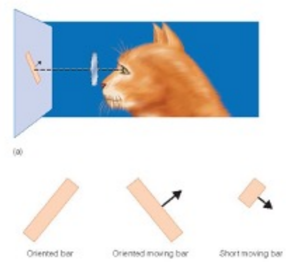
Brains!

Module 6, Day 2

Representation in the Brain

- Hubel & Wiesel (1960s): representation in one neuron
  - https://www.youtube.com/watch?v=y_l4kQ5wjiw
  - https://www.youtube.com/watch?v=Yoo4GWiAx94



- Feature detectors: neurons that respond best to a specific stimulus
  - Such as orientation, movement and length
- What happens when we look at a tree?

This tree is represented in the brain by the combined response of many thousands of feature detector neurons

They found out that each neuron in the visual area of the cortex respond to a specific type of stimulation presented to a small area of the retina

Each of the thousands of neurons that fire when we look at a tree, fire to different features of a tree

A tree is represented by the combined response of many feature detectors

Video1: 6.5 minutes (play just the first 3 minutes)

Video2: 1 minute

Video1: play second part with the tree (minute 3-4:30)

Neurons that respond to complex stimuli

- Charles Gross performed an experiment in which he recorded from single neurons in the monkey's temporal lobe
  - Found a neuron that refused to respond to any of their "simple" stimuli of lines, circles squares
  - One of the experimenters, by mistake, pointed at something in the room, casting a shadow of his hand on the screen
  - The neuron fired
  - The neuron responded to a handlike shape with fingers pointing up
  - Also found neurons that only responded to faces
  - Neurons in the visual cortex respond to simple shapes, whereas neurons in the temporal lobe response to more complex geometrical stimuli

Much of the early discoveries in visual processing in the brain that did not involve human patients involved non-human animals. With the advances in neuroimaging, that changed to some degree.

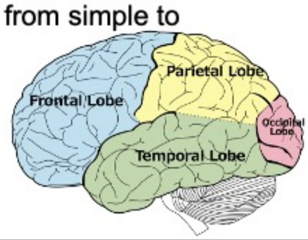
Each experiment lasted 3-4 days
Why? Had to search and search for what the response was – didn't yet have a clear idea about what that brain area was doing wrt vision.

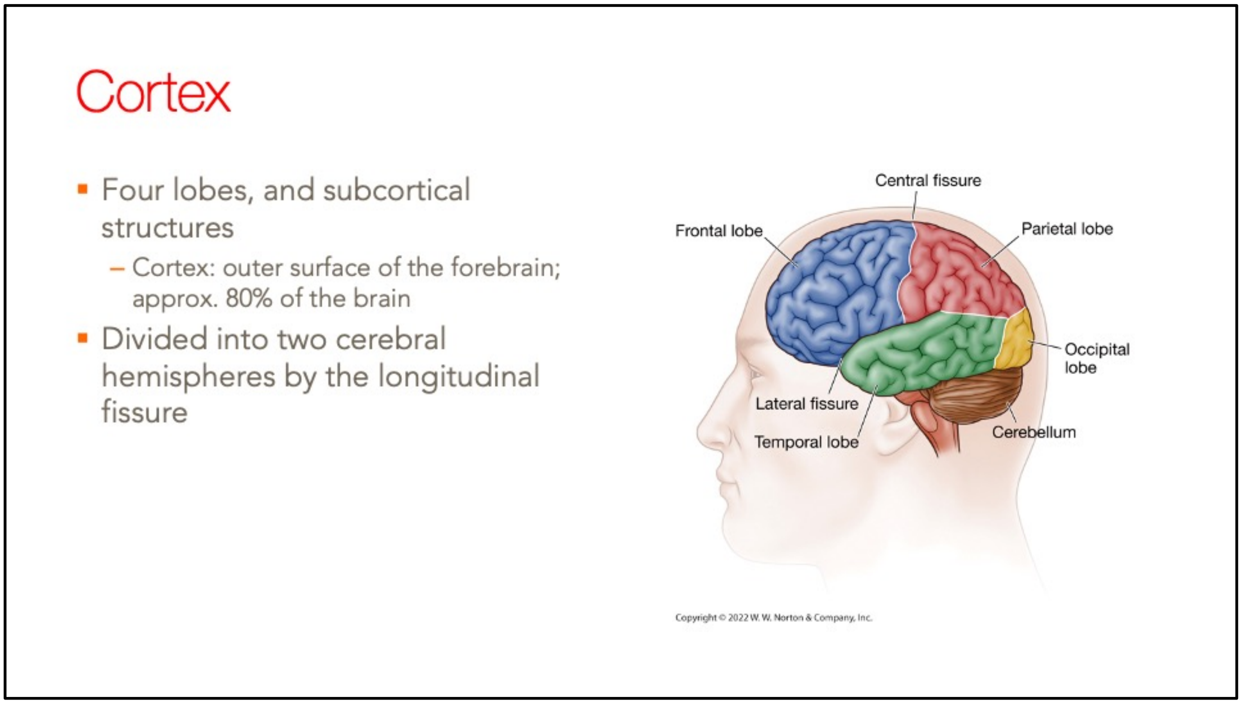
Hierarchical Processing

When we perceive different objects, we do so in a specific order that moves from lower to higher levels of processing in the brain

- Neurons that respond to simple stimuli send their axons to higher levels of the visual system
- These neurons in turn send their axons to higher areas combining and interacting further

Hierarchical Processing: Ascension from lower to higher levels in the brain corresponds to perceiving objects that move from simple to higher levels of complexity





Forebrain: comprises most of the parts of the brain that are visible from the outer surface, including:

- The **cortex**, a thin convoluted sheet of tissue, 3 mm thick, which would cover approximately 300 sq. in. if fully stretched out (20% larger than the area covered by an extra-large pizza)
- The **longitudinal fissure** runs from the front of the brain to the back and separates the left and right cerebral hemispheres.

FIGURE 2.2 THE LOBES OF THE HUMAN BRAIN
Panel A (pictured above) identifies the various lobes and some of the brain's prominent features. Actual brains, however, are uniformly colored. The four lobes of the forebrain surround (and hide from view) the midbrain and most of the hindbrain. (The cerebellum is the only part of the hindbrain that is visible in the figure, and, in fact, the temporal lobe has been pushed upward a bit in the left panel to make the cerebellum more visible.) This side view shows the left cerebral hemisphere; the structures on the right side of the brain are similar. However the two halves of the brain have somewhat

different functions, and so the results of brain injury depend on which half is damaged. The symptoms of Capgras syndrome, for example, result from damage to specific sites on the right side of the frontal and temporal lobes.

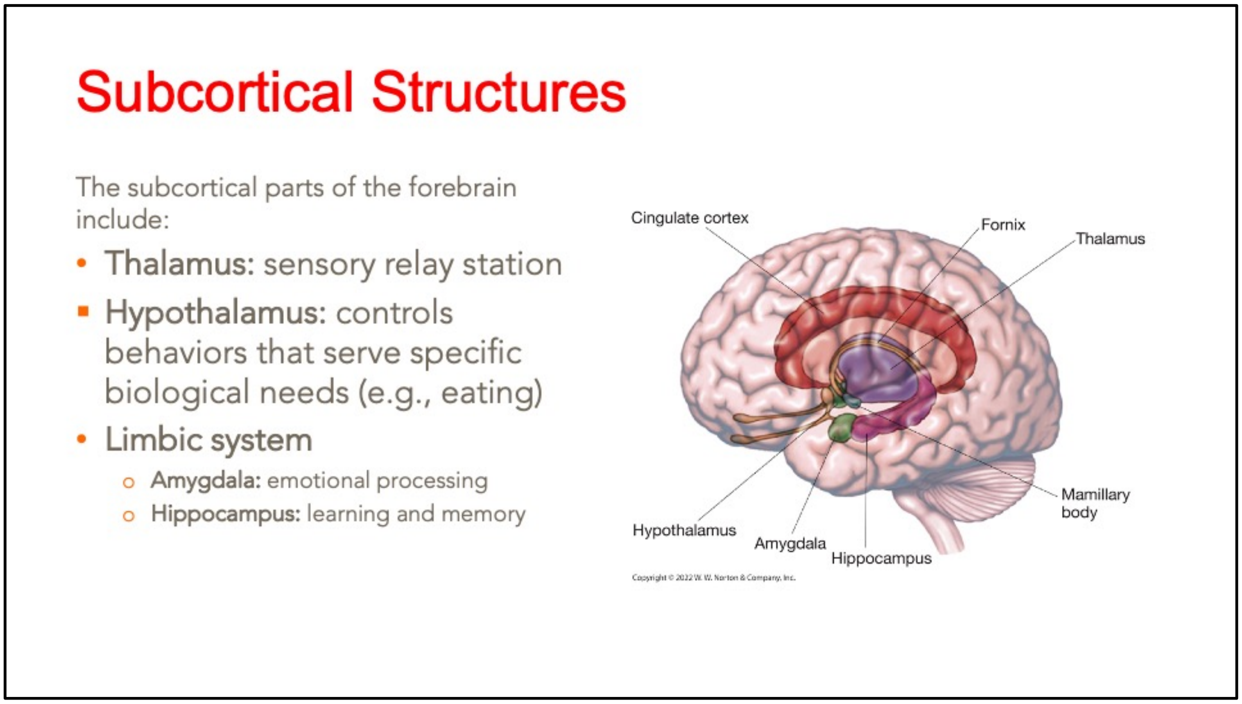


FIGURE 2.5 THE LIMBIC SYSTEM AND THE HIPPOCAMPUS
Color is used in this drawing to help you visualize the arrangement of these brain structures. Imagine that the cortex is semitransparent, allowing you to look into the brain to see the (subcortical) structures highlighted here. The limbic system includes a number of subcortical structures that play a crucial role in learning and memory and in emotional processing.

The **thalamus** acts as a relay station for nearly all the sensory information going to the cortex.

The **hypothalamus**, a structure that plays a crucial role in controlling behaviors that serve specific biological needs—behaviors that include eating, drinking, and sexual activity—lies beneath the thalamus.

Surrounding the thalamus and hypothalamus is another set of interconnected structures that together form the **limbic system** (see Figure 2.5).

Included here is the **amygdala** (plural: amygdalae) and close by is the **hippocampus** (plural: hippocampi), both located underneath the cortex in the temporal lobe.

The hippocampus is involved in learning and memory, and the patient H.M., discussed in Chapter 1, developed his profound amnesia after surgeons removed these structures.

The amygdala is involved in emotional processing, as we saw in the example with Capgras syndrome, where lack of activity in this area was linked to a lack of emotional response to seeing familiar people.

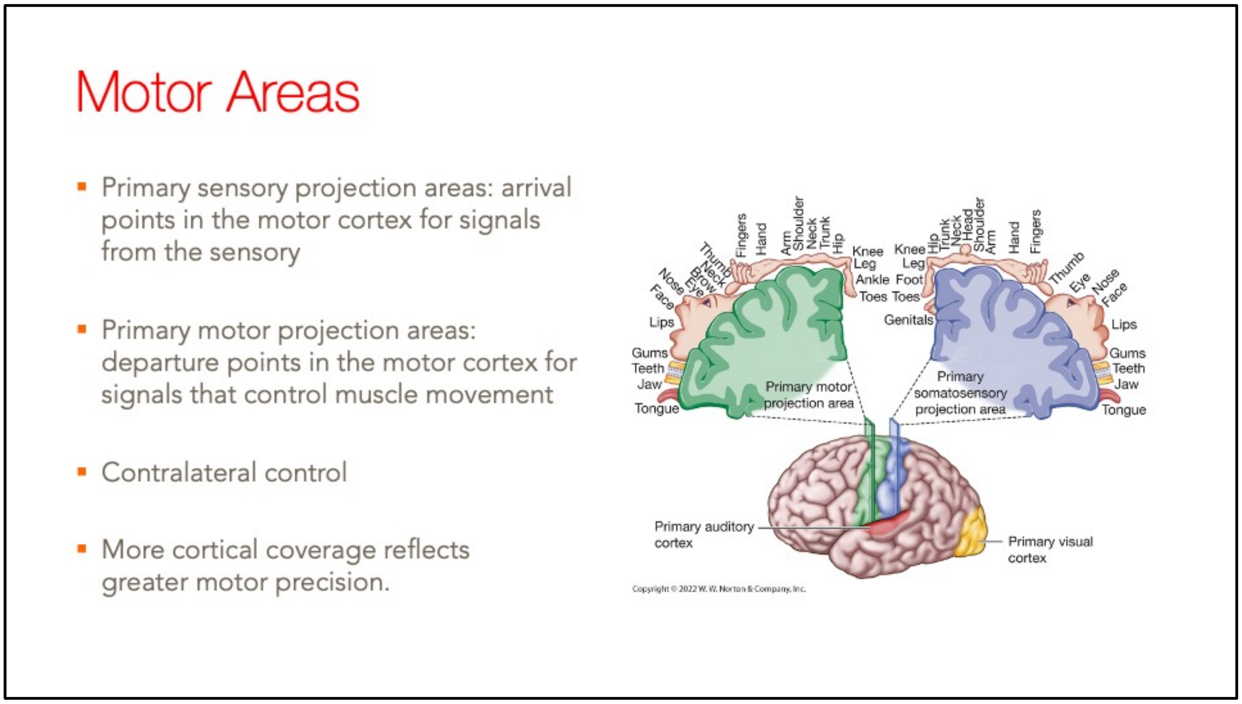


FIGURE 2.10 (left side) THE PRIMARY PROJECTION AREAS
The primary motor projection area is located at the rearmost edge of the frontal lobe, and each region within this projection area controls the motion of a specific body part.

Primary motor projection areas: departure points for signals leaving the motor cortex to control muscle movement; located in the *posterior frontal lobes*.
The figure shows that areas of the body that we can move with great precision (e.g., fingers and lips) have a lot of cortical area devoted to them; areas of the body over which we have less control (e.g., the shoulder and the back) receive less cortical coverage.

Primary sensory projection areas: arrival points for signals coming from the senses (e.g., eyes, ears) to the motor cortex

Movement is contralaterally controlled: stimulation to the left hemisphere leads to movement on the right side of the body, and vice versa.

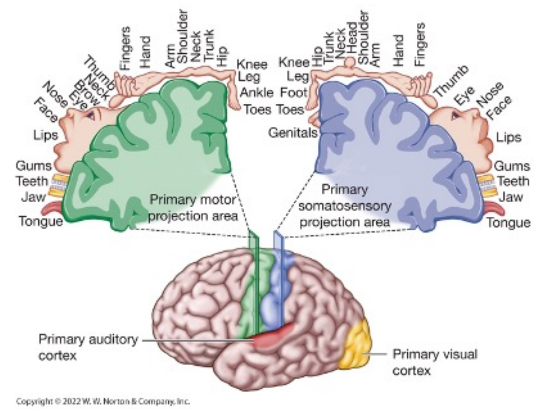
Sensory Areas

Somatosensory area: skin sensations

Primary auditory cortex: auditory sensations

Primary visual cortex: visual sensations

- Contralateral organization
- Cortical space assigned based on acuity



In the somatosensory area (in the parietal lobe), each part of the body's surface is represented by its own region on the cortex; areas of the body that are near to each other are typically represented by similar nearby areas in the brain. In the visual area (occipital lobe), each region of visual space has its own cortical representation, and adjacent areas of visual space are usually represented by adjacent brain sites. In the auditory projection area (temporal lobe), different frequencies of sound have their own cortical sites, and adjacent brain sites are responsive to adjacent frequencies.

The assignment of cortical space is governed by function, not by anatomical proportions (e.g., parts of the body that aren't very discriminating with regard to touch—even if they're physically large—get relatively little cortical area. Other, more sensitive areas of the body (the lips, tongue, and fingers) get much more space.

FIGURE 2.10 THE PRIMARY PROJECTION AREAS

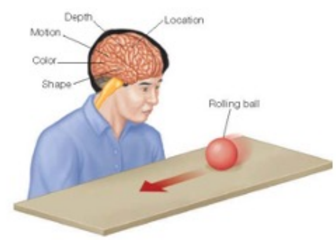
The primary motor projection area is located at the rearmost edge of the frontal lobe, and each region within this projection area controls the motion of a specific body part, as illustrated on the top left. The primary somatosensory projection area, receiving information from the skin, is at the forward edge of the parietal lobe; each region within this area receives input from a specific body part. The primary projection areas for vision and hearing are located in the occipital and temporal lobes, respectively. These two areas are also organized systematically. For example, in the visual projection area, adjacent areas of the brain receive visual inputs that come from adjacent areas in visual space.

Distributed Representation in the Brain

- In addition to localization of function, specific functions are processed by many different areas of the brain
- Many different areas may contribute to a function
- May appear to contradict the notion of localization of function, but the two concepts are actually complementary

Our experience contains little or no evidence of this widely distributed activity

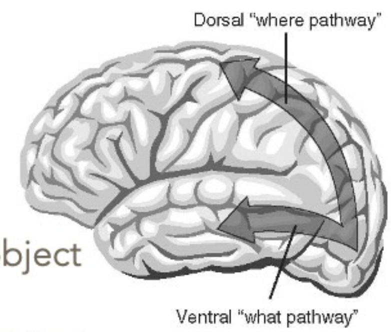
We simply just see the ball



Rolling red ball causes a wide distribution of activity in the brain: process the color, movement, shape, depth, location
But our experience is coherent. We simply just see the ball

Distributed Processing in the Brain

- Massive parallel processing throughout the brain to perform mental functions



- Example in perception:
  - –Ventral “what pathway” – processes identity of perceived object
  - –Dorsal “where pathway” – processes location of perceived object

Fundamentals of Cognitive Psychology, 2e by Ronald T. Kellogg ©SAGE Publications, Inc.

"vision for perception" "vision for action”

Can one part be damaged with the other functioning?

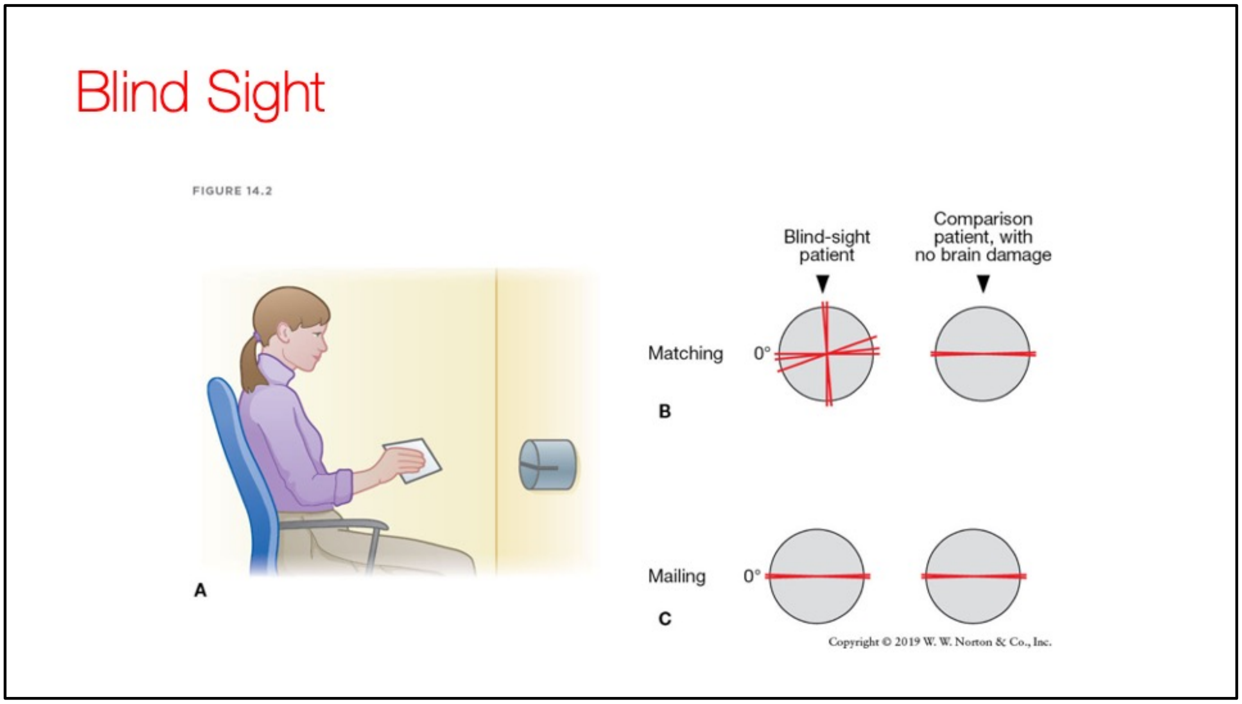


FIGURE 14.2 CONSCIOUS SEEING, UNCONSCIOUS SEEING

In this study, (Panel A) participants held a card and, in one condition, were asked to hold the card at an angle that matched the orientation of the slot in front of them. In another condition, they were asked to imagine that they were "mailing" the card, placing it into a "mail slot." In the matching task, the blind-sight patient made many errors (Panel B). In the "mailing" task, in contrast, the blind-sight patient performed perfectly, consistently matching the card's orientation to the orientation of the slot. It seems, then, that the patient is (consciously) blind, but able to see and to use the information she sees in guiding her own actions. (after goodale, milner, jacobson, & carey, 1991)

Double Dissociation

- When damage to one part of the brain causes function A to be absent while function B is present, and damage to another area causes function B to be absent while function A is present
- Allows us to identify functions that are controlled by different parts of the brain
- Double dissociations have been demonstrated for face recognition and object recognition
  - Patients who can't recognize faces (function A) but who can recognize objects (function B), and other patients who can do B but not A.
- Double dissociations enable us to conclude that function A and B served by different mechanisms, which operate independently of one-another

Broca's Aphasia

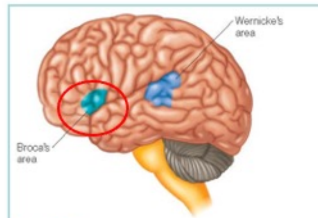


Figure 2.17 Broca's area, in the frontal lobe, and Wernicke's area, in the temporal lobe, were identified in early research as being specialized for language production and comprehension, respectively. © Cengage Learning

Wernicke's Aphasia

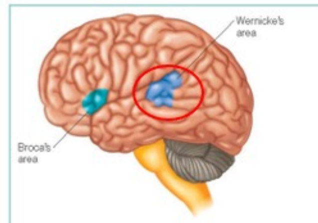


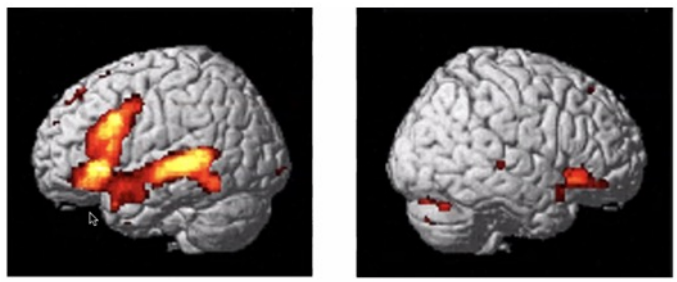
Figure 2.17 Broca's area, in the frontal lobe, and Wernicke's area, in the temporal lobe, were identified in early research as being specialized for language production and comprehension, respectively. © Cengage Learning

Broca's Aphasia

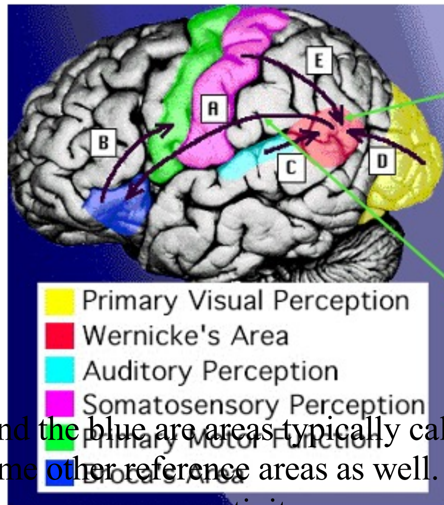
Wernicke's Aphasia

Subject Engaged in Auditory Description Decision Task

- Listen to sentences and evaluate if they are true.
- …"Things that hang on the wall in museums are painting" …



Language and Related Areas



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Wernicke's Area is an *association area* bringing together information from several modalities

Wernicke's Area is connected to Broca's Area through a bundle of nerve fibers called the *arcuate fasciculus*

The red and the blue are areas typically called Broca's and Wernicke's areas.
Added some other reference areas as well.
Arrows show some connectivity.

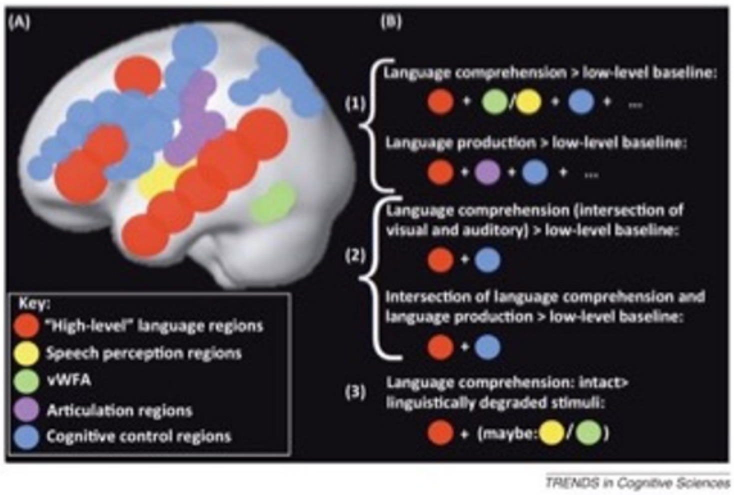
When a word is heard, the sensation from the ears is received by the primary auditory cortex, but the word cannot be understood until the signal has been processed in Wernicke's area nearby.

If the word is to be spoken, some representation of it is thought to be transmitted from Wernicke's area to Broca's area, through a bundle of nerve fibers called the arcuate fasciculus.

In Broca's area the word evokes a detailed program for articulation, which is supplied to the face area of the motor cortex.

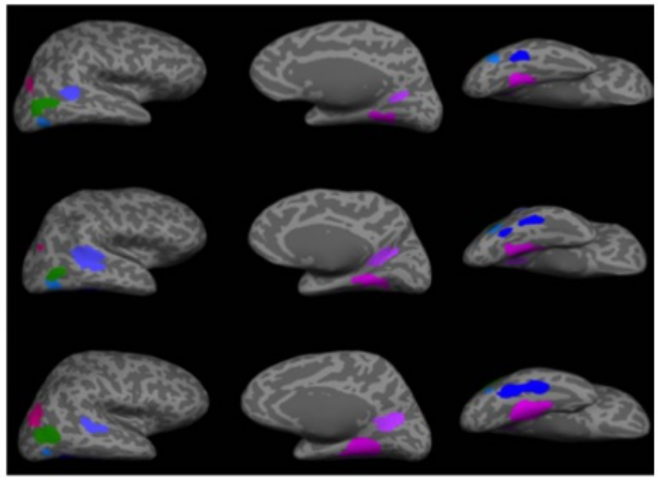
The motor cortex in turn drives the muscles of the lips, the tongue, the larynx, and so on.

Results from many neuroimaging studies of language



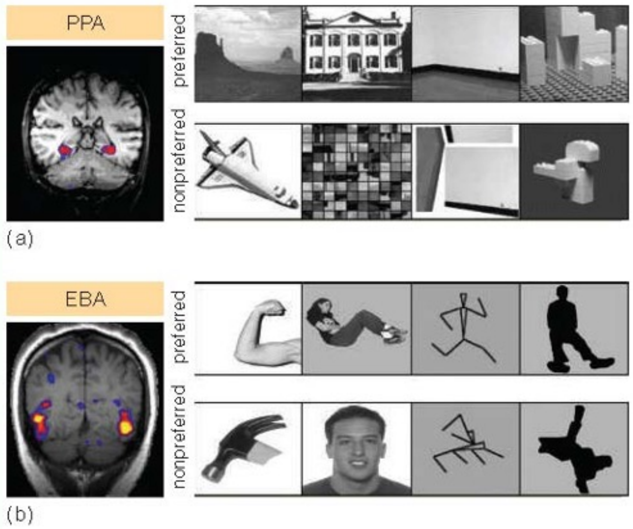
Brain Imaging: Evidence for Localization of Function

- Fusiform face area (FFA) responds specifically to faces
  - Temporal lobe
  - Damage to this area causes prosopagnosia
- Parahippocampal place area (PPA) responds specifically to places (indoor/outdoor scenes)
  - Temporal lobe
- Extrastriate body area (EBA) responds specifically to pictures of bodies and parts of bodies, but not faces
  - Occipital lobe (visual cortex)

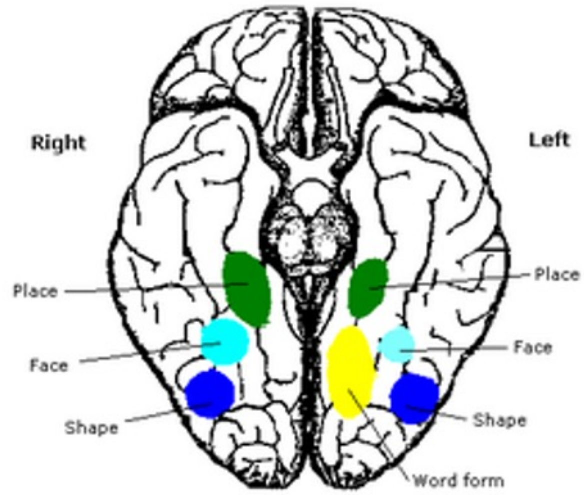


PPA: spatial layout, both empty room and fully furnished rooms

Brain Imaging: Evidence for Localization of Function



Visual word form area (VWFA, yellow), and other areas, seen from below



Source: https://en.wikipedia.org/wiki/Fusiform_face_area

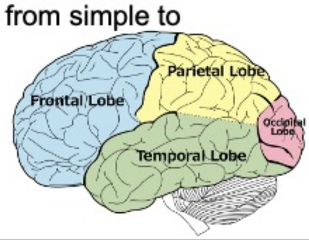
Hierarchical Processing

When we perceive different objects, we do so in a specific order that moves from lower to higher levels of processing in the brain

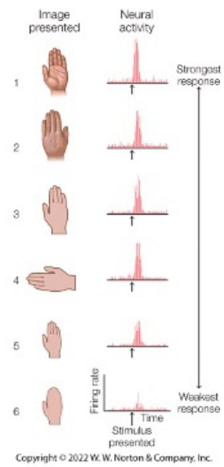
- Neurons that respond to simple stimuli send their axons to higher levels of the visual system
- These neurons in turn send their axons to higher areas combining and interacting further

Hierarchical Processing: Ascension from lower to higher levels in the brain corresponds to perceiving objects that move from simple to higher levels of complexity

Sensory coding: how neurons represent various characteristics of the environment



Examples of coding of representations in neurons



How are object recognition processes implemented in the brain?

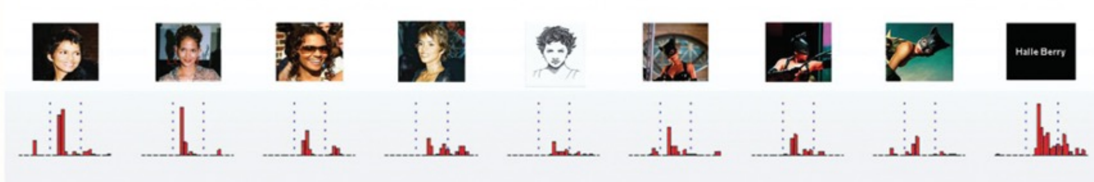
Neural recordings suggest that cells in the inferotemporal (IT) cortex respond to specific target objects and fire most strongly when that target is in view.

FIGURE 4.12 SINGLE-CELL RECORDINGS FROM A "HAND DETECTOR" CELL
Neurons in the inferotemporal cortex fire in response to complex inputs. The neural activity shown here was from a cell responsive to hand shapes. The cell even fired (although weakly) to a mitten shape that lacked distinct fingers.

Some of the brain's cells fire strongly only to a particular view of an object—that is, the object viewed from a particular angle. If the object is viewed from a different angle, the cell's response is reduced.

Other cells, in contrast, fire strongly to virtually any view of the target object; these cells are said to be viewpoint independent. Presumably, cells responding directly to the input's shape trigger viewpoint-*dependent* detectors ("Aha! It's a cat viewed from the side"), and these in turn trigger viewpoint-independent cells ("Aha! It's a cat").

Examples of coding of representations in neurons



Quiroga et al. 2005. Invariant visual representation by single neurons in the human brain. *Nature*, 435(23), 1102–1107.

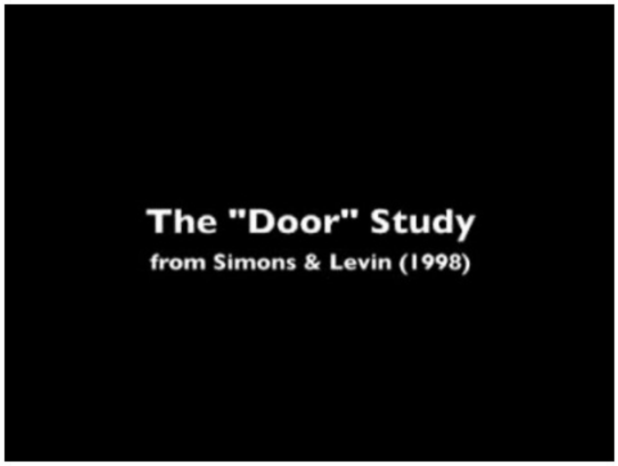
Although cells may respond to specific target objects, they can also fire (less strongly) in response to other inputs. For example, the “Halle Berry cell” fires strongly when Berry is in view, but it also fires in response to other inputs. As a result, the firing of this cell cannot—on its own—consistently mean “Halle Berry is in view.”

FIGURE 4.13 A HALLE BERRY NEURON?
Researchers recorded the activity in a single neuron in the hippocampus of a patient undergoing epilepsy surgery. Each of these pictures shows an input that was placed in front of the patient’s eyes, together with the cell’s response to that input. The dotted lines indicate when the input was presented and when it was removed from view. The neuron fired strongly in response to pictures of Berry, even when she appeared in her Catwoman costume, and even when her name was presented.

What do we learn about cognition from these findings? Does it affect our understanding of any of Marr’s levels?

DOES OUR BRAIN REPRESENT EVERYTHING THAT WE SENSE?

Inattention/change blindness



Inattention/change blindness

The brain doesn't represent everything that we sense

- Our mind/brain is selective in what it processes
- Our perceptual systems are not just cranking away at everything that impinges on our sensory organs.