Brain Anatomy and Function

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Vocabulary

• Saggital: the vertical plane that divides right and left
• Coronal: vertical plane that divides into front and back
• Axial: horizontal plane that divides top and bottom
• Dorsal: near the back or upper surface
• Frontal: toward the front
• Ventral: lower toward the front
Brain Anatomy

• The human brain weighs about 3 pounds and uses 20% of the energy of our body (but very efficiently – about 11 watts.) It never rests. The “sleeping” brain is as active as the conscious brain. We just don’t know what its doing.

• The human brain is over 3x as large as a typical mammal with an equivalent body size. Most of the difference is the cerebral cortex, a layer of nerve cells over the cerebrum. Especially expanded are the frontal lobes. The portion devoted to vision is also expanded.
Brain Anatomy

• The brain is protected by the thick bones of the skull, a thick membrane (meninges), cerebrospinal fluid, and isolated from the bloodstream by the blood-brain barrier.

• The consistency of the brain is similar to soft gelatin.

• The brain is estimated to contain 80-90,000,000,000 glial cells and 80-90,000,000,000,000 neurons. There are 1,000,000,000,000,000,000 synaptic connections. The purpose of these cells is communication.
Brain Anatomy

• The brain consists of 3 main parts
  – The brainstem
  – The cerebellum
  – The cerebrum
Cerebrum

• The cerebrum is divided into two hemispheres - right and left – which are joined by a bundle of fibers called the corpus callosum. Each hemisphere controls the opposite side of the body.
• The left hemisphere specializes in speech, comprehension, arithmetic, writing. It is fanatic about organizing and categorizing.
• The right hemisphere specializes in artistic and spatial ability, creativity, musical skills. It sees the world as pre-organized sensations.
• 8% of people are left handed and may have language skills in the right hemisphere (33%).
Seeing Patterns is the Default Mode

• We cannot stop ourselves from seeing patterns in the world. “Split brain” experiments and other tests have shown that we are better at explaining than understanding. (Or at least, our left hemisphere is dominant almost all the time. The right hemisphere tends to answer “I don’t know” when confronted with the inexplicable.)
The Narrative

• We are compelled by our biology to invent a cause for everything that happens. These narratives often blind us to the complexity of what is happening around us. It creates an impression of understanding that is often not accurate because it blocks our awareness of details. We believe the world is less random than it is. Which sentence do you prefer?:
  – The king died and then the queen died.
  – The king died and then the queen died of grief.
Dopamine

• High levels of dopamine also appear to lower skepticism and make people more vulnerable to pattern detection. Treatment of Parkinson’s Disease with L-dopa, for instance, can lead patients to be more superstitious, more interested in astrology and gambling, etc.

• Dopamine dysfunction is also linked to paranoia – seeing patterns in events when other people do not.
Deep Brain Structures

- Thalamus: relay station for almost all information coming to the cortex. Important for pain, attention, alertness
- Hypothalamus: master control of the autonomic nervous system: arousal level, noxious events, hunger, thirst, sleep, sexual response, body temperature, blood pressure, emotions, and hormone secretion. Links nervous system to the endocrine response to stress. Will prime the amygdala to consolidate fearful memories.
- Pituitary gland: the master gland – sexual development, bone and muscle growth, stress reactions, immune system
- Pineal gland: body’s internal clock - circadian rhythms, melatonin
Deep Brain Structures

• Basal ganglia: movement coordination with cerebellum to control fine and large motor movements. Secretary to the prefrontal cortex. It is tightly connected to the prefrontal cortex. Parkinson’s disease results from lack of dopamine here. With the insula, the center of the emotion of disgust – physical and moral.

• Nucleus accumbens: part of the basal ganglia, a reward center associated with drug intoxication. Intoxication and withdrawal happen here. (Addiction occurs in the prefrontal cortex, hippocampus, amygdala)

• Limbic system: cingulate gyri, hypothalamus, amygdala, hippocampus – emotions, learning, memory
Amygdala

• The amygdala receives input from the thalamus about body states (stress, alarm) and responds to emotional input and memories. It mediates arousal, directs motivation.
• It enhances learning and memory for emotional events. This includes recognizing when others are afraid.
• The amygdala processes most emotional information in teens. (Adults rely more on the prefrontal cortex to understand and evaluate fear.)
The cerebral cortex is so large it overshadows every other part of the brain. This is where consciousness resides. Extensive damage here will produce a permanent coma.

The cortex is a sheet of neural tissue, folded to fit inside the skull. (A groove is called a sulcus and a ridge is called a gyrus.) Each hemisphere has a total cortical surface area of 1.3 square feet.
Cerebral Cortex

• The cerebral cortex contains about 70% of the brain’s nerve cells, although it is only a quarter inch thick. The high concentration of nerve cell bodies gives the cortex a darker color than the rest of the brain –”gray matter.”

• Underneath the cortex, the brain is full of connecting fibers of neurons (axons) that are largely covered in myelin (fat insulation) – “white matter.”
Cerebral Cortex: Lobes

• There are five “lobes” of the cerebral cortex, 4 named after the bones that overlie them.
  – Frontal lobe: speaking/writing (Broca’s area), personality, judgment, body movement, concentration, inhibition
  – Parietal lobe: touch, spatial/visual perception
  – Occipital lobe: vision
  – Temporal lobe: understanding language (Wernicke’s area), memory, hearing, sequence organizing
  – Insula, or insula cortex, underneath the parietal lobe: integration of sensation and emotion
Right Frontal Insula: Sensory/Emotional Integration

• This area lights up when you feel the quintessential human emotions: love, hate, lust, disgust, gratitude, resentment, self-confidence, embarrassment, trust, contempt, empathy, pride, guilt, etc. People with damage here will not feel disgust, for instance.

• In every single study of every emotion in humans, the right frontal insula and anterior cingulate light up together. In humans, emotions, feelings, motivations, ideas, and intentions are combined to a unique degree.
Insula

- The insula is also critical in helping us infer emotional states in others. The mirror neuron system also does this.
The Frontal Cortex

• The frontal/prefrontal cortex evolved from the motor cortex and is the most complex part of the brain. It is does not fully mature for at least 25 years. The frontal lobe is the last to develop and the first to degrade.

• There are three major divisions: medial-frontal, orbital frontal, and dorsolateral
Medial Frontal Cortex

- Includes the anterior cingulate (emotion and social thinking).
- Integrates information in support of complex goals and aspirations.
- Becomes more active when jazz musicians improvise. May, in part, be the center of the “personal”, the “self.”
- This is the area damaged in Phineas Gage.
Orbitofrontal Cortex
Orbitofrontal Cortex

• The orbitofrontal cortex is very closely associated with the limbic system. It is highly involved with emotion, mood, drives, and rewards. It is a key area in integrating emotions into decision-making. But it also regulates emotion, controls moods, and is involved in decision-making tasks.

• It receives a lot of sensory input. It can evaluate behavioral responses to the environment. Animals without a prefrontal cortex lose the ability to extinguish fearful memories that are no longer relevant.
Dorsolateral Prefrontal Cortex
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• Coldly calculating. Involved in executive functioning, organizing behavior, solving complex problems, shifting strategies even when there is strong emotional investment in that strategy. Good at utilitarian approaches.

• Involved in self-monitoring. It is inhibitory. Activity decreases here when jazz musicians improvise.

• It maintains an attentional set – determines relevance.
Dorsolateral Prefrontal Cortex

• Important for working memory – a few seconds to remember a phone number that was just given to you.

• Problems may lead to environmental dependency syndrome.

• Damage is localized to problems with executive decision making, not abnormal personality, social function, or aggression.
Dorsolateral Prefrontal Cortex

- Information overload causes this area to shut down. This may account for the phenomena that when people get too much information, they make worse and worse decisions (vacation spot, jeans, stocks...).
- Will power and making decisions (active control) are energies that can be depleted in an individual. Endurance can grow with practice.
- Our brains are not naturally equipped to integrate extremely large or disparate types of information. They evolved primarily to negotiate social situations and survive natural threats.
The temporal lobe is involved in auditory perception. It is important in understanding the meaning of words and visual symbols. It contains the hippocampus which plays a key role in long-term memory.

The left temporal lobe contains Wernicke’s area which works in tandem with Broca’s area making human language possible.

The underside (ventral) part of the temporal lobe contains the fusiform gyrus, where recognition of faces takes place.
Right Temporo-Parietal Junction

• The temporoparietal junction (TPJ) is an area of the brain where the temporal and parietal lobes meet, at the posterior end of the Sylvan fissure. This area is known to play a crucial role in self-other distinction (our body in space) and theory of mind. Damage to this area has been implicated in producing out of the body experiences. It is also the spatial location of auditory hallucinations in schizophrenia.

• Electromagnetic disruption here has been shown to impair individual’s abilities to make moral decisions!