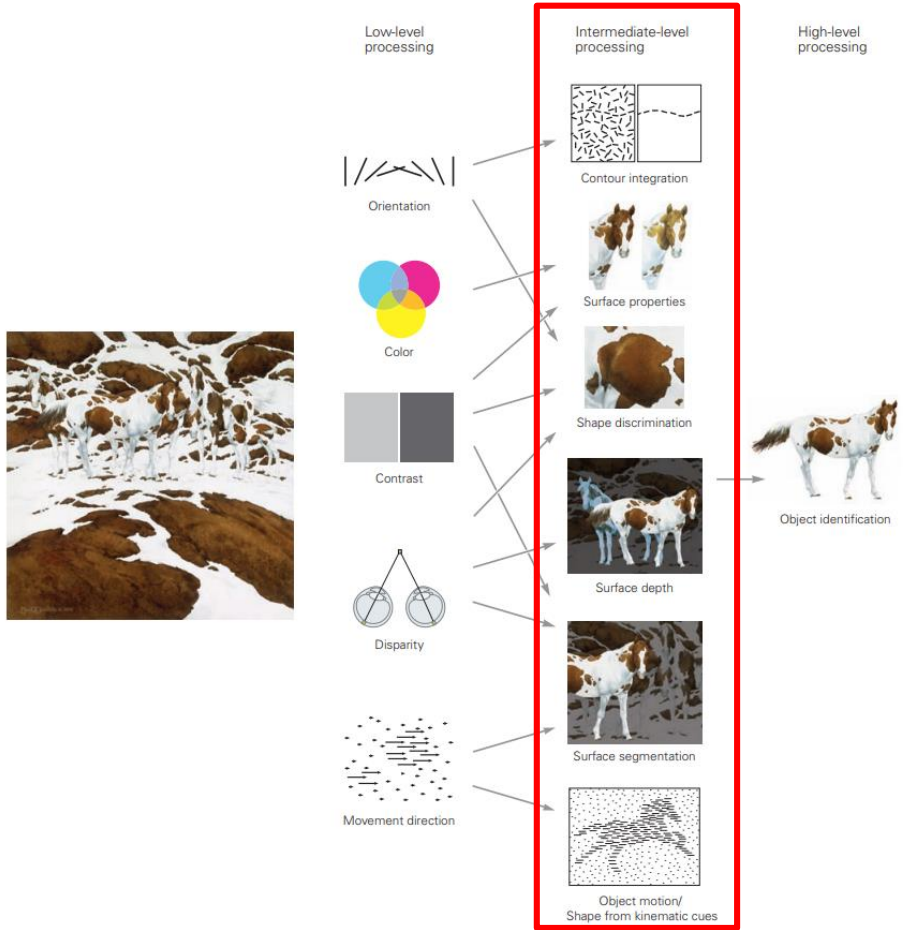
Vision II

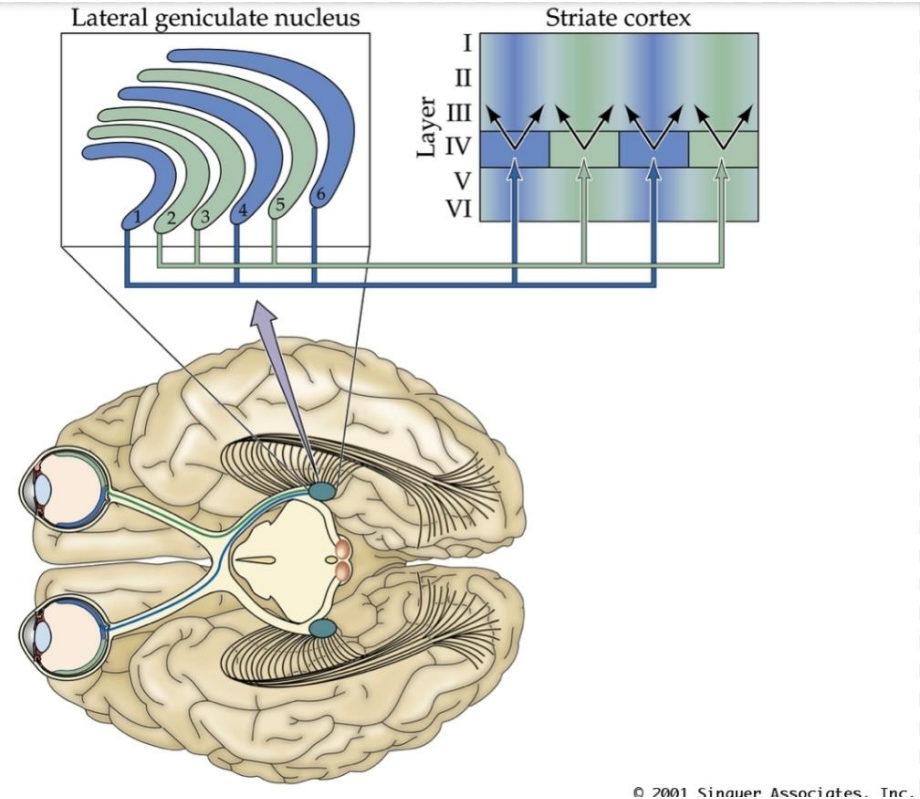
Visual Cortex and More
3-4-19

Visual processing in the nervous system



The intermediate level of image processing occurs in the visual cortex and involves organizing the elements of orientation, color, contrast, motion, etc. detected by the retina into shapes, contours, surface properties, and object motion, and other spatial relationships.

V1 ocular dominance columns

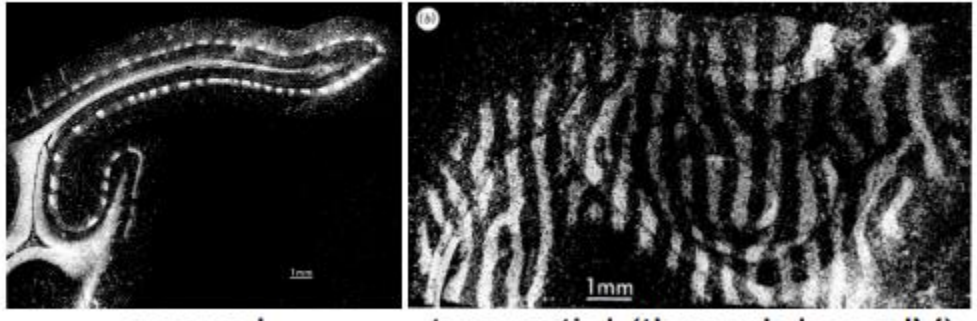


- The visual cortex is divided into six layers.
- Axons from the LGN synapse first synapse in **layer IV** of the primary visual cortex (**V1**). Both the LGN and primary visual cortex maintain separation of signals from each eye.
- Each column in primary visual cortex processes signal from one eye.
- Ocular dominance columns are only observed in layer IV; the other layers are binocular (process information from both eyes).

Monocular Deprivation during critical period

- Monocular deprivation during critical period disrupts the formation of ocular dominance columns.
- Critical period= time during development when the brain is most “plastic,” or adaptable, to environmental influence.
- Suturing one eye of a monkey during critical period results in reduction of ocular dominance column in that eye.

Normal adult



coronal tangential (through layer IV)

After monocular deprivation

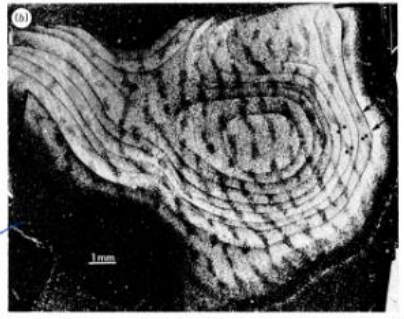


FIGURE 32. Transneuronal autoradiography of left occipital lobe of macaque monkey whose right eye was sutured closed at 2 weeks, and studied at 18 months. Left (normal) eye injected with tritiated proline-fucose mixture 2 weeks before brain was sectioned. (a) Section tangential to layer IVc, dark field, as in figure 23. Note expansion of labelled columns and shrinkage of the gaps. The serial reconstruction, (b), was made from a number of sections parallel to a and including a. The positions of six lesions, determined from neighbouring sections, are shown near the right border. These lesions were made during the electrical recordings, in two penetrations (arrows), at points of eye transition. Note how each lesion falls on a column border. (From Hubel *et al.* 1977.)

Primary visual cortex is also organized into light orientation columns.

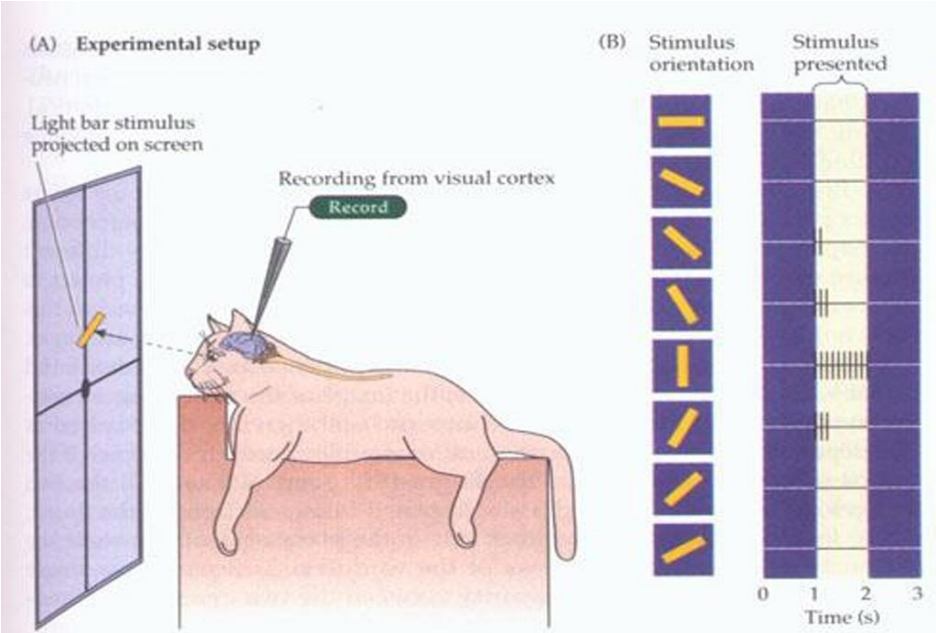
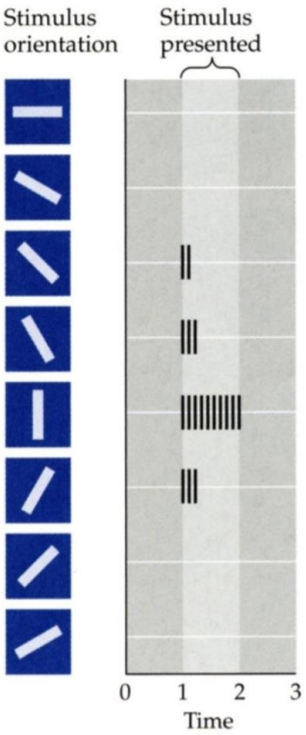


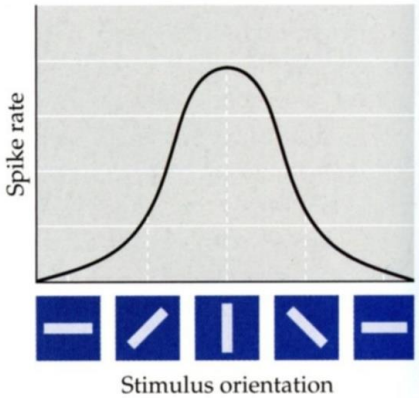
Figure 11.9 Neurons in the visual cortex respond selectively to oriented edges. (A) An anesthetized animal is fitted with contact lenses to focus the eyes on a screen, where images can be projected; an extracellualr electrode records the responses of neurons in the visual cortex. (B) Neurons in visual cortex typically respond vigorously to a bar of light oriented at a particular angle and weakly—or not at all—to other orientations.

- Experimental setup:
- In an anesthetized animal, place an electrode in V1 to record electrical activity in extracellular space of visual cortex.
- Present anesthetized animals with bars of light in with different orientation, observe electrical activity.

Hubel and Wiesel

V1 orientation columns





- Neurons in particular areas, or columns, of V1 are strongly activated by a bar of light in one orientation and are weakly activated or not activated at all by other orientations of light.
- Unlike ocular dominance columns, V1 orientation columns **span multiple layers** of cortex.

V1 Hypercolumns

- Together, ocular dominance columns and orientation columns form **hypercolumns.**
- One hypercolumn includes one left ocular dominance column, one right ocular dominance column, and the orientation columns associated with them.

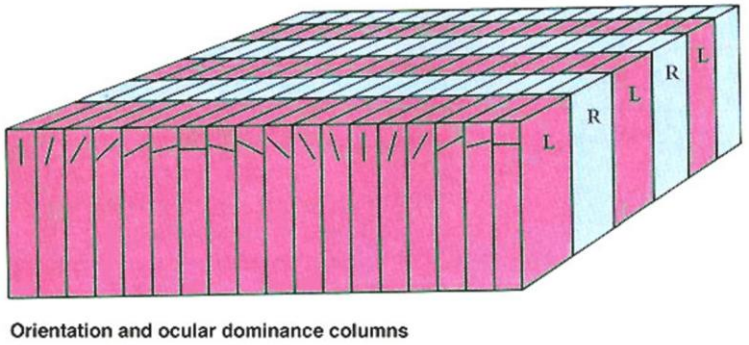
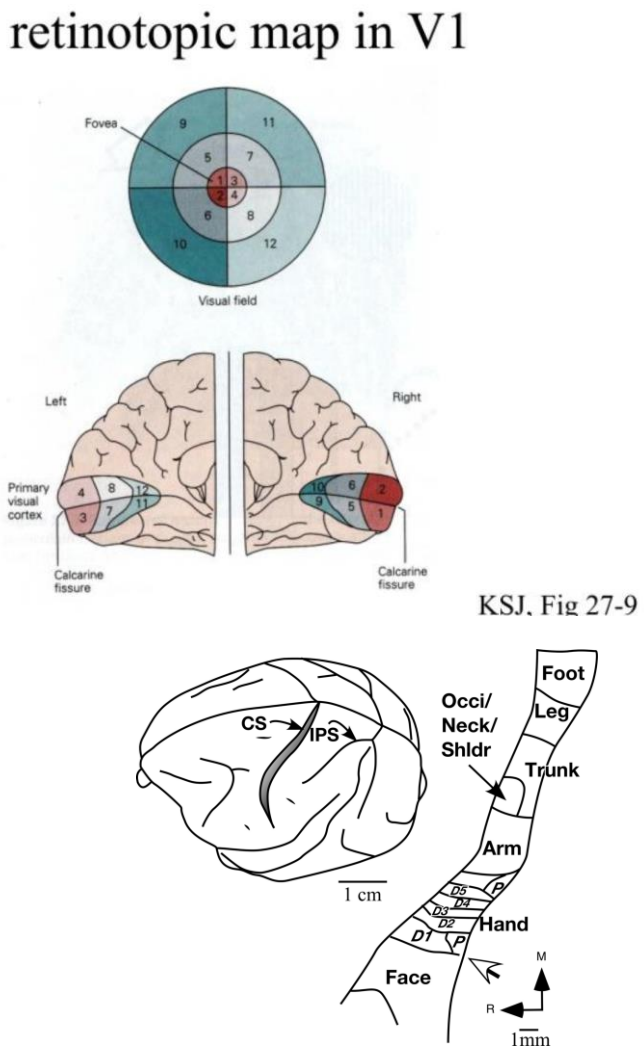


Figure 23. The ice-cube model of the cortex. It illustrates how the cortex is divided, at the same time, into two kinds of slabs, one set of ocular dominance (left and right) and one set for orientation. The model should not be taken literally: Neither set is as regular as this, and the orientation slabs especially are far from parallel or straight.

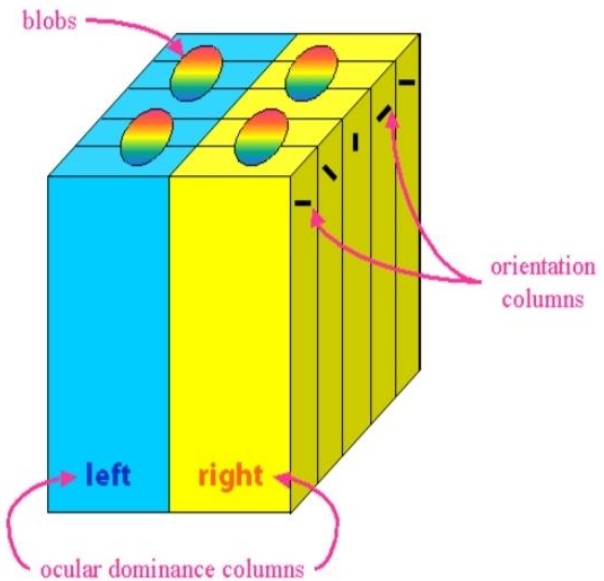
Retinotopy

- One hypercolumn processes information from one small section of the retina, and a neighboring hypercolumn processes a neighboring section of retina. This organization is referred to as **retinotopy**, and is also seen in the LGN.
- This kind of organization is a theme within the nervous system and also observed in somatosensory cortex. In S1, this is referred to as **somatotopy**.

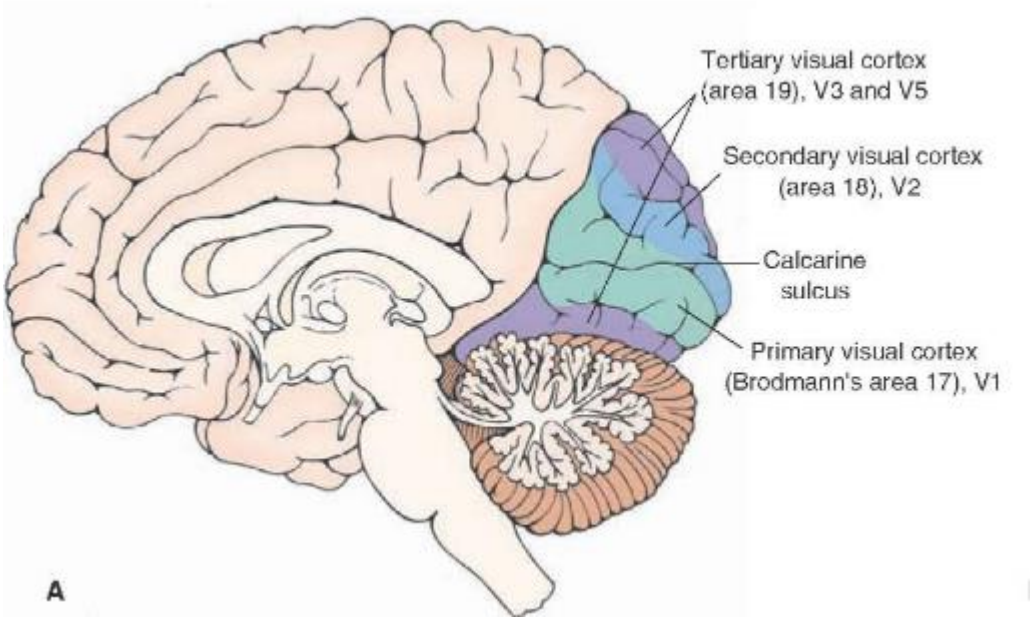


V1 cytochrome oxidase blobs

- In layers 2,3,4.
- not orientation selective.
- color sensitive.

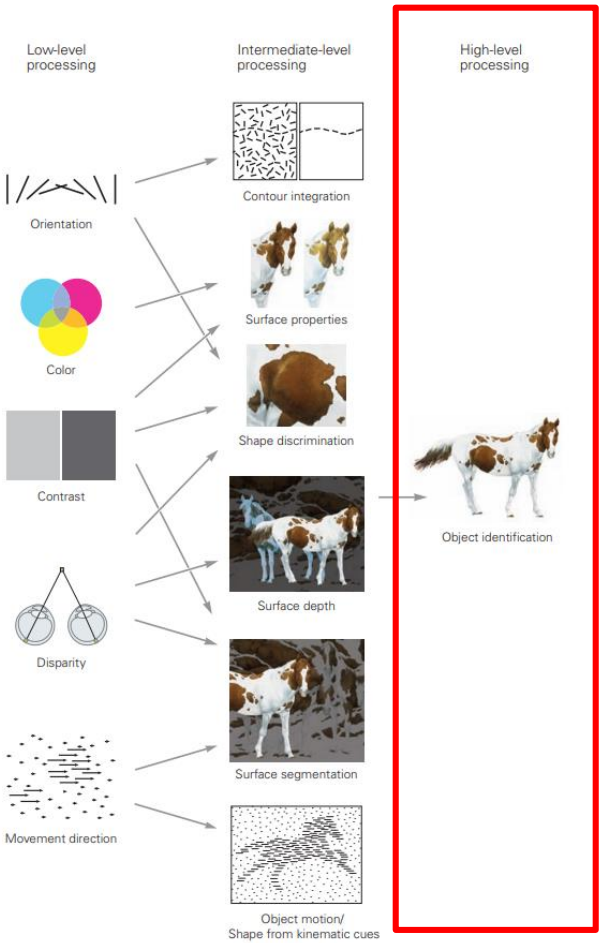


The visual cortex



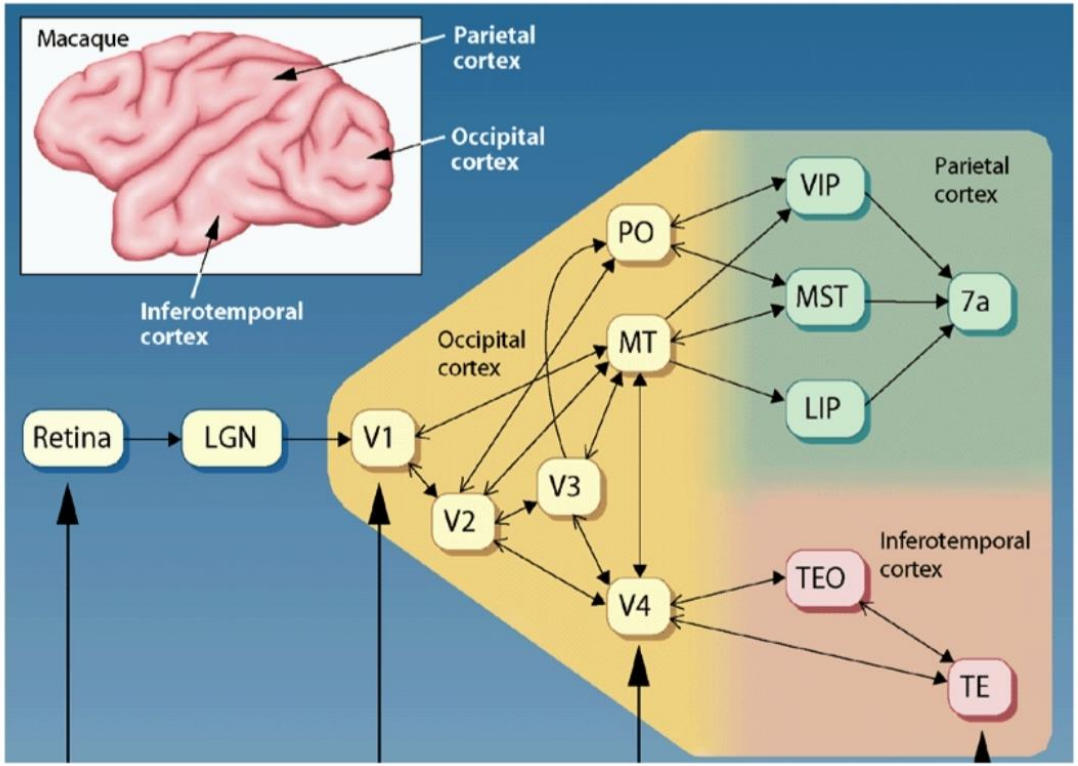
- Image processing in the visual cortex becomes more complicated at higher levels (V2, V3, etc.)
- The exact roles and properties of V2 and above are not as clear as those of V1, are a matter of debate and research.

High level processing



High level processing involves other brain areas and cognition processes that affect our vision.

Visual cortex and beyond



- Visual perception of the world around us requires other cognition processes in other areas of the brain.
- What do we mean by “perception”?

What do we mean by “visual perception”?

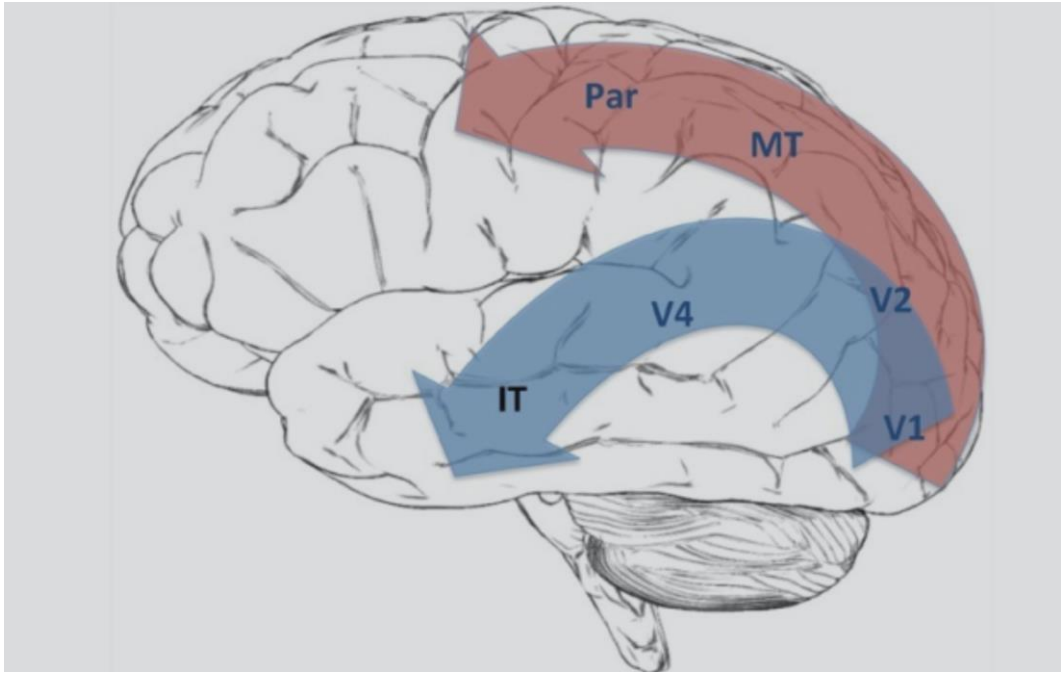
“The term ‘perception’ is being used here, not in the broad sense of any processing of sensory input, but in the more restricted sense of assigning meaning and significance to external objects and events. This use...tends to be identified with one's phenomenological experience of the world.”

-Melvyn A. Goodale

Knowing the function of other areas of the brain, can you imagine the roles they may play in visual perception?

- Prefrontal cortex- decision making
- Parietal lobe- somatosensation, peripersonal space (the space around our bodies, how we occupy that space).
- Hippocampus- memory
- Amygdala- emotion

Dorsal vs. ventral pathways: two theories



- Dorsal pathway originates in V1, goes dorsally to parietal cortex.
- Ventral pathway originates in V1, goes ventrally to temporal cortex.
- Two theories on function of pathways:

1. Ventral processes “what” (object vision), dorsal processes “where” (spatial vision)
2. Ventral processes representation of objects in space, dorsal processes visual control of actions directed towards objects in space.

Visual perception is influenced by a lot of factors, including:

- Attention
- Past experiences/familiarity with objects
- Context- surrounding visual scene

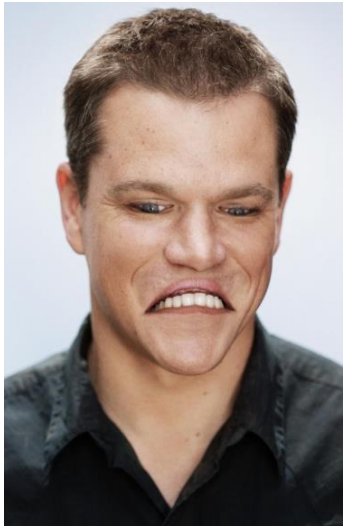
Attention shapes vision

https://youtu.be/vJG698U2Mvo

Past experiences shape vision

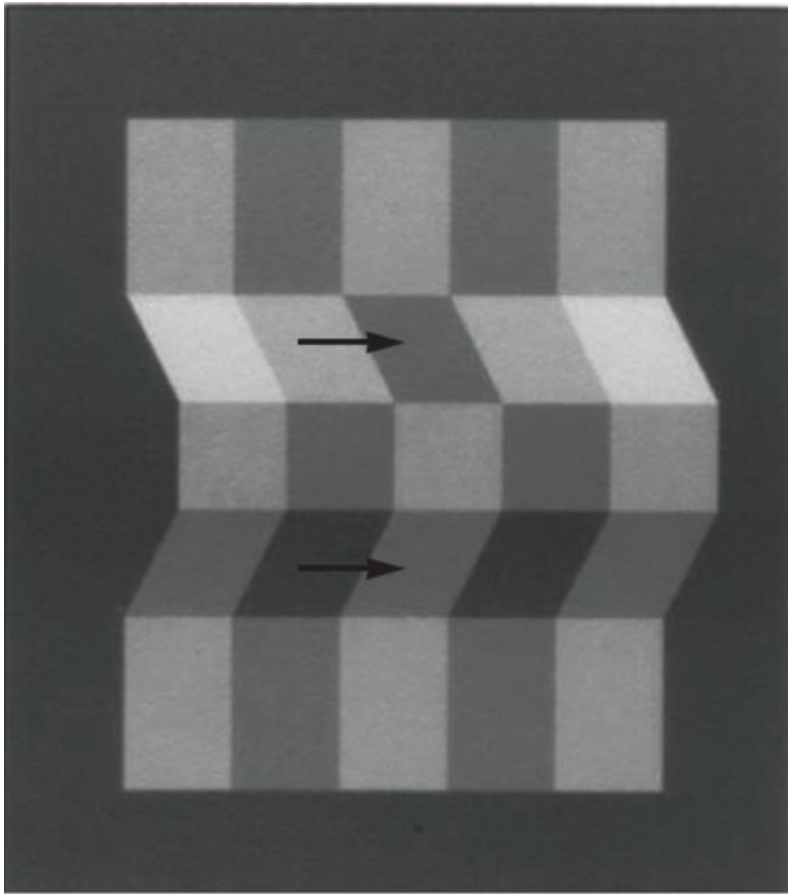
The Thatcher Effect:

Past experiences shape vision



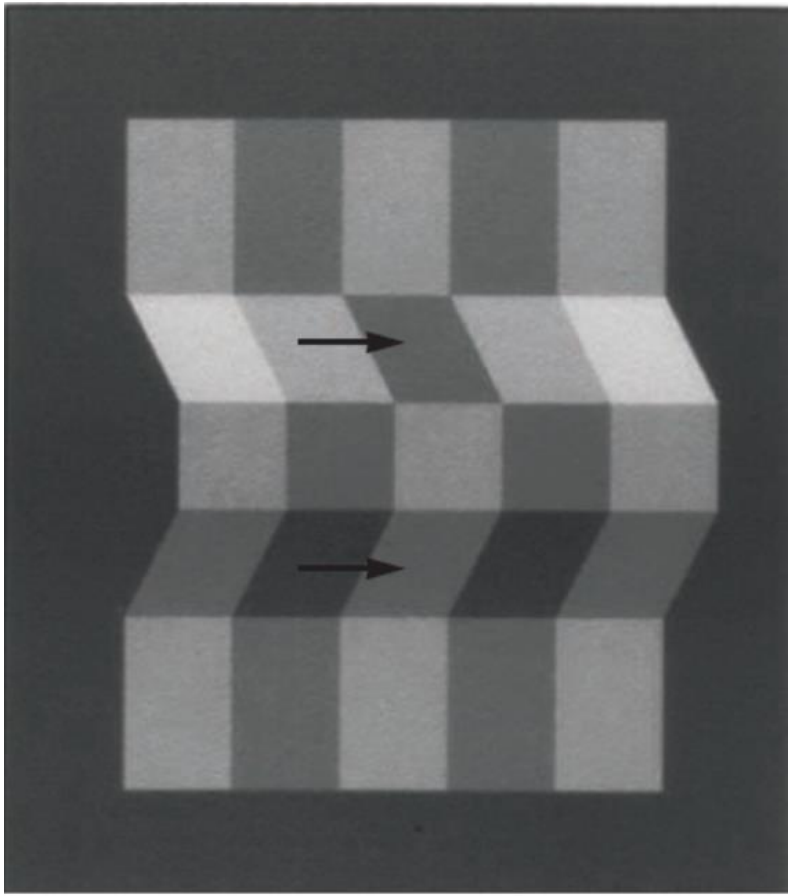
- Thatcher effect: difficulty in detection of strange facial features when face is turned upside down.
- Our brain is trained to visualize faces right side up- when faces are turned upside down, but components such as the eye and mouth are kept right side up, our brain perceives no problem with this. Yet, when the image is right side up, and the eyes/mouth are upside down, our brain perceives a huge problem.
- The brain makes assumptions on what we already know.

Past experiences and context shape vision



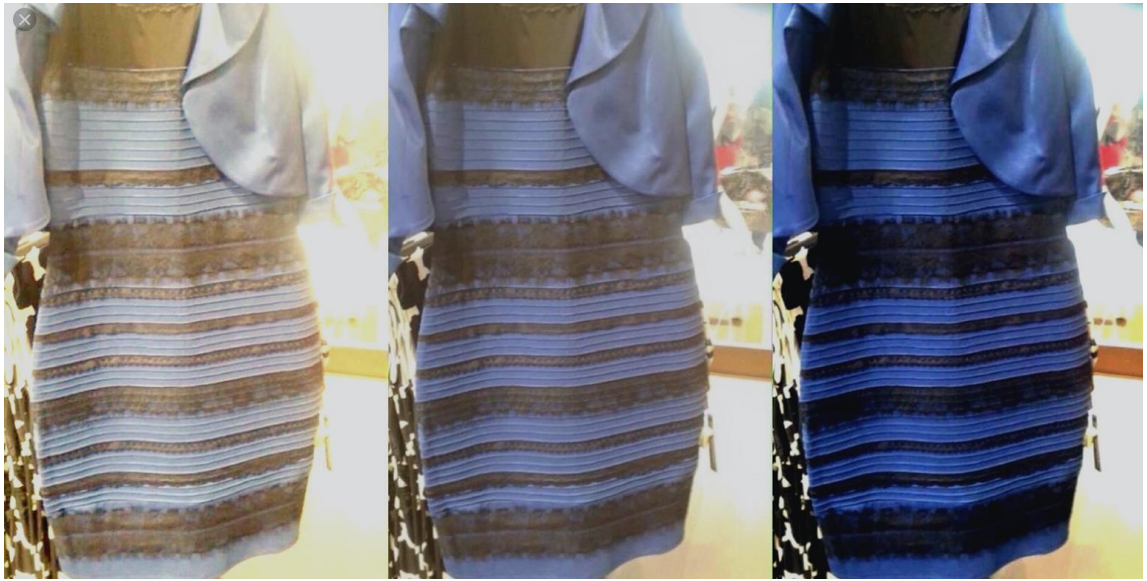
- Are the boxes in line with the top arrow darker or lighter than those in line with the bottom arrow?

Past experiences and context shape vision



- Perception of brightness is influenced by 3D shape **(context)**.
- The apparent brightness of the squares in line with the bottom arrow is darker than those in line with the top arrow.
- The actual brightness of each line of squares is the same- our visual systems expect that images facing illumination from the top (i.e. the sun) will yield a brighter image than those images facing the bottom **(past experiences)**.

Past experiences and context shape vision

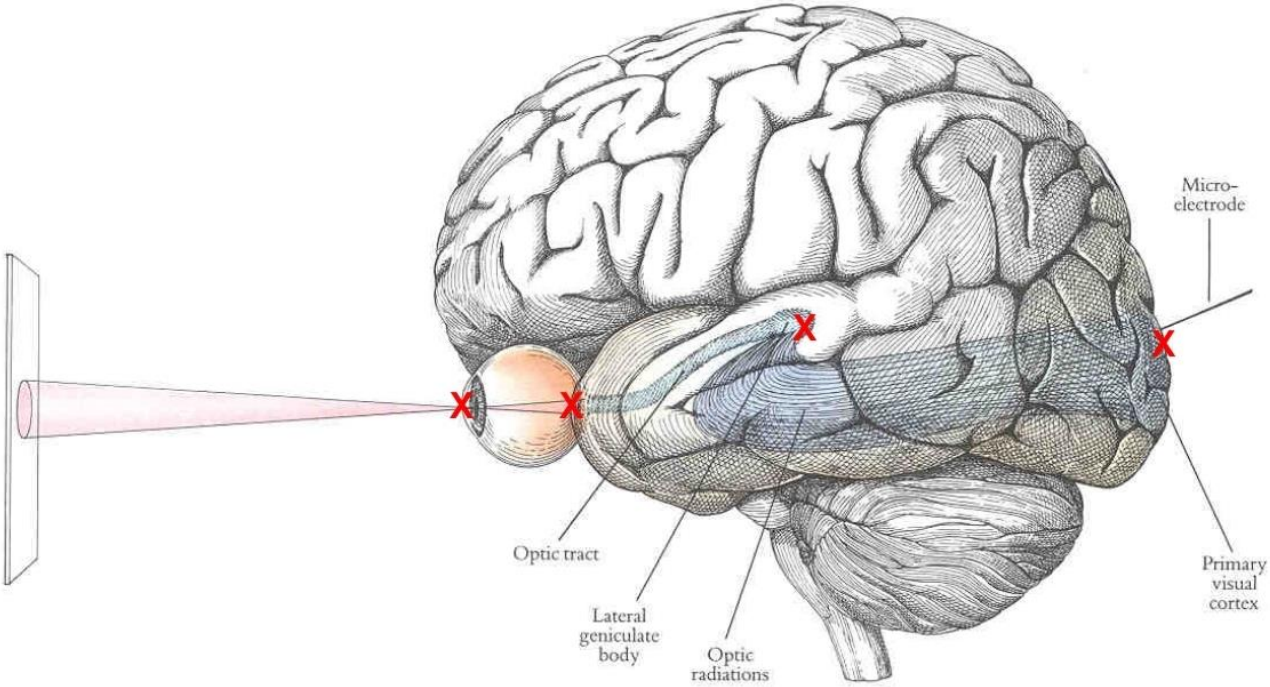


- The perception of the dress color is influenced by our perception of the lighting conditions **(context)**.
- The lighting conditions in this picture are difficult to see- different brains make different assumptions about the lighting conditions based on what they most frequently encounter **(past experiences)**.
- If one perceives the dress to be in a shadow or natural daylight, they assume the dress to be white and gold, the brain subtracts out the overrepresentation of dark colors.
- See below link for more details if you're interested!
- https://slate.com/technology/2017/04/heres-why-people-saw-the-dress-differently.html

Past experiences and context shape vision

- The contrast and colors shape our perception of what we see in the picture **(context)**.
- **Past experiences** may also dictate what we perceive the picture to be.

So, what does it mean to be visually impaired?



Cortical Visual Impairment (CVI)

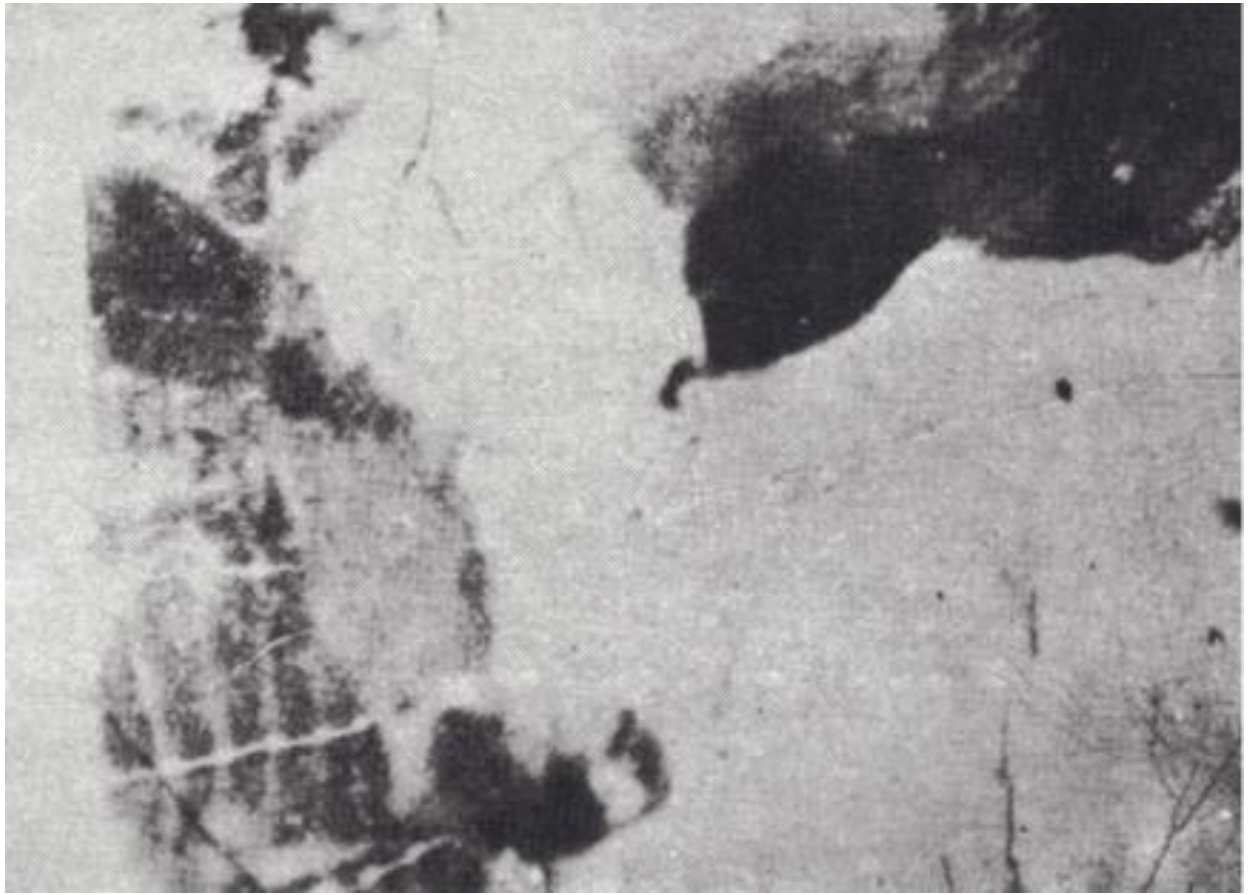
- Visual impairment due to brain injury.
- A very broad umbrella term- “brain injury” can refer to a lot of things:
  - Stroke, traumatic brain injury, lesions, etc.
  - CVI found in children is often due to complications with pregnancy or comorbid with other illnesses of the brain.
- The retina functions, but the cortex cannot interpret retinal signals.

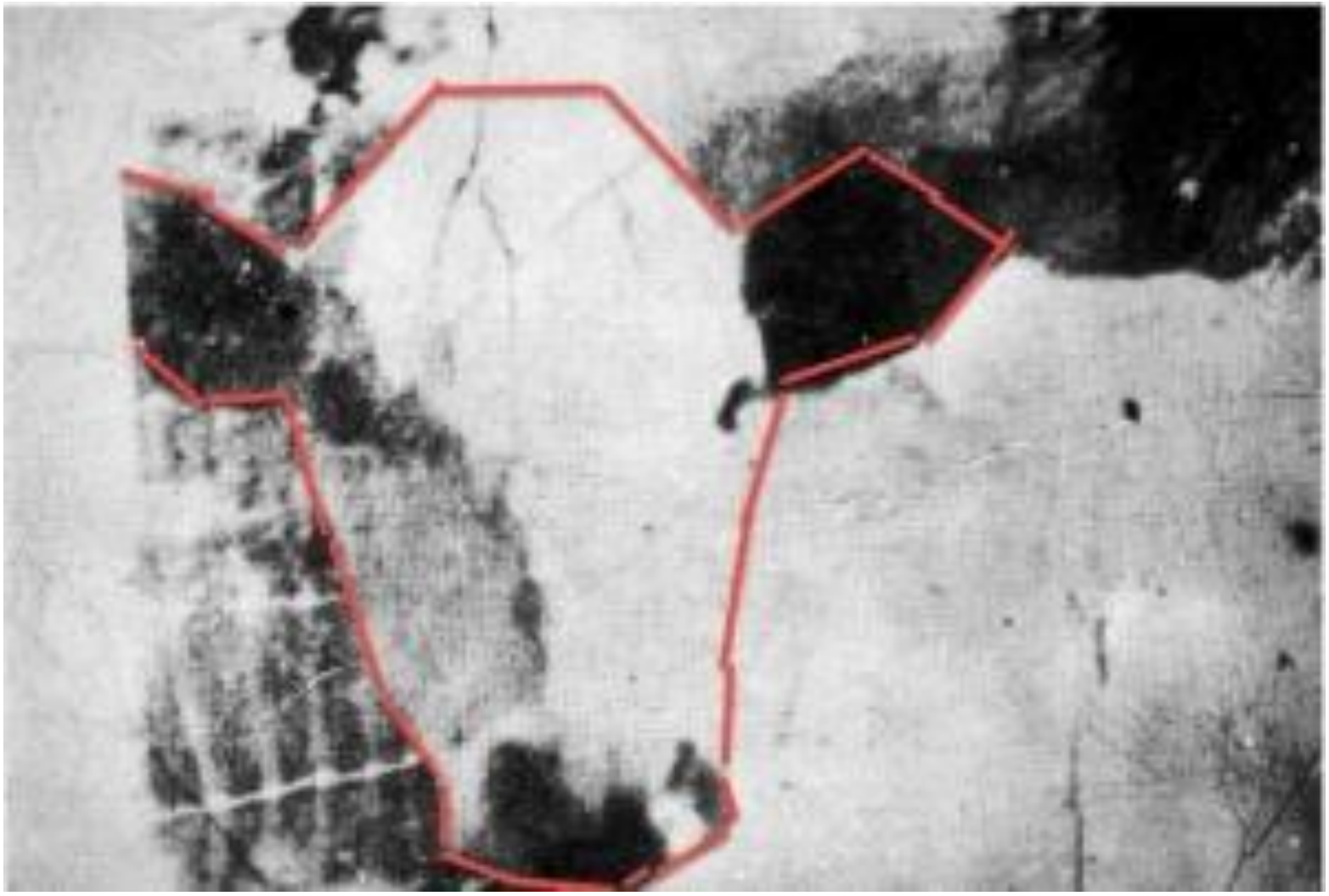
What is it like to have CVI: What is pictured here?

What is it like to have CVI: What is pictured here?

- We can detect the lines, shading, contours, colors… but not the thing itself.
- Our brains search for a visual memory to match with this picture.

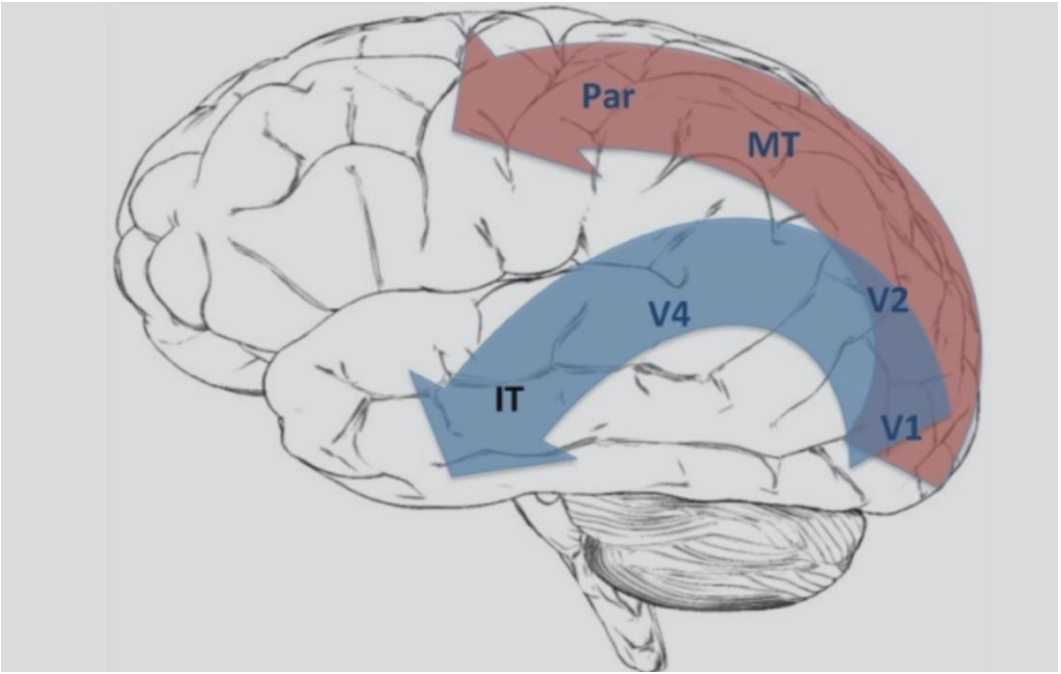
What is this picture?- different orientation





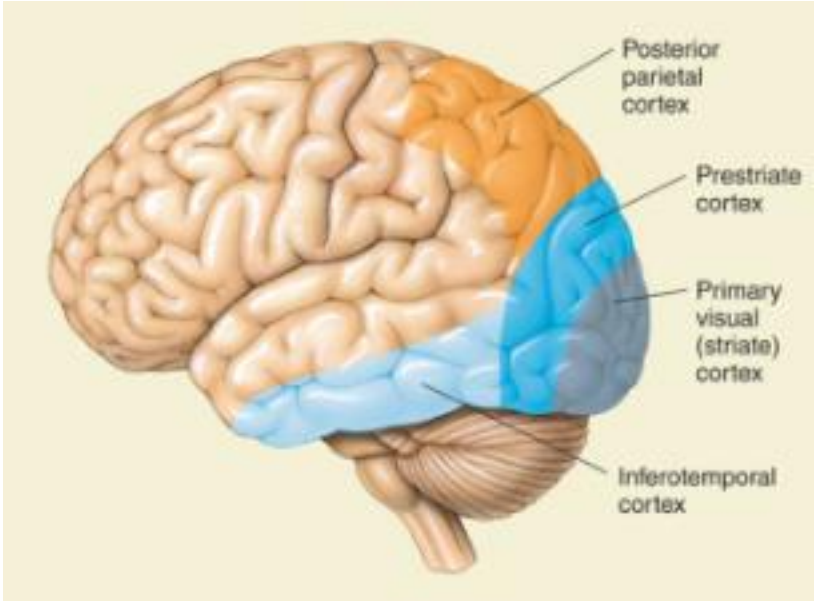
Damage to the ventral stream

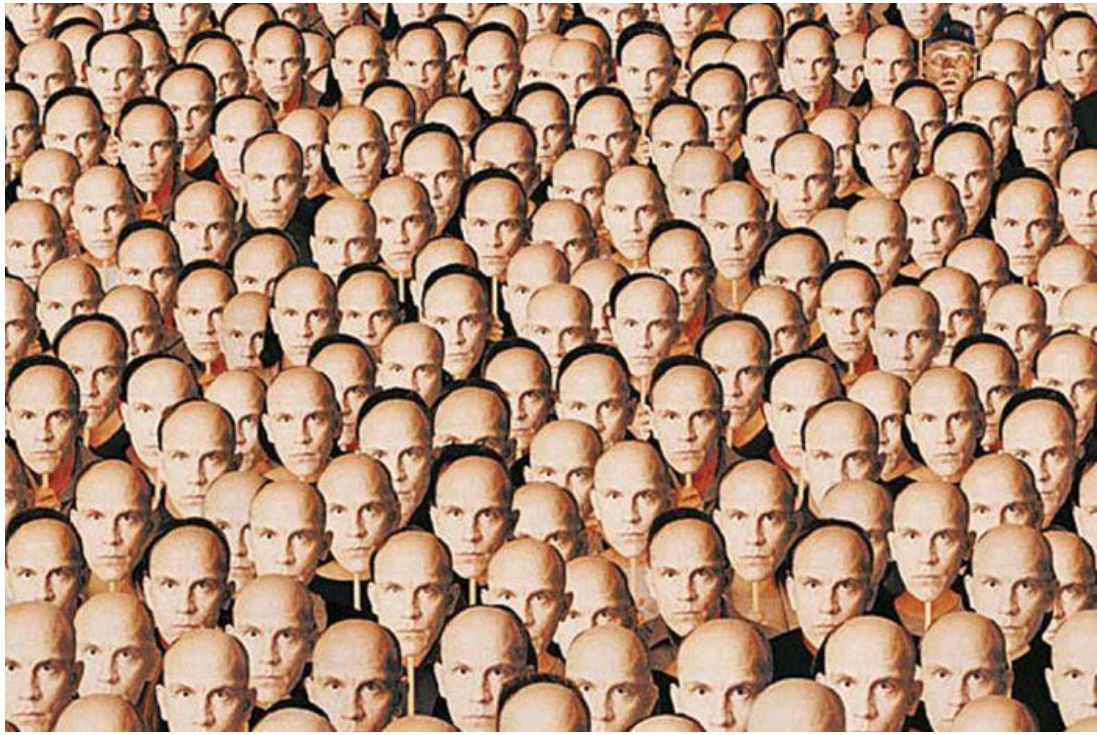
- Impaired recognition of objects, shapes, letters.
- Impaired orientation.
- Difficulty in route finding.



Inferotemporal cortex

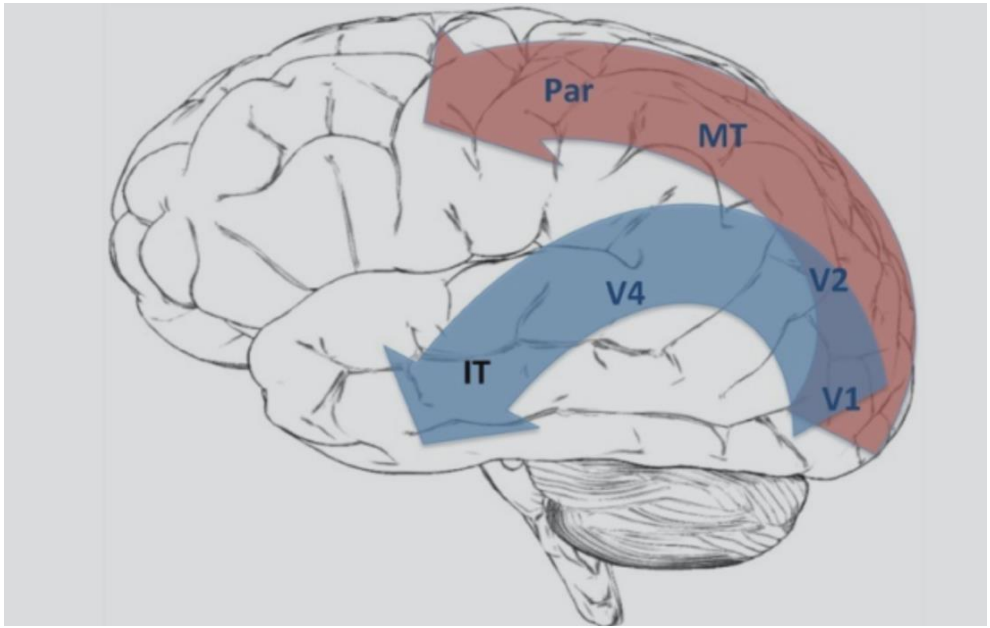
- Object and facial recognition are computed primarily in IT cortex.
- Lesions here result in **prosopagnosia**: Inability to recognize faces.





Damage to the dorsal stream

- Balint's syndrome:
  - Impaired visual guidance of movement (optic ataxia)
  - Inability to see more than one item at once (simultagnosia)
  - Inability to move eyes to a target (oculomotor apraxia)
- Visual search, ability to interpret complex visual scenes
  - Background vs foreground
  - Surrounding details
  - Finding a particular item within a complex visual scene.



Medial temporal area

- Lesions of area MT result in loss of motion detection.
- People who have MT lesions do not see car movement. A moving car looks stationary.