Anatomy and function of the brain

Mammalian brain (especially human brain) is the most complex machine known:

- billions of neurons (perhaps 100 billion in humans), billions of other CNS cells
- each neuron can have thousands of axonal and dendritic connections to other neurons:

**What do we know?**

We understand a lot about how the individual components (neurons) work.

We understand a little about overall anatomy: which function occurs where; how the parts are connected ("wiring diagram")

We understand *very little* about mechanisms of "emergent properties:" memory, learning, perception, consciousness, thought.

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- each neuron can have thousands of axonal and dendritic connections to other neurons:

We don’t even know why we *sleep***

... even though we spend 30% of our lives sleeping.

We understand *very little* about mechanisms of "emergent properties:" memory, learning, perception, consciousness, thought.
Anatomy and function of the brain

Mammalian brain (especially human brain) is the most complex machine known:

- Bill human
- Each and other, and their ‘programming’ ...

But all of these ‘higher functions’ of the brain are thought to be determined by the properties of neurons and the way neurons in the brain connect and interact with each other, and their ‘programming’ ... nothing more.

Our lack of understanding is just a reflection of how complex the brain is, not any special properties:

The mind and the ‘soul’ are simply biology .... but they are very, very, very complicated biology!

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Anatomy and function of the brain

Generalized mammalian brain anatomy

(front)

Hypothalamus

pituitary

spinal cord
Anatomy and function of the brain

Generalized mammalian brain anatomy

**midbrain**

**pons**

**medulla**

- relay messages (sensory and motor) between peripheral NS and brain.
- many autonomic reflexes associated with homeostasis.

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Generalized mammalian brain anatomy

**Cerebellum**

- coordination of movement; largely inhibitory -- smooths and modulates motor commands.
- may also be involved in memory.
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Generalized mammalian brain anatomy

**cerebral cortex**
- sensory and motor processing
- "intelligence:" learning, memory, language
- Two nearly separate hemispheres, with somewhat different functions
  -- left hemisphere usually dominates; mainly concerned with "logical" functions like math, writing, thought, speech, etc.
  -- right hemisphere is "emotional:" biased towards spatial relationships, musical and artistic abilities, and expression of emotions.

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Generalized mammalian brain anatomy

**corpus callosum**
junction of the two cerebral hemispheres.
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Generalized mammalian brain anatomy: Cross-section

- **Gray matter:** mainly cell bodies (processing)
- **White matter:** mainly axons (wiring)

Other concentrations of cell bodies (*ganglia, nuclei*) occur throughout the brain.

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Left cerebral hemisphere

- **Frontal lobe**
  - motor
  - frontal association area
  - speech
- **Parietal lobe**
  - sensory
  - speech
  - taste
  - reading
- **Occipital lobe**
  - visual
  - processing
- **Temporal lobe**
  - hearing
  - smell

Some localization of function in cerebral hemispheres is known…

- size of brain volume used for a function is ~ to importance of that function (e.g., olfactory area *small* in humans, *very big* in dogs)
Anatomy and function of the brain

Cortical specialization
(proportion of brain sensory areas devoted to each body region)

This shows what a **male human**’s body would look like if it had the same relative proportions as the **touch receptor area** of the cortex:

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Anatomy and function of the brain

Cortical specialization
(proportion of brain sensory areas devoted to each body region)

This shows what two **small mammals** would look like if it had the same relative proportions as the **touch receptor area** of the cortex:
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How did we learn what is known about brain function (especially that certain functions are located in particular parts of the brain)?

• examine function in animals (or people) where certain areas of the brain have been accidentally or intentionally destroyed.

• stimulate or record from brain regions. Stimulation can cause motor responses, or elicit sensations (Wilder Penfield).

• anatomical techniques ("staining" of individual neurons) can be used to trace the wiring

• isotopically labeled compounds (i.e. hormones or fuel molecules) can reveal where these are bound or metabolized in the brain.

• new imaging techniques can reveal regions where the brain is metabolically active (magnetic resonance imaging; PET scanning, etc.).

• biotechnology and molecular techniques (gene knockouts, etc.).
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The famous case of Phineas Gage….

A construction supervisor in the Rutland & Burland Railroad, a man of great honesty, frugality, sobriety, and piety. In September, 1848, he was tamping a powder charge in preparation for blasting rock, using a 3-foot, 13 lb iron bar…

when the charge detonated prematurely.

Anatomy and function of the brain

The iron bar was blasted through Phineas’ head. He lost sight in one eye, but remarkably, he never lost consciousness and eventually healed.

He died 13 years later.

His skull is in a museum at Harvard University:
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The injury caused horrific damage to the front of Phineas’ brain:

(reconstructions based on the skull)

Anatomy and function of the brain

What is remarkable about the case of Phineas Gage is not that he survived this damage (although that was amazing).

What most impressed is doctors and friends is that he changed: “Gage was no longer Gage,” as they said.

He became a foul-mouthed, hell-raising, irresponsible liar -- completely different from his character before the accident.

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Phineas Gage was one of the very first instances when scientists realized that particular parts of one’s personality “reside” in particular parts of the brain:

the biological basis of behavior
Anatomy and function of the brain

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Gage’s wound also shows that the brain has considerable redundancy and different regions can work relatively independently of each other …. Very unlike most computer systems! Distributed processing (?)

Anatomy and function of the brain

In effect, Phineas Gage suffered a left frontal lobotomy.

In the late 19th and early to mid-20th century, doctors and psychiatrists began to use a related technique on patients with severe mental illness.

This lead to one of the more barbaric episodes in the history of medicine.

Lobotomies were performed in very crude fashion -- one recommended technique was to insert an ice-pick through the top of the eye socket:

- inserted about 2 inches through the tear gland duct opening (tapped in with “a smart blow” with a hammer)
- moved back and forth through a ~30-degree arc to sever the connections to the rest of the brain
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This is what happened during a lobotomy:

Obviously, this had drastic effects on personality and behavior.

Sometimes it worked:

From the prestigious American Journal of Psychiatry (55 years ago):

21 year old hebephrenic schizophrenic lobotomized after 30 electroshocks and 29 insulin comas “failed to produce more than temporary improvements … following the operation he was paroled to his father… he is now studying engineering.”

Usually the results were much less positive. Most patients suffered serious personality impairments… but the most amazing aspect is that this severe trauma did not completely obliterate brain function.

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How does the brain process information (above the level of neurons and synapses)?

Not very clear…

• sensory processing often done in spatially separated stages (vision, especially)

• clusters of neurons seem to respond to specific patterns (e.g., edge detectors, motion detectors in visual processing)

• in some cases (visual cortex), processing steps appear to be arranged in discrete layers in the cortex:
Anatomy and function of the brain

“Mapping” of touch receptors on cerebral cortex

Sensory processing for skin touch receptors

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Anatomy and function of the brain

“Mapping:” geographical position on cerebral cortex corresponds (roughly) to geographical position on the body surface.

- breaks down at fine scale

- *same general mapping* also evident in the motor cortex

- to a lesser extent, also true for other senses