Cogs 17 Neurobiology of Cognition

A few general concepts concerning the science of mind…

Mind-Body Problem - What *is* the relationship between the brain and the mind?

Dualism - Per Descarte (1600's): Brain not = Mind (Soul); Brain is physical, Mind is immaterial

Monism - Prevalent contemporary stand: Brain does = Mind; Mind is the activity of the physical Brain

But, what of Consciousness? = "Me"; Subjective experience of those aspects of Mind to which I have access

Most contemporaries presume other humans conscious. But other animals? Robots? How would you tell?

"The Hard Problem" – Why should consciousness exist? What is the physical nature of consciousness?

This course presents a materialist description of the structure and function of the brain - The ??? are up to you…

Lecture 1a: Anatomy of the Nervous System

Anatomical Terms referring to Orientation/Positioning

Dorsal = toward the back of the body and, in the human head, toward the top	
Ventral = toward the stomach and, in the human head, toward the bottom	
Rostral / Anterior = toward the front end	**Caudal / Posterior** = toward the rear end
Superior = above another part	**Inferior** = below another part
Lateral = toward the sides, away from the midline	**Medial** = toward midline, away from the sides
Coronal Plane = plane through brain as seen from the front	("Corona" = "Crown")
Saggital Plane = plane through brain as seen from the side	(Saggitarius, the Archer)
Horizontal Plane = plane through brain as seen from above	(Sometimes called the Transverse Plane)
Ipsilateral = making a connection on the *same* side (left/right) of the Nervous System	
Contralateral = making a connection on the *opposite* side (left/right) of the Nervous System	

Divisions of the Nervous System

Central Nervous System (CNS) = Spinal Cord and Brain

- The entire CNS is encased in bone (skull, spinal column) and sheathed in the 3-layered **Meninges**

Peripheral Nervous System (PNS) = Nerves outside the CNS. Its two Subsystems are…

- Somatic Nervous System: Responsible for interaction with external environment (Sensory/Motor)
- Automonic Nervous System: Regulates internal environment (Controls internal organs)

Support Structures

Meninges: Dura Mater ("Tough mother") = thick outer layer immediately under bone

Arachnoid Mater ("Spider mother") = spider-web-like spongy layer (Subarachnoid Space filled with CSF)

Pia Mater ("Pious mother") = pliant inner layer, conforms to brain & spine surface, includes blood vessels

Meningitis = inflammation of Meninges

Ventricles (hollow, inter-connected cavities) in brain, produce **Cerebral Spinal Fluid (CSF)**

- 2 Lateral and Third Ventricles in Forebrain, Cerebral Aqueduct in Midbrain, Fourth ventricle in Hindbrain
- CSF is drawn into Subarachnoid space of Meninges and Central Canal of spine
  - Helps to cushion, support (float) jellylike brain, protect Cord, provides reservoir of hormones & nutrition
  - Has half-life of ~ 3 hours, drains from Subarachnoid space into veins, reabsorbed into blood
- If flow from Ventricles blocked => Hydrocephalus ("water on the brain"); may be surgically drained

Blood Vessels - A complex web of arteries (incoming) & veins (outgoing) feed (mainly **glucose**) & cleanse brain

- Brain = less than 2% of body weight but requires 20% of continuous blood supply !
- Supply cut off for 6 seconds => unconsciousness; for 4-6 minutes => permanent brain damage

- **Blood-Brain Barrier** = Semi-permeable barrier, provides strict controls over chemical content of brain
  - Proper functioning of Neurons depends on regulation of chemistry of intra & extra-cellular fluids
  - Also protects brain from infection since lacks body's immune-system protection & cells can't regenerate
- Barrier consists mainly of specialized capillaries (smallest blood vessels)
  - In most of the body, gaps between cells of capillary walls allow passage of chemicals in/out
  - In the brain, cells tightly joined (**no gaps**) = Blood-Brain Barrier
- In addition, Glia Cells - **Astrocytes** - (see next week's lecture) also help create barrier
- Only small uncharged (e.g. O2, CO2) and some fat-soluble molecules can passively cross barrier
  - Fat-solubles include thiamin (vitamin B1, req for glucose use), nicotine, heroin, cannabinol
  - Others (e.g. Glucose = primary nutrient) must be actively transported (energetic, protein-mediated)
- Note: Barrier weaker in Medulla (see below), allowing some toxins to pass, trigger vomiting

The Brain

Hindbrain = Ancient, posterior part of brain consisting of ***Medulla***, ***Pons*** and ***Cerebellum***

Medulla ("Medulla Oblongata") = Controls breathing, heart-rate, vomiting, coughing, and other **vital reflexes**
- Overdose of cocaine, heroin etc. can be fatal via pathological effects on Medulla

Pons (Latin for "Bridge") Relays info between Cortex & Cerebellum and between Brain & Spinal Cord
- Pons (& Medulla) also include Cranial Nerves V through XII that carry sensory/motor info to/from the head
- Plus they include **Reticular Formation** (involved in Arousal) and **Raphe System** (involved in Sleep)

Cerebellum ("Little Brain") Motor programs; Organizes online sensory input to guide movement; Modifiable by learning
- Critical in timing actions, including for graceful, coordinated activity; Also important in relevant shifting of attention

NOTE: Hindbrain (*not* including Cerebellum), together with Midbrain and Diencephalon of Forebrain (see below)
are also known as the **Brain Stem** (structures along the center-most section of the brain)

Midbrain = Central structures above Hindbrain; Proportionally larger & more important in simpler brains

Tectum = Part of sensory pathways to brain. (Latin for "Roof", as in "Plate Tectonics" in geology)
- Consists of **Superior Colliculus** (Vision – including for "**Blindsight**") and **Inferior Colliculus** (Audition)

Tegmentum = Major motor pathways Lies below Tectum (Latin for "Covering" or "Rug")
- Includes **Red Nucleus** & **Substantia Nigra** w/Dopaminergic neurons that degenerate in Parkinson's Disease
- Contains Cranial Nerves III and IV (controlling eye movements) - Also part of Reticular Formation for arousal

Forebrain = Most anterior portion of brain. Two divisions: Diencephalon (part of Brain Stem) & Telencephalon (the rest)

Diencephalon

Thalamus = paired central structures atop midbrain, Primary source of input to Cerebral Cortex
- Most sensory & motor systems (except olfaction) have nuclei here, project to visual, auditory, motor etc. cortex
- Other nuclei, many involved in arousal of cortex, have widespread cortical projections
- Also includes intrinsic neurons for information processing within Thalamus

Hypothalamus ("Hypo" = "low, below") = small structure with many nuclei, just ventral to Thalamus
- Oversees "**4 Fs**" = Feeding, Fighting, Fleeing, & Sex (critical survival functions) - Also **Temp** and **Clock**
  - Via neural & hormonal connections to, especially, Autonomic Nervous System
- Controls Endrocrine (hormone) systems via affect on adjacent **Pituitary Gland** (the "Master Gland")
  - Produces "releasing hormones" that flow via veins to Anterior Pituitary stimulating that gland to release
  - Produces other hormones sent (like NTs) via axons to Posterior Pituitary, then circulate in bloodstream

Telencephalon (The other division of the **Forebrain**)

Limbic System = "Limbus" = "Border", surrounding most of the above-mentioned structures
- Involved in **Motivational** and **Emotional** behavior. - Most structures are similar across mammals.
- Includes (w/Hypothalamus, above) Hippocampus, Amygdala, Cingulate Gyrus, Olfactory Bulb & others

Hippocampus = "Seahorse", posterior and inferior to the Thalamus/Hypothalamus
- Important in forming new memories, and active in spatial mapping

Amygdala = "Almond" at anterior end of Hippocampus in temporal lobe, near Lateral Ventricles
- Important in emotional expression, especially anger and fear, and in interpreting emotion in others

Cingulate Gyrus - or "Limbic Cortex", forms layer immediately inferior to Cerebral Cortex, **+/- Evaluation**
- A "Re-Entrant" system that interacts w/Cortex & with other Limbic structures to assess good/bad

Olfactory Bulb - extends on stalk out of brain toward nasal cavity
- Receives input from olfactory (smell) receptors in nasal cavity
  - After endogenous processing, axons go directly to Olfactory Cortex (Orbitofrontal area, just behind eyes)
- Important exchange w/rest of Limbic System responsible for emotional-memory-evoking capacity of smell
  - Also, olfaction is enhanced if emotionally aroused (hungry, thirsty, fearful, or sexually aroused)

Basal Ganglia = Complex set of sub-cortical structures including Caudate Nucleus, Putamen & Globus Pallidus
- Lateral to most of above-mentioned structures, acts as major interface between them and the Cortex
  - A "Re-Entrant" system whose most abundant connections are to the Frontal Cortex
- Involved in the control of movement, especially planned sequential behaviors, mediated by memory and emotion
  - Involved in task-setting, implicated in deficits like Obsessive-Compulsive Disorder & ADD
- Degeneration of Midbrain neurons whose axons reach Basal Ganglia => Parkinson's Disease,
  with its symptoms of tremors, rigidity of limbs, poor balance & difficulty in initiating movements

Basal Forebrain = Cortical area just anterior to Hypothalamus
- Includes key structures for attention, and especially arousal of Cortex
- Projects to Cortex, main source of **ACh** (excitatory NT Acetylcholine) in brain, and (de-arousing) **GABA**
- Implicated in sleep/arousal cycles, arousal of Broca's (speech). Pathologies: Parkinson's Disease & Alzheimer's