

Brain 101: Mysteries of the Brain

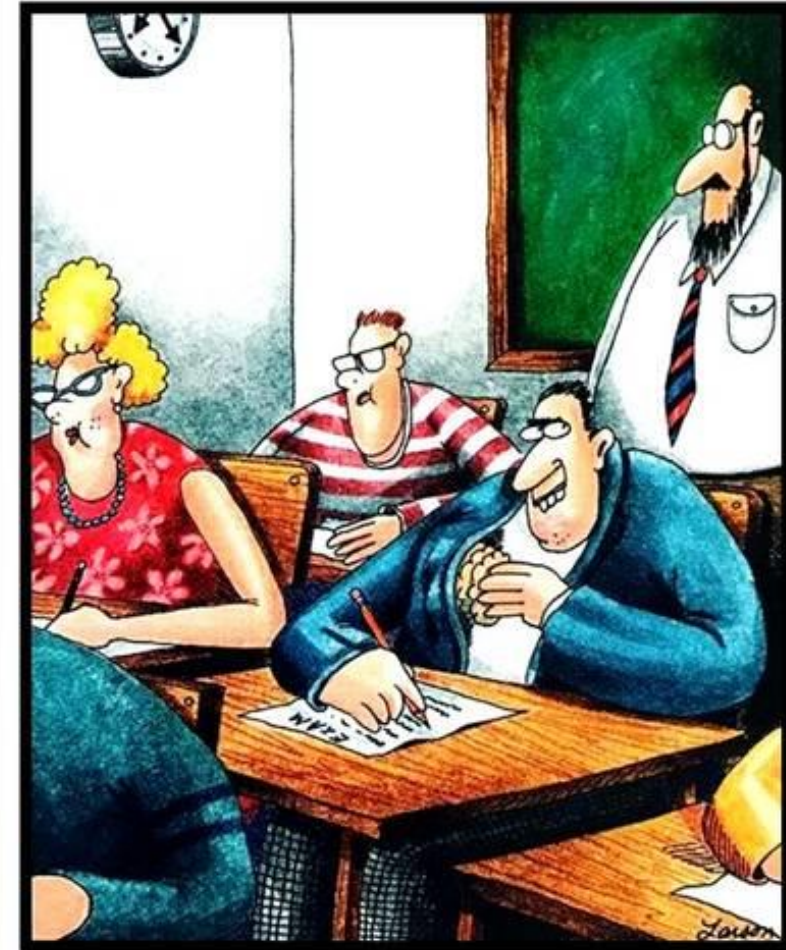
Credit Gary Larson



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Adjunct Professor, UTMB

The Brain 20.0

Credit Gary Larson



Midway through the exam, Allen pulls out
a bigger brain.

What Season is it? It's Vaccine Season!

- They are safe
- They are effective
- They save lives; especially the old, the very young and those with underlying disease....
- Vaccines **DO NOT** cause autism!!!!

Fall vaccines –

- Flu - New mRNA vaccine – precise targeting of circulating flu strains
- COVID
- RSV
- Shingles
- Pneumococcal (pneumonia vaccines)

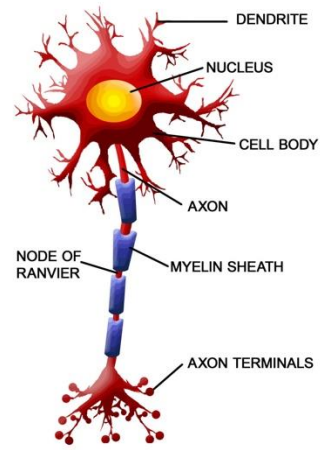
Check with your physician!

Human Brain Facts



Core Properties

- **Average weight:** ~ **3 pounds**, similar to a 14" laptop (~2% body weight) and ~ 6" L X 5.5" W X 3.5"H
- **Surface area:** The cerebral cortex covers ~2.5 sq ft about the size of a 24" computer monitor
- **Composition:** Roughly **60% fat**, with the remaining 40% made of water, protein, carbohydrates, and salts. (Shared across mammals)
- **Neurons:** Approximately **86 billion neurons** and ~100 trillion synaptic connections forming a complex network

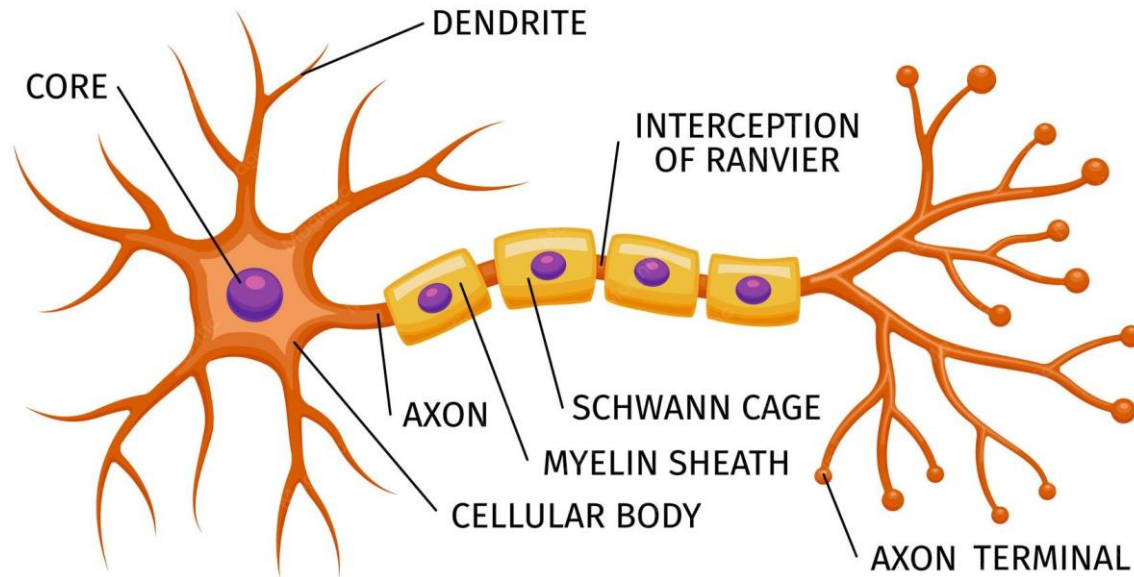


Neurons are What We Call Nerve Cells

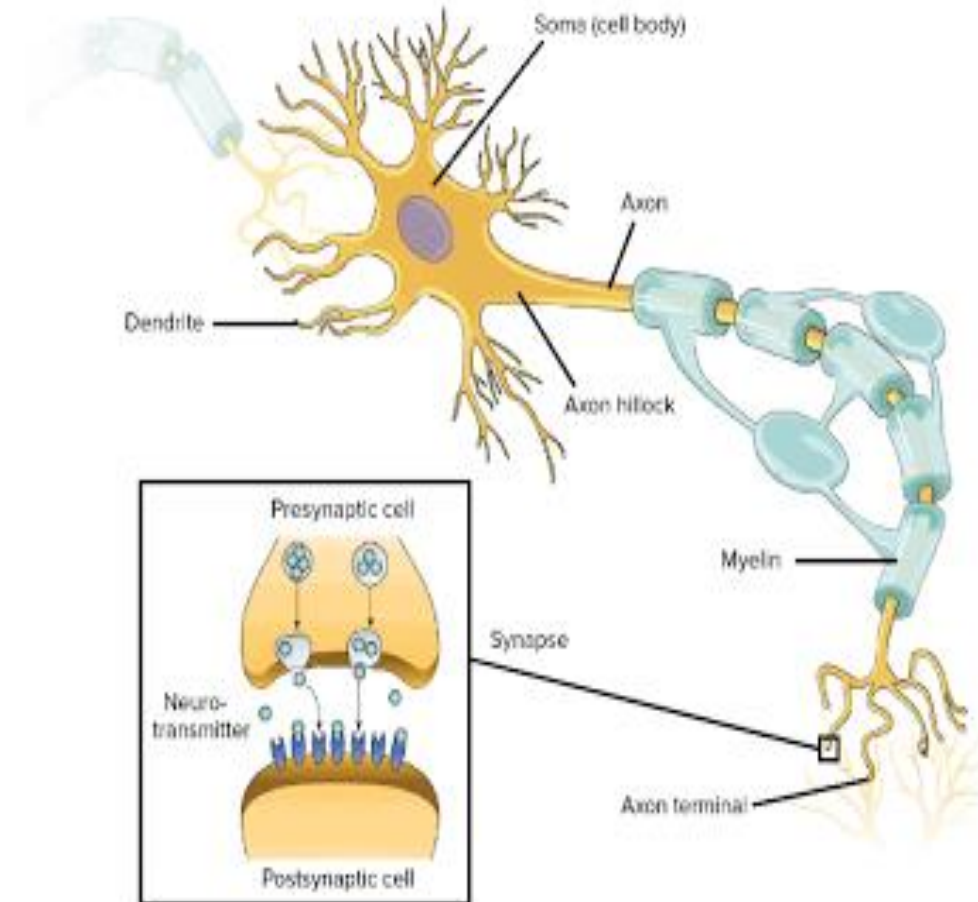
- A neuron is a specialized nerve cell that receives, processes, and transmits electrical and chemical signals throughout the nervous system
- A neuron is the fundamental unit of the nervous system responsible for **communication within the body**. Neurons generate electrical impulses which allow them to transmit information across networks.

How do Neurons Work?

STRUCTURE OF THE NEURON



Myelin sheath – fatty insulator
Loss is cause of MS

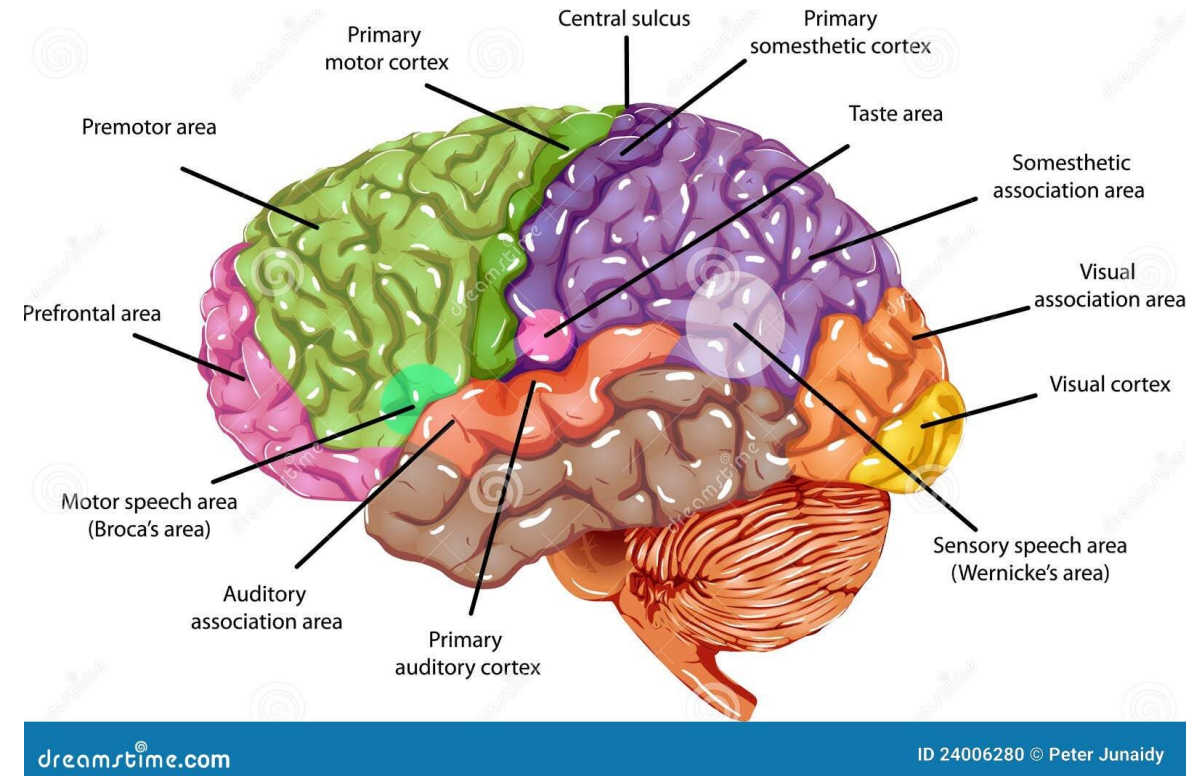


Human Brains Facts

- **Myth** - You use ~10% of their brain. **Fact:** Virtually every part gets used, and most of the brain is active all the time.
- **Fact:** With age, the brain's volume and/or weight decrease, synaptic connections reduce, and a possible decline in cognitive functions.
- **Fact:** The brain has a limited but real ability to repair itself. ***Neuroplasticity*** aids recovery by allowing other parts of the brain to take over functions of damaged areas.
- **Fact:** The brain consumes about 20% of the body's total energy. A constant supply of glucose and oxygen is needed.

Human Brain Facts

- Power - 20 Watts
- Storage capacity – 1 petabyte (entire content of the internet in 2015)
- Power comes from parallel processing (computers are mostly linear processors)
- Neocortex – what makes us human – outer surface of our brains associated with motor functions, cognition and language



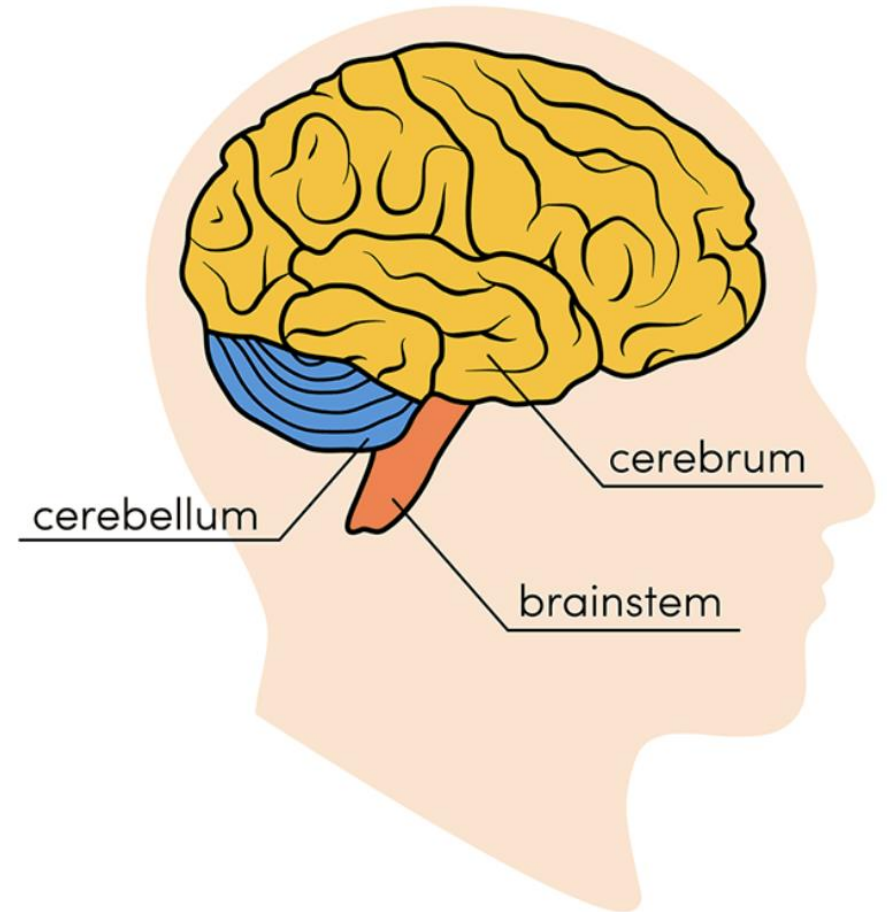
Fun Fact: Internet now has ~200 zettabytes – 200 trillion gigabytes! 1 zettabyte = 250 billion DVDs

The Speed of Our Brains Information Processing

- Information processing involves acquiring, recording, organizing, retrieving, displaying, and disseminating information
- Modern computer CPUs/GPUs operate in **billions of cycles per second** (gigahertz range)
- In contrast, in our brains neurons fire at **hundreds of cycles per second** (hertz range); 10 bits/sec
- However, using parallel processing of ~86 billion neurons and 100 trillion synapses, the human brain's total throughput is estimated at 100–1,000 quadrillion operations per second
- **Power Needs** – the Brain - ~20 watts, High End gpu - **300–700 watts**

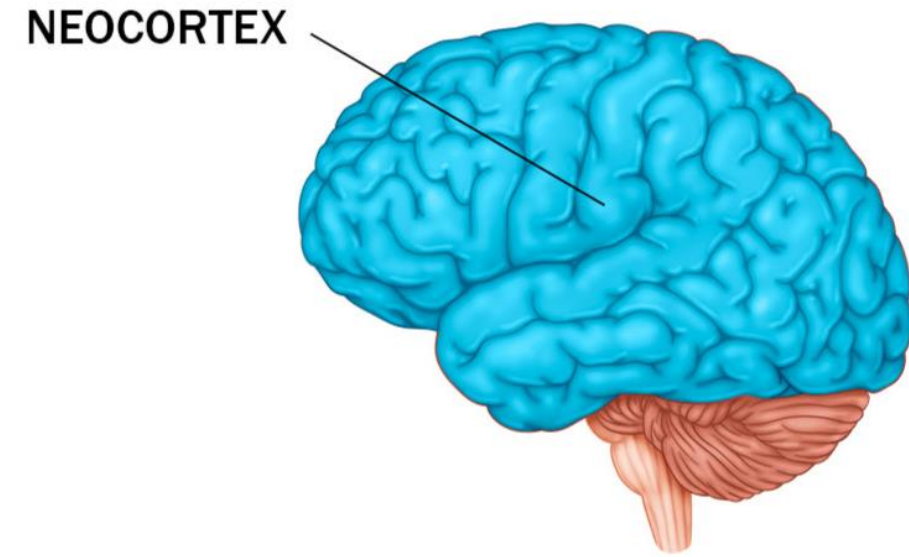
Major Divisions of the Brain

- The brain is broadly divided into **three major sections**:
- **Cerebrum** – largest part; higher cognition, voluntary movement.
- **Cerebellum** – coordination, balance, motor learning.
- **Brainstem** – autonomic functions (breathing, heart rate, consciousness).



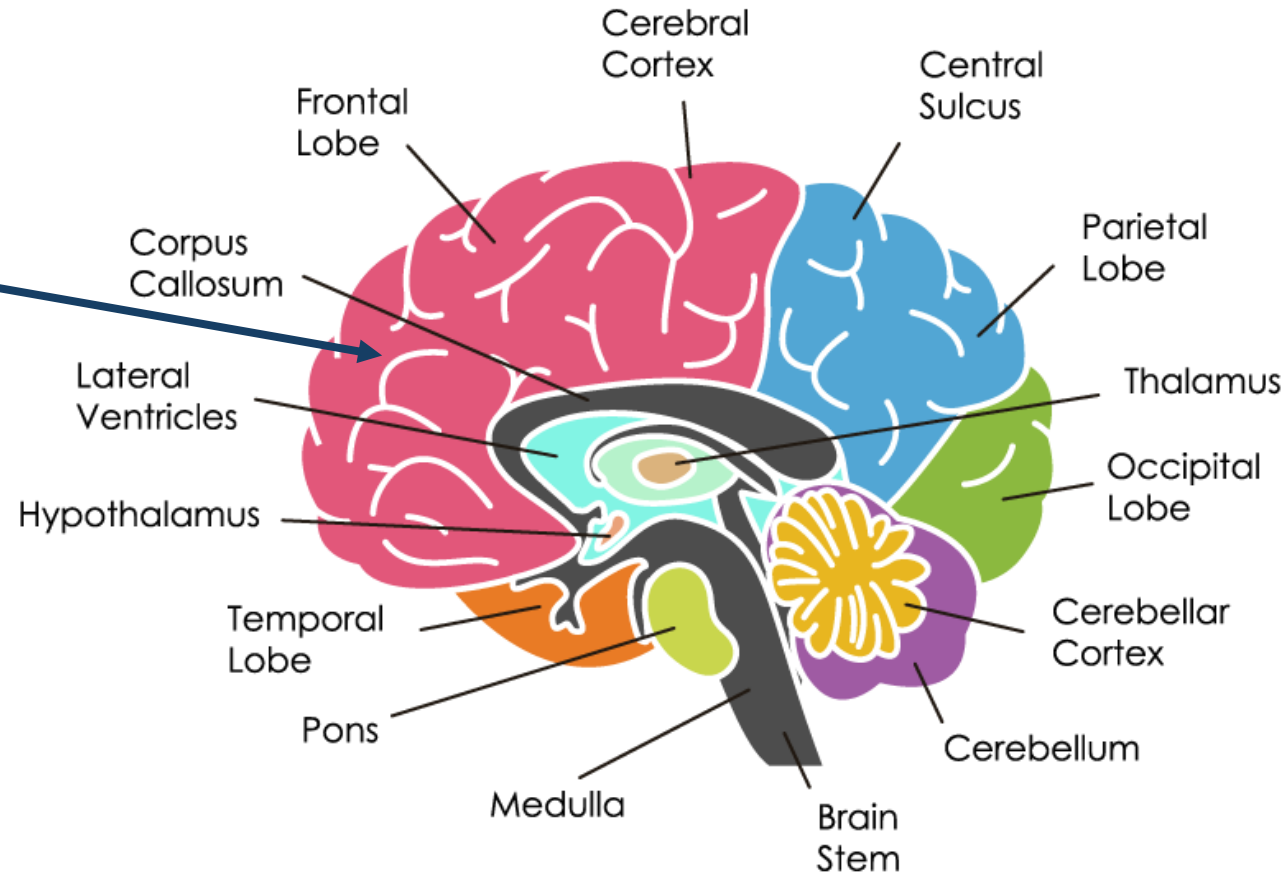
Neocortex Expansion: The Human Brain's Biggest Advantage

- The **neocortex** — responsible for sensory integration, language, reasoning, and conscious thought
- Humans have **the largest neocortex proportion** among primates.
- The cortex is **highly folded (gyrification)** to maximize surface area.

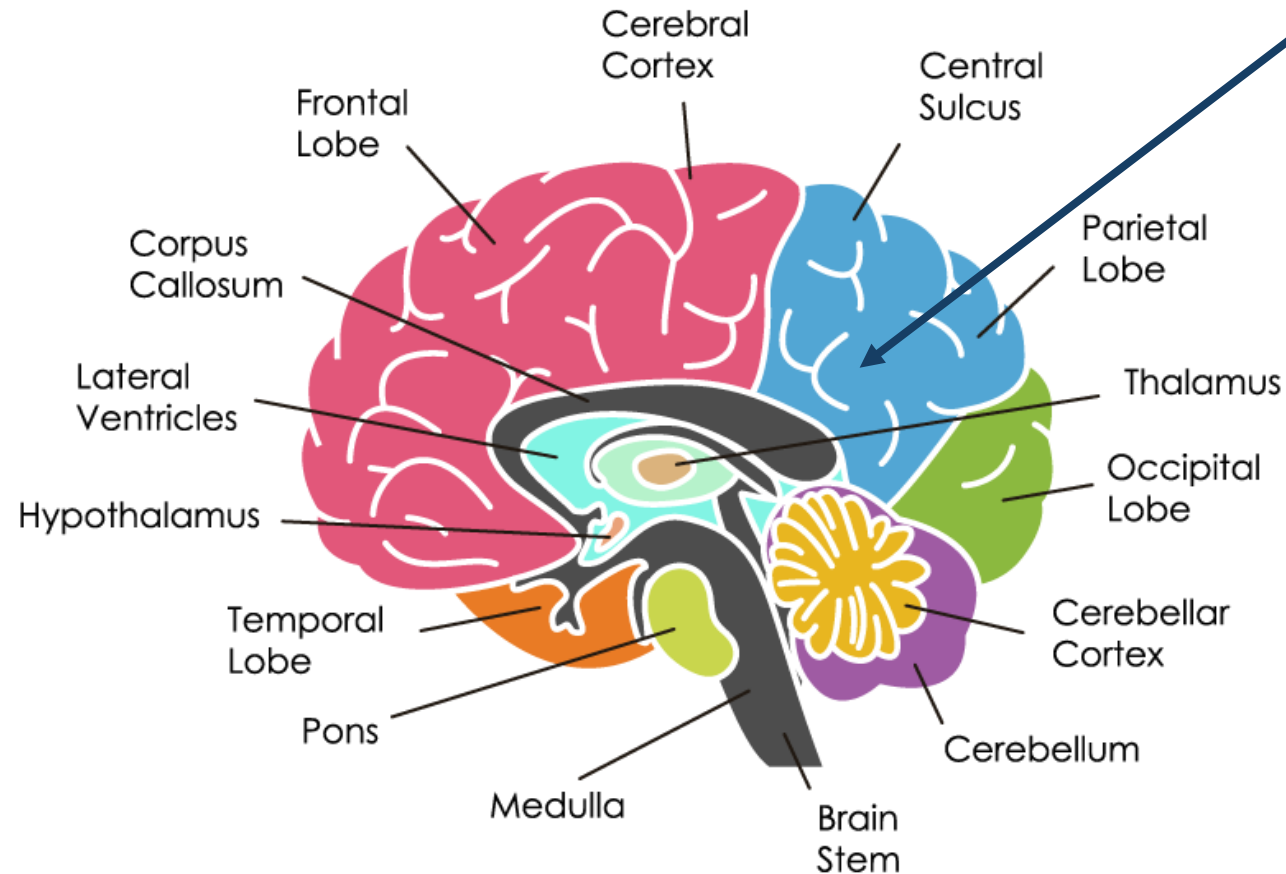


Where in the Brain is Important Information Retrieved from?

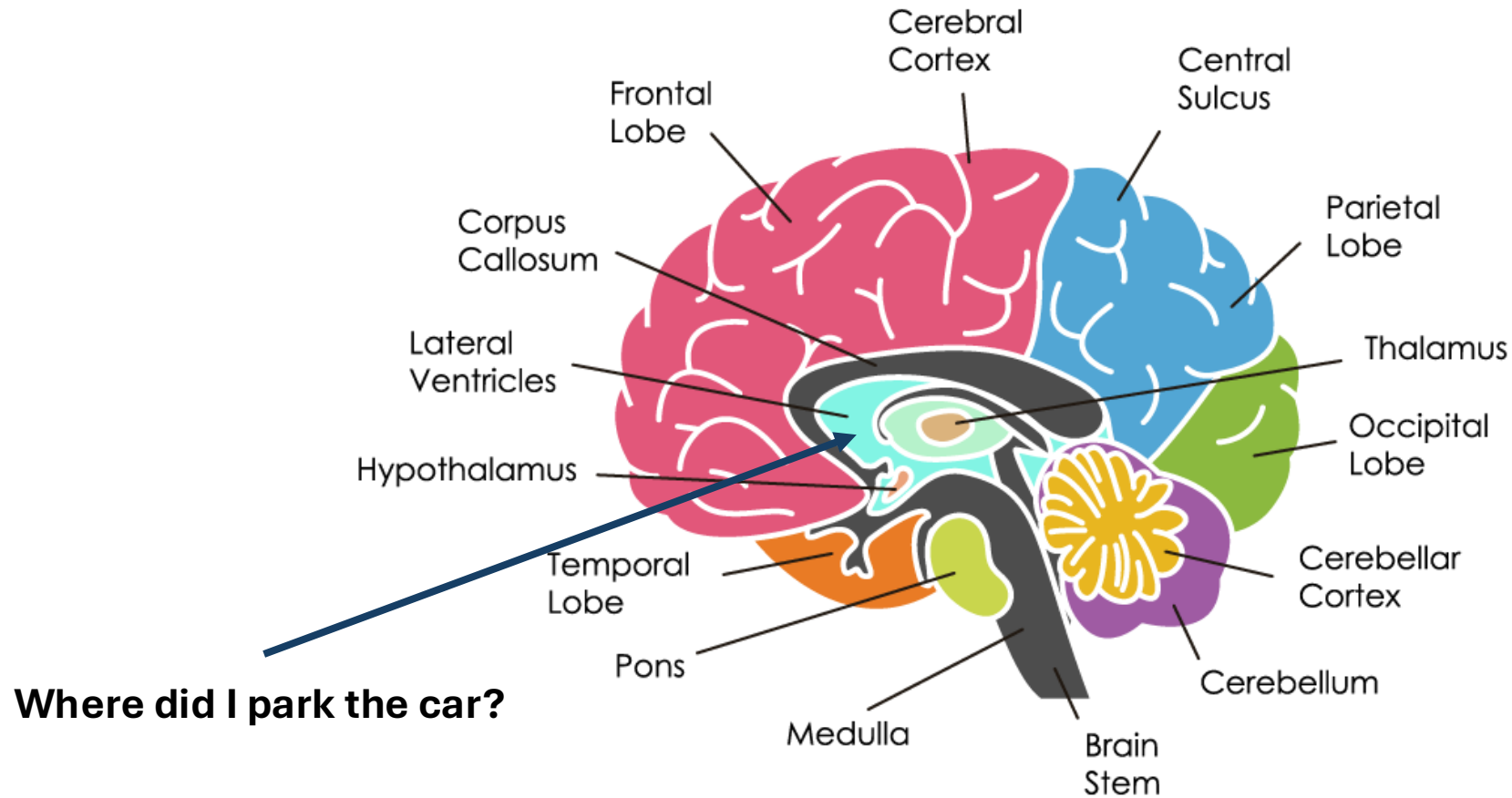
Where is my phone?



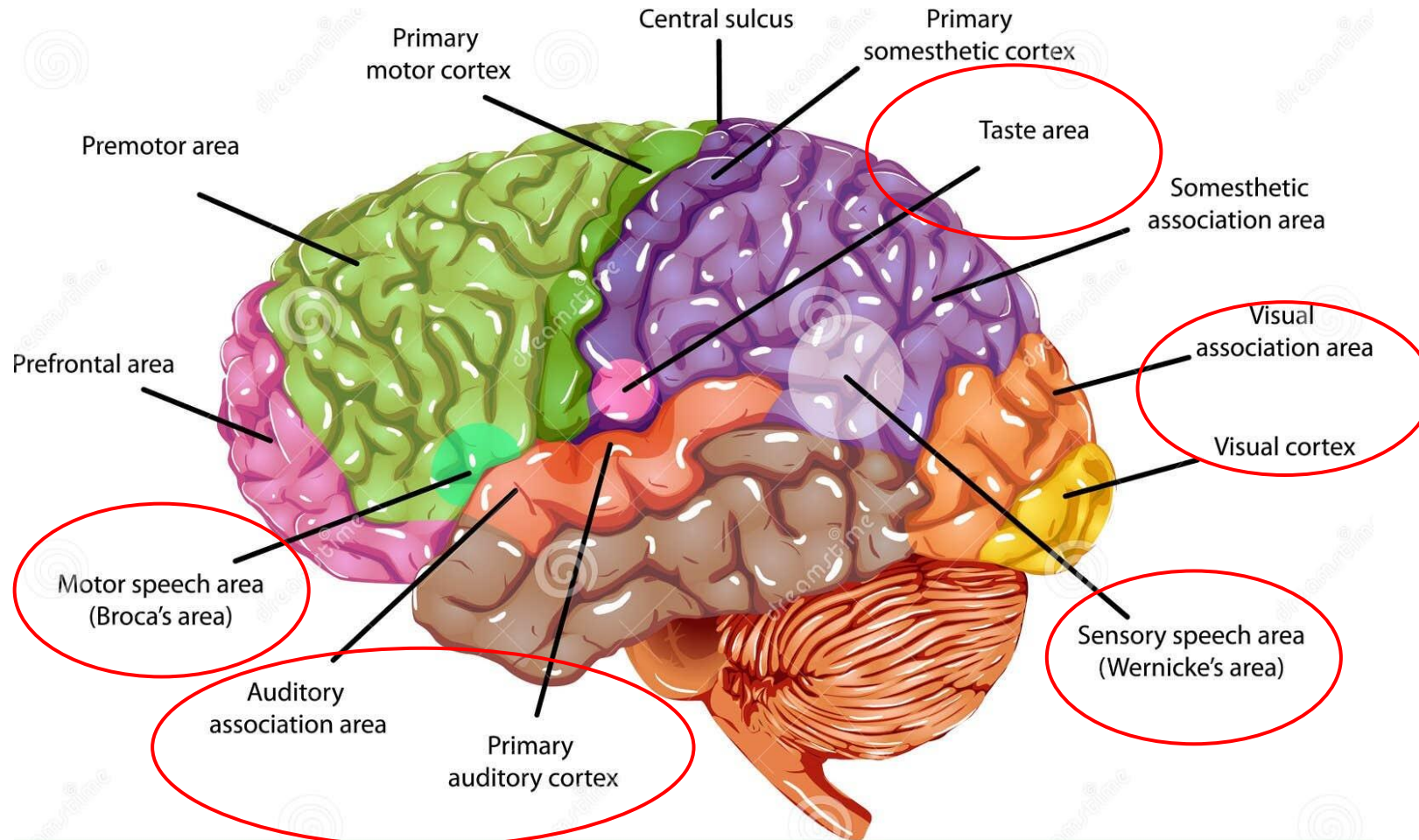
Where in the Brain is Important Information Retrieved from?



Where in the Brain is Important Information Retrieved from?



Functional Parts of the Brain



Do We Have a Second Brain?

- **Our gut** (or the digestive system) is called our second brain. It contains > 100 million nerve cells lining your stomach and intestines.

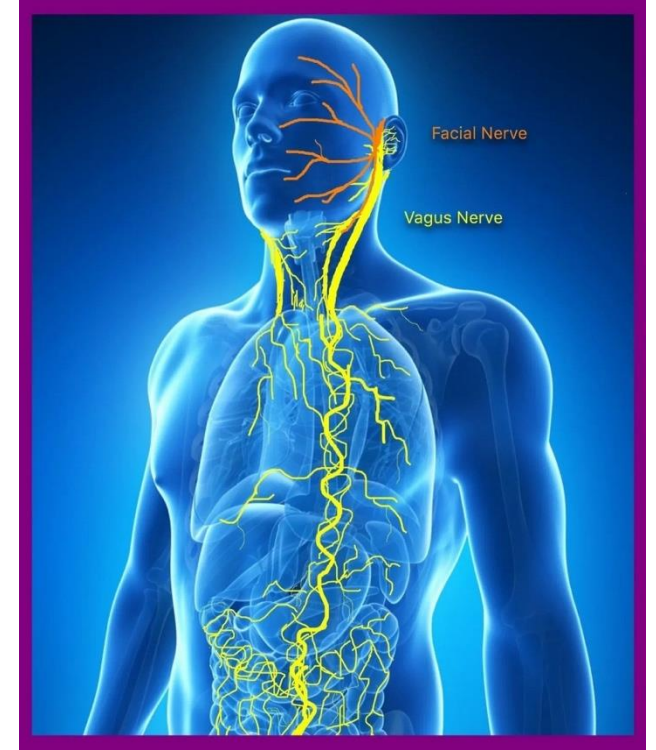
This network is the “enteric nervous system”

- **Independent action:** It can control digestion and run on its own without help from your head.
- **Massive nerve supply:** It holds more nerve cells than your spinal cord.
- **Chemical matches:** It makes many of the same “signaling” body chemicals as your brain, like serotonin.

It talks to your main brain through the Vagus nerve

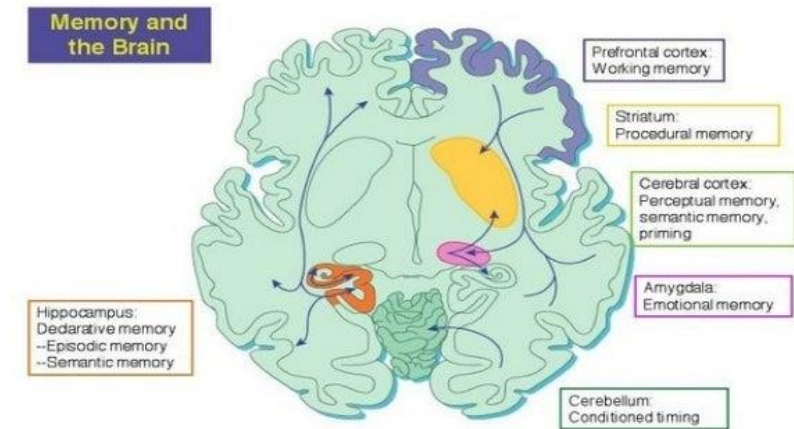
Vagus Nerve

- **Two-way talk:** Messages to/from the brain.
- **Brain to body:** ~ 20% of the fibers send signals to change your heart rate and start digestion.
- **Body to brain:** ~80% of the fibers send sensory data upward about the status of your organs
- **Inflammation switch:** Senses swelling or injury and signals the brain
- **Mood link:** If your gut is stressed, the nerve carries that stress up to your brain, causing anxiety.
- **Heart control:** It lowers your heart rate and blood pressure when you are calm.
- **Digestion trigger:** It signals your stomach to release acid and increase activity in the intestines

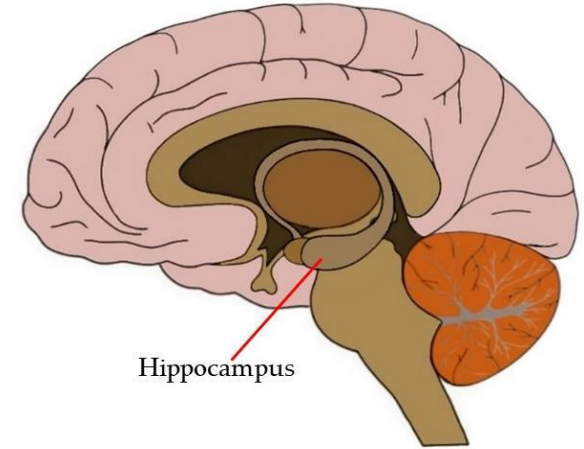


How are Memories Formed?

- Episodic memory recalls where and when the memory was formed
- Episodic memory has sensory elements meaning you remember sights seen or sounds heard
- Any memory not forgotten enters storage.
- Several areas of the brain are involved depending on the type of memory and the kind of information encoded to remember it. The hippocampus is important for storing and multiple types of memory.



Hippocampus

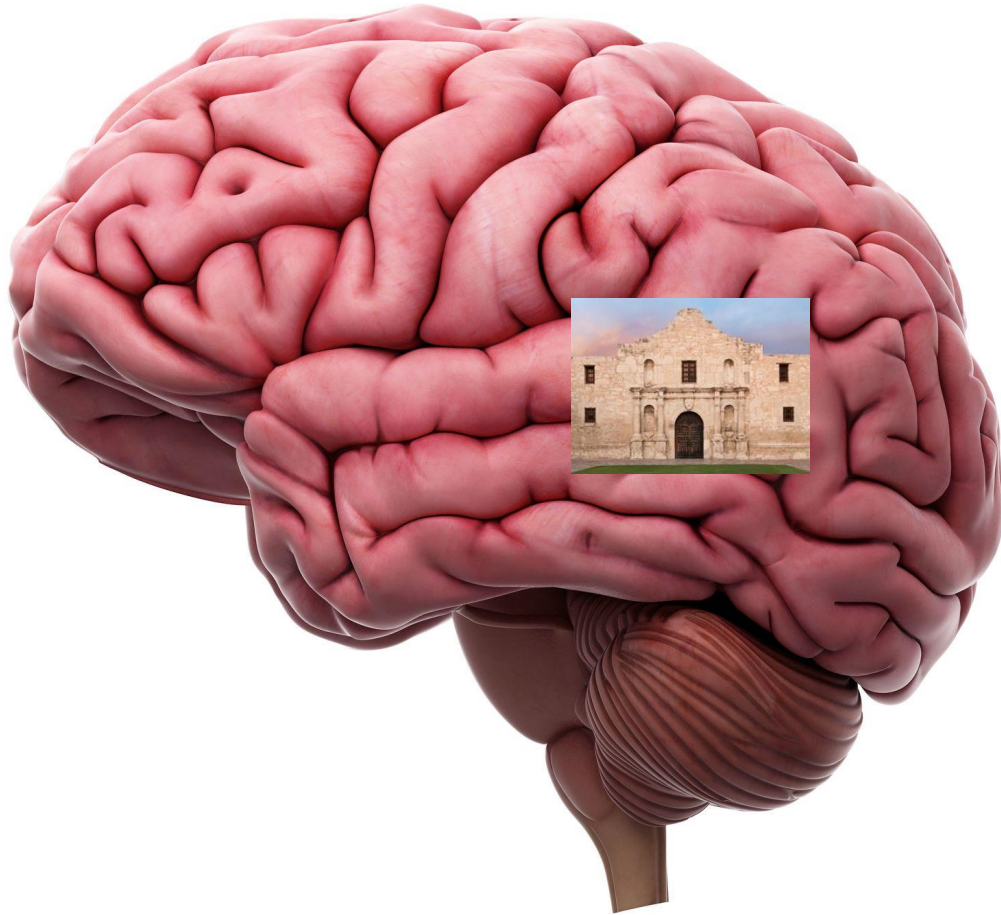


This is a seahorse-shaped region that's responsible for memory and learning. Initial memories are formed here. The hippocampus can be affected by Alzheimer's disease.

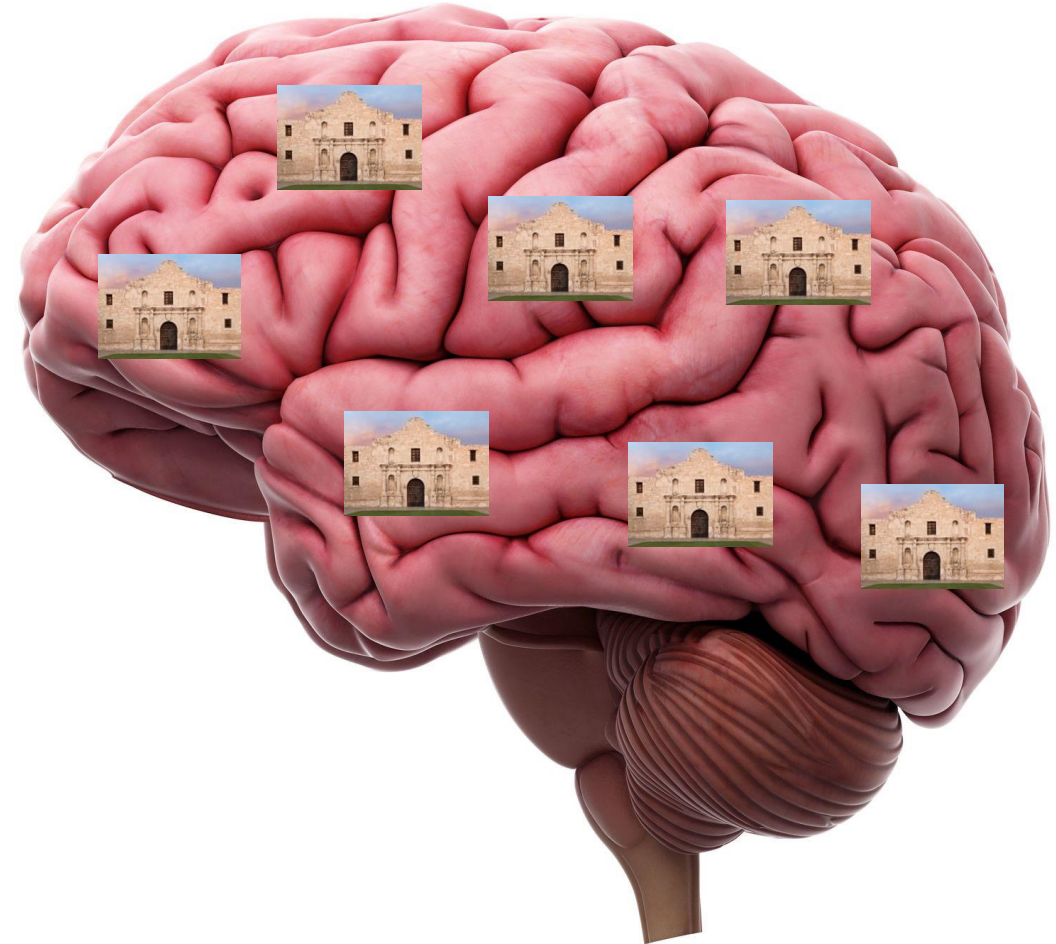
Longer term memories are stored elsewhere in the brain (cortex).

Remember(ing) the Alamo!

What you might think!



Reality!



Long-term storage: Distributed networks

Long-term memories are **not stored in one place**.

Instead:

- **Episodic details:** initially hippocampal, later shared the cortex
- **Semantic (language and symbols) knowledge:** largely neocortical.
- **Procedural memories:** stored in the cerebellum and basal ganglia.

As memories age, the hippocampus becomes less involved

Retrieval: Reconstructing the stored pattern

- Retrieval is not replay — it's **reconstruction**.
- The hippocampus uses **pattern completion** to reactivate the stored neural pattern
- Cortical regions help select relevant memories
- Reactivation can strengthen or modify the memory, making retrieval itself a form of learning.

Engram = An Memory

An engram is the physical or biochemical change in the brain that represents a memory

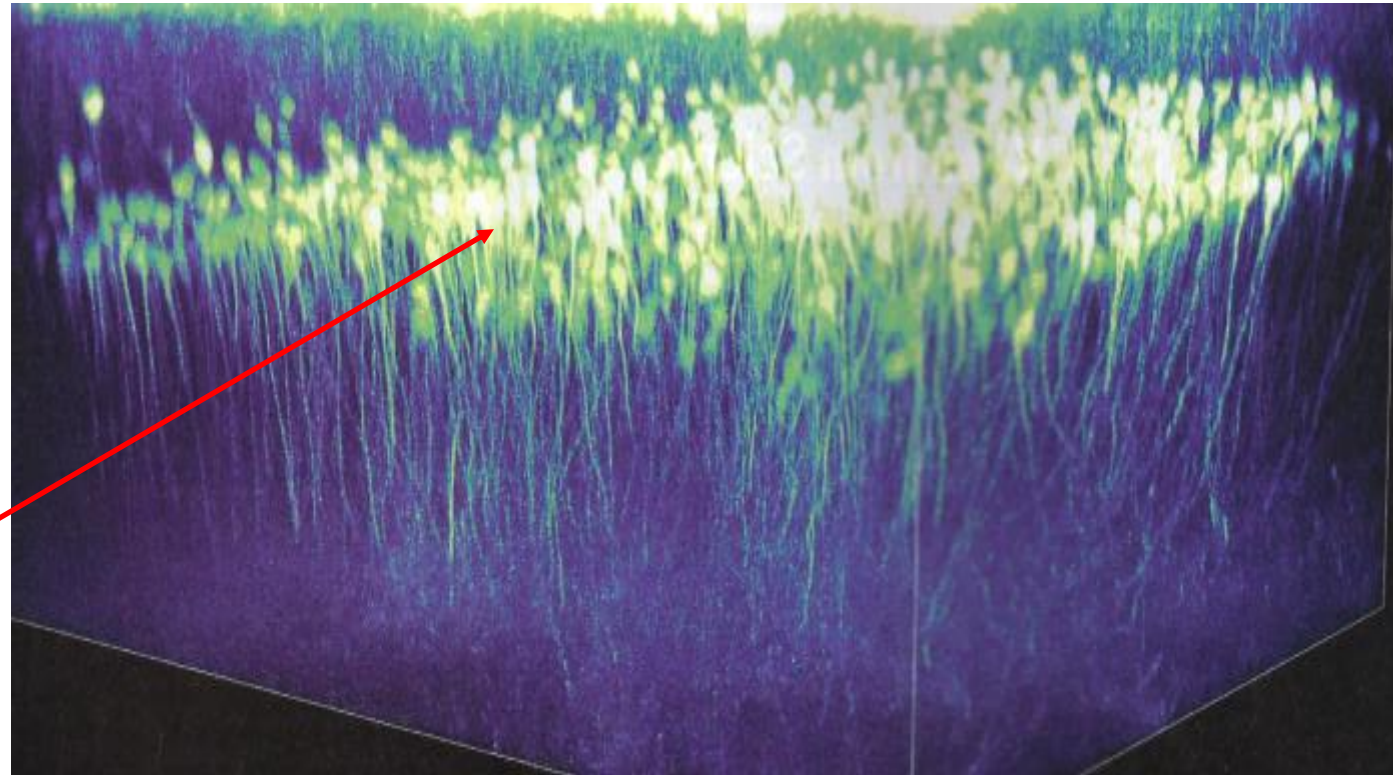
- : are network of neurons
- : are formed in the hippocampus and then moved to the cortex for long-term storage
- : allow the brain to encode, store, and retrieve experiences
- : acts like a time capsule, preserving a specific experience, enabling recall of sensory, emotional, and cognitive aspects of that memory

What does Memory (Engrams) Storage Look like in the Brain?

Spines and synapses form memories.

When mice subjected to hibernation, there was a substantial reduction in the spines and synapses. When the mice recovered from the hibernation, more than 80% of the dendritic spines reappeared.

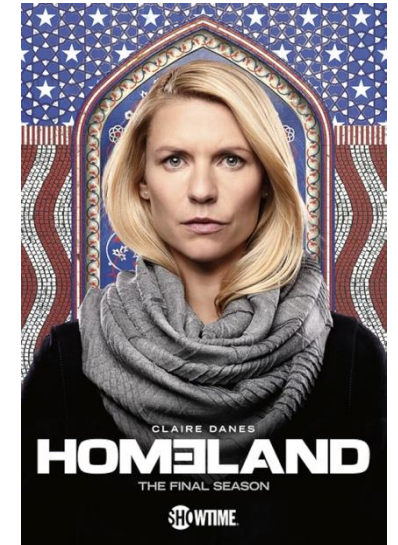
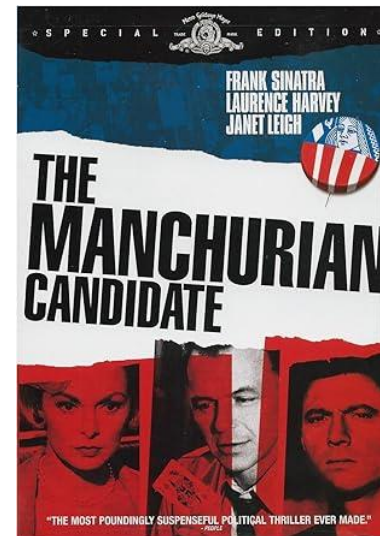
Spines



How to Map/Manipulate a Memory

- **“Tag” neurons that activate during learning** with light activated chemicals, neurons involved in forming a memory can be made to glow. (Optogenetics – Nobel Prize awarded this week!)
- **Those neurons** appear in dozens of brain regions (hippocampus).
- **When you trigger a memory**, the same neurons light up again.
- **You can manipulate the memory** by stimulating the engram cells, silence a memory or create a false memory!
- Possible treatment for PTSD!

Oh No! It's Real

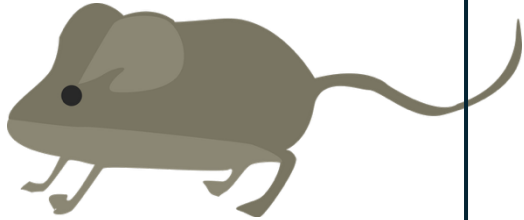


Memory and the Microbiome

- The Human Microbiome consists of >39 trillion bacteria, fungi, and Archaea (ancient bacteria!)
- Your microbiome changes as you age
- And your memory CHANGES as you age! (anyone want to contest that?)
- New research points to your microbiome as a culprit in your memory issues!
- Cool Experiment in mice to show this

Experiment in Mice

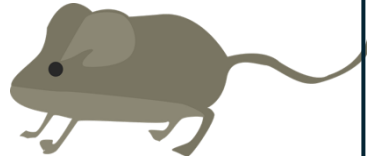
 **Old Cage**



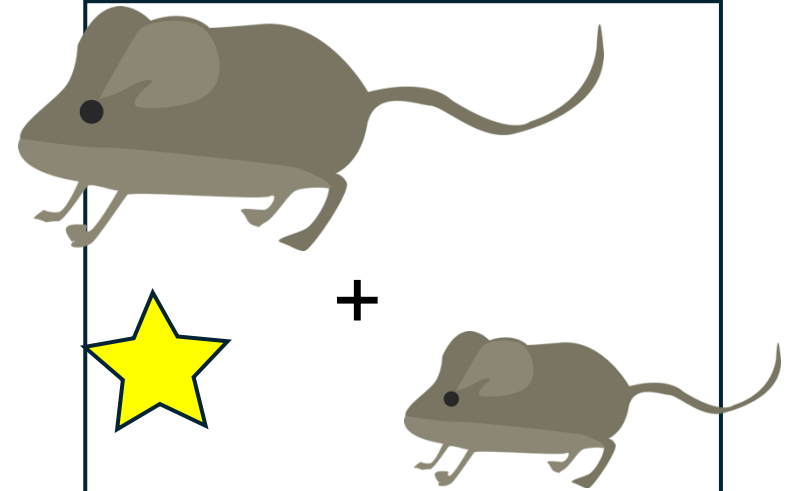
Old Mice
Can't remember
novel objects

Young Cage

Young Mice
Easily remembers
novel objects



Mixed Cage



Mixed – Both Young & Old
Both can't remember novel
objects

Why does this happen?

Why Does This Happen?

- When mice co-habitat they “share each others microbiome” - **(they eat each others poop!)**
- This changes the intestinal microbiome of the young mice and their ability to remember objects – they display memory loss!
- It appears to come down to one bacteria - *Parabacteriodes goldsteinii*
- But how?

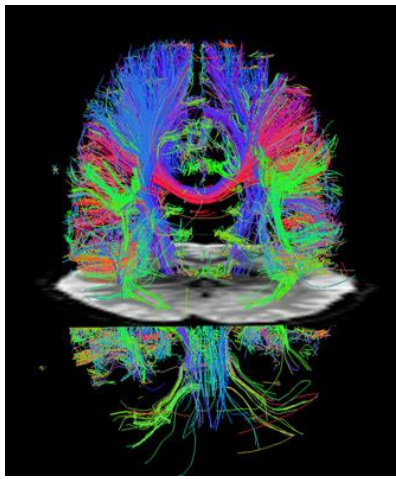
How Does This Occur?

- This bacterium produces chemicals (fatty acids) that excite gut immune cells. This impairs the vagus nerve.
- Normal communication with the brain (hippocampus) – where memories are formed is impaired and memories can't be formed.
- **Implications:**
 - Does something similar occur in humans? If so, can something as easy as a probiotic help memory?
- **New Adage:** take care of your microbiome and it will take care of your memory!

Levels of Microplastics in the Brain Rising

- Microplastics are tiny plastic particles <5 mm in the environment
- We are widely contaminated with them (semen, blood, breast milk, placenta, bone marrow) even kids!
- Estimates are that the amount of microplastics in the brain increased 50% in the past 8 years.
- **Disease implications:**
 - 6 times higher in people who had dementia
 - Higher in placentas from premature births
 - Linked to heart attacks and strokes
 - Can block smaller blood vessels and cause neurological damage



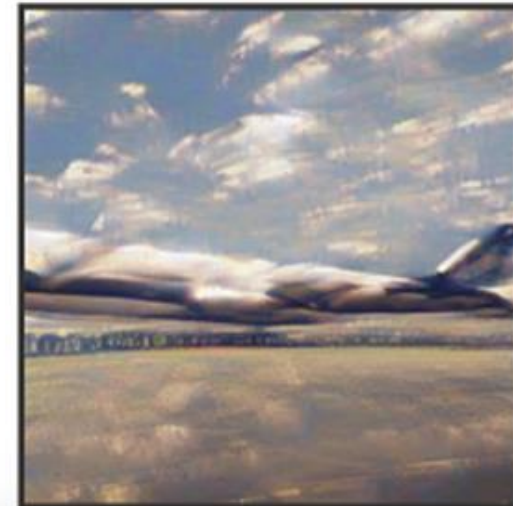


Read my Mind!

- fMRI Brain scans – AI analysis can read brain scans and display realistic images of what we see!
- Uses brain scans fMRI of the lobes of the brain that are involved in image perception
- Previously, it was shown that fMRI could decipher what people were reading from just fMRI brain scans!
- With AI, scientists can read fMRI brain scans and assemble a picture of what people were seeing!.

- Science - [AI re-creates what people see by reading their brain scans | Science | AAAS](#)

Actual Pictures



Brain Scans

The background of the slide features a complex molecular structure with various atoms and bonds, rendered in a blue and red color scheme. A semi-transparent dark blue box is overlaid on the top left, containing the text "Medical Discovery News" and "Bridging the World of Medical Discovery and You".

Medical Discovery News

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