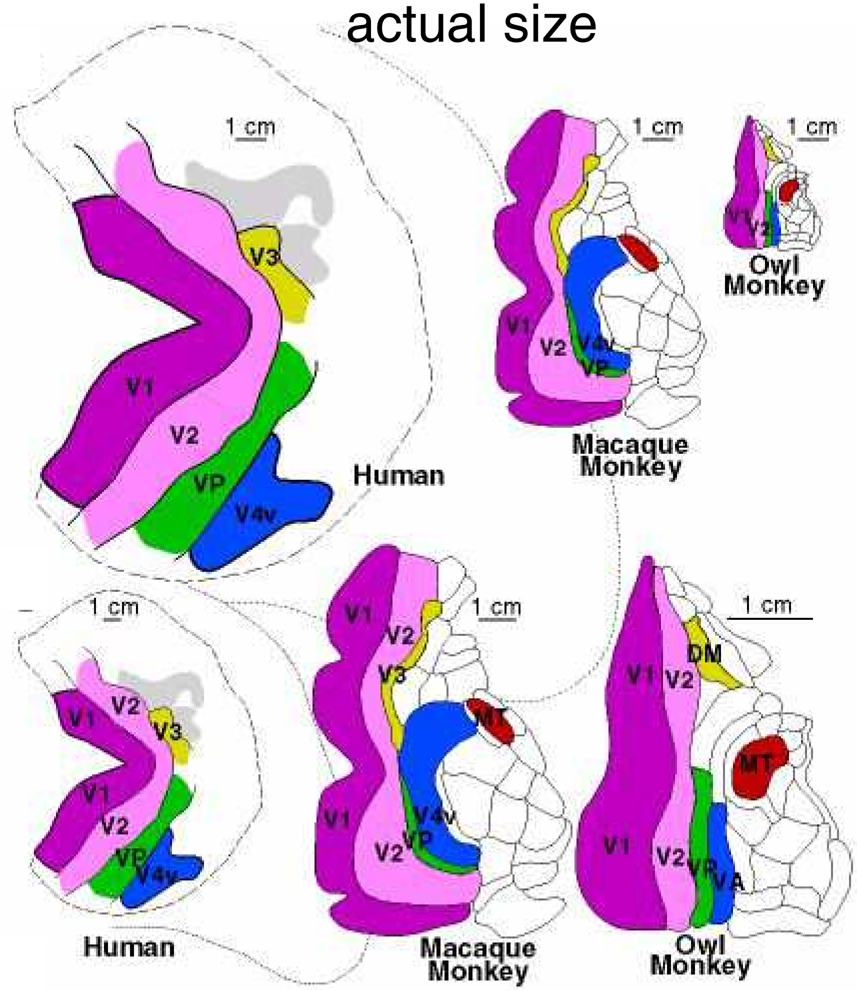
V1 (primary visual cortex, striate cortex, area 17)

receives feedback projections from IT, FEF, MST, MT (not reciprocal)

receptive fields tuned to color, spatial frequency, contrast, orientation, motion direction, eye, binocular disparity



actual size



rescaled to same size

Topographic organization of V1

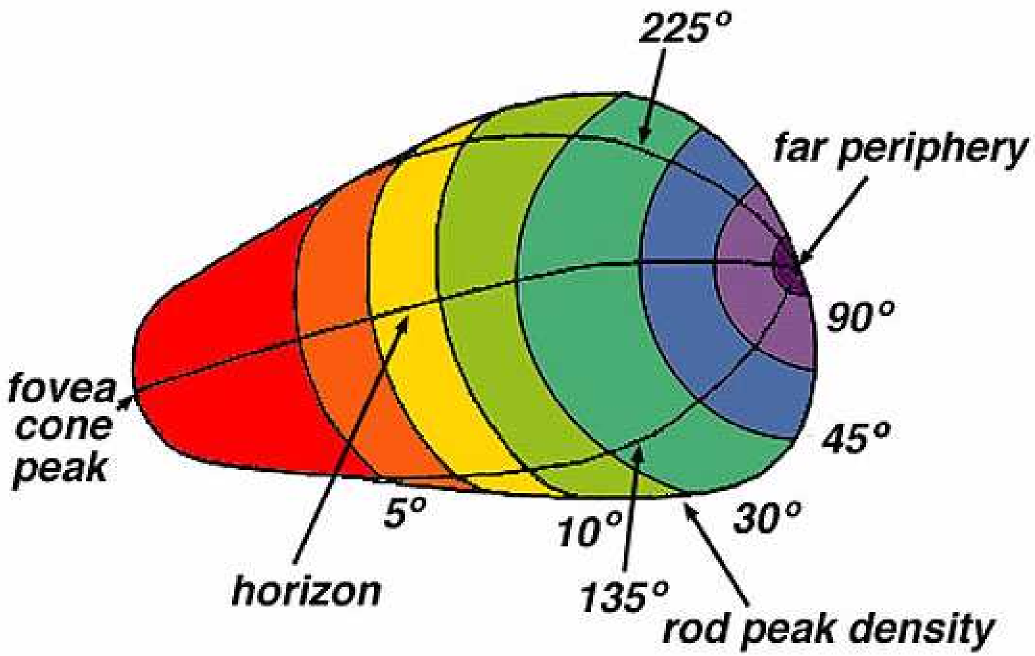


Figure 20. The unfolded striate cortex has a shape like a pear. It would be a quarter sphere if the visual fields were equally represented everywhere, but instead it is greatly distorted by the disproportionate representation of parts near the center of gaze (fovea), a feature termed "cortical magnification". In contrast, the far periphery is greatly underrepresented.

V2, V3, V3A (extrastriate)

V4 (extrastriate)

color perception

IT (inferotemporal)

form perception

broad receptive fields

stages within IT: posterior, central, anterior (PIT, CIT, AIT)

MT, MST

projections from V1

process motion

parietal, frontal attentional areas

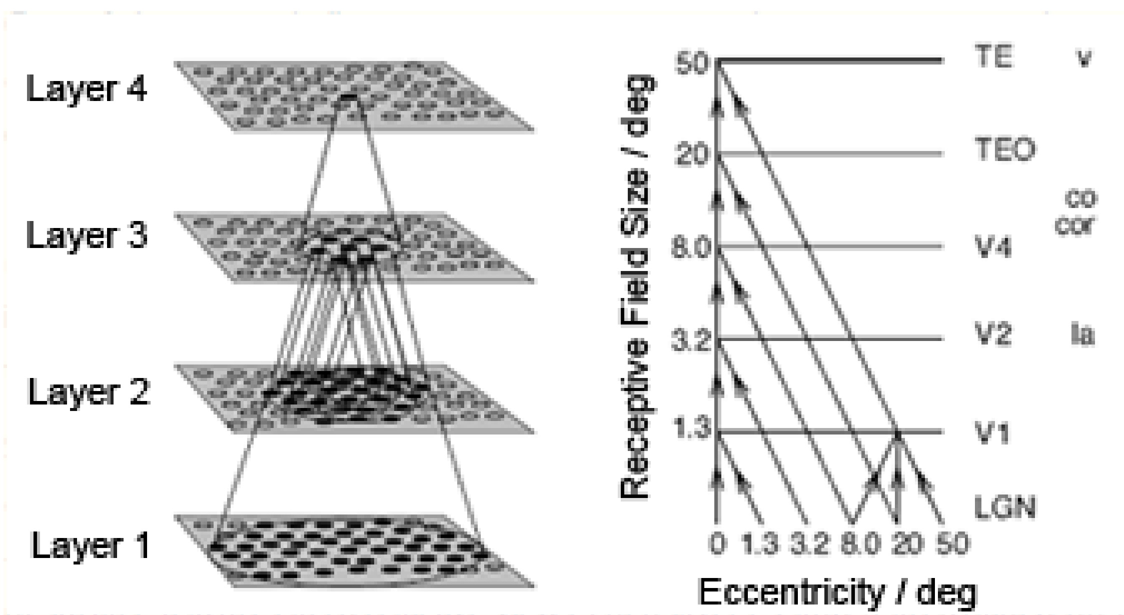
projections from V4, MT

Hierarchical Architecture

Early stages: simple features, small receptive fields

Late stages: complex features, large receptive fields

e.g., Stringer and Rolls (2002)

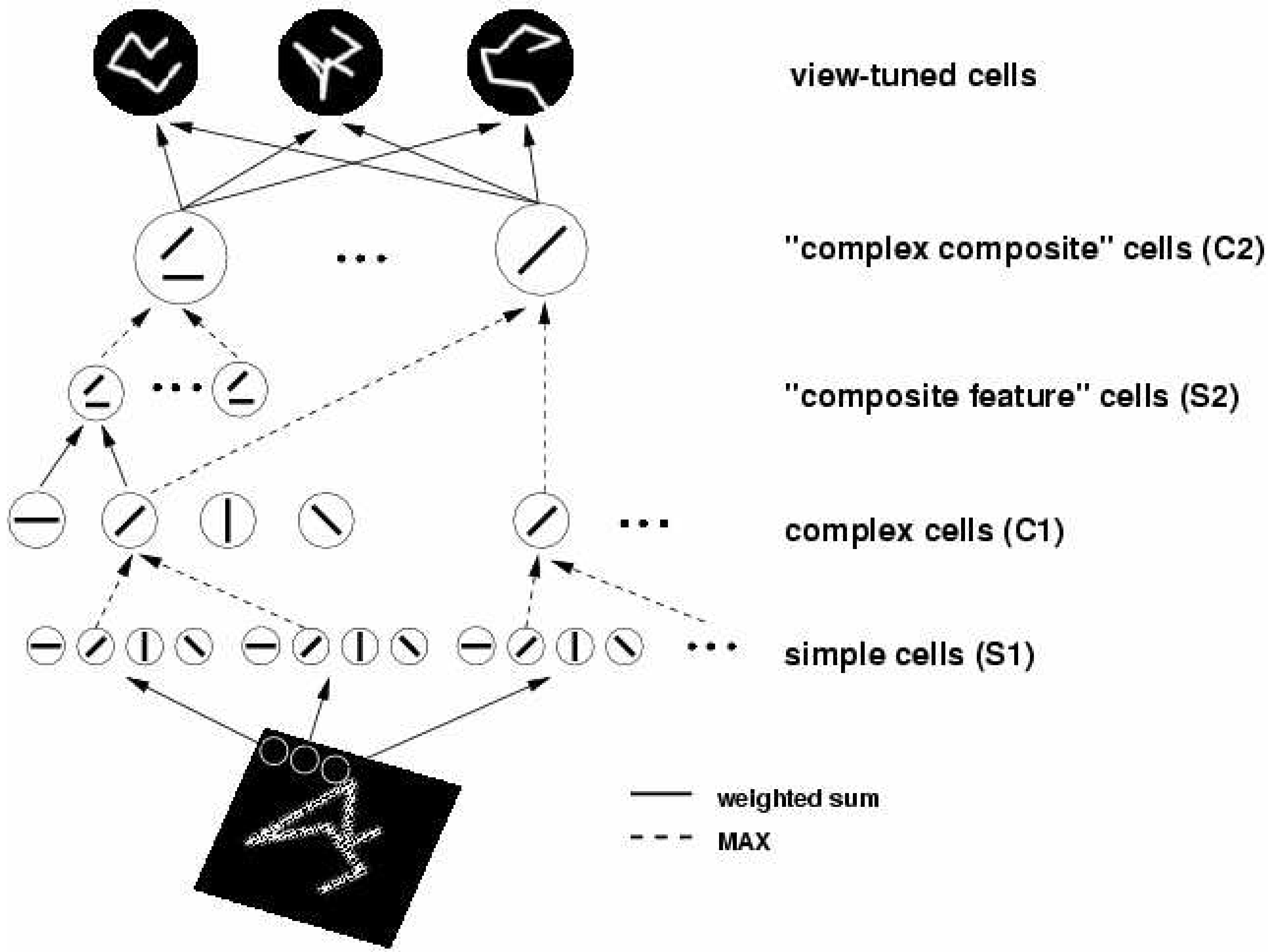


Hierarchical Architecture

Early stages: simple features, small receptive fields

Late stages: complex features, large receptive fields

e.g., Reisenhuber & Poggio model



Two Theories: The Role of V1 in Conscious Vision

Hierarchical theories

Awareness arises at later stages of visual system

Damage to V1 disrupts flow of information to high-level areas

Because V1 lacks direct projections to higher visual areas and frontal cortex (response initiation), it is not essential.

Prediction: awareness more tightly correlated with activity in extrastriate areas than in V1

Prediction: disruption of V1 activity should not impair awareness if extrastriate activity remains the same.

Interactive theories

V1 takes part in dynamic recurrent circuits with extrastriate areas necessary for awareness, possibly as a high-resolution ‘master map’ for binding

Disruption of V1 activity should always impair awareness even if extrastriate areas remain intact.

Prediction: disruption of V1 activity should always impair awareness

Evidence Consistent With Interactive Theories

Blindsight

V1 lesions -> loss of awareness in region of visual field

residual visual ability, e.g., forced choice discrimination above chance

visual information still reaches extrastriate areas (e.g., V3A, Mt, V4/V8, LOC)

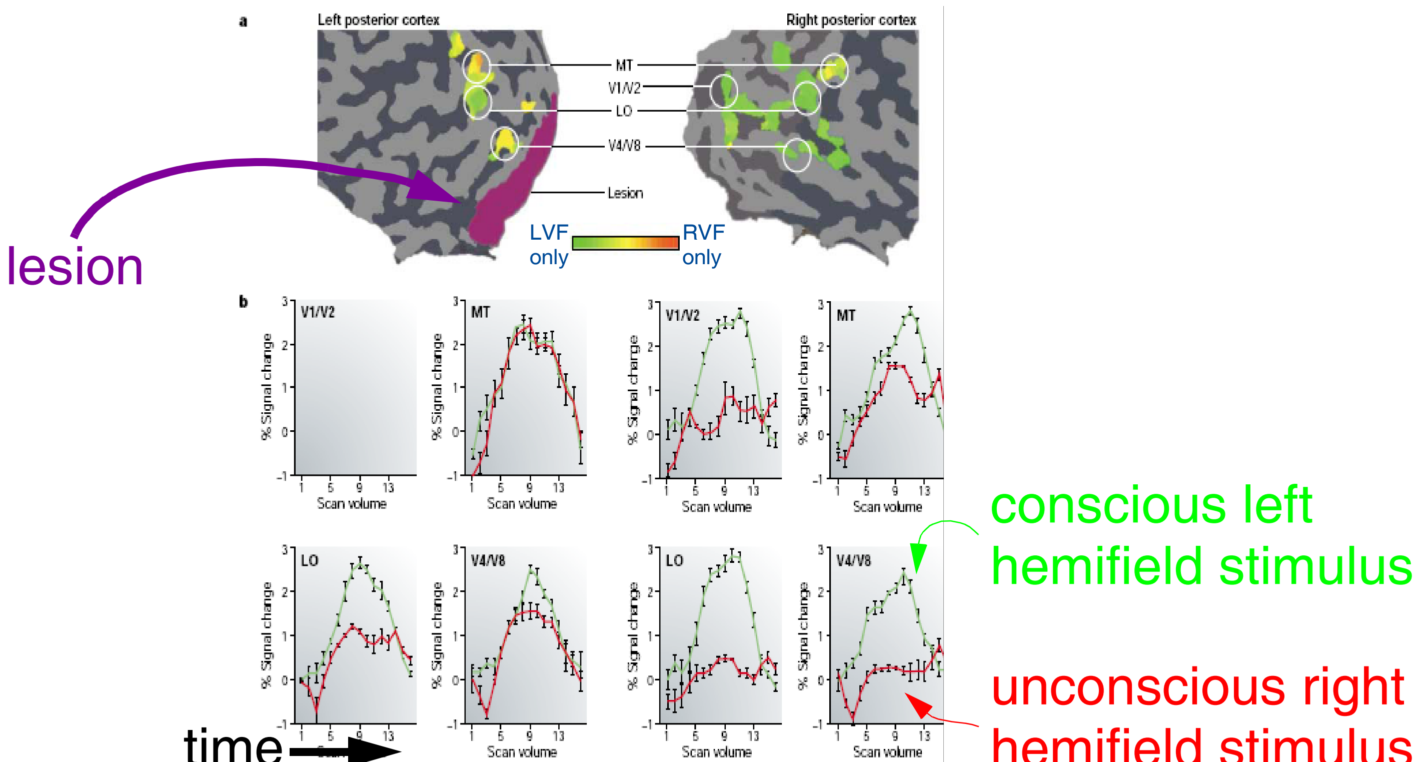


Figure 2 | **Extrastriate activations to objects in the absence of primary visual cortex (V1) and reported awareness.** a | Flattened cortical representation of left and right posterior cortex for blindsight patient GY with the site of the V1 lesion shown in purple. Regions activated by objects presented to either the intact left visual field or impaired right visual field are indicated by a colour scale (green represents left visual field only; red represents right visual field only; yellow represents both fields). Areas MT, V4/V8 and the lateral occipital area (LO) were all activated by stimuli presented to the blind hemifield. b | Time course of functional magnetic resonance imaging activity from visual areas V1/V2, MT, LO and V4/V8 for perceived left hemifield objects (green line) and unperceived right hemifield objects (red line). Reproduced, with permission, from REF. 42 © (2001) Elsevier Science.

Extrastriate lesions are more restricted, less devastating than V1 lesions

- e.g., loss of motion perception with MT lesions
- e.g., loss of color vision with V4/V8 lesions
- e.g., prosopagnosia

Target detection

- monkey study
  - fixation at center
  - make eye movement to location of figure defined by texture/orientation
  - multiunit recording from V1 RF that is either figure or ground on a given trial
- neural activity in V1 is related to perception/ response but occurs late in processing

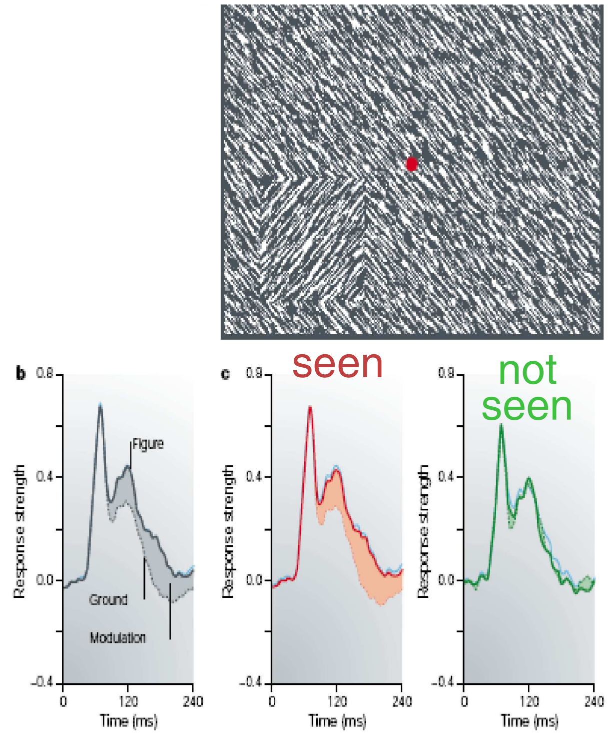


Figure 4 | **Multi-unit activity in primary visual cortex correlates with conscious detection of visual figures on a background. a** | Figure–ground displays were generated using orientation-defined texture. Animals fixated on a central point and were required to saccade to the figure, which could appear in one of three locations. **b** | Average multi-unit responses across the recorded neural population for figure-present trials. Modulation is the difference between the response to figure (thick line) and the response to ground (dashed line) and is shaded. Standard error of the mean is shown by the blue line above the figure response. **c** | Figure and ground responses for 'seen' (red) and 'not seen' (green) figure-present trials. Reproduced, with permission, from *Nature* REF. 75 © (2001) Macmillan Magazines Ltd.

Transcranial Magnetic Stimulation (TMS) studies

- Perception of briefly flashed stimulus disrupted by TMS pulse over V1/V2
  - TMS produces maximal disruption 70-120 ms after stimulus onset, which might be due to disruption of feedback signals from higher areas.
  - TMS of higher areas (MT) is most effective at stimulus onset
- Eliciting motion phosphenes by applying TMS to MT
  - Second TMS pulse applied either to V1 or MT at various times before or after phosphene eliciting pulse
  - Phosphene disrupted by V1 pulse if lag is ~25 msec
- TMS to MT fails to elicit motion phosphene to patient with ipsilesional V1 damage.

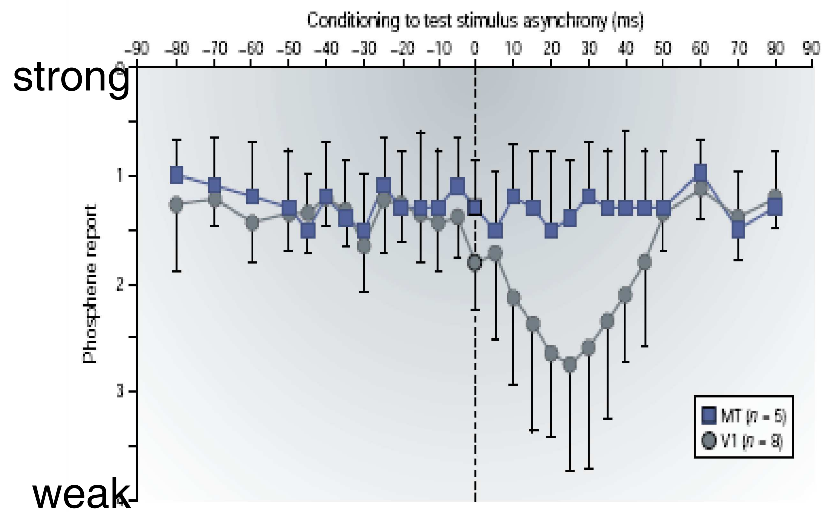


Figure 5 | **Relationship between timing of primary visual cortex disruption and visual awareness.** Transcranial magnetic stimulation (TMS) was applied to area MT to elicit a motion phosphene while a conditioning pulse was applied to either primary visual cortex (V1) or MT at different relative times. The conditioning pulse was set to subthreshold levels for evoking a phosphene. Subjects reported whether they perceived: 1, a clearly moving phosphene; 2, a weakly moving phosphene; 3, a stationary phosphene; or 4, no phosphene. TMS applied over V1 between 5 and 45 ms after TMS over MT disrupted the perception of the phosphene, whereas a conditioning pulse applied to MT had no disruptive effect at any time interval. These findings support the proposal that feedback connections from MT to V1 might be necessary for awareness of motion. Reproduced, with permission, from REF. 125 © (2001) American Association for the Advancement of Science.

Evidence Consistent with Hierarchical Theories

Bistable perception (reversible figures)

Increased activity of extrastriate, parietal, frontal areas increased at time of reported alternation; decreased activity of striate area

Are higher areas directing lower areas to reorganize?

Internally generated visual experiences (hallucinations, dreams, migraines, synesthesia, imagery)

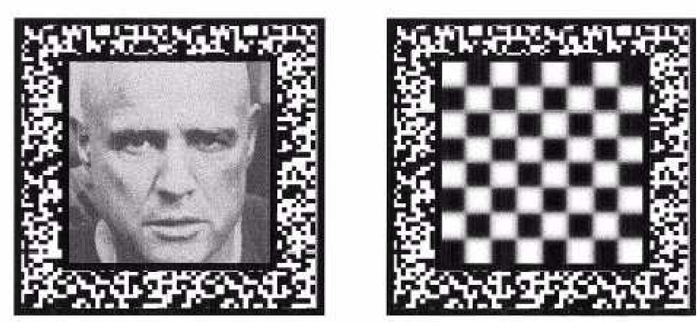
Produce awareness but V1 activity is greatly reduced relative to real-world input.

Stimulation of temporal lobe can elicit hallucinations of people, scenes, objects.

Evidence Consistent With Both Theories

Binocular rivalry

presentation of incompatible images to the two eyes

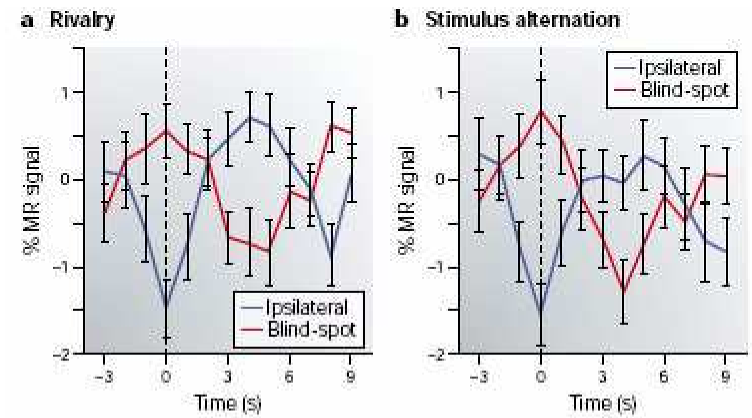


comparison of rivalry vs. stimulus alternation with same statistics

Probe monocular region of V1 corresponding to blind spot (all activity in this region is internally generated)

fMRI modulations during rivalry were as large as those evoked by physical alternation
-> rivalry might be resolved in V1

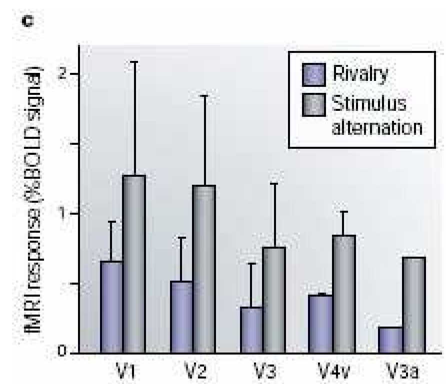
more consistent with interactive view



Rivalry with low and high contrast gratings

effects of rivalry are no stronger in higher visual areas

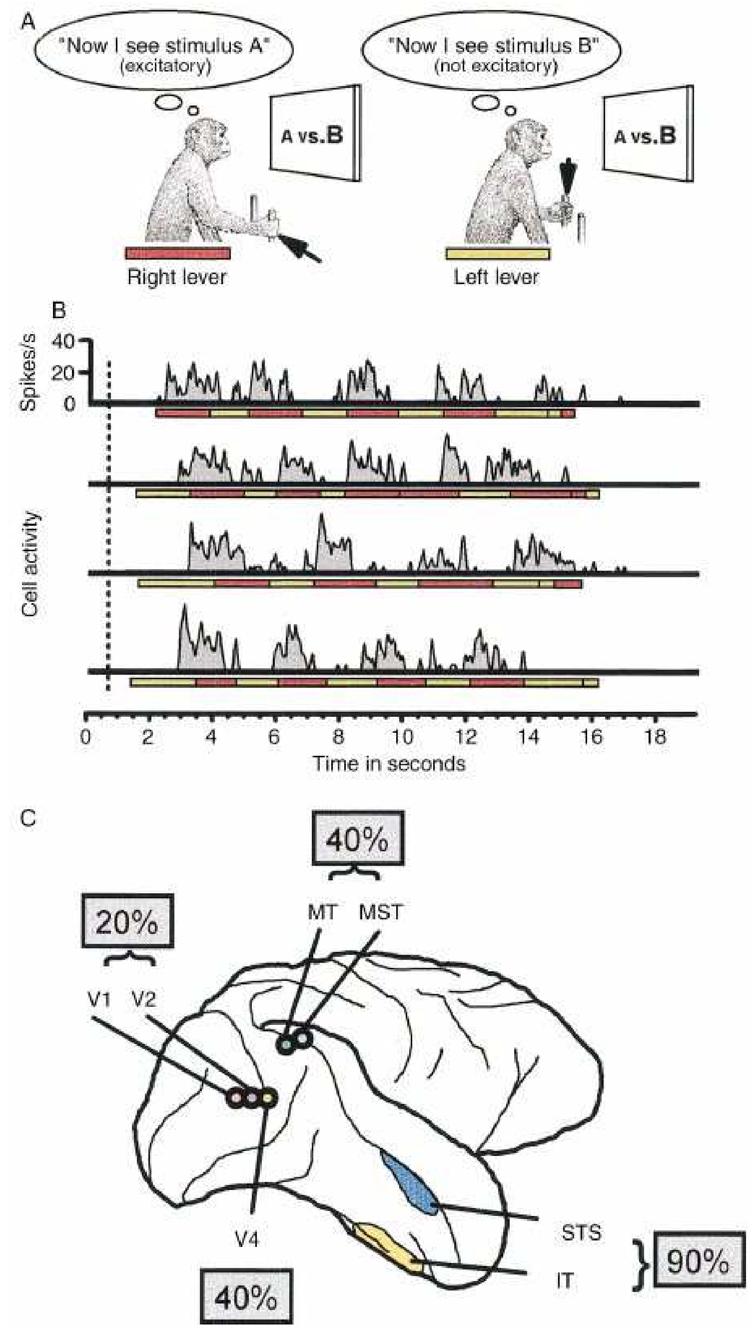
also more consistent with interactive view



These human studies suggest that neural activity in V1 linked tightly to perception.

But monkey data...

But monkey data suggests higher areas more tightly linked to perception...



Conclusions

V1 is the only single cortical visual area necessary for awareness.

V1 is not sufficient for awareness

e.g., V1 response to gratings whose frequency is too high to be perceived

Late component of V1 activity reflects top-down feedback

Data are probably more consistent with interactive theory.

Strength of qualia depend on V1

e.g., adaptation effects: adaptation to orientation, color, motion -> decrease in V1 activity

e.g., internally generated visual experiences lead to some V1 activity, but not as much as with real-world input

Defining Consciousness: A Psychological Perspective (Allport, 1977)

Criteria for the presence or absence of awareness of X

e.g., X = black ink on page, letters, words, commands

1. Potential action

X can directly guide or control choice of actions

However, many types of actions: speech, reaching for object, pupil dilation

2. Memory

Individual must be able to overtly recall or recognize X later

3. Self-evaluation

Individual must be able to indicate confidence in awareness of X, as well as lack of confidence on occasion.

Indication can be verbal or nonverbal (betting, willingness to act on)