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2021 Annual Fall Conference

My Brain Made Me Do It!

Neurophysiological Correlations of Human Psychiatric Illness and Covid 19 Update

10/7/21

PRESENTER

Emmet M. Kenney Jr., M.D.

Child & Adolescent and
General Psychiatrist
Associate Professor of Psychiatry
and Pediatrics,
UND School Of Medicine

Objectives:

At the end of this presentation the participant will be able to:

Discuss and recognize key regionalization of brain function and neuroanatomical structures involved in attention and memory

At the end of this presentation the participant will be able to:

Discuss and recognize key regionalization of brain function and neuroanatomical structures involved in inhibition and executive functioning

At the end of this presentation the participant will be able to:

Discuss overlap of executive functioning and inhibition and attention in illness states of ADHD, Bipolar Disorder, Schizophrenia, Depression, OCD, other anxiety Disorders, Impulse Control and other Disorders

At the end of this presentation the participant will be able to:

Be aware of the most recent findings of how infection with COVID-19 has influenced such brain functions

3 Big Take-Aways

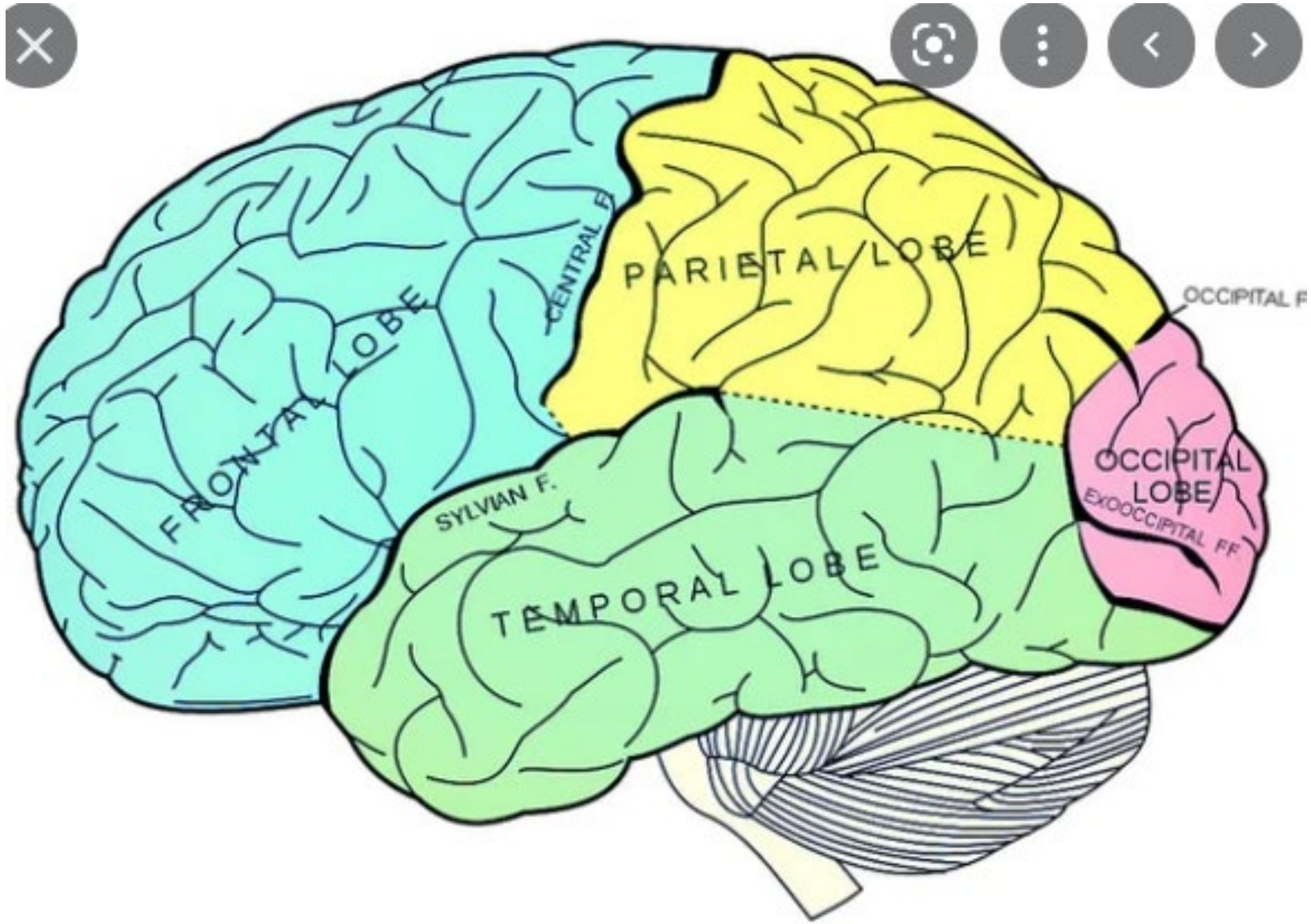
#1. The Brain has A LOT to do with Human Behavior

3 Big Take-Aways

#2. Most of the Brain is involved in Human Behavior

3 Big Take-Aways

#3. There is a lot of overlap in the areas of the brain that affect Human Behavior and different types of behavior.


FRONTAL LOBE
CENTRAL F.
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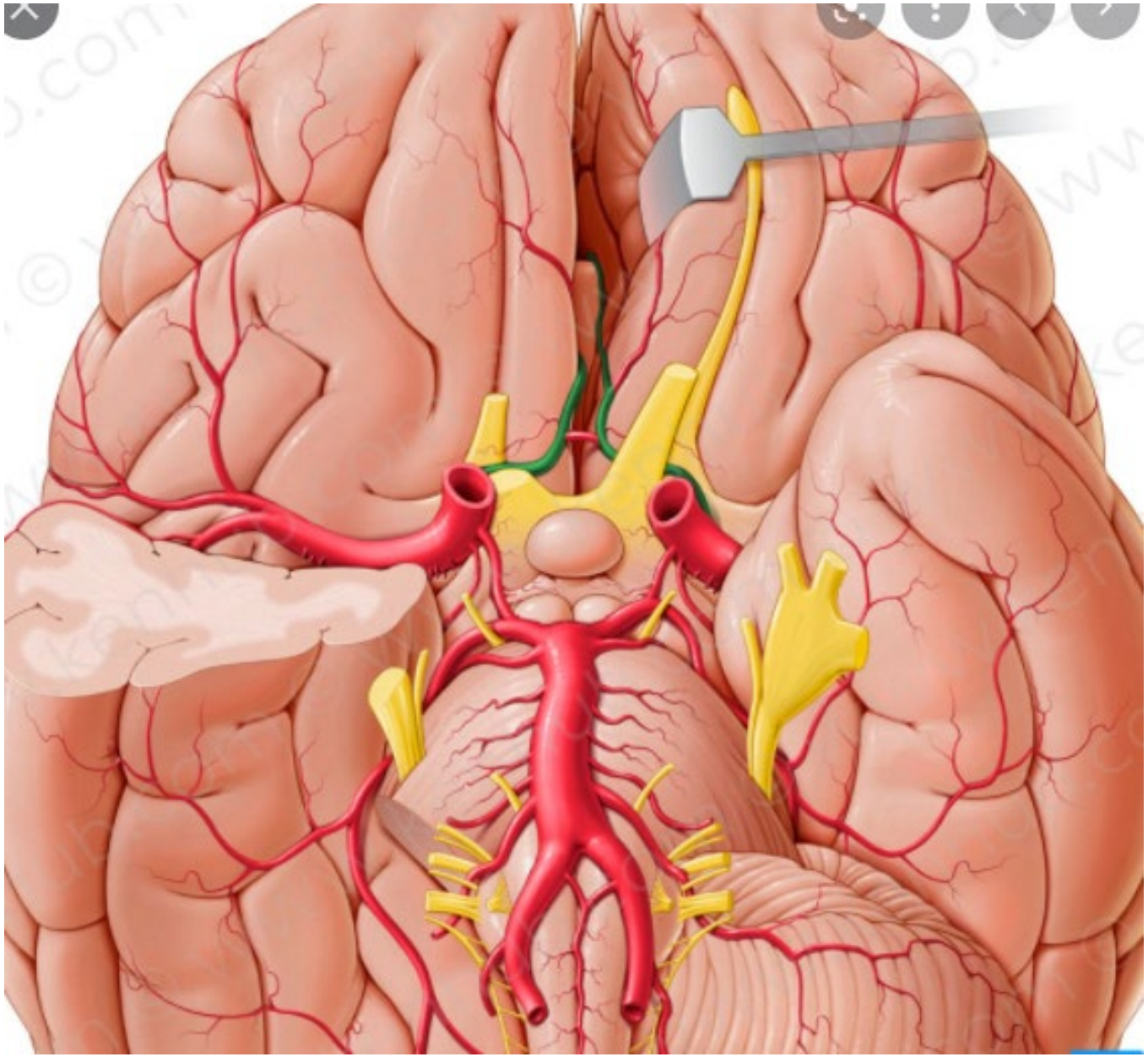
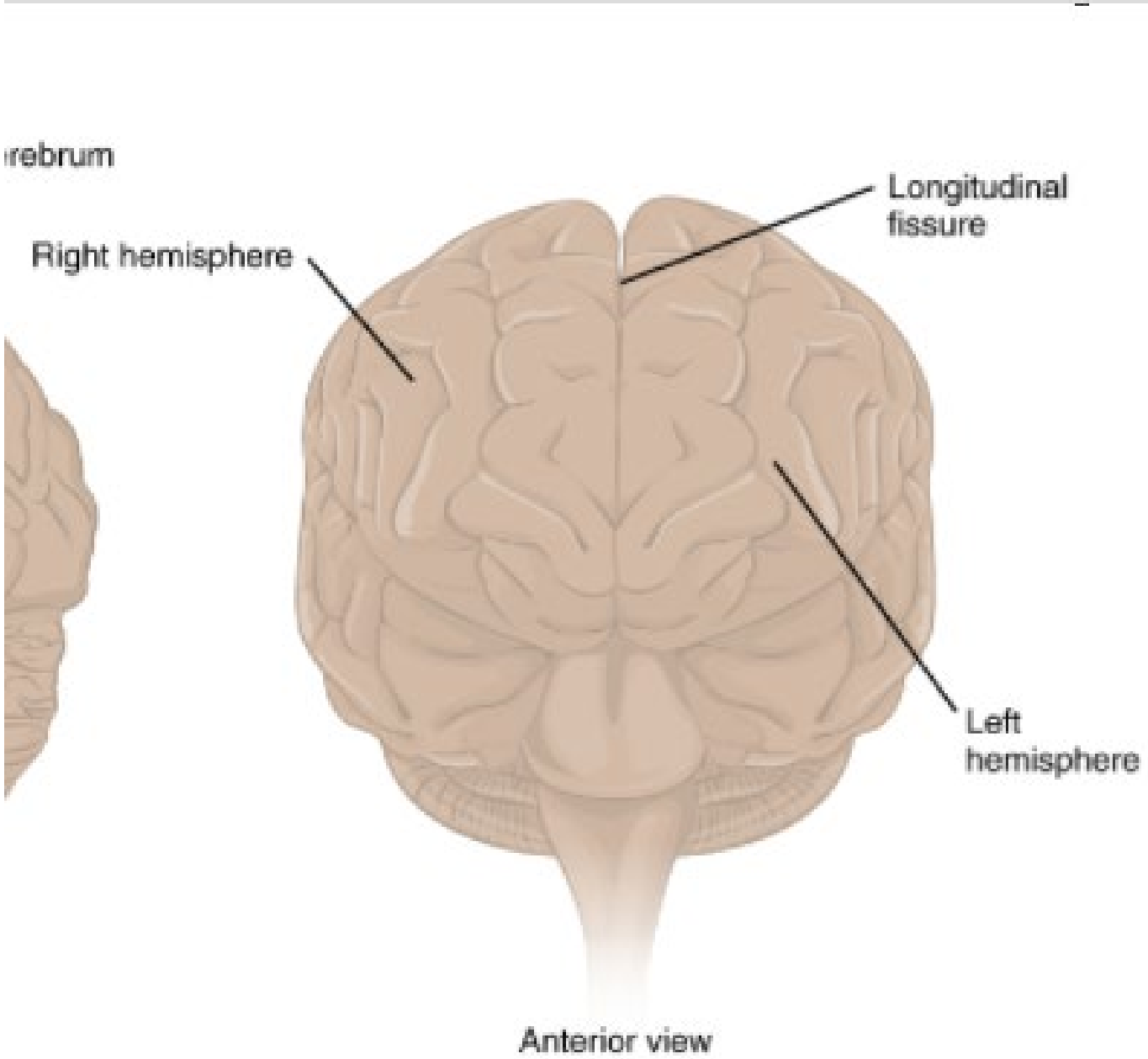
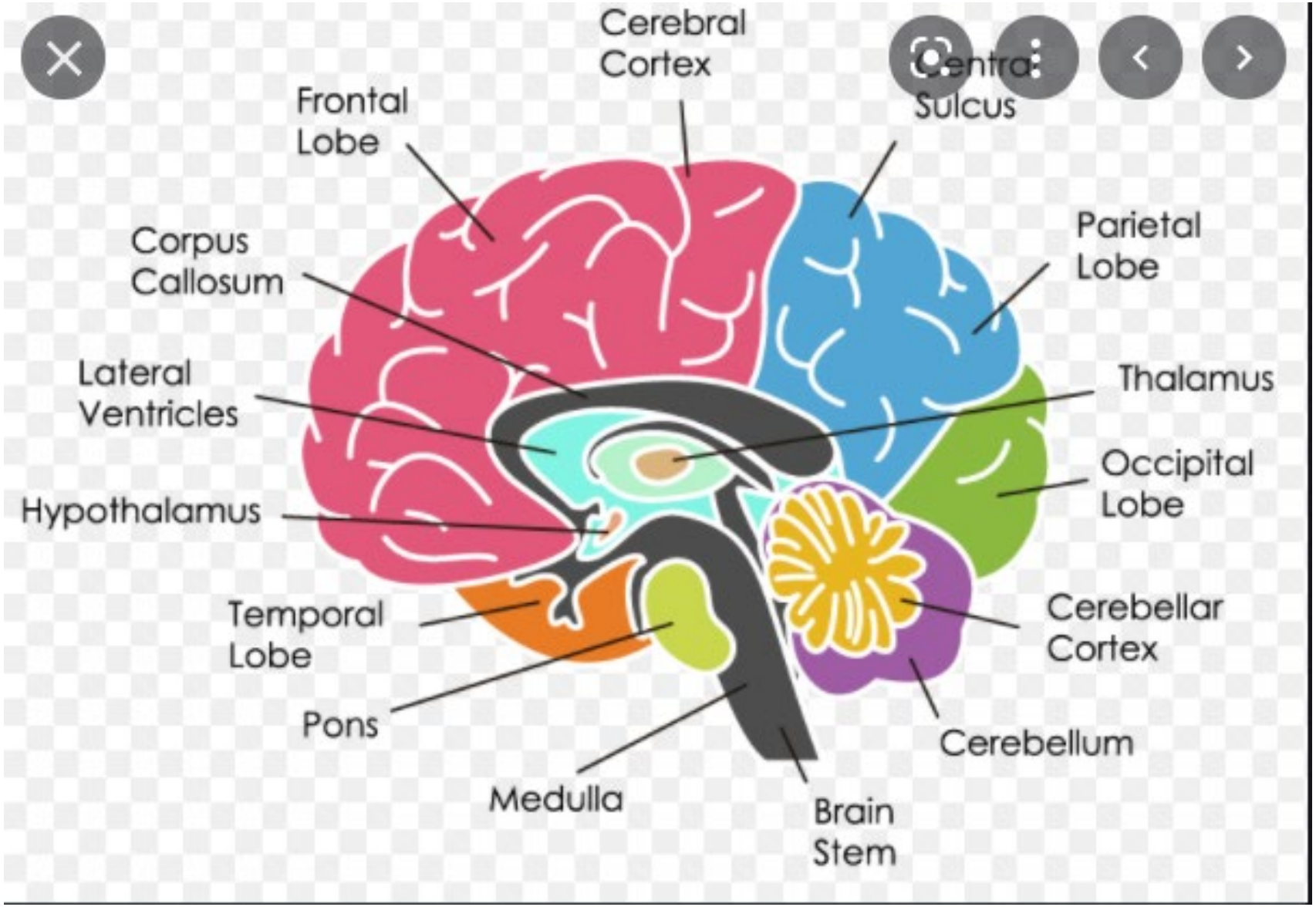
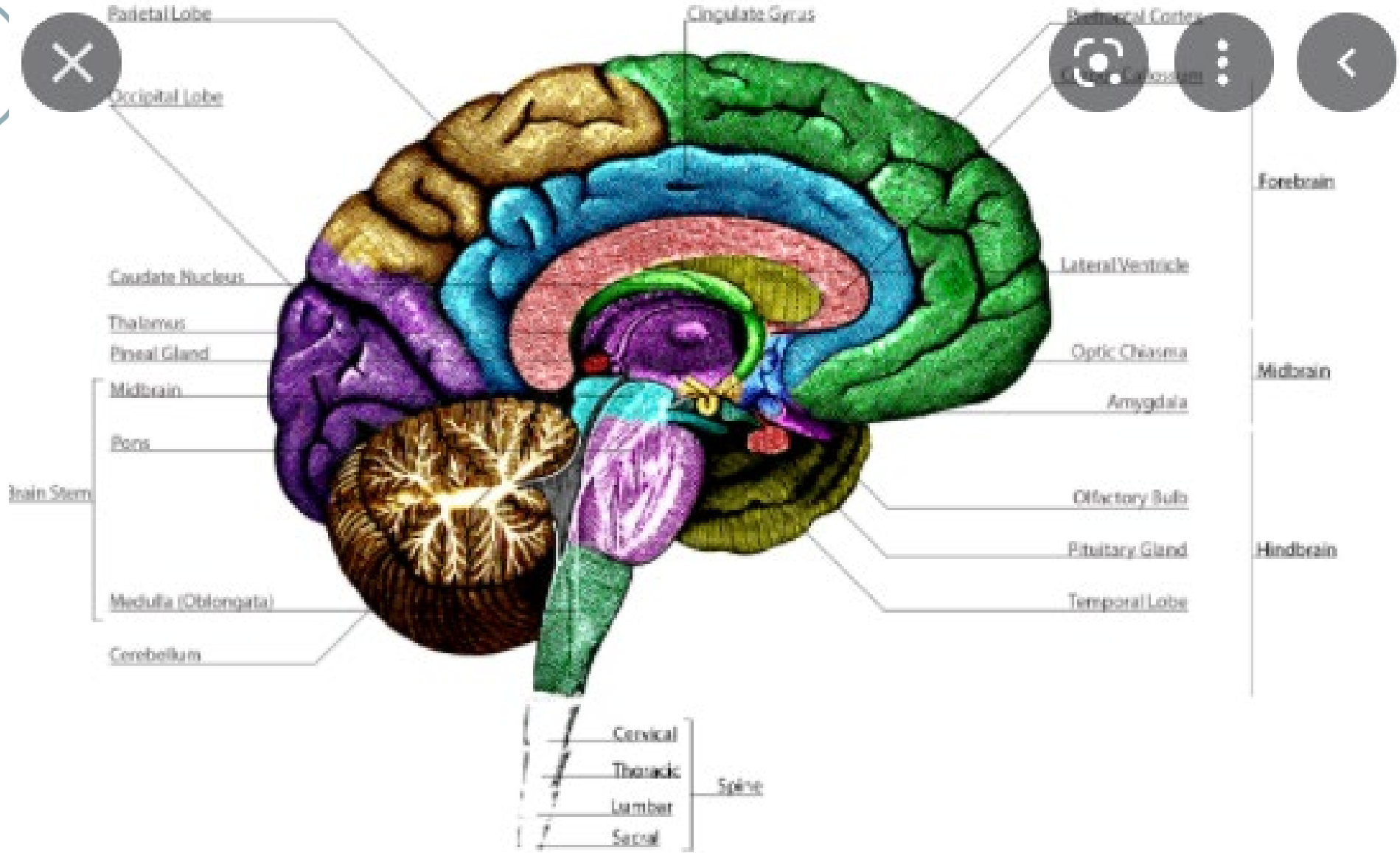
OCCIPITAL LOBE
EXOOCCIPITAL FF




rebrum
Right hemisphere
Longitudinal fissure
Left hemisphere
Anterior view

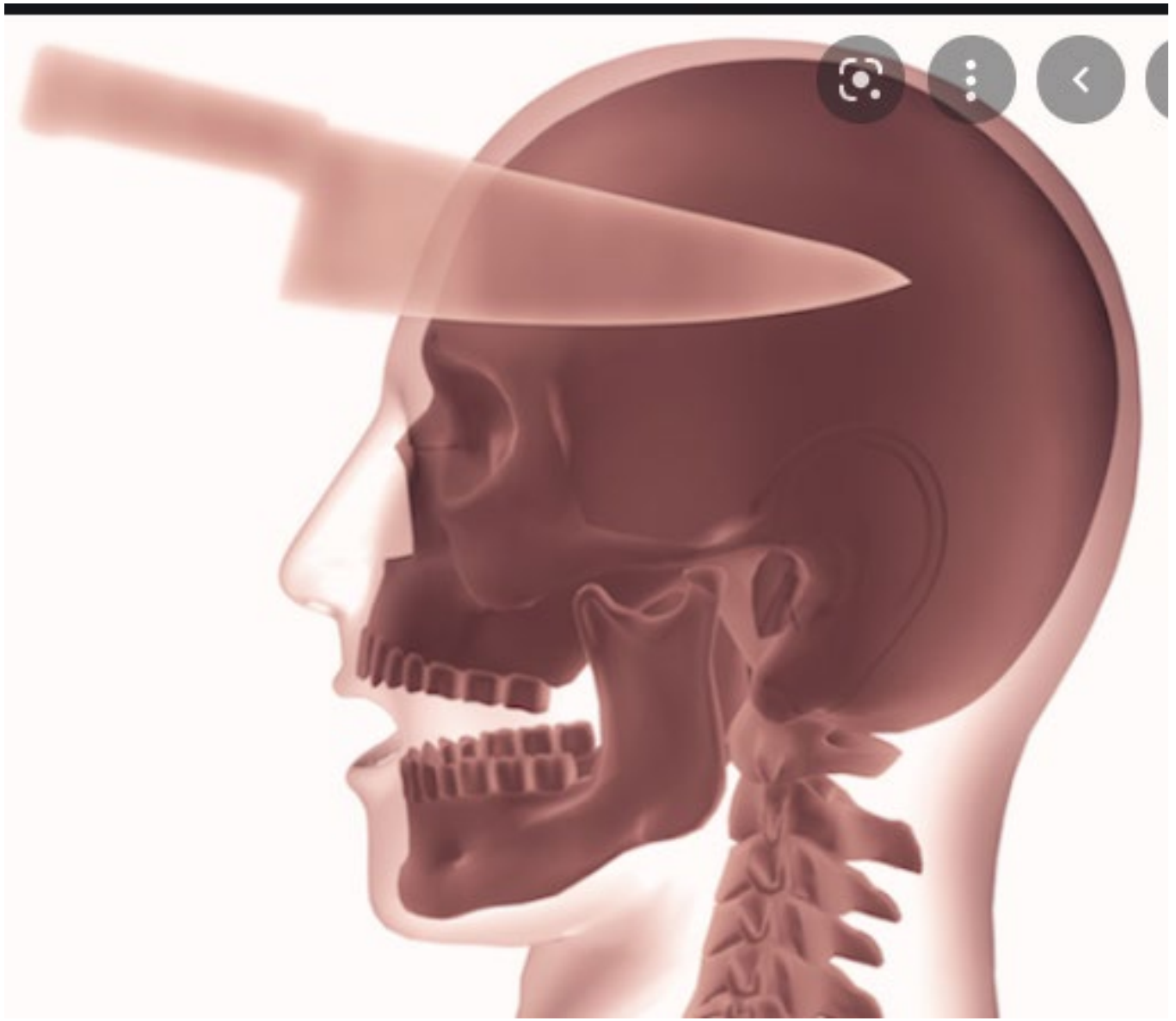

Cerebral Cortex
Frontal Lobe
Central Sulcus
Corpus Callosum
Parietal Lobe
Lateral Ventricles
Thalamus
Occipital Lobe
Hypothalamus
Temporal Lobe
Cerebellar Cortex
Pons
Cerebellum
Medulla
Brain Stem


Parietal Lobe
Occipital Lobe
Caudate Nucleus
Thalamus
Pineal Gland
Midbrain
Pons
Brain Stem
Medulla (Oblongata)
Cerebellum
Cingulate Gyrus
Lateral Ventricle
Optic Chiasma
Amygdala
Olfactory Bulb
Pituitary Gland
Temporal Lobe
Forebrain
Midbrain
Hindbrain
Cervical
Thoracic
Lumbar
Sacral
Spine

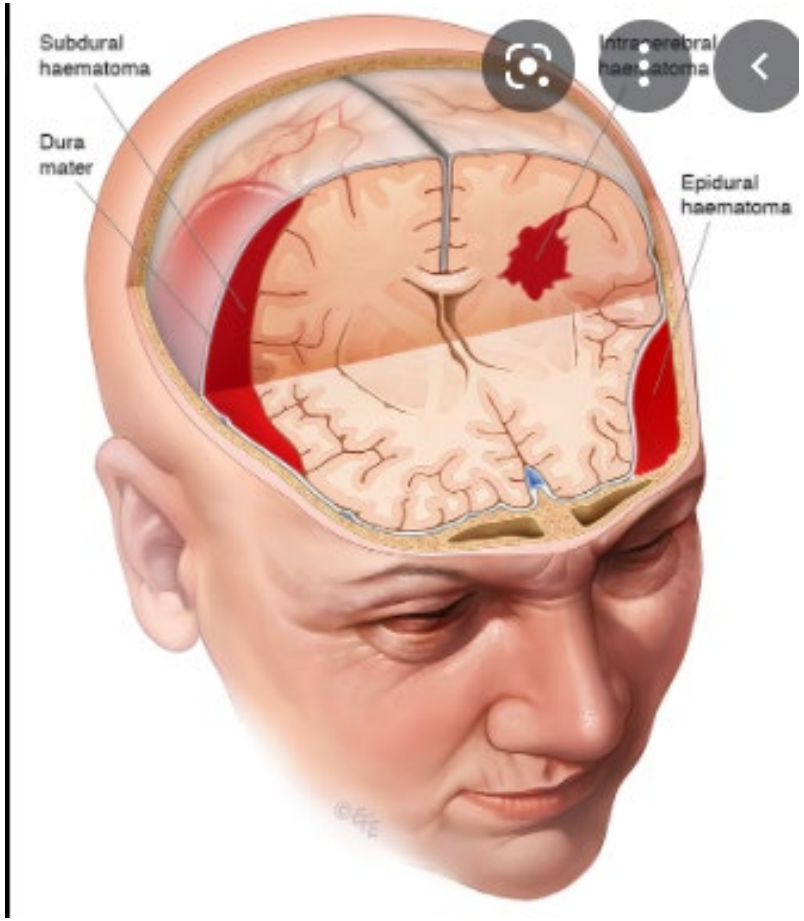
How Do We Know What the Human Brain Does?

How Do We Know What the Human Brain Does? Combat

How Do We Know What the Human Brain Does? Accidents. Phineas Gage



How Do We Know What the Human Brain Does?

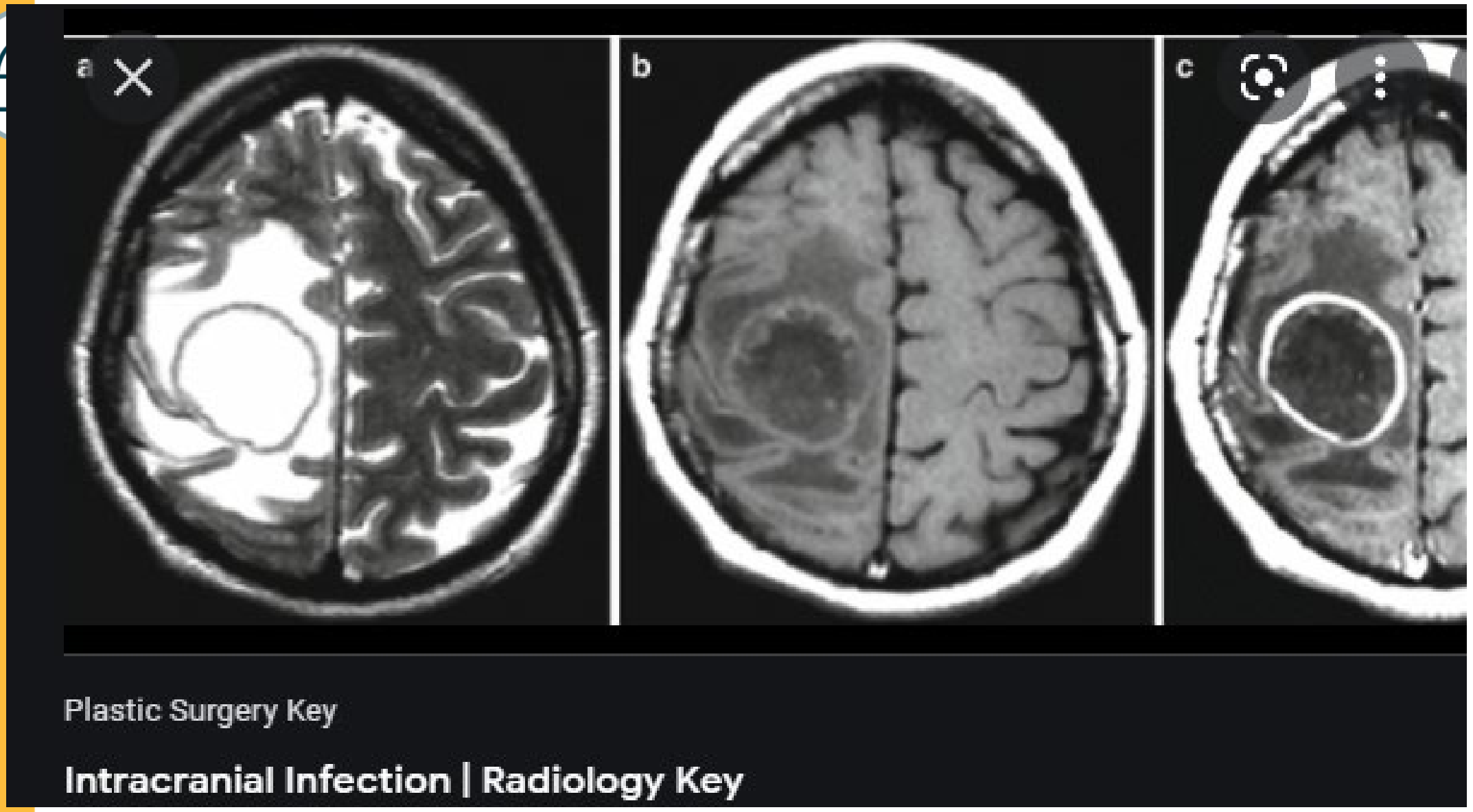


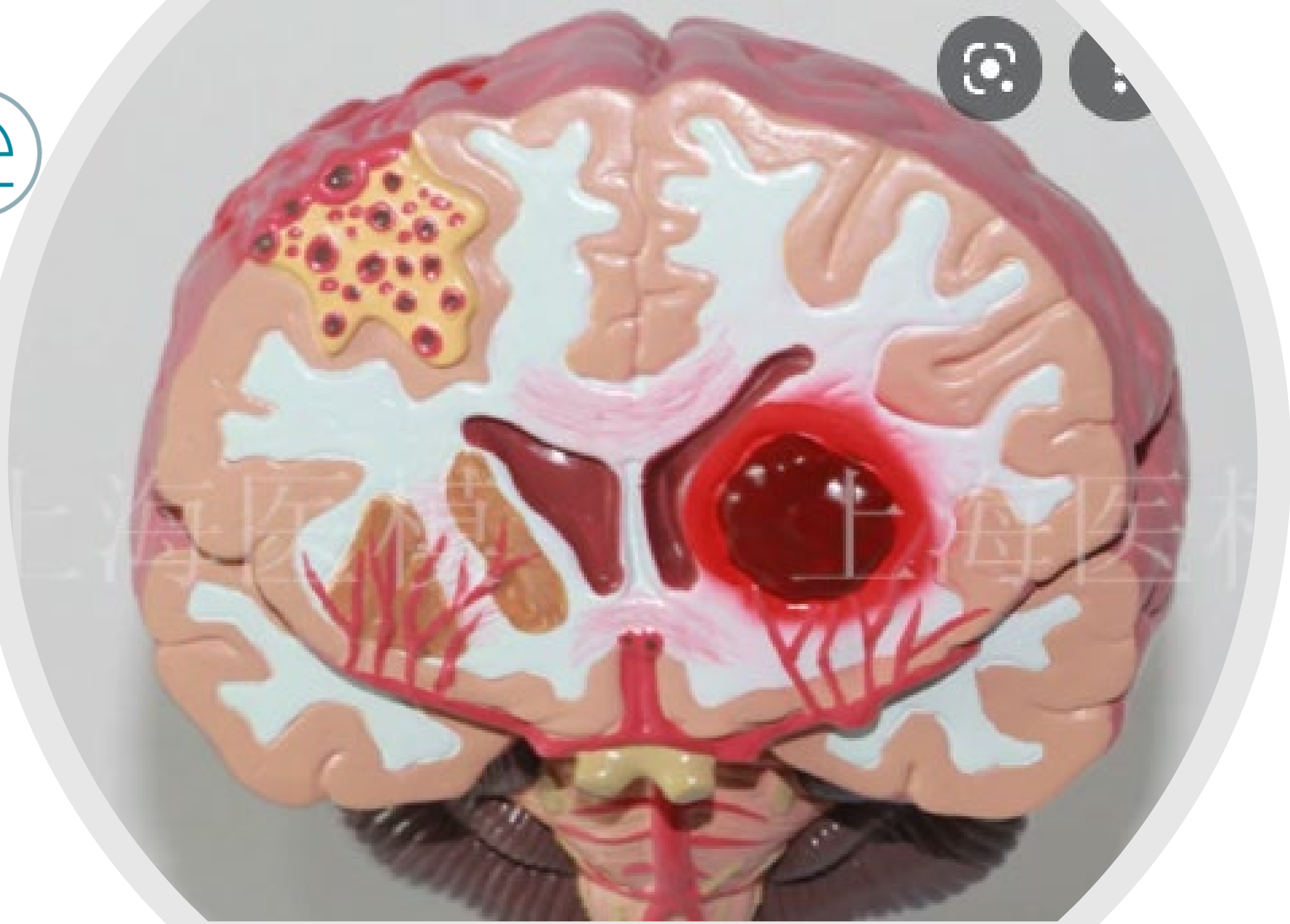
Ischemic Stroke

Clot blocks blood flow

Hemorrhagic Stroke

Bleeding inside or around brain


a
b
c
Plastic Surgery Key
Intracranial Infection | Radiology Key



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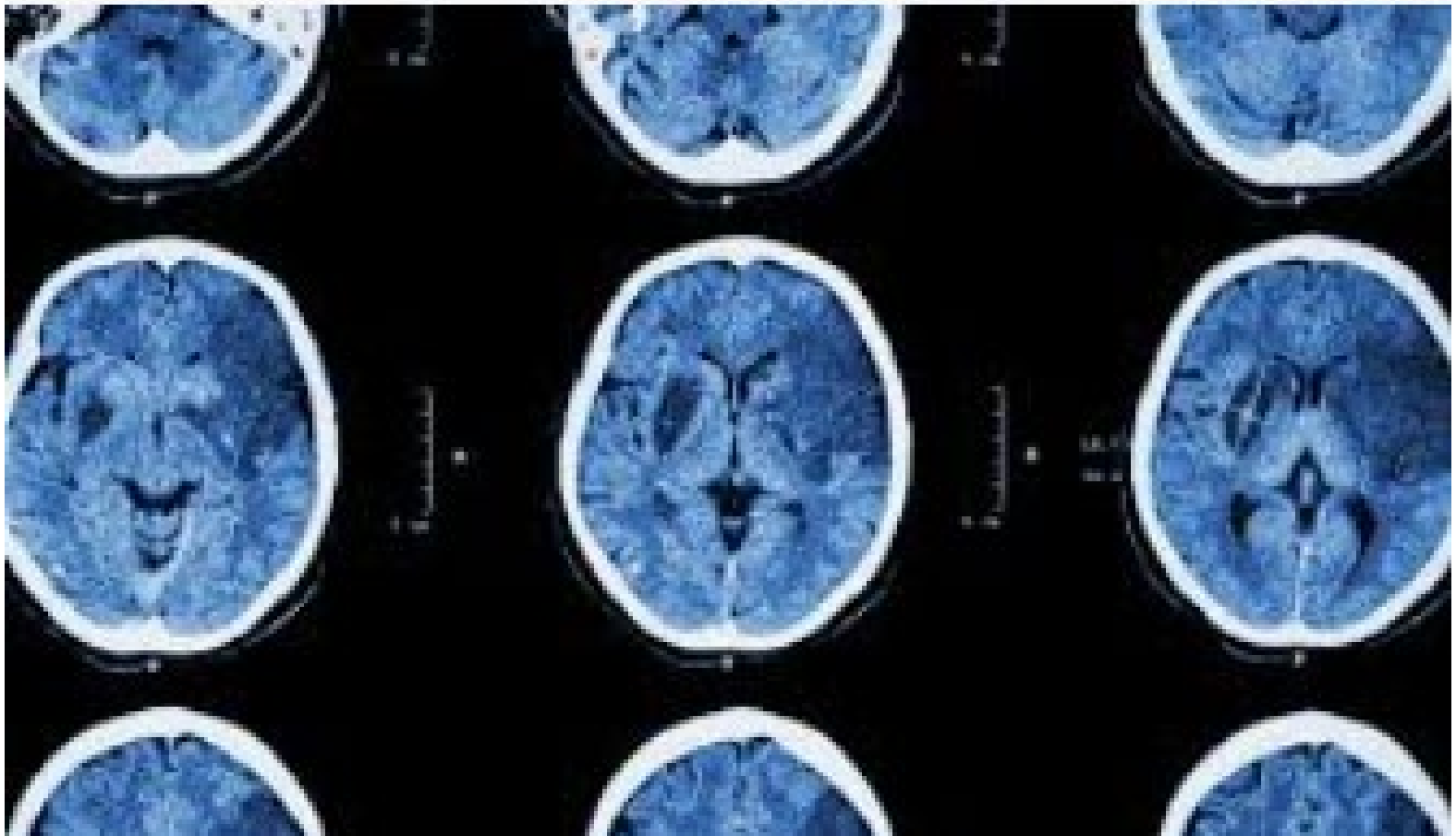
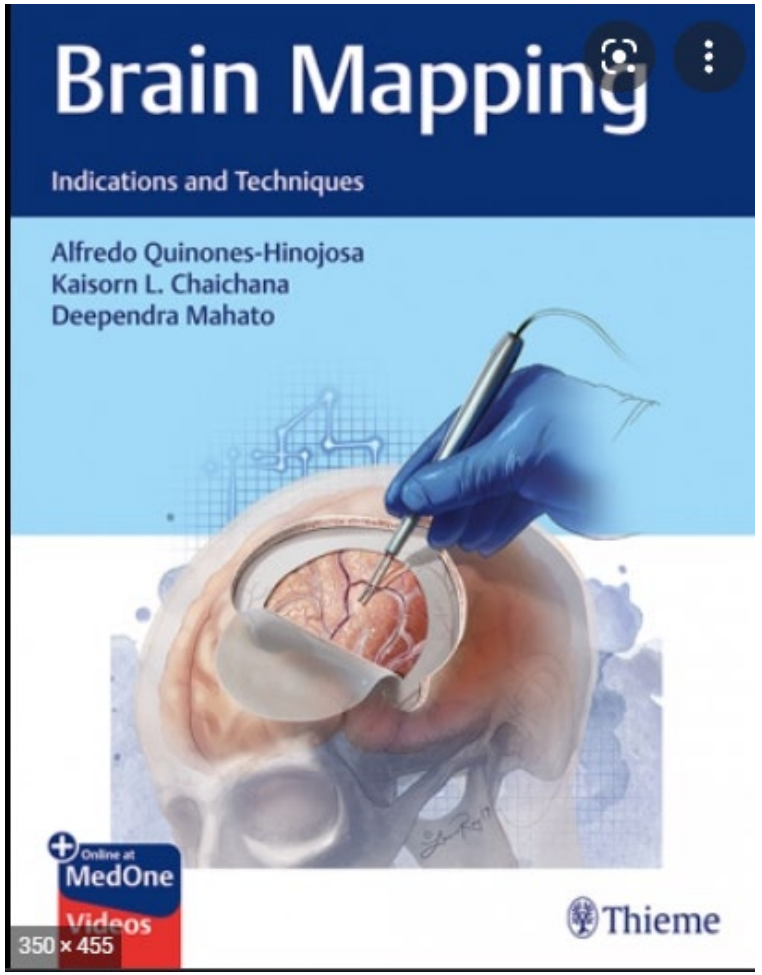
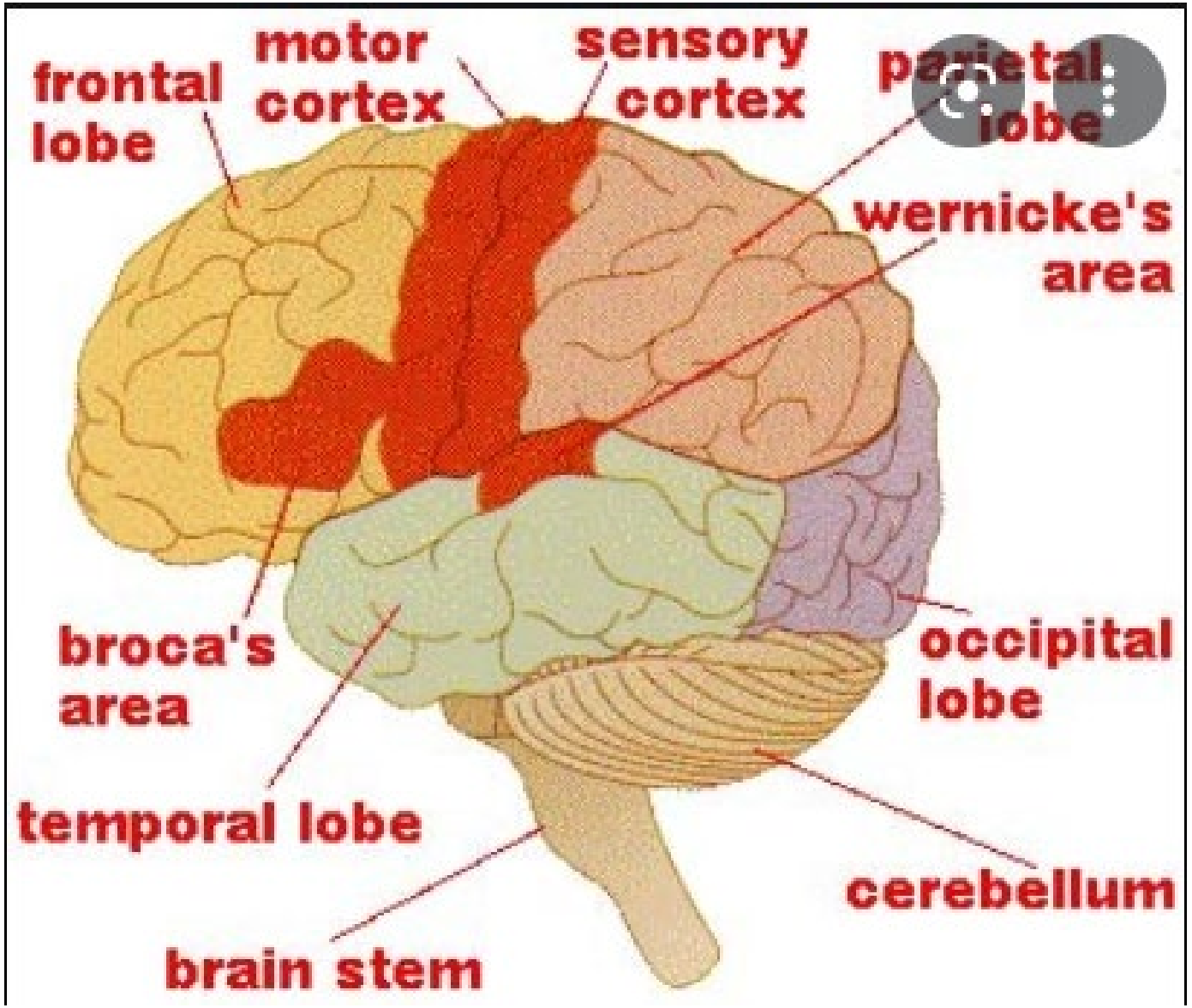
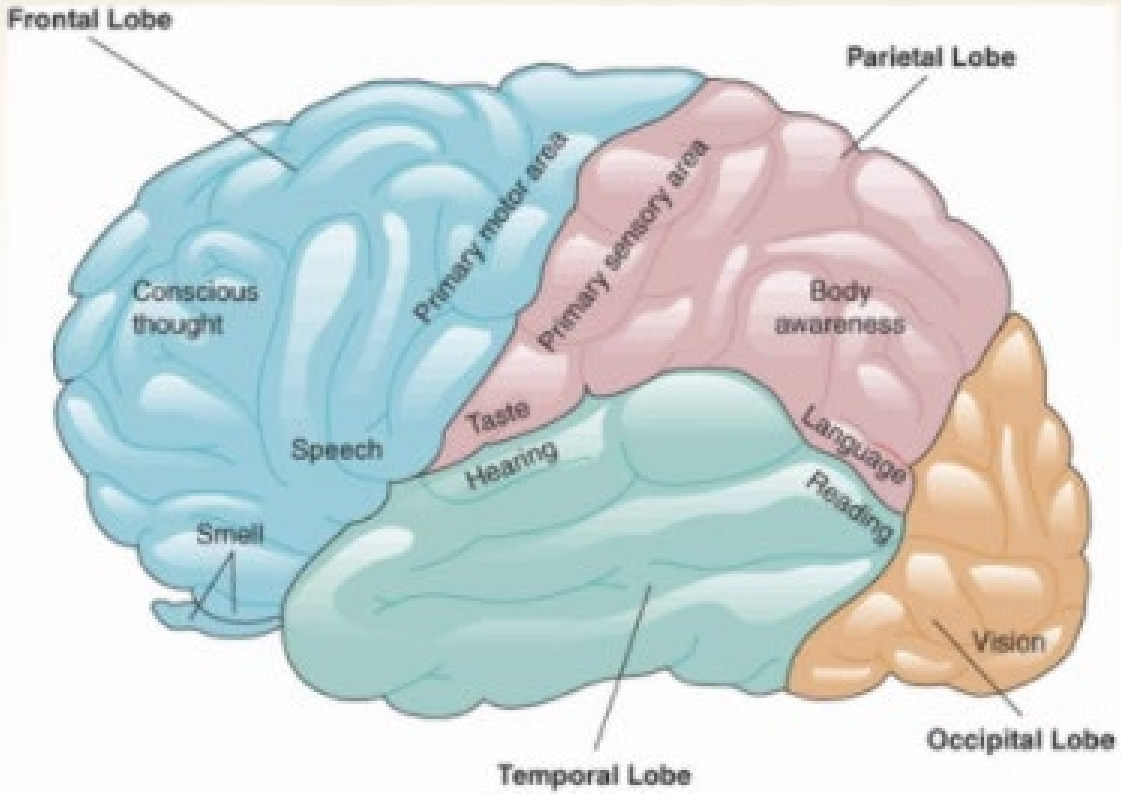


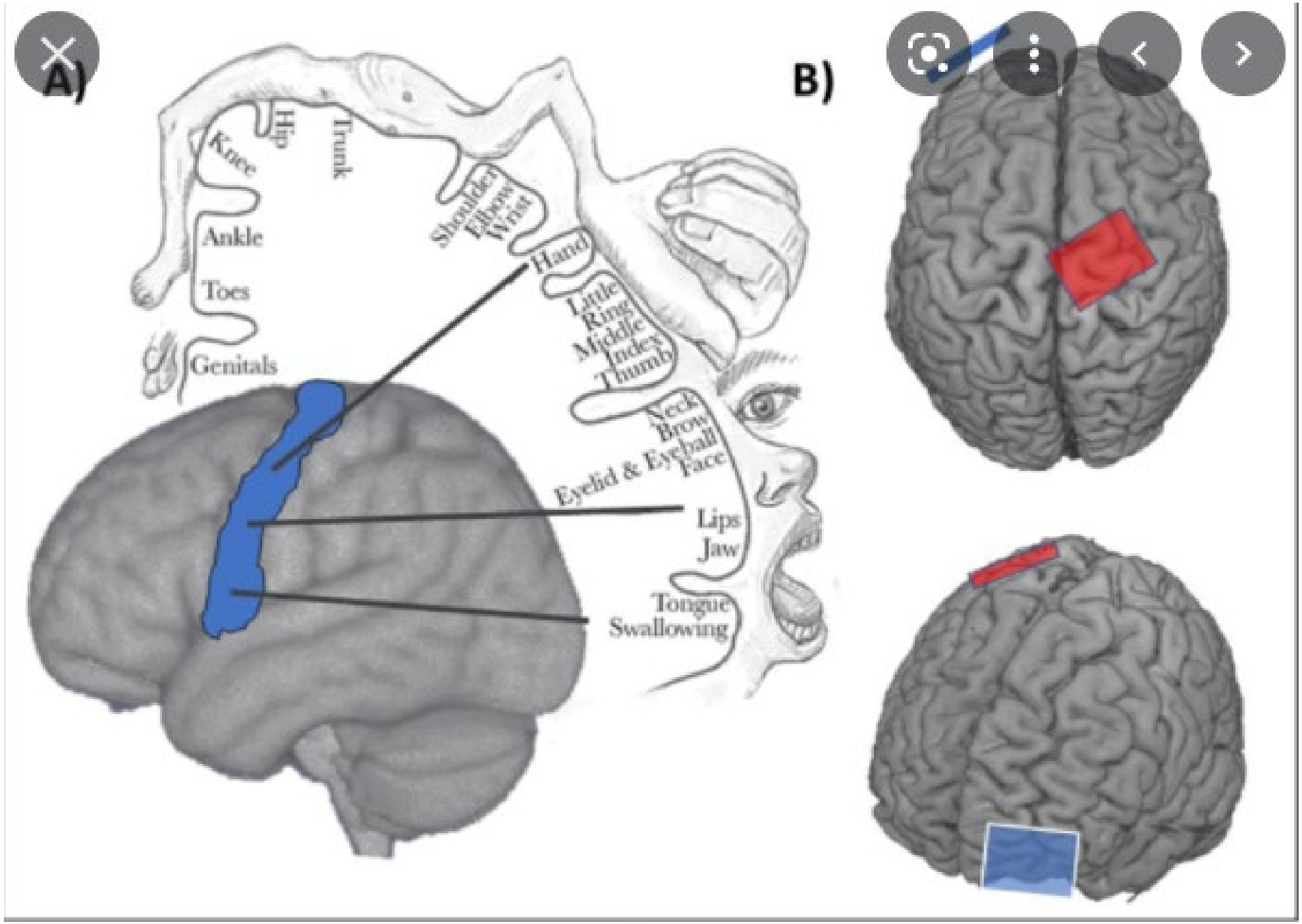
How Do We Know What the Human Brain Does?




frontal lobe
motor cortex
sensory cortex
parietal lobe
wernicke's area
broca's area
occipital lobe
temporal lobe
cerebellum
brain stem

Areas of the Brain Affected by Stroke




A)
Hip
Knee
Ankle
Toes
Genitals
Trunk
Shoulder
Elbow
Wrist
Hand
Little
Ring
Middle
Index
Thumb
Neck
Brow
Eyelid & Eyeball
Face
Lips
Jaw
Tongue
Swallowing
B)

Attention

Attention

Attention has captured great interest in psychological and neuroscience research for over 100 years. This fascination is related to the broad explanatory power that is commonly invested with the concept of attention. Attention is generally used to indicate any brain function that influences behavioral performance. One aspect of attention involves sustaining vigilance of multiple hours or even days to maintain performance across a task.

Attention

A different aspect of attention involves switching engagement with different stimuli within a fraction of a second. Comparing just these 2 aspects of attention, it is clear that phenomena embraced by the term span broad timescales and goals, ranging from glancing at a stimulus to completing a long-lasting task. As expected from its expansive scope, its definitions vary substantially across neuropsychological studies of attention.

Attention

Definitions of attention commonly involve the concepts of limited capacity for sensory encoding and the resulting need for selective processing. A popular account defines attention as a biased competition that occurs in multiple brain structures and stages of processing, with the goal of appropriately assigning limited resources for sensory representation of the immediate interest of the subject.

Attention

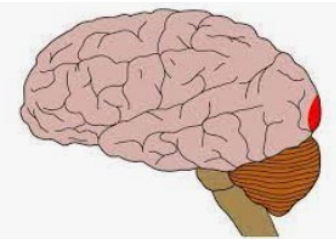
Other definitions instead see attention's primary role as dealing with too many resources for the limited number of effectors. Some emphasize that selection is first resolved in the cortical areas associated with higher processing, such as the prefrontal and parietal cortices, and then broadcasted to areas associated with earlier processing.

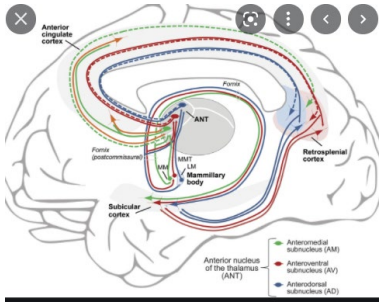
Attention

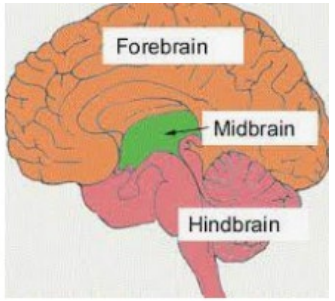
Others emphasize that selection is resolved in the basal ganglia and modulation of firing rates of neurons in the neocortex result from this subcortical selection process.

Widespread Involvement of Brain Areas in Visual Spatial Attention

Attention-related changes in visual responses have been reported in many brain areas, including most of visual cortex, prefrontal cortex, and nuclei in the thalamus and midbrain







Explicit memory

There are three areas of the brain involved in explicit memory: the hippocampus, the neo-cortex and the amygdala.

Hippocampus

The hippocampus, located in the brain's temporal lobe, is where episodic memories are formed and indexed for later access. Episodic memories are autobiographical memories from specific events in our lives, like the coffee we had with a friend last week.

How do we know this? In 1953, a patient named Henry Molaison had his hippocampus surgically removed during an operation in the United States to treat his epilepsy. His epilepsy was cured, and Molaison lived a further 55 healthy years. However, after the surgery he was only able to form episodic memories that lasted a matter of minutes; he was completely unable to permanently store new information. As a result, Molaison's memory became mostly limited to events that occurred years before his surgery, in the distant past. He was, however, still able to improve his performance on various motor tasks, even though he had no memory of ever encountering or practising them. This indicated that although the hippocampus is crucial for laying down memories, it is not the site of permanent memory storage and isn't needed for motor memories.

The study of Henry Molaison was revolutionary because it showed that multiple types of memory existed. We now know that rather than relying on the hippocampus, implicit motor learning occurs in other brain areas – the basal ganglia and cerebellum.

Executive Function

The term *executive functions* refers to the higher-level cognitive skills you use to control and coordinate your other cognitive abilities and behaviors. The term is a business metaphor, suggesting that your executive functions are akin to the chief executive that monitors all of the different departments so that the company can move forward as efficiently and effectively as possible. How we organize our lives, how we plan and how we then execute those plans is largely guided by our executive system.

Executive functions can be divided into organizational and regulatory abilities. *Organization* includes gathering information and structuring it for evaluation. *Regulation* involves evaluating the available information and modulating your responses to the environment. Seeing a wonderful dessert in front of you may be tempting to devour, but your executive system might remind you that eating it would conflict with your inner goals, such as losing weight.

- **Organization** – attention, planning, sequencing, problem-solving, working memory, cognitive flexibility, abstract thinking, rule acquisition, selecting relevant sensory information
- **Regulation** – initiation of action, self-control, emotional regulation, monitoring internal and external stimuli, initiating and inhibiting context-specific behavior, moral reasoning, decision-making

Disorders of Executive Functions

Because these skills integrate information at a higher level across cognitive domains, damage to the executive system typically involves a cluster of deficiencies, not just one ability. The loss of that ***administrative*** control affects the ability to organize and regulate multiple types of information and often cause behavioral change.

Damage to the executive system often leads to:

- Difficulty organizing
- Difficulty in planning and initiation (getting started)
- Inability to multitask
- Difficulty with verbal fluency
- Trouble planning for the future
- Difficulty processing, storing, and/or retrieving information
- Mood swings
- Lack of concern for people and animals
- Loss of interest in activities
- Socially inappropriate behavior
- Inability to learn from consequences from past actions
- Difficulty with abstract concepts (the inability to make the leap from the symbolic to the real world)
- Unawareness or denial that their behavior is a problem

Anatomy of Executive Functions

Executive deficits have been associated with damage to the most forward areas of the frontal lobes (located just above your eyes), as well as the cortical (i.e., parietal lobes) and subcortical structures that connect to the frontal lobes. The executive system involves the prefrontal cortex, basal ganglia and thalamus.

The frontal lobes are the last areas of the brain to fully develop. This area of the brain was evolutionarily late to appear and is much larger in human beings than in our closest nonhuman primate relatives. The frontal lobes typically account for about 40% of the human brain.

Neocortex

The neocortex is the largest part of the cerebral cortex, the sheet of neural tissue that forms the outside surface of the brain, distinctive in higher mammals for its wrinkly appearance. In humans, the neocortex is involved in higher functions such as sensory perception, generation of motor commands, spatial reasoning and language. Over time, information from certain memories that are temporarily stored in the hippocampus can be transferred to the neocortex as general knowledge – things like knowing that coffee provides a pick-me-up. Researchers think this transfer from hippocampus to neocortex happens as we sleep.

Amygdala

The amygdala, an almond-shaped structure in the brain's temporal lobe, attaches emotional significance to memories. This is particularly important because strong emotional memories (e.g. those associated with shame, joy, love or grief) are difficult to forget. The permanence of these memories suggests that interactions between the amygdala, hippocampus and neocortex are crucial in determining the 'stability' of a memory – that is, how effectively it is retained over time.

There's an additional aspect to the amygdala's involvement in memory. The amygdala doesn't just modify the strength and emotional content of memories; it also plays a key role in forming new memories specifically related to fear. Fearful memories are able to be formed after only a few repetitions. This makes 'fear learning' a popular way to investigate the mechanisms of memory formation, consolidation and recall. Understanding how the amygdala processes fear is important because of its relevance to post-traumatic stress disorder (PTSD), which affects many of our veterans as well as police, paramedics and others exposed to trauma. Anxiety in learning situations is also likely to involve the amygdala, and may lead to avoidance of particularly challenging or stressful tasks.

Assessment

The instruments used to assess executive behavior draw on the cognitive skills described above, such as mental agility, planning, organization, inhibition and freedom from distraction. Widely used tests include the Word Fluency Task, Stroop Test, Wisconsin Card Sorting Test and the Trail Making Test.

Executive function deficits can occur as the result of a variety of neurologic conditions including traumatic brain injury, neurodegenerative diseases including frontotemporal dementia, cerebrovascular disease, as well as a number of psychiatric and developmental disorders, including obsessive-compulsive disorder, Tourette's syndrome, depression, schizophrenia, attention-deficit/hyperactivity disorder, autism and addiction.

Frontal Lobes Functions (Orange)

- Attention
- Concentration
- Self-Monitoring
- Organization
- Expressive Language (Speaking)
- Motor Planning & Initiation
- Awareness of Abilities
- Awareness of Limitations
- Personality
- Mental Flexibility
- Inhibition of Behavior
- Emotions
- Problem Solving
- Planning

Temporal Lobes Functions (Pink)

- Memory
- Understanding Language (Receptive Language)
- Sequencing
- Hearing
- Organization

An injury to the temporal lobes may lead individuals to demonstrate difficulty with communication or memory.

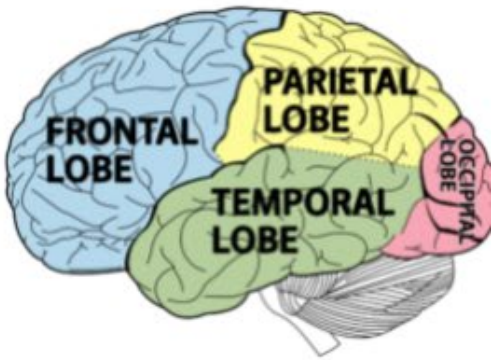
Parietal Lobes Functions (Blue)

- Sense of Touch
- Spatial Perception (Depth Perception)
- Identification of Sizes, Shapes, Colors
- Visual Perception

ADHD: Attention & Memory

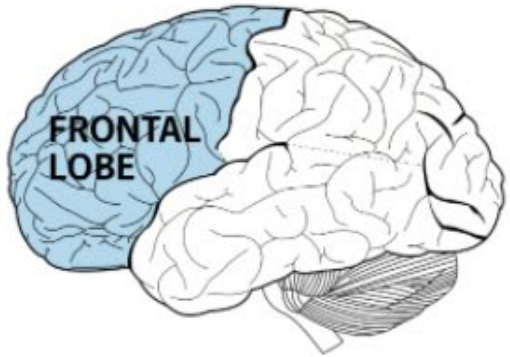
Brain Structure

Research has shown that some structures in the brain in children with ADHD can be smaller than those areas of the brain in children without ADHD.



The brain is an organ that controls thinking, feeling, and behavior. The brain is divided into sections called lobes.

The front of the brain behind the forehead is the frontal lobe. The frontal lobe is the part of the brain that helps people to organize, plan, pay attention, and make decisions. Parts of the frontal lobe may mature a few years later in people with ADHD.

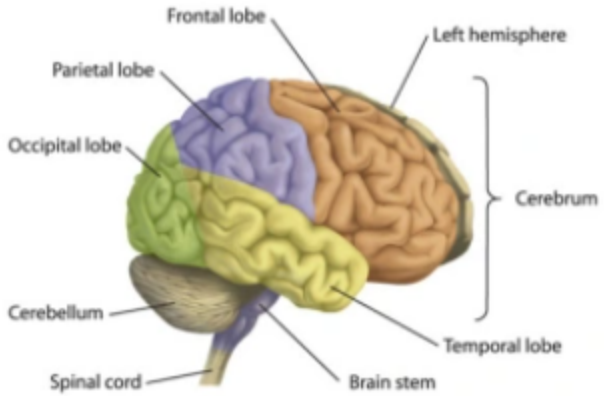


The frontal lobe is the area of the brain responsible for:

- Problem Solving
- Memory
- Language
- Motivation
- Judgment
- Impulse control
- Social behavior

WHAT IS 'ATTENTION' AND WHERE IS IT IN THE BRAIN?

This is the third in a series on Understanding Attention Deficit/Hyperactivity Disorder (ADHD). Today we look closer at the nature of attentiveness and its location in the brain.



Attention is the ability of the brain to selectively concentrate on one aspect of the environment while ignoring other things. There are two types of attention in two separate regions of the brain. The prefrontal cortex (directly behind the forehead) is in charge of willful concentration; if you are studying for a test or writing a novel, the impetus and the orders come from there. But if there is a sudden, riveting event – the attack of a tiger or the scream of a child – it is the parietal cortex (behind the ear) that is activated. Scientists have learned that these two brain regions sustain concentration when the neurons emit pulses of electricity at specific rates – faster frequencies for the automatic processing of the parietal region, slower frequencies for the deliberate, intentional work of the prefrontal region.

ADHD: Attention & Memory

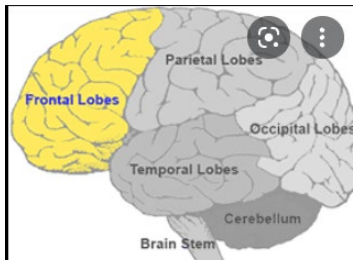
Networks: The Brain is made up of nerve cells called neurons that transmit signals in the brain. Signals travel through the brain in groups of nerves called “networks”. Researchers have identified several major networks that work differently in people with ADHD. These networks are involved in reward, focus, planning, attention, shifting between tasks, and movement.

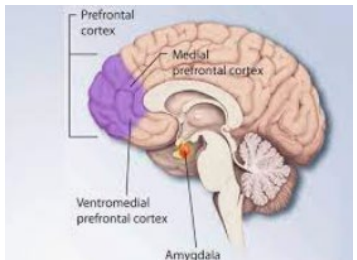
ADHD: Attention & Memory

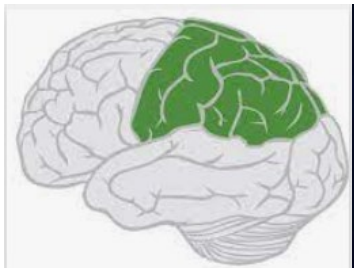
Neurotransmitters: There are chemicals that help to transmit signals form one nerve cell to the next through the networks of the brain. These chemicals are called neurotransmitters. Dopamine and norepinephrine are two neurotransmitters that may play a role in ADHD.

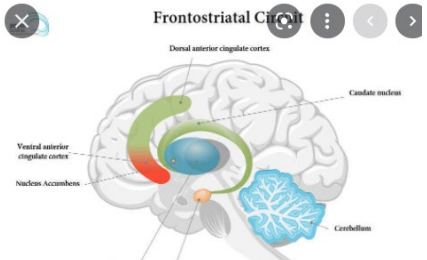
ADHD: Attention & Memory

The underlying brain regions predominantly thought to be involved are frontal and prefrontal; the parietal lobe and cerebellum may also be involved. In one functional MRI study, children with ADHD who performed response-inhibition tasks were reported to have differing activation in frontostriatal areas.









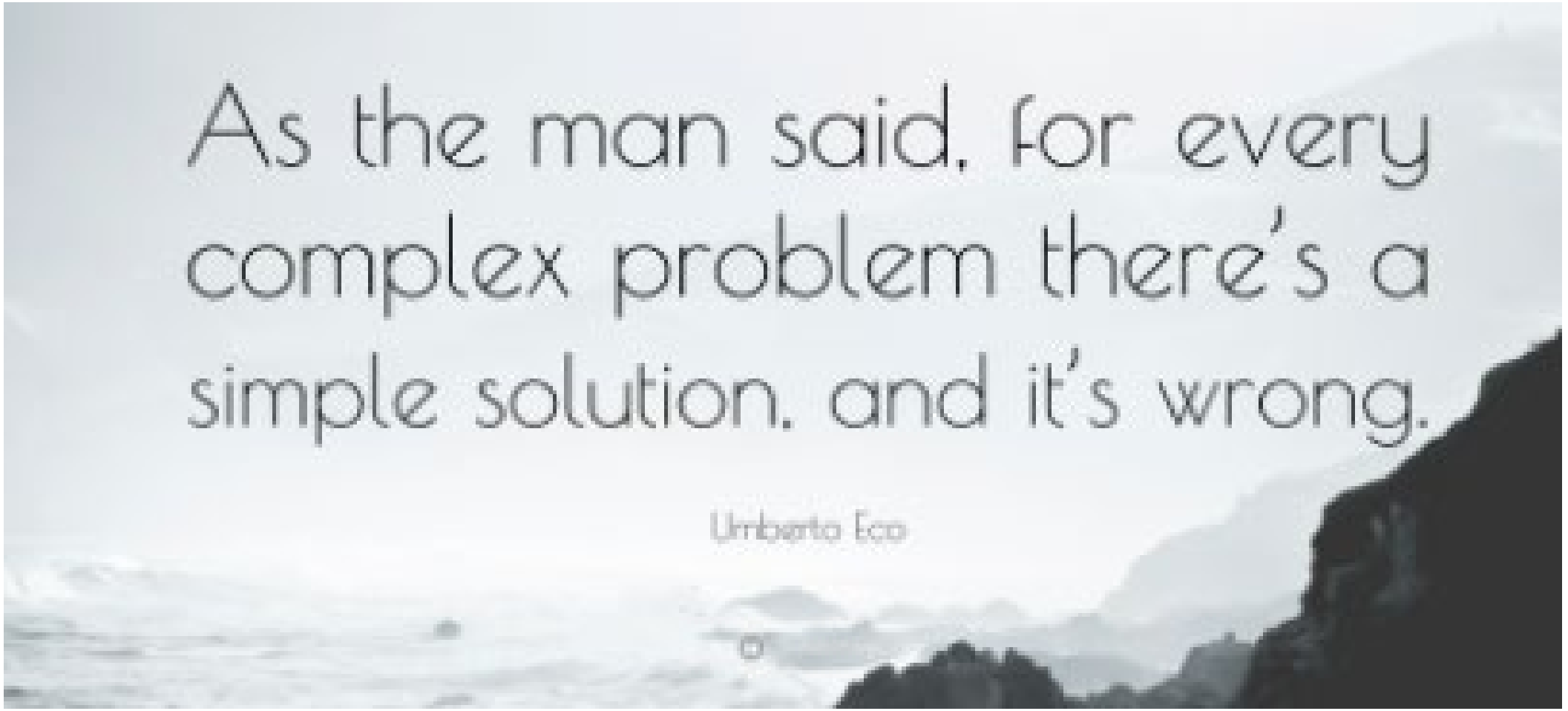
ADHD: Attention & Memory

ADHD medications increase activity in the prefrontal cortex and attention related areas of the parietal cortex during challenging mental tasks.

The human brain is magnificent and complex. The brain is made up of many parts, each with a specific and important function. It controls our ability to balance, walk, talk, and eat. It coordinates and regulates our breathing, blood circulation, and heart rate. It is responsible for our ability to speak, to process and remember information, make decisions, and feel emotions. Every brain is unique, ever-changing, and extremely sensitive to its environment.

The brain is divided into functional sections, called **lobes**:

- **Frontal Lobe** (shown in orange)
- **Temporal Lobe** (pink)
- **Parietal Lobe** (blue)
- **Occipital Lobe** (green)
- **Cerebellum** (red)
- **Brain Stem** (yellow)


As the man said, for every complex problem there's a simple solution, and it's wrong.
Umberto Eco

ADHD

The Neuroscience of the ADHD Brain

ADHD brains have low levels of a neurotransmitter called norepinephrine. Norepinephrine is linked arm-in-arm with dopamine.

ADHD

Dopamine is the thing that helps control the brain’s reward and pleasure center.

ADHD

The ADHD brain has impaired activity in **four** functional regions of the brain.

ADHD

1. Frontal Cortex

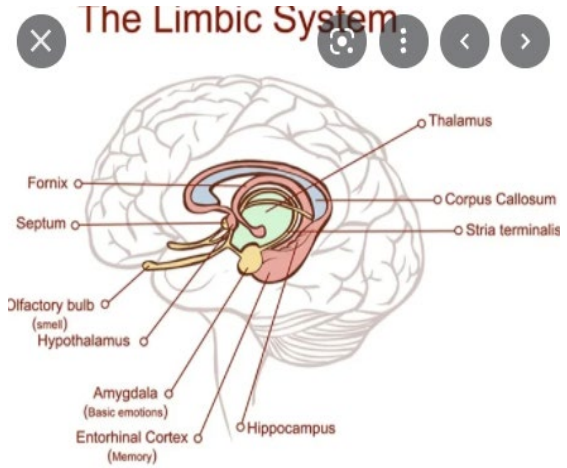
This region controls high-level functions:

- Attention
- Executive Function
- Organization

ADHD

2. Limbic System

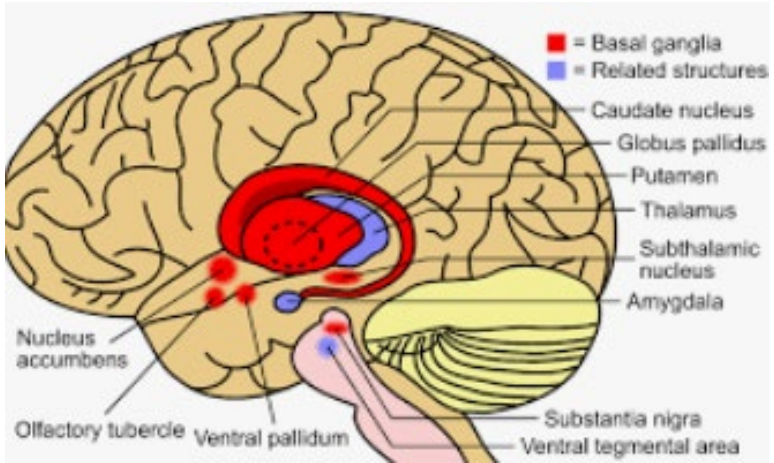
This region is located deeper in the brain. It regulates our emotions and attention.



ADHD

3. Basal Ganglia

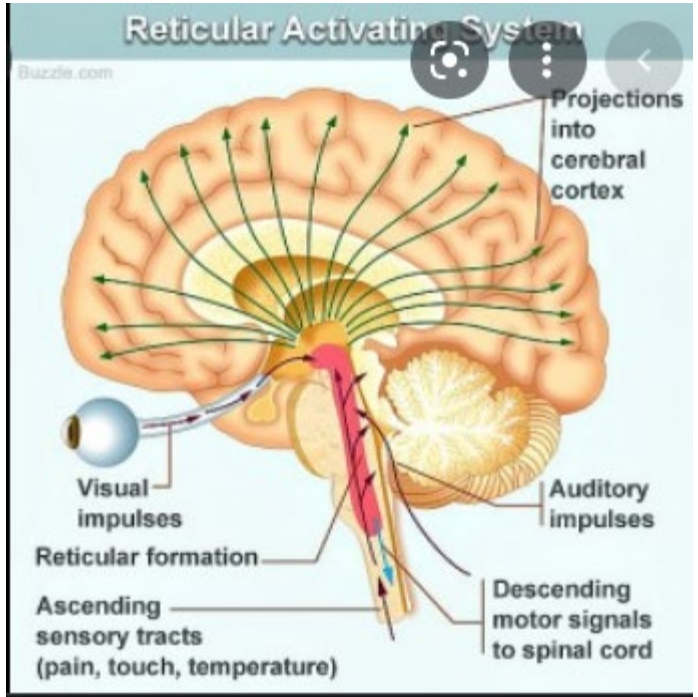
A deficiency here can cause inter-brain communication & information to “short-circuit.” That results in inattention or impulsivity.



ADHD

4. Reticular Activating System

This is the major relay system among the many pathways that enter & leave the brain. A deficiency here can cause inattention, impulsivity, or hyperactivity.



Bipolar Disorder

Experts believe bipolar disorder is partly caused by an underlying problem with specific brain circuits and the functioning of brain chemicals called neurotransmitters.

Bipolar Disorder

Three brain chemicals, norepinephrine (noradrenaline), serotonin, and dopamine,- are involved in both brain and bodily functions. Norepinephrine and serotonin have been consistently linked to psychiatric mood disorders such as depression and bipolar disorder.

Bipolar Disorder

Nerve pathways within areas of the brain that regulate pleasure and emotional reward are regulated by dopamine. Disruption of circuits that communicate using dopamine in other brain areas appears connected to psychosis and schizophrenia, a severe mental disorder characterized by distortions in reality and illogical thought patterns and behaviors.

Bipolar Disorder

Studies of neurocognitive function in bipolar disorder indicate deficits in three core domains: attention, executive function, and emotional processing.

Bipolar Disorder

Functional imaging studies implicate pathophysiology in distributed neural circuitry that includes the prefrontal and anterior cingulate cortices, as well as subcortical limbic structures including the amygdala and the ventral striatum.

Bipolar Disorder

In MRI studies, Participants with bipolar disorder exhibited thinner cortical gray matter in frontal, temporal and parietal regions of both brain hemispheres.

Bipolar disorder had the largest effect on left pars opercularis, left fusiform gyrus and left rostral middle frontal cortex.

Bipolar Disorder

When accounting for age at the time of MRI, longer illness duration was associated with reduced cortical thickness in frontal, medial parietal, and occipital regions.

Bipolar Disorder

Commonly prescribed medications, including lithium, antiepileptic and antipsychotic treatments were significantly associated with cortical thickness and surface area. This remained when accounting for participants who received multiple medications.

Bipolar Disorder

A volume decrease in specific parts of the brain's hippocampus -- long identified as a hub of mood and memory processing -- was linked to bipolar disorder in a study.

Bipolar Disorder

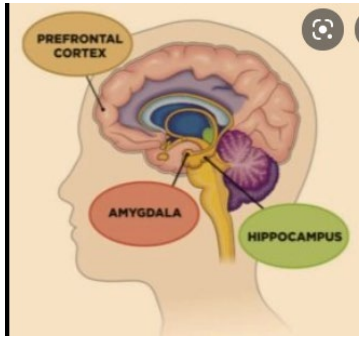
Further, in patients with bipolar I disorder, the volumes of certain areas such as the right Anterior Cingulate 1 decreased as the illness duration increased. Volumes of other Anterior Cingulate areas and hippocampal tail were more reduced in subjects who had more manic episodes.

Schizophrenia

Brain Structures

There are several brain structures that are affected in patients with schizophrenia. The **prefrontal cortex** is at the very front and top of the brain, and it helps people think logically and organize their thoughts.

Schizophrenia



Many studies have shown that people with schizophrenia have less activity in their prefrontal cortex. This may be one reason that they suffer from delusions; after all, if they aren't using their prefrontal cortex as much as most people, they aren't using the part of their brain that induces logical thinking.

Schizophrenia

Studies have also shown that schizophrenic patients suffering from hallucinations show brain activity in the **visual and auditory cortices**. These areas of the brain process vision and sound information from the eyes and the ears.

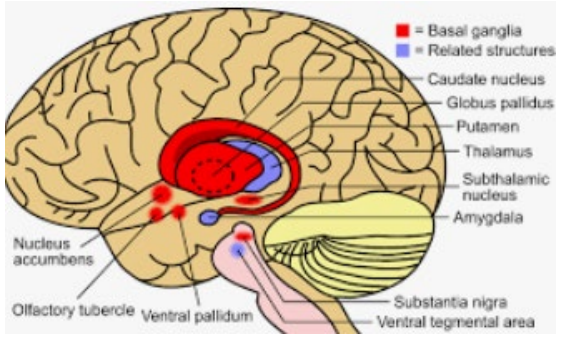
Schizophrenia

In schizophrenics, the brain acts the same way whether the patient is seeing or hearing something real or just hallucinating. In other words, the hallucinations are as real to a schizophrenic's brain as reality.

Schizophrenia

Some schizophrenics also suffer from disorganized thought patterns. Since the prefrontal cortex also helps organize thoughts, less activity in that area might be a cause of disordered thinking, as well as delusions.

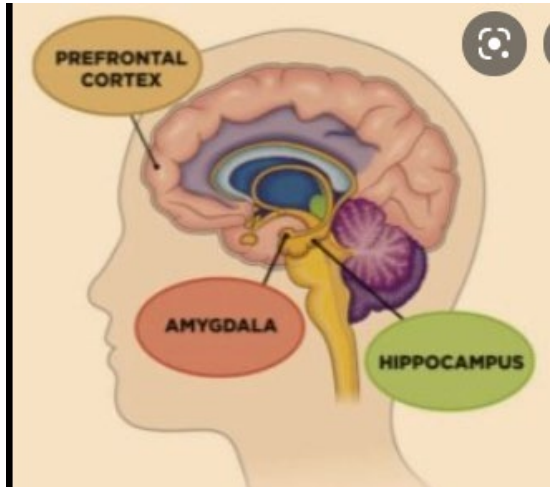
Schizophrenia



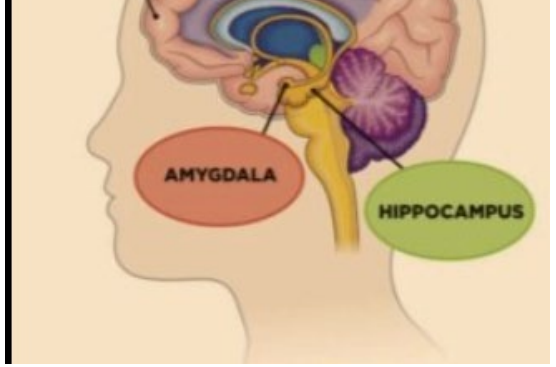
The **basal ganglia** is located deep inside the brain, and it involves movement and thinking skills. Some studies have shown that patients with schizophrenia have larger basal ganglia than normal people. This might affect the movement patterns of schizophrenics, who often have motor dysfunctions.

Schizophrenia

Another brain structure that is different in patients with schizophrenia is the **amygdala**. The amygdala is the part of the brain that is responsible for basic feelings, like fear, lust and hunger.

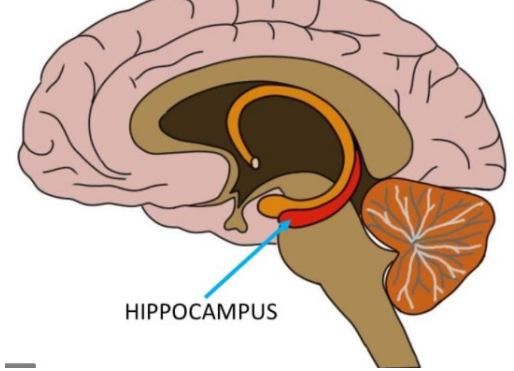


Schizophrenia



Patients with schizophrenia often have little emotion, and not surprisingly, the amygdala is smaller in people with schizophrenia. After all, if the part of the brain that is in charge of emotions is small, then chances are you won't feel emotions very strongly.

Depression

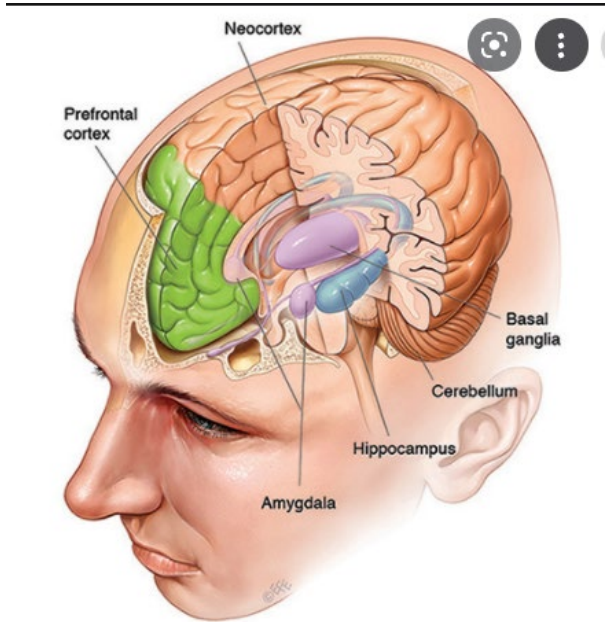


Subcortical limbic structures

The main subcortical limbic brain regions implicated in depression are the amygdala, hippocampus, and dorsomedial thalamus. Both structural and functional abnormalities in these areas have been found in depression.

Depression

Decreased hippocampal volumes have been noted in subjects with depression. Subjects who remit with treatment have even been shown to have larger pre-treatment hippocampal volumes.



Depression

Those with smaller hippocampal volumes were more prone to relapse. Decreased amygdala core volumes has been reported in depression.

Depression

The insula, particularly its anterior subdivision, has been implicated in experience of emotions such as disgust, self-reflection and assessment of internal visceral states, and response to stimuli of taste and smell.

Depression

In depression, insular activation has been reported to be increased in response to disgust inducing stimuli and negative pictures. Insular volume has been noted to correlate with depression scores.

Depression

One study on the other hand reported increased insular activation in response to negative stimuli after antidepressant treatment.

Depression

On the whole, these findings suggest increased sensitivity of the insula to internal visceral and cognitive processes during depression.

Depression

Cortical abnormalities

Cortical brain areas implicated in depression are the dorsal and medial prefrontal cortex, the dorsal and ventral anterior cingulate cortex, the orbital frontal cortex and the insula.

Depression

A decreased metabolism in the prefrontal cortex, especially dorsolateral and dorsoventral brain regions, is a frequently replicated finding in Major Depression.

Depression

Deficient prefrontal perfusion in these regions, coupled with a reduction in problem-solving abilities and higher propensity to act on negative emotions, has been implicated in suicidal behavior.

Depression

Whether this finding is a primary abnormality or secondary one is not clear. However, this finding has been successfully used to formulate a therapeutic strategy to stimulate the dorsolateral prefrontal cortex using transcranial magnetic stimulation.

Depression

The decrease in dorsolateral prefrontal cortex metabolism/blood flow in depression has also been found to reverse with antidepressant treatment.

Obsessive Compulsive Disorder

Three brain areas – the orbitofrontal cortex, the anterior cingulate cortex, and the head of the caudate nucleus – have been consistently implicated in a large number of resting, symptom provocation, and pre/post-treatment studies of adults with OCD.

Obsessive Compulsive Disorder

These areas (a) are hyperactive at rest in adults with OCD relative to healthy controls, (b) become more active with symptom provocation, and (c) no longer show hyperactivity at rest following successful treatment with either medication or cognitive-behavioral therapy

Obsessive Compulsive Disorder

Prevailing theories indicate that OCD is a biological disease. Functional brain imaging studies have produced a model for pathophysiology of OCD which involves hyperactivity in certain subcortical and cortical regions.

Obsessive Compulsive Disorder

The resulting increase in thalamic activity produces increased activity in orbitofrontal cortex, which, via the cingulate gyrus, completes the circuit to the caudate and produces increased activity in the head of the caudate.

Obsessive Compulsive Disorder

Hypothetically, primitive cleaning and checking behaviors are "hard-wired" in the thalamus.

Obsessive Compulsive Disorder

This is supported by evidence from MRI (magnetic resonance imaging) studies, which have found an abnormally small caudate in some OCD patients, and by positron emission tomography (PET scan) studies, which have found increased metabolism in orbital frontal cortex, cingulate gyrus, and caudate, with decreases following successful treatment.

Obsessive Compulsive Disorder

The association of OCD with Tourette's syndrome and Sydenham's chorea, which are believed to involve basal ganglia pathology, is also consistent with this model.

Anxiety Disorders

The brain circuits and regions associated with anxiety disorders are beginning to be understood with the development of functional and structural imaging.

Anxiety Disorders

The brain amygdala appears key in modulating fear and anxiety. Patients with anxiety disorders often show heightened amygdala response to anxiety cues.

Anxiety Disorders

The amygdala and other limbic system structures are connected to prefrontal cortex regions. Hyperresponsiveness of the amygdala may relate to reduced activation thresholds when responding to perceived social threat.

Anxiety Disorders

Prefrontal-limbic activation abnormalities have been shown to reverse with clinical response to psychologic or pharmacologic interventions.

The Perfect Storm for a Public Health Nightmare:

- Something New
- Something Deadly
- Something that is hard to understand
- An environment for a demand for rapid information, regardless of accuracy
- An environment for communication of intensification of concern (modern media)

Ultimately, Fear!

Enter: Covid-19!

COVID

COVID-19 does appear to affect brain function in some people. Specific neurological symptoms seen in people with COVID-19 include loss of smell, inability to taste, muscle weakness, tingling or numbness in the hands and feet, dizziness, confusion, delirium, seizures, and stroke.

COVID Infection

Infected astrocytes could explain some of the neurological symptoms associated with COVID-19, especially fatigue, depression and ‘brain fog’, which includes confusion and forgetfulness. Those kinds of symptoms may not be reflective of neuronal damage, but could be reflective of dysfunctions of some sort. That could be consistent with astrocyte vulnerability.

COVID Infection

Blocking blood flow

Evidence has also accumulated that SARS-CoV-2 can affect the brain by reducing blood flow to it — impairing neurons' function and ultimately killing them.

COVID Infection

Pericytes are cells found on small blood vessels called capillaries throughout the body — including in the brain. A February preprint reported that SARS-CoV-2 could infect pericyte-like cells in brain organoids.

COVID Infection

Brain alterations associated with SARS-CoV-2 infection in individuals with both acute and mild COVID-19, predominated in the olfactory brain network, which includes limbic and prefrontal structures.

COVID

Does the Virus Invade the Brain?

SARS-CoV-2 is known to penetrate the olfactory mucosa, causing loss of smell, and may enter the brain, migrating from the cribriform plate along the olfactory tract[2] or through vagal or trigeminal pathways; however, definitive evidence for this is lacking.

COVID

SARS-CoV-2 could pass the blood-brain barrier because inflammatory cytokines induce blood-brain barrier instability or via monocytes.[4] It could reach brain tissue via circumventricular organs, midline structures around the third and fourth ventricles, that monitor blood and cerebral spinal fluid content via fenestrated capillaries lacking the junctional proteins expressed in the blood-brain barrier.

COVID

Histopathologic analysis of whole human brain showed microglial nodules and phagocytosis of neurons (neuronophagia) in brain stem and less frequently in cortex and limbic structures, associated with sparse lymphocytic infiltration, and no correlations between histopathologic findings and levels of viral messenger RNA in the same brain.

COVID

While loss of taste, nausea, and vomiting may be related to circumventricular organs and brain stem viral invasion, other short-term and long-lasting neuronophagias are more likely due to neuroinflammation and hypoxic injury. Brain stem involvement may explain persistent autonomic abnormalities and anxiety.

OK, now, What part of this child's brain is causing this?