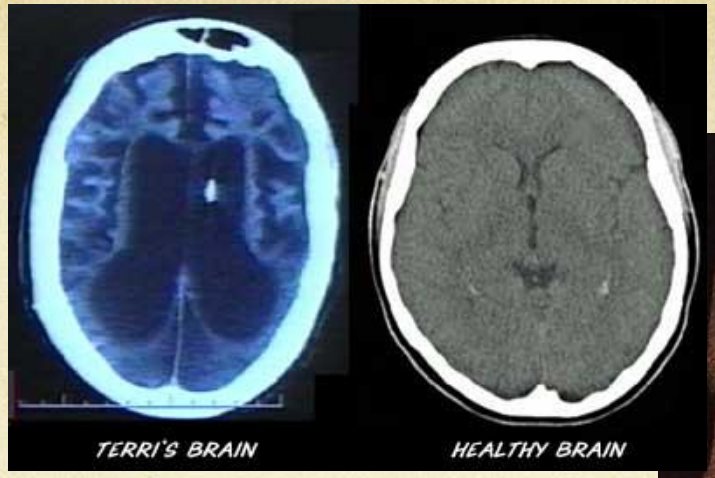
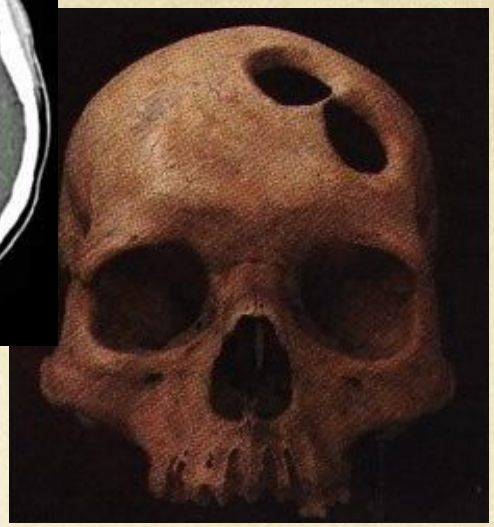




UNIT 1
Fundamentals of neuropsychology

-Neha Bhansali

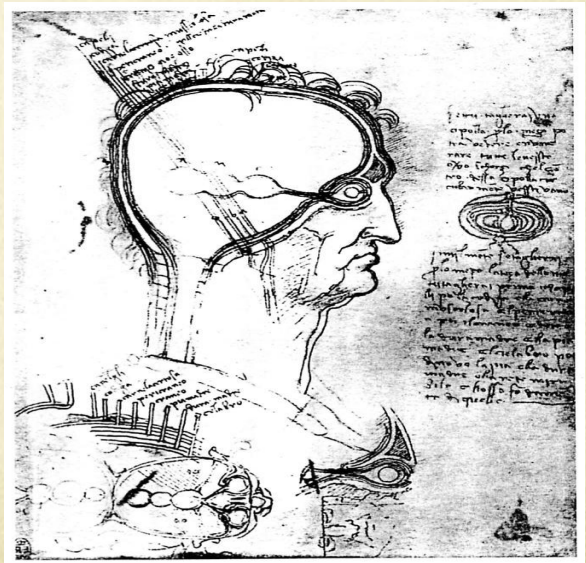
1.1 History

- Trephination discovered by archaeologists
  - Stone Age:
    - Trephination:
      - Cutting or drilling hole in skull.
      - Many survived.
      - Often more than once.

- Often after trauma.
  - But not always.
  - Hence, a “magical” treatment?
- Notice variation in location.
  - Localization of functions?
- Still done today.
  - For repairing depressed skull fracture.
  - For relieving pressure, draining blood.

- Greek Perspectives
  - *Heraclitus -* Mind is enormous with boundaries we'll never reach.
    - Epilepsy is not a mystical phenomena but caused by medical problems.
  - *Plato-*Three parts to the soul:
    - Appetite, reason, and temper.
    - Reason is in the brain.
  - *Aristotle (Mentalism)*
    - The heart is the source for mental processes and behavior.
  - *Hippocrates-* all emotions arise from the brain. Recognized that paralysis occurs on opposite side of brain damage

- *Galen* of Pergamon (129-199 AD):
  - Identified major brain structures.
    - Detailed anatomy of the brain.
    - Included the ventricles.
    - ventricular localization hypothesis.
    - But could not dissect.



- Ventricular Localization Hypothesis- the mental and spiritual processes lie inside the ventricles of the brain

- Supported by *Leonardo Da Vinci*(1452-1519)
    - Became known as cell doctrine:
        - There were three "cells" in the brain.
        - Each with different function.
        - Idea persisted for 2000 years.

- *Albertus Magnus* in 12th century :
  - Behavior results from combination of structures.
    - Cortex, midbrain, cerebellum.- Origins of Triune Brain theory
- *Andreas Vesalius* (1514-1564):
  - Detailed anatomic drawings.- Anatomic Theater
  - Corrected mistakes of Galen.
    - Views of Galen not accurate.
    - Ridiculed the ventricular localization hypothesis
    - Human's have higher brain mass

- *Rene Descartes* (1596-1650):
  - Mind-Body Dualism:
    - Proposed split between the mind or mental processes and the body or physical abilities.
      - Separate but they do interact.
      - Mental processes in the pineal gland which he called "pineal body".

Darwin' s Materialisim

"Rational behavior can be fully explained by the workings of the nervous system."

Evolutionary perspective "The nervous system is one such trait, an adaptation that emerged only once in animal evolution"

George mendel- heritable factors (mid 1800s)

"Environment plays a role in how genes express traits"

- Current times rise of epigenetics

- *Thomas Willis* (1621-1675)- British Anatomist:
  - Studied blood circulation in the brain.
    - Identified the Circle of Willis.
    - Confluence of the carotid and vertebral arteries at base of brain.
  - Also placed significant functions in the cortex.- Corpus Striatum
    - Such as memory and will.
    - Identified Various parts of the brain and coined names of the areas

Rise of Scientific Theories -18th Century

- Faculty Psychology and Localization:
  - *Franz Gall* (1758-1828) and Phrenology:
    - Localization of different functions to different areas of the brain begins here.
      - Brain consists of separable organs.
      - Each associated with a particular psychological state.
        - Friendliness, hope, spirituality, acquisitiveness, etc.
        - 35 affective and intellectual faculties.
    - Also places emphasis on cortex.
      - Grey matter is functioning neural tissue.

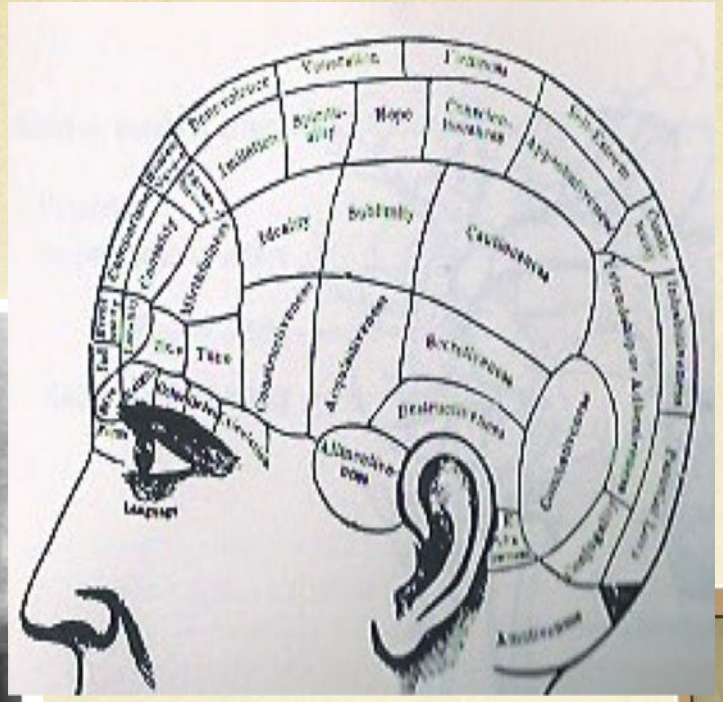


FIGURE 1.4 Franz Joseph Gall (1758–1828), one of the founders of phrenology.

- The Theory:
  - Wanted to associate different personality and cognitive traits with the size of the relevant brain organ.
  - Faculties localized to specific organs of the cortex.
  - Bigger equals better, more skill or quantity/quality.
  - Size of each organ indicated by prominence of skull.
    - If the area of the brain enlarged then so too is the skull.
    - Reverse is also true.

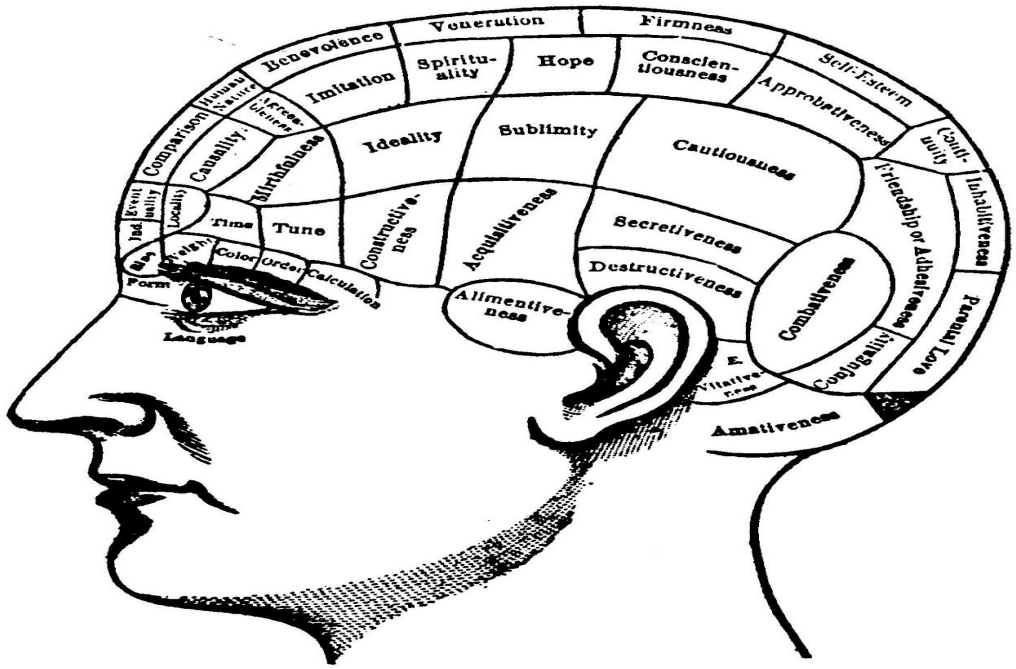


Figure 1-1 According to the nineteenth-century doctrine of phrenology, complex traits such as combativeness, spirituality, hope, and conscientiousness are controlled by specific areas in the brain, which expand as the traits develop. This enlargement of local areas of the brain was thought to produce characteristic bumps and ridges on the overlying skull, from which an individual's character could be determined. This map, taken from a drawing of the early 1800s, purports to show 35 intellectual and emotional faculties in distinct areas of the skull and the cerebral cortex underneath.

- *Johann Spurzheim* was Gall's student and lectured extensively on Phrenology in the US
- Erroneously Phrenologists suggested that skulls of white people were superior and Hispanics were savage
- Scientists were skeptical that a single part of the brain can be responsible for all behavior
- Emphasized and Wished to Study role of Cortex?

Cortical Localization

Paul Broca (1824-1880):Patient "TAN"

- Support for localization of function from case studies.
- Presented two cases of individuals:
  - Lesions of the left frontal lobe.
  - Contralateral paralysis.
  - Motor speech deficits.
  - Now called Broca's or nonfluent aphasia.

a

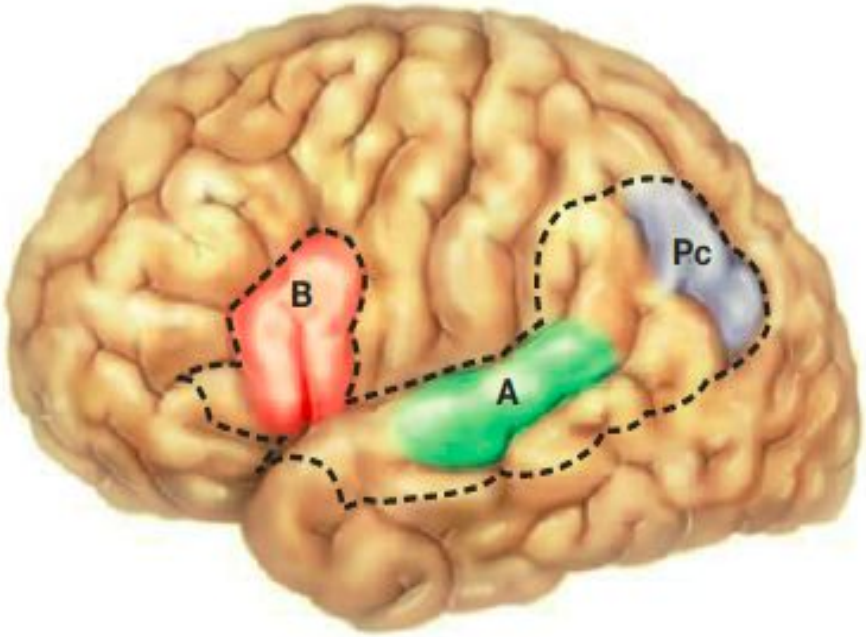


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FIGURE 1.8 (a) Paul Broca (1824–1880). (b) The connections between the speech centers, from Wernicke's 1876 article on aphasia. A = Wernicke's sensory speech center; B = Broca's area for speech; Pc = Wernicke's area concerned with language comprehension and meaning.

Carl Wernicke (1848-1904):

- Described his own patient in 1874.
  - His patient was still fluent.
  - But his speech made no sense.
  - Could not understand speech.
  - Lesion in the left posterior temporal lobe.
  - Area now called Wernicke's area.
  - This is Wernicke's or fluent aphasia.
- What is the implication?
  - Language is NOT strictly localized in the brain.
  - It is in two areas (well, more than that as you will see later on).

- "Wernicke's model of language organization in the left hemisphere is illustrated in Figure 1.7A. He proposed that auditory information travels to the temporal lobes from the auditory receptors in the ears."

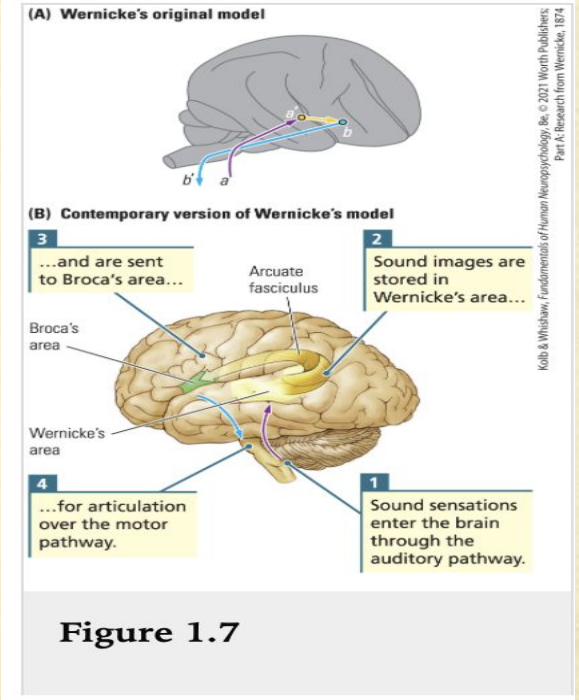

Figure 1.7

- “Wernicke also predicted a new language disorder but never saw such a case”
- “Wernicke also predicted a new language disorder but never saw such a case. He suggested that, if the arcuate fibers connecting the two speech areas were cut, disconnecting the areas but without inflicting damage on either one, a speech deficit that Wernicke described as conduction aphasia would result. In this condition, speech sounds and movements are retained, but speech is impaired because it cannot be conducted from one region to the other
- Norman Geschwind (1974) updated the speech model (Figure 1.7B) in what is now referred to as the Wernicke-Geschwind model”

- Wernicke's idea of disconnection offered investigators a completely new way of viewing symptoms of brain damage by proposing that, although different brain regions have different functions, they are interdependent: to work, they must interact

- Henry Hecaen:
  - Investigate the functions of the right hemisphere.
  - At the time much emphasis placed on the "dominant" left hemisphere.
    - After all, that is where language is located.
    - But Hecaen demonstrated right hemisphere importance for visuoperceptual and visuoconstructional processes.
  - Also important paper on prosopagnosia.

  - And work on left-handed brains.

Distributed Function-Equipotentiality

- Limitations and Problems with Localization:
  - *Pierre Flourens* (1794-1867):Aggregate Field Theory
    - Major opponent and critique of Gall.
      - Disagreed with localization view.
      - Conducted ablation studies.
        - Removed parts of bird brains.
        - Examined the behavioral effects.
        - Effects on willing, judging, remembering, and perceiving.
        - But site was irrelevant, all regions contributed.
        - Functions gradually recover.

- RISE OF EQUIPOTENTIALITY THEORY

FIGURE 1.7 John Hughlings Jackson (1835–1911), an English neurologist who was one of the first to recognize the localizationist view.

a

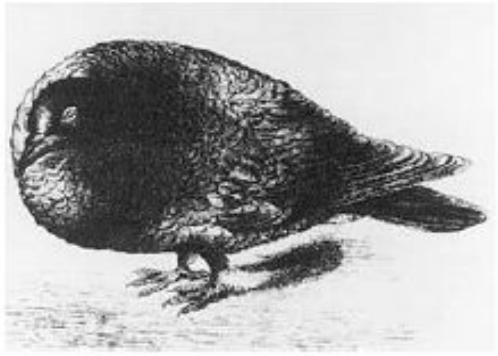

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FIGURE 1.6 (a) Marie-Jean-Pierre Flourens (1794–1867), who supported the idea later termed the *aggregate field theory*. (b) The posture of a pigeon deprived of its cerebral hemispheres, as described by Flourens.

- *Karl Lashley* (1890-1958):
  - Accepted localization.
    - For basic sensory processes and motor functions.
  - But also supported equipotentiality.
    - Rat maze learning directly proportional to amount of tissue removed.
  - Three Principles:
    - Mass Action Principle: brain functions as whole, entire brain involved in all activities, relation between dysfunction and extent of damage.
    - Principle of Equipotentiality: all brain cells have potential to carry out any of the functions.
    - Principle of Vicarious Function: if one area damaged the other areas will pick it up. - PLASTICITY

Integrated Theories-Hierarchical Organization

- Integrated Theories:
  - As with so many things, not either/or.
  - *Hughlings Jackson (1835-1911)*:
    - Higher functions not unitary.
      - Made up of smaller units.
      - Consider language.
        - Reception, expression, repetition, speech sounds, motor programs.
      - All behavior requires interaction of these functional units.
      - Hence, all behavior reflects brain operating as a whole.
      - But each area also has a specific role
      - No single area exclusively associated with any given behavior.

- Teuber's principle of double dissociation(1955):
  - How do we know what functions are in which areas?
  - Two conditions must be met:
    - Destruction of an area causes a specific behavioral deficit.
      - Damage to left inferior frontal lobe causes nonfluent aphasia.
    - Destruction of other areas does not cause that behavioral deficit.
      - Damage to occipital lobes does not cause nonfluent aphasia.
      - Rather, damage to occipital lobes causes other impairments (homonymous hemianopia).
      - And homonymous hemianopia NOT caused by damage to left inferior frontal lobe.

Multiple Memory Systems

- William Scoville- HM Case(1953)
- Two Brains and the corpus callosum (1980s)- Roger Sperry and Michael Gazzaniga

Conscious and Unconscious Neural Streams

- "David Milner and Canadian neuropsychologist Melvyn Goodale"-patient DF and visual agnosia and ataxia
- Goodale and Milner (2004) proposed that the ventral stream mediates actions controlled by conscious visual perception, whereas the dorsal stream mediates actions controlled by unconscious visual processes.

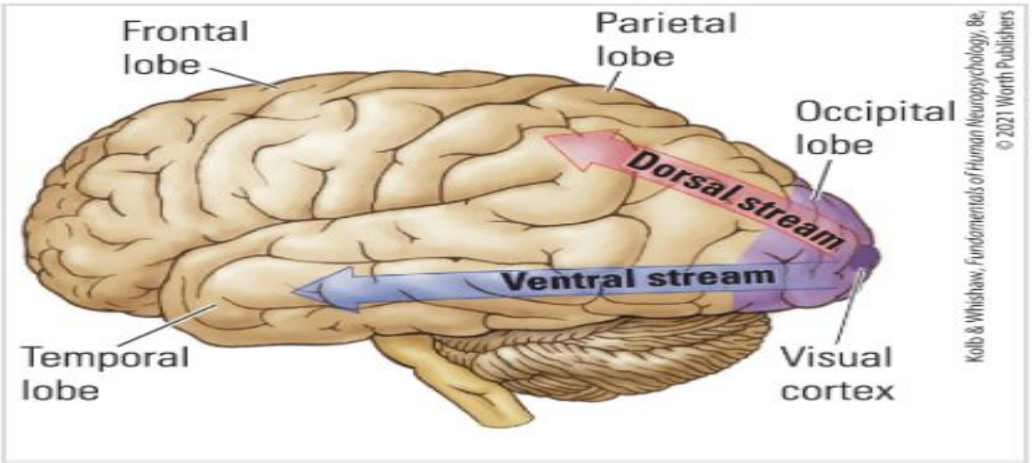

Figure 1.8

Neural Streams The dorsal stream, from the visual cortex (the occipital lobe) to the parietal lobe, mediates vision for action, unconscious vision that controls our movements. The ventral stream, from the visual cortex to the temporal lobe, mediates our conscious representations of what we see.

The Neuron Theory

Rise of Staining and Cytoarchitectonics

- German Neurologists started microscopic investigation of brain using upcoming staining techniques
- In 1909, Korbinian Broadmann used Nissl Staining technique(kind of tissue staining) and came out with his cortical map
- Each region was given a number on the cortical map
- Many other neurologists like Oskar Vogt, Theodor Meynert et also made their own maps using staining techniques

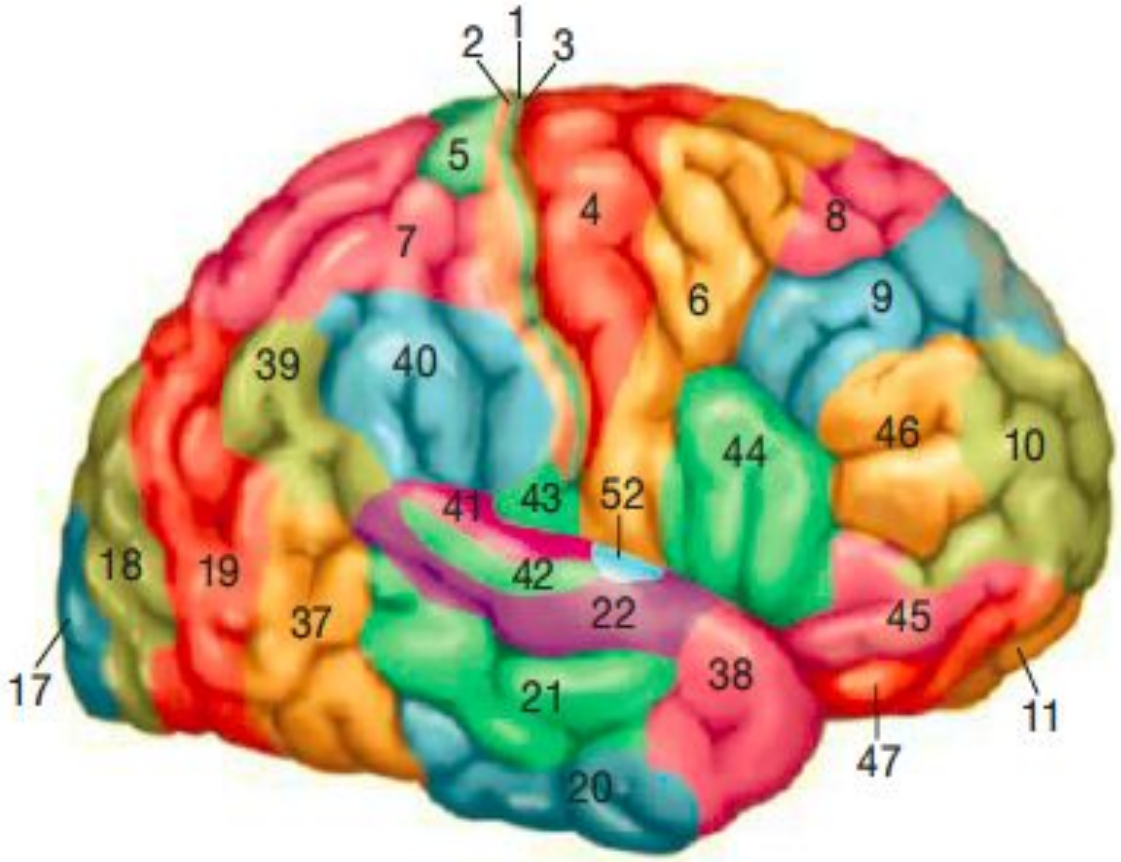

FIGURE 1.9 Sampling of the 52 distinct areas described by Brodmann on the basis of cell structure and arrangement.

a

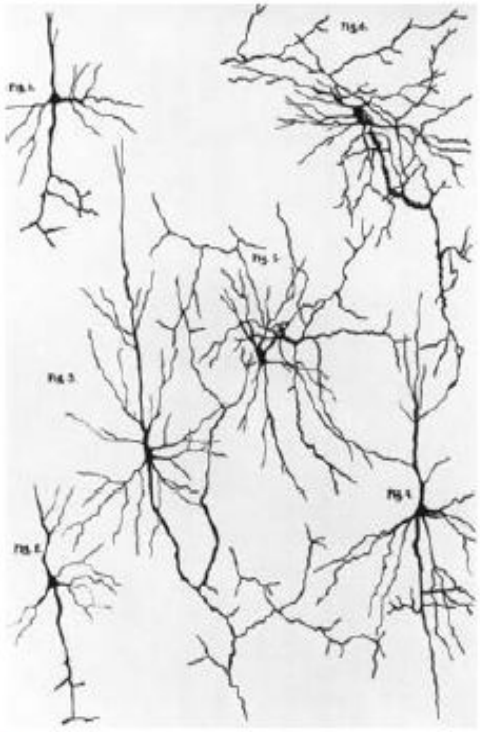

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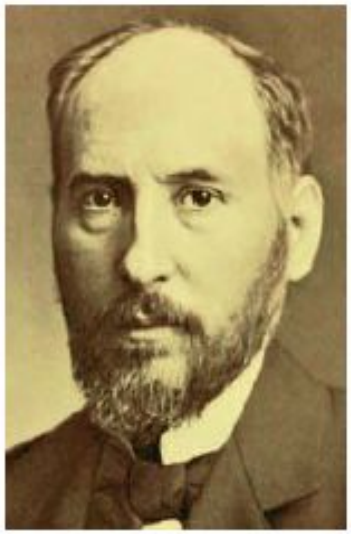
FIGURE 1.10 (a) Camillo Golgi (1843–1926), cowinner of the Nobel Prize in 1906. (b) Golgi's drawings of different types of ganglion cells in dog and cat.



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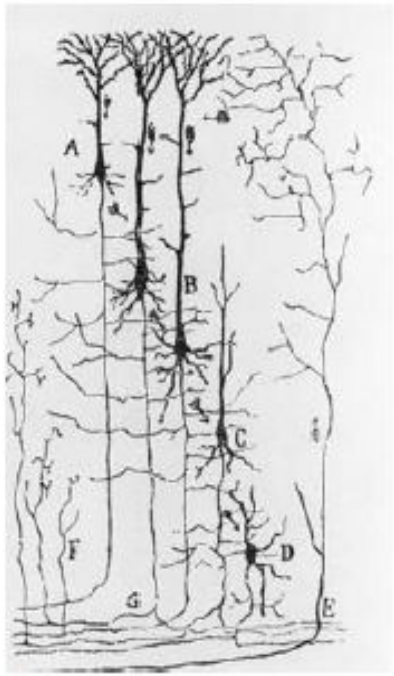

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FIGURE 1.11 (a) Santiago Ramón y Cajal (1852–1934), cowinner of the Nobel Prize in 1906. (b) Ramón y Cajal's drawing of the afferent inflow to the mammalian cortex.

- Ramon Y Cajal identified that neuron were different than other cells
- 1st to come up with notion that nervous system is made up of individual cells as opposed to Golgi who believed it it one unitary mass
- Cajal is thus called as father of modern neuroscience
- Both Golgi and Cajal won Nobel Prize for Medicine in 1906

Connections Between Neurons As the Basis of Learning

- Charles Scott Sherrington (1857–1952), an English physiologist, had examined how nerves connect to muscles
- Otto Loewi (1953) eventually demonstrated that chemicals carry the message across the synapse.- neurotransmitters
- Canadian neuropsychologist Donald Hebb (1949) proposed a theory of consciousness based on learning: when individual cells are activated at the same time, they establish connecting synapses or strengthen existing ones and thus become a functional unit. – "Neurons that fire together wire together" – neural basis of learning and memory

- “He also proposed that families of neurons thus connected form cell assemblies to represent units of behavior, such as an idea. ”

- *Arthur Benton:*
  - Also examined role of the right hemisphere.
  - Developed many tests that are widely used.
    - Facial Recognition.
    - Judgment of Line Orientation.
    - Visual Form Discrimination.
    - Visual Retention Test.
- *Norman Geschwind:*
  - Examined disconnection syndromes.
    - Behavioral disturbances arise from damage to the connections between centers of the brain.

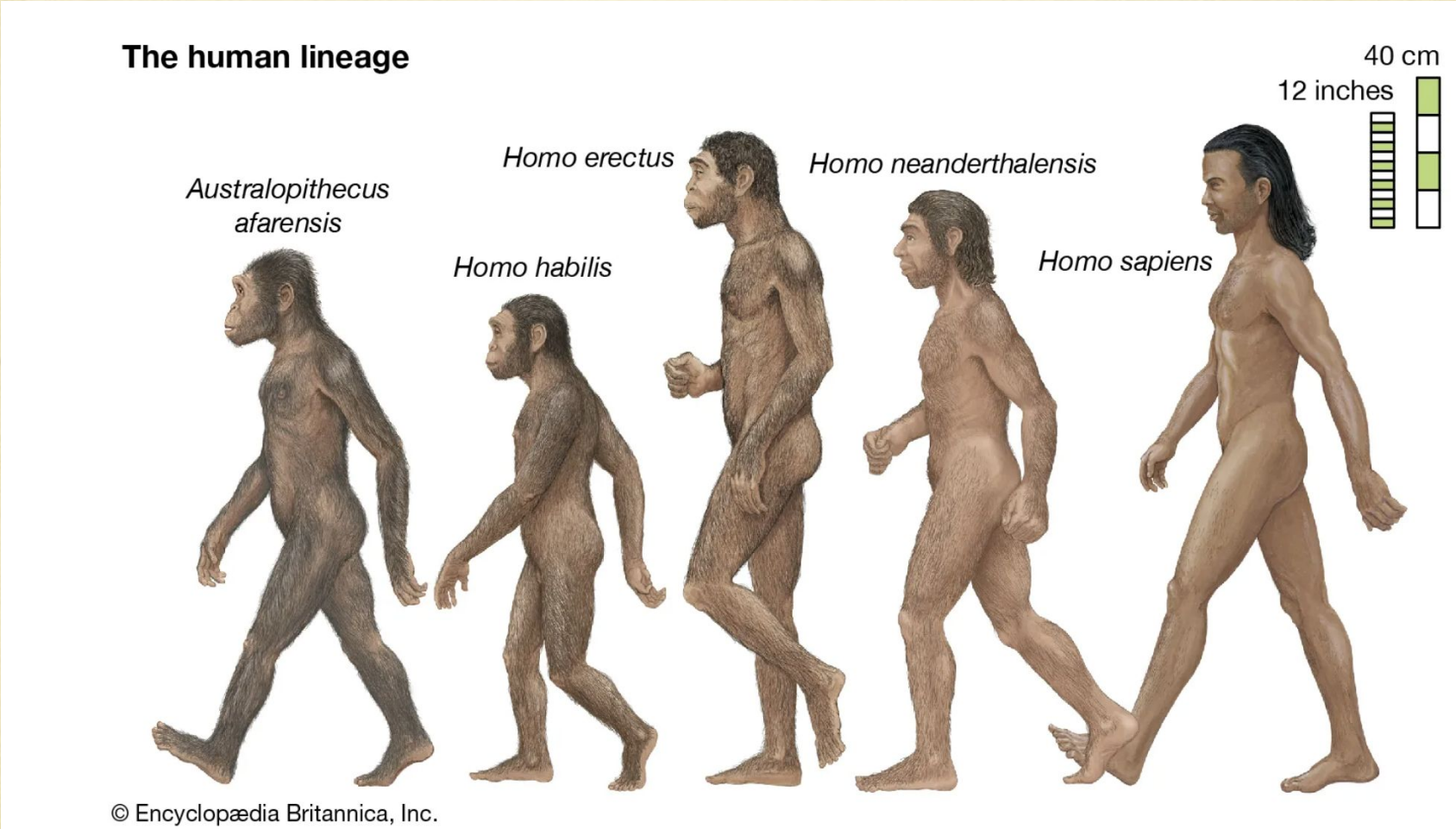
- Also examined anatomy.
  - Dominance of left hemisphere for speech must have anatomical basis.
  - Found that left auditory association cortex was indeed larger.

- *Alexander Luria*'s Functional Model
- Each Area of the Brain involved in one of the 3 basic functions which he called Units
- 1st Unit- Brainstem & related association areas= regulates arousal of brain and muscle tone
- 2nd Unit-Posterior cortical areas = reception, integration & analysis of sensory information
- 3rd Unit- Frontal & Prefrontal cortex= planning, executing and verifying behavior
- All behavior requires integration of ALL 3 units

- For each behavior, Luria created at functional system – what interaction of different areas required to complete a behavior
- PLURIPOTENTIALITY
- Disruption at any area can lead to problems in that behavior
- However, the brain functions do have plasticity to some extent

- *Wilder Penfield(1891-1976) – pioneered Electrical Stimulation of brain during surgery to map out brain areas to identify damaged areas*
- *Term Neuropsychology – 1st used by Hans Leukas Teuber . However, Donald Hebb first used the term at an APA presentation 1948 . Hebb was Penfield's student and continued working with patients who had undergone brain surgery .*
- *Cognitive Neuroscience term was first used by George Miller and Michael Gazzaniga in 1970s*

Origins of the Human Brain and Behavior



- Even as recently as 20,000 to 40,000 years ago, numerous hominin species coexisted, including modern humans, Neanderthals in Europe, Denisovans in Siberia, Homo floresiensis on the island of Flores in Indonesia
- “Fossils of Neanderthals — named after Neander, Germany, where their skulls were found — were the first ancestral humans to be discovered”

Ethologist Jane Goodall's (1986) behavioral "studies of chimpanzees paint a picture of a species so similar to humans that one has the impression of looking into a mirror."

In the Gallup (1970) mirror test, a chimpanzee points to a dot that has been placed on its forehead. That the chimp attends to the dot is a sign of self-recognition, a cognitive ability displayed by apes and humans.

- Australopithecus (from the Latin word austral, meaning "southern," and the Greek word pithekos, meaning "ape")

- "Scientists have deduced their upright posture from the shape of their back, pelvic, knee, and foot bones and from a set of fossilized footprints that a family of australopiths left behind when they walked through freshly fallen volcanic ash some 3.8 million years ago. The footprints feature the impressions of a well-developed arch and an unrotated big toe, more like human feet than like feet of other apes. However, their brain size was not much different from that of a chimpanzee.

- The oldest fossils designated as genus Homo (human) are those found by Mary and Louis Leakey in the Olduvai Gorge in Tanzania in 1964, dated to about 2 million years old.-
- more closely resembled modern humans in having larger brains

- The first humans whose populations spread widely beyond Africa migrated into Europe and into Asia. This species was Homo erectus (“upright human”), so named because of the mistaken notion that its predecessor, H. habilis, had a stooped posture.
- 1.6 million years ago.
- .

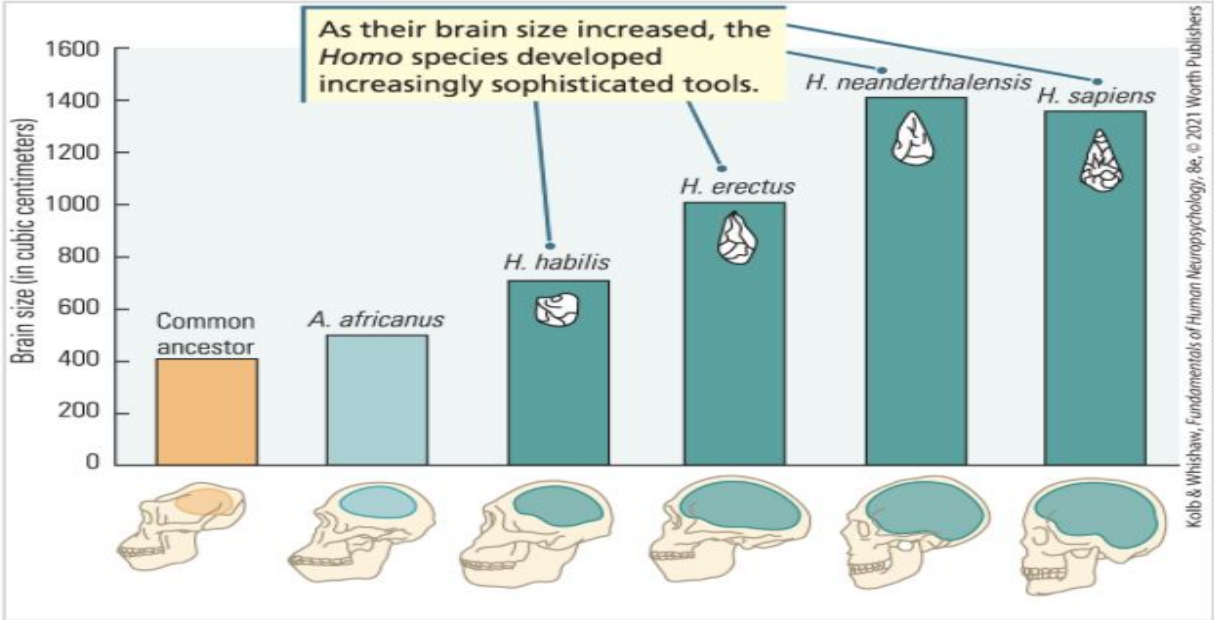
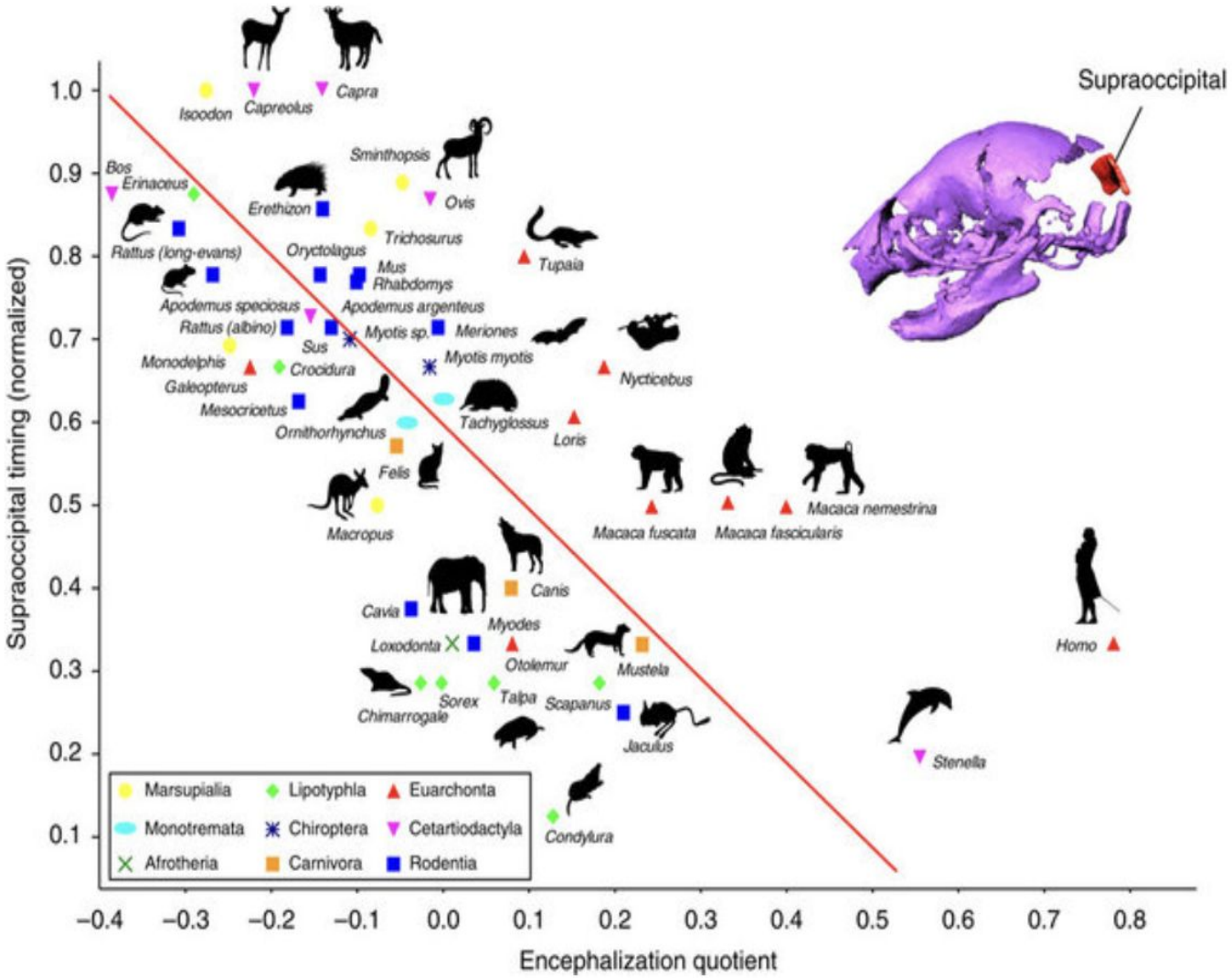


Figure 2.4

Increases in Hominin Brain Size The brain of *Australopithecus* was about the same size as that of living chimpanzees, but succeeding members of the hominin lineage display a steady increase in brain size. Note also the increasing tool complexity across *Homo* species. (Data from Johanson & Edey, 1981.)

- Having a large brain clearly has been adaptive for humans, but many animals have large brains. Whales' and elephants' gross brain sizes are much larger than ours.
- How is relative brain size measured, and what does it signify?
- The two main ways of estimating relative brain size are to compare brain size to body size and to count brain cells.

- “Harry Jerison (1973) developed an index of brain size that compares the brains of different species relative to their differing body sizes. ”
- “Using the ratio of actual brain size to expected brain size for a typical mammal of a particular body size, Jerison developed a quantitative measure, the encephalization quotient (EQ). ”
- Different formulas for mammals, reptiles and birds


Supraoccipital
Supraoccipital timing (normalized)
Encephalization quotient
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
−0.4
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Isoodon
Capreolus
Capra
Sminthopsis
Ovis
Bos
Erinaceus
Erethizon
Trichosurus
Rattus (long-evans)
Oryctolagus
Mus
Rhabdomys
Tupaia
Apodemus speciosus
Apodemus argenteus
Rattus (albino)
Myotis sp.
Meriones
Sus
Monodelphis
Crocidura
Myotis myotis
Nycticebus
Galeopterus
Mesocricetus
Tachyglossus
Ornithorhynchus
Loris
Felis
Macaca fuscata
Macaca fascicularis
Macaca nemestrina
Macropus
Canis
Cavia
Myodes
Loxodonta
Otolemur
Mustela
Homo
Sorex
Talpa
Scapanus
Chimarrogale
Jaculus
Stenella
Condylura
Marsupialia
Lipotyphla
Euarchonta
Monotremata
Chiroptera
Cetartiodactyla
Afrotheria
Carnivora
Rodentia

- “The farther an animal’s brain falls to the right of the trend line in Figure 2.5, the smaller its EQ. The higher an animal’s brain lies to the left of the trend line, the larger its EQ.

Table 2.1 Brain Sizes of Species Most Commonly Studied in Neuropsychology

Species	Brain volume (ml)	Encephalization quotient
Rat	2.3	0.40
Cat	25.3	1.01
Rhesus monkey	106.4	2.09
Chimpanzee	440.0	2.48
Human	1350.0	7.30

- The understanding of brain size has been improved by Suzana Herculano-Houzel (2018), who proposes that a useful estimate of the brain's ability to produce complex behavior can be obtained by counting neurons, the brain's functional units.

- She argues that body size and brain size can evolve independently.

- Packing Density - "Using a method that involves dissolving the cell membranes of brain neurons and then collecting and counting the cell nuclei, Herculano-Houzel has measured both the packing density and cell number in a variety of species, including primates."

- Australopithecus had about 50 to 60 billion neurons, Homo habilis about 60 billion, and Homo erectus about 75 to 90 billion; modern humans have about 86 billion neurons.

- Similar neuron counts in other animal species with large EQs show that the packing density of their neurons in the cortex is comparatively low.

- Eg. “dolphins, despite their large EQ, have on the order of 30 billion neurons, and the number of neurons in their cortex is similar to that of the chimpanzee. Cell counts show that what makes modern humans special is that we have the largest number of brain cells in the cortex of all animals”

Why Hominin Brain is enlarged

- 1.adaptive advantages that so many neurons confer
- 2.how humans support their metabolic cost.

Most common Hypotheses

drastic climate changes forced hominins to adapt and led to more complex food-finding and food-handling behaviors.

the primate lifestyle favors an increasingly complex nervous system that humans capitalized on

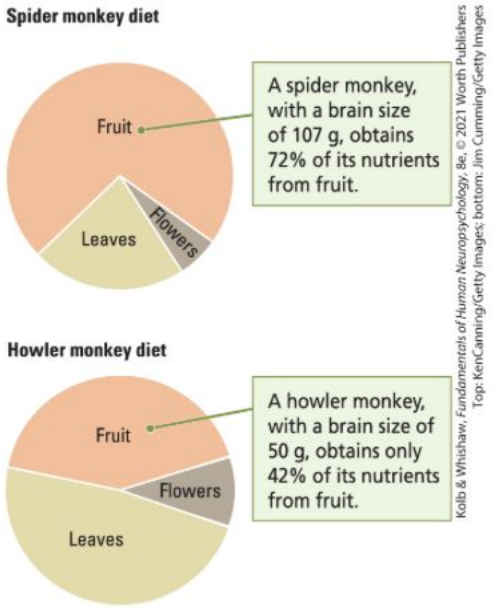
“links brain growth to brain cooling, and a fourth proposes that a slowed maturation rate favors larger brains.”

- “About 8 million years ago, a massive tectonic event (deformation of Earth’s crust) produced the Great Rift Valley, which runs through the eastern part of Africa from south to north. ”
- The fossil record shows that in the drier eastern region, apes evolved rapidly into upright hominins in response to the selective environmental pressures that formed their new home.

- “Just before Homo habilis appeared 2 million years ago, the African climate rapidly grew even drier, with spreading grasslands and even fewer trees. ”
- “H. habilis adapted to this new habitat by scavenging the dead of the large herds of grazing animals that then roamed the open grasslands.”
- been associated with further climate change: a rapid cooling that lowered sea levels (by trapping more water as ice) and opened up land bridges into Europe and Asia-“H. erectus evolved hunting skills and produced better tools for killing, skinning, and butchering animals”

- “Anthropologist Rick Potts (2017) suggests that Homo sapiens has evolved to adapt to change itself and that this adaptability has allowed us to populate almost every climatic region on Earth.-our adaptability has yet to be severely tested.
- Primate Lifestyle-
- “Robin Dunbar (1998) argues that a primate’s social group size, a cornerstone of its lifestyle, is correlated with brain size. His conclusion: the average group size of about 150 favored by modern humans explains their large brains.
- Foraging-
- “In contrast, apes that eat fruit, such as chimpanzees and humans, have relatively large brains.”

- Katharine Milton (2003) documented the relationship between fruit foraging and larger brains by examining the feeding behavior and brain size of two South American (New World) monkeys of the same body size. She found that the spider monkey obtains nearly three-quarters of its nutrients from eating fruit and has a brain twice as large as that of the howler monkey, which obtains less than half its nutrients from fruit."
- What is so special about eating fruit that favors a larger brain? Good sensory skills, such as color
- vision
- good motor skills
- Good spatial memory skills
- Fight with Competitors – Complex social relationships



Katharine Milton, who examined the feeding behavior and brain size of two New World monkeys equal in body size, concludes that finding fruit requires more skill and a bigger brain than is required for eating leaves.

- Having a parent who can teach fruit-finding skills is helpful to a fruit eater, so being both a good learner and a good teacher is useful.
- The payoff in eating fruit is its excellent nutritional value for nourishing a large, energy-dependent brain that uses more than 20% of the body's resources
- scavenged, hunted, and gathered-Cooperation and travel

- Hominin brain development is food cooking (Fonseca-Azevedo & Herculano-Houzel, 2012). The energy consumed by a single neuron is similar in all animals, so primates with abundant neurons are challenged to support their metabolic costs. ”
- The use of fire by Homo erectus and later hominins allowed for cooking, which predigests food and thus maximizes caloric gain to the point that much less time need be devoted to foraging.
- Finally, a high degree of male–male, female–female, and male–female cooperation among hominins in food gathering and cooking would have further supported the evolution of a larger brain.”

- Food and thus maximizes caloric gain to the point that much less time need be devoted to foraging. Finally, a high degree of male–male, female–female, and male–female cooperation among hominins in food gathering and cooking would have further supported the evolution of a larger brain."
- " Dean Falk (1990) developed the "radiator hypothesis" from her car mechanic's remark that, to increase the size of a car's engine, you also have to increase the size of the radiator that cools it."
- " Falk reasoned that, if the brain's radiator, the circulating blood, adapted into a more effective cooling system, brain size could increase."

- Falk argued that, unlike australopith skulls, Homo skulls contain holes through which cranial blood vessels pass. These holes suggest that Homo species had a much more widely dispersed blood flow from the brain, which would have greatly enhanced brain cooling.
- Smaller masticatory muscles in turn led to smaller, more delicate bones in the head. Smaller bones in turn allowed for selectivity in diet and access to more energy-rich food.

- “In the slowing of maturation, a process called ***neoteny*** , juvenile stages of predecessors become the adult features of descendants”
- Many anatomical features link us with the juvenile stages of other primates, including a small face, vaulted cranium, unrotated big toe, upright posture, and primary distribution of hair on the head, armpits, and pubic areas.
- Because the head of a human infant is large relative to body size, neoteny has also led to adults with proportionally larger bodies and larger skulls to house larger brains.

- The shape of a baby chimpanzee's head is more similar to the shape of an adult human's head than to an adult chimpanzee's head (Figure 2.6)
- Adult humans also retain some behaviors of primate infants, including play, exploration, and intense interest in novelty and learning.
- "Flightless birds are neotenic adult birds, domesticated dogs are neotenic wolves, and sheep are neotenic goats"

- “Among a number of views about what promotes neoteny, one is that at times of abundant resources, less physiologically and behaviorally”

- mature individual organisms can successfully reproduce, yielding offspring that share this trait. This “babies having babies” situation could lead to a population in which individual members have immature physical features and behavioral traits while also being sexually mature.

- Large differences appear among the brains of individuals, but the reasons for those differences are numerous
- Brain size also changes over an individual's life span. Just as good nutrition early in life can promote larger body size, it also contributes to increased brain size. A culturally enriched environment is associated with growth of existing brain cells and thus increased brain size."
- "One way that the brain stores new skills and memories is to add cells and to form new connections among brain cells. These plastic adaptations in turn contribute to increased brain size."

- “The most remarkable thing that our brains have allowed us to develop is culture — the complex learned behaviors passed from generation to generation through teaching and experience.”
- “Only 30,000 years ago, modern humans created the first artistic relics: elaborate paintings on cave walls and carved ivory and stone figurines. Agriculture appeared still more recently, about 15,000 years ago, and reading and writing were developed only about 7000 years ago.”
- .

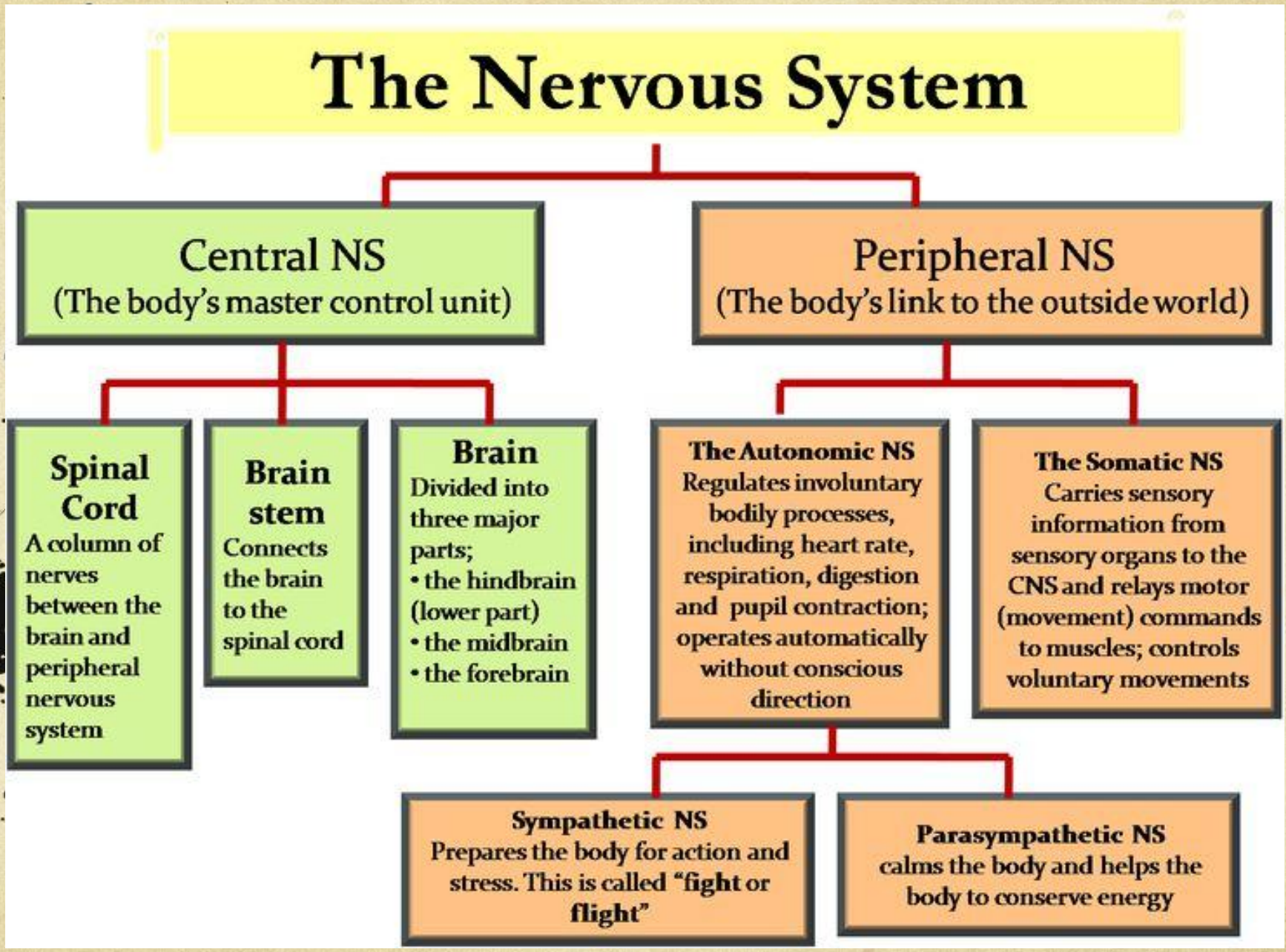
- . The presence of a primary visual cortex with a striped appearance (striate cortex) confers on the tree shrew an ability to see branches, heights, and the insects it craves. This ability is not important to, and striate cortex is not present in, ground-dwelling animals such as the hedgehog. It is from the tree shrew's ancestors that we inherit our visual abilities and large visual cortex.

- The large temporal lobe in the galagos (a species of primate) is related to this animal's ability to select for itself a highly varied diet of insects, fruits, leaves, and more, and, correspondingly, for memory ability. It is from the ancestors of the galagos that we inherit our equally varied diet and excellent memory.

- . The large frontal lobes of the rhesus monkey are related to its complex group social life. It is from the rhesus monkey's ancestors that we inherit our large frontal lobes and complex social interactions.

- The large parietal lobe that humans share with other apes is a correlate of our ability to perform the skilled movements required in toolmaking. It is from our ape ancestors that we developed our toolmaking ability.

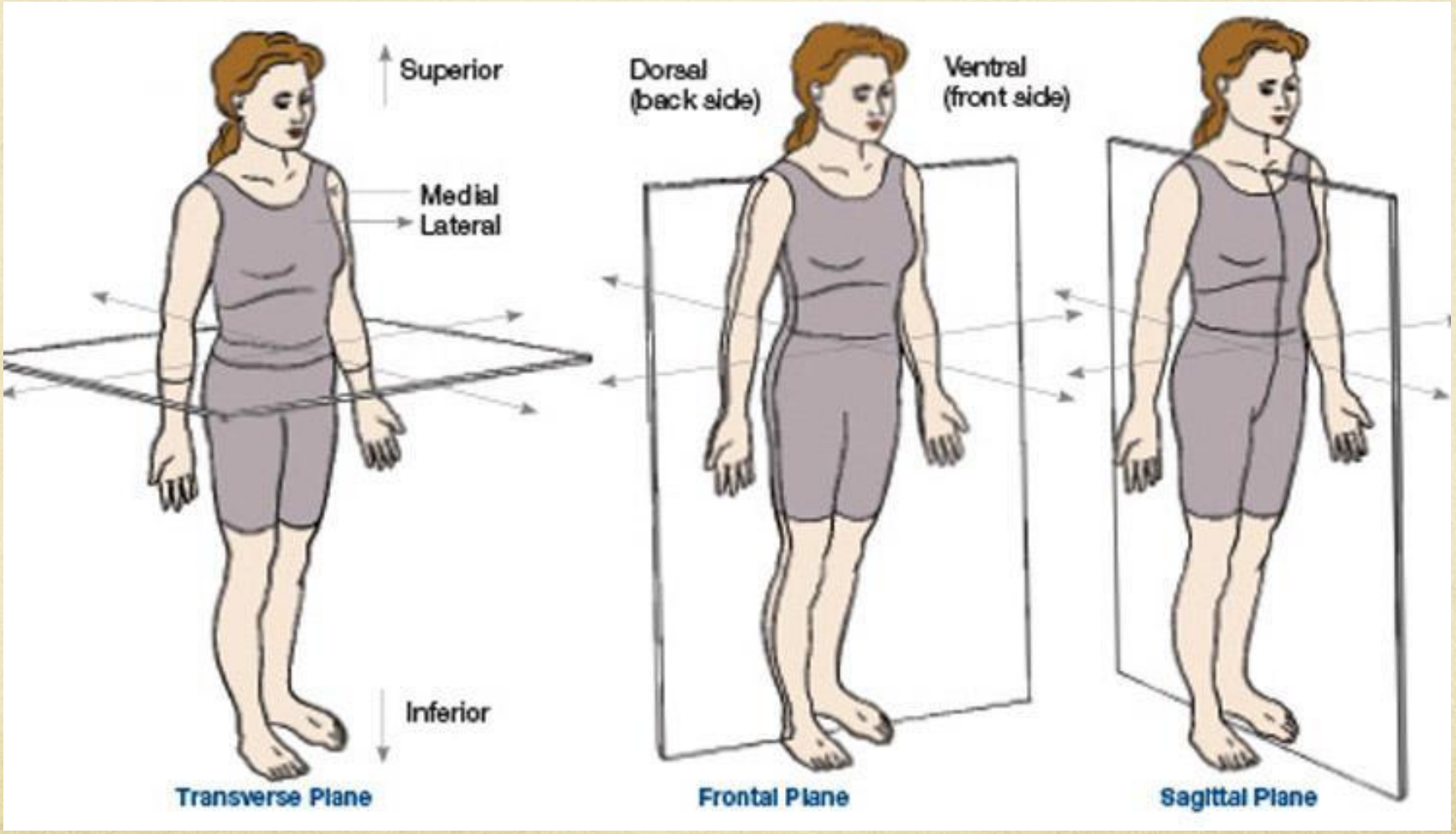
The Nervous System



Organization of the Nervous System

ORGANIZATION OF THE BRAIN

PLANES OF MOTION



IMPORTANT TERMINOLOGY

TRANSVERSE PLANE / HORIZONTAL PLANE - SUPERIOR (ABOVE/UP) & INFERRIOR (DOWN / BELOW)

FRONTAL PLANE/ CORONAL PLANE- DORSAL/POSTERIOR (BACK SIDE) & VENTRAL/ANTERIOR

SAGITTAL PLANE : -LEFT & RIGHT

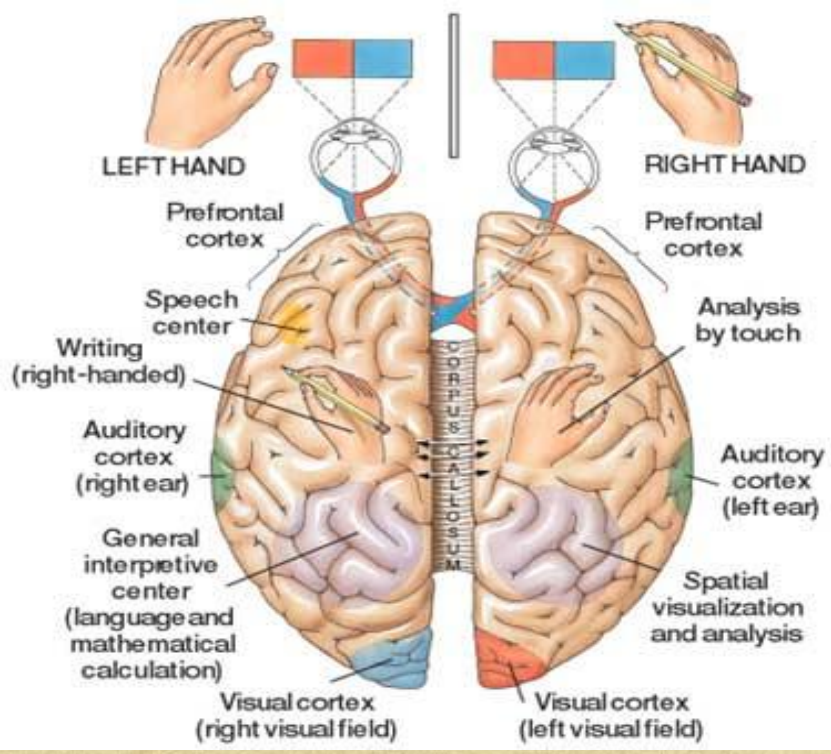
Medial - towards centre

lateral - towards surface

caudal- towards tail end- posterior part - ideally dorsal & inferior

Brain Structure

- 2 hemispheres – Right and Left
- Corpus Callosum connects the 2 hemispheres



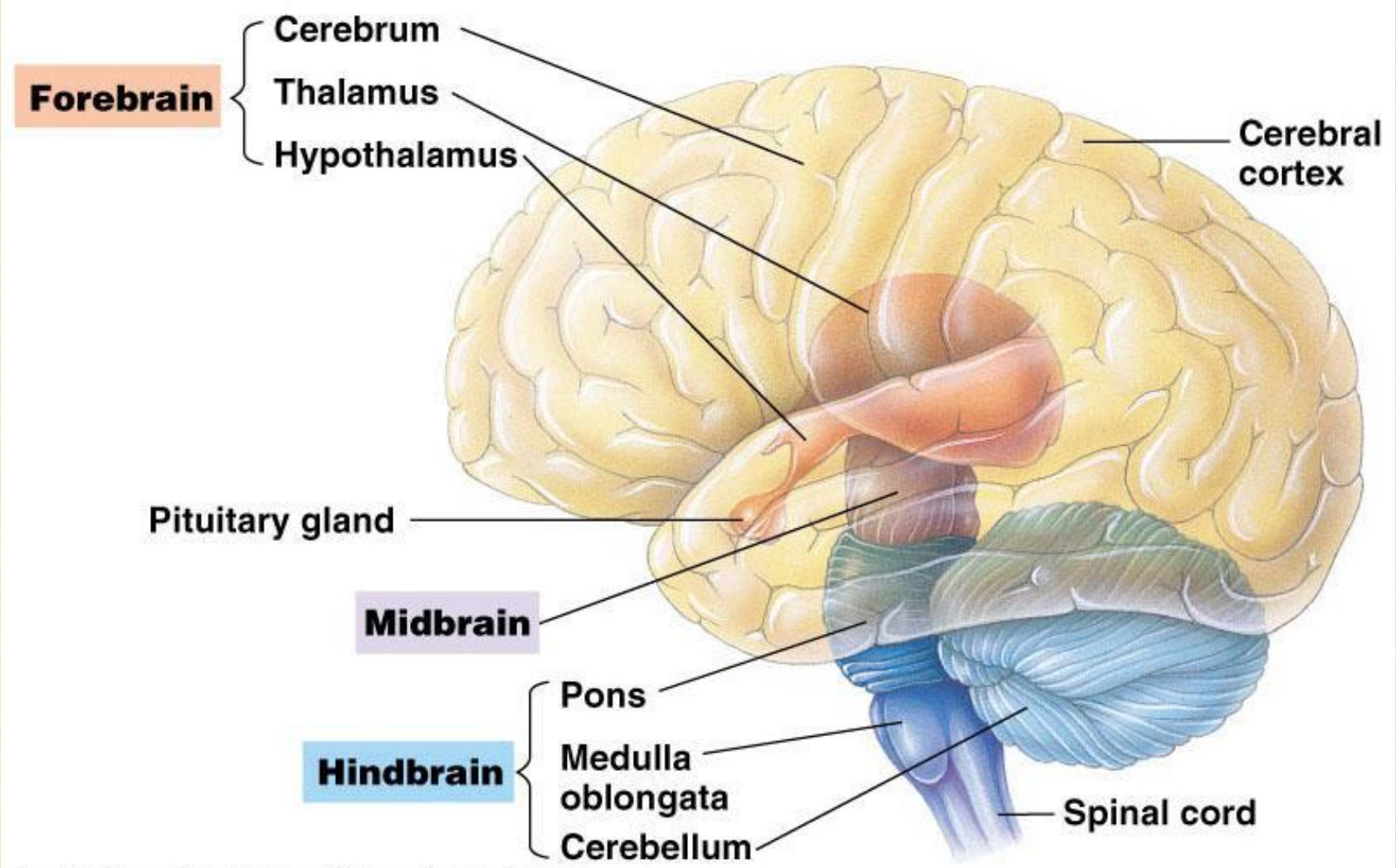
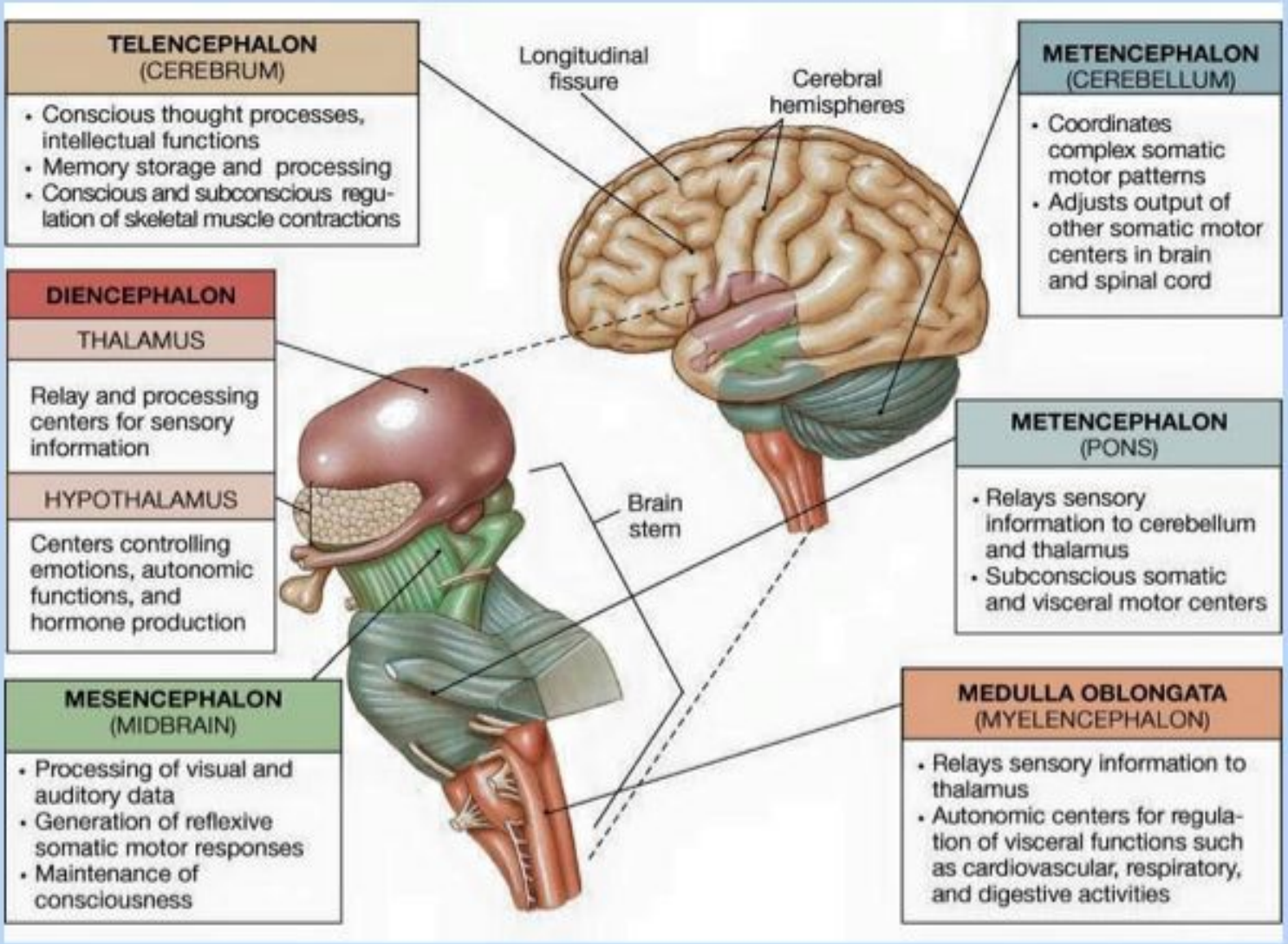

Forebrain
Cerebrum
Thalamus
Hypothalamus
Cerebral cortex
Pituitary gland
Midbrain
Hindbrain
Pons
Medulla oblongata
Cerebellum
Spinal cord

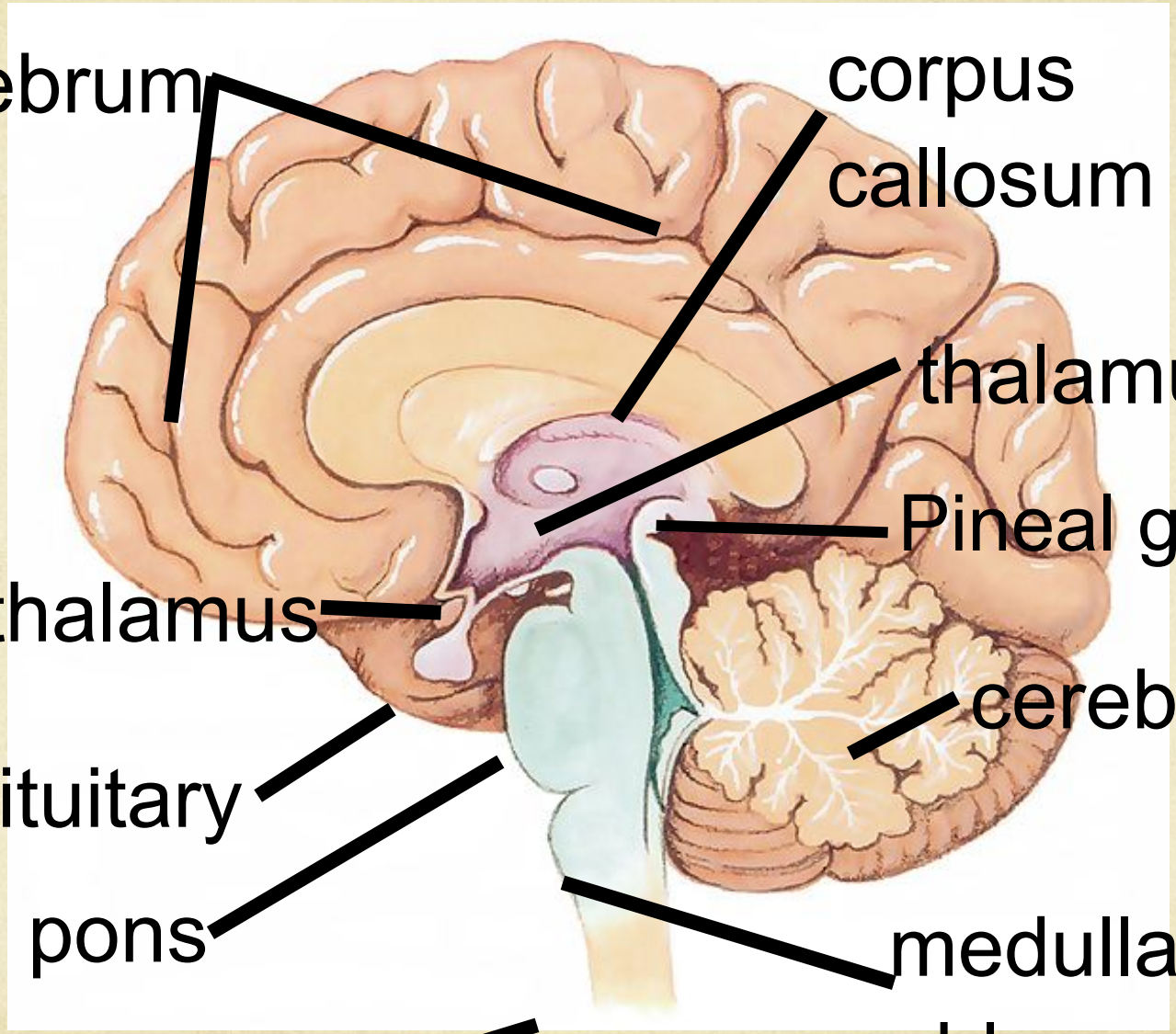
Fig. 48.20

Encephalon

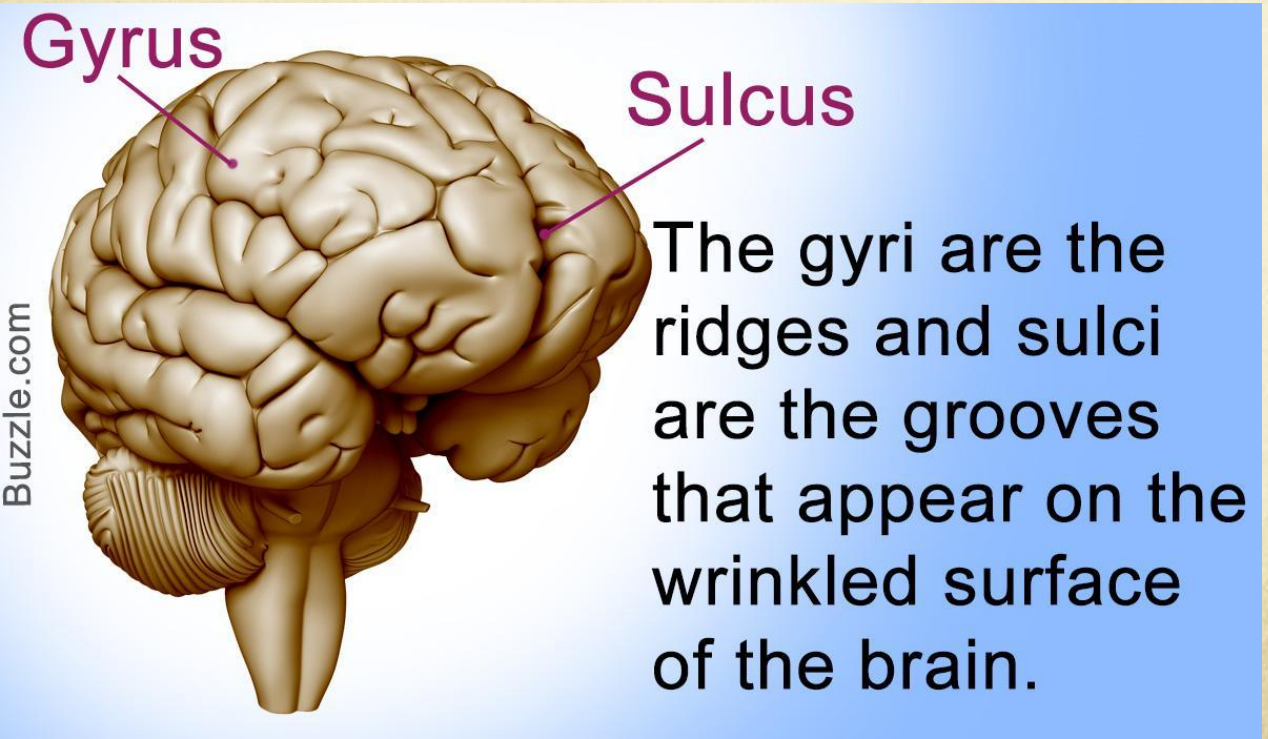
Higher brain structures that are enclosed within the skull

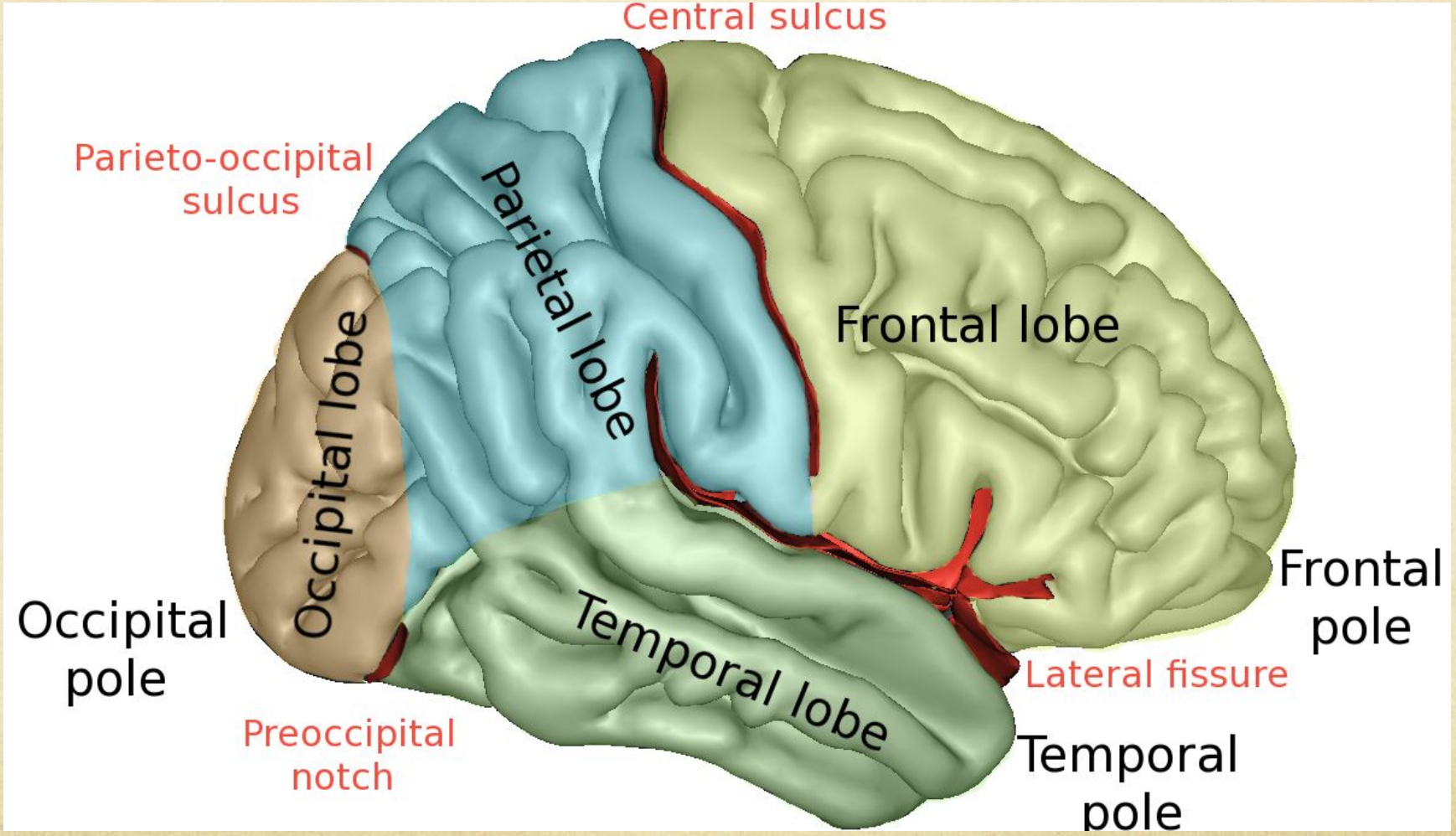
Major Division	Subdivisions	Structures	Cavity
Forebrain (prosencephalon)	Telencephalon (endbrain)	Cerebral cortex Basal ganglia Basal forebrain Hippocampal complex Corpus callosum	Lateral ventricles
	Diencephalon (between brain)	Epithalamus Thalamus Hypothalamus	Third ventricle
Midbrain (mesencephalon)	Mesencephalon (midbrain)	Tectum Tegmentum	Cerebral aqueduct
Hindbrain (rhombencephalon)	Metencephalon	Pons Cerebellum	Fourth ventricle
	Myelencephalon	Medulla oblongata	


TELENCEPHALON
(CEREBRUM)
• Conscious thought processes, intellectual functions
• Memory storage and processing
• Conscious and subconscious regulation of skeletal muscle contractions
Longitudinal fissure
Cerebral hemispheres
METENCEPHALON
(CEREBELLUM)
• Coordinates complex somatic motor patterns
• Adjusts output of other somatic motor centers in brain and spinal cord
DIENCEPHALON
THALAMUS
Relay and processing centers for sensory information
HYPOTHALAMUS
Centers controlling emotions, autonomic functions, and hormone production
Brain stem
METENCEPHALON
(PONS)
• Relays sensory information to cerebellum and thalamus
• Subconscious somatic and visceral motor centers
MESENCEPHALON
(MIDBRAIN)
• Processing of visual and auditory data
• Generation of reflexive somatic motor responses
• Maintenance of consciousness
MEDULLA OBLONGATA
(MYELENCEPHALON)
• Relays sensory information to thalamus
• Autonomic centers for regulation of visceral functions such as cardiovascular, respiratory, and digestive activities


cerebrum
corpus
callosum
thalamus
Pineal gland
hypothalamus
cerebellum
pituitary
pons
medulla
oblongata
spinal cord

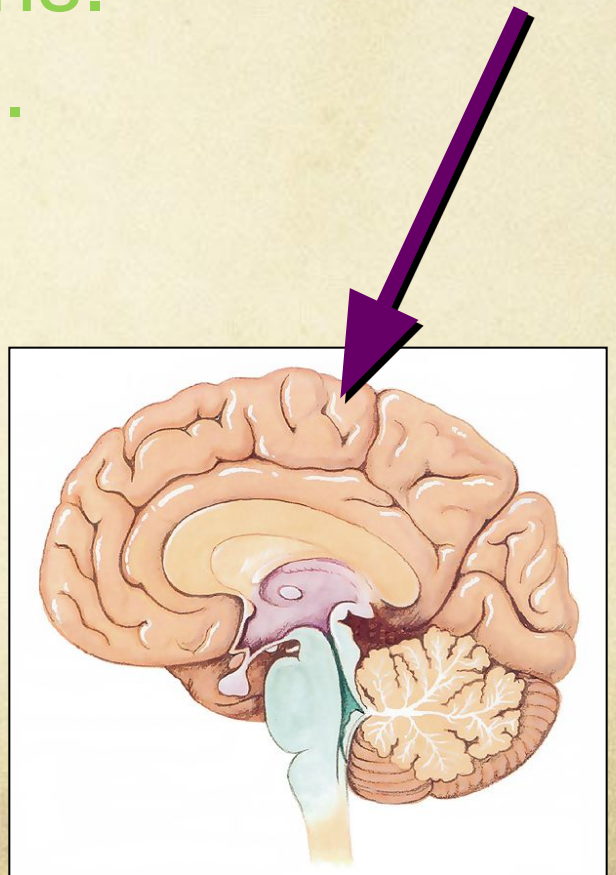
Each cerebral hemisphere is divided into Four lobes by sulci and gyri.
The sulci (or fissures) are the grooves and the gyri are the "bumps”that can be seen on the surface of the brain




Central sulcus
Parieto-occipital sulcus
Parietal lobe
Occipital lobe
Frontal lobe
Occipital pole
Temporal lobe
Frontal pole
Lateral fissure
Preoccipital notch
Temporal pole

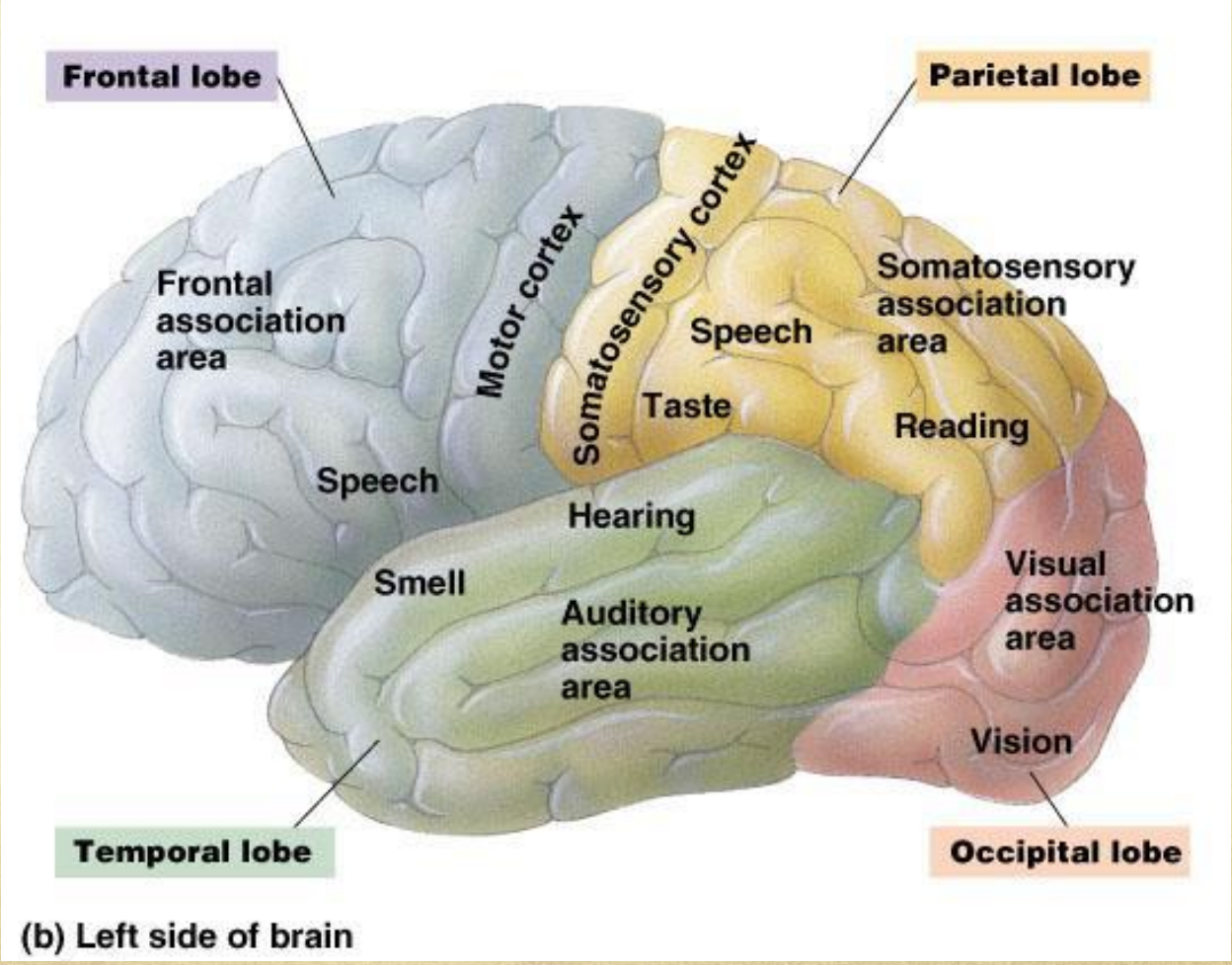
Cerebrum/ Cerebral Cortex

- Involved with higher brain functions.
- Processes sensory information.
- Initiates motor functions.
- Integrates information.



Regions of the cerebrum are specialized for different functions

- The cerebrum is divided into frontal, temporal, occipital, and parietal lobes.



Frontal lobe.

- Contains the primary motor cortex.
- Higher order cognitive functioning

Parietal lobe.

- Contains the primary somatosensory cortex
- Olfaction/Gustatory

Temporal Lobe

Auditory -sounds +listening

Olfaction

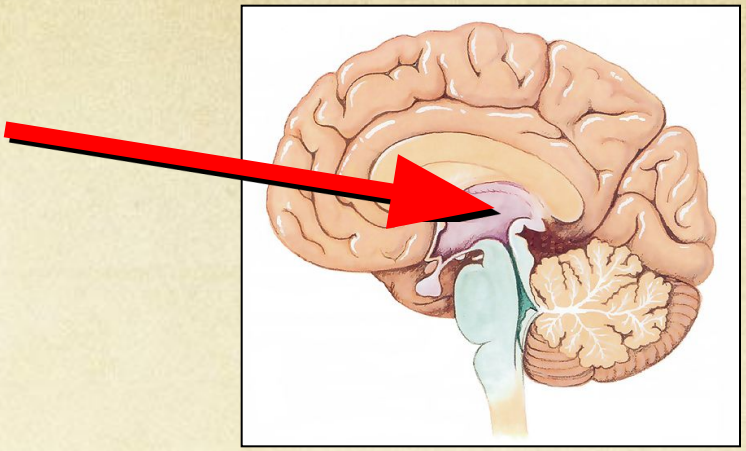
Occipital Lobe

Visual processing

- Integrative Function of the Association Areas.
  - Much of the cerebrum is given over to association areas.
    - Areas where sensory information is integrated and assessed and motor responses are planned.

- The brain exhibits plasticity of function.
  - For example, infants with intractable epilepsy may have an entire cerebral hemisphere removed.
    - The remaining hemisphere can provide the function normally provided by both hemispheres.

Thalamus



- Relay center for sensory tracts from the spinal cord to the cerebrum.
- Contains centers for sensation of pain, temperature, and touch.
- Involved with emotions and alerting or arousal mechanisms.

- The Reticular System, Arousal, and Sleep.
  - The reticular activating system (RAS) of the **reticular formation.**
    - Regulates sleep and arousal.
    - Acts as a sensory filter.

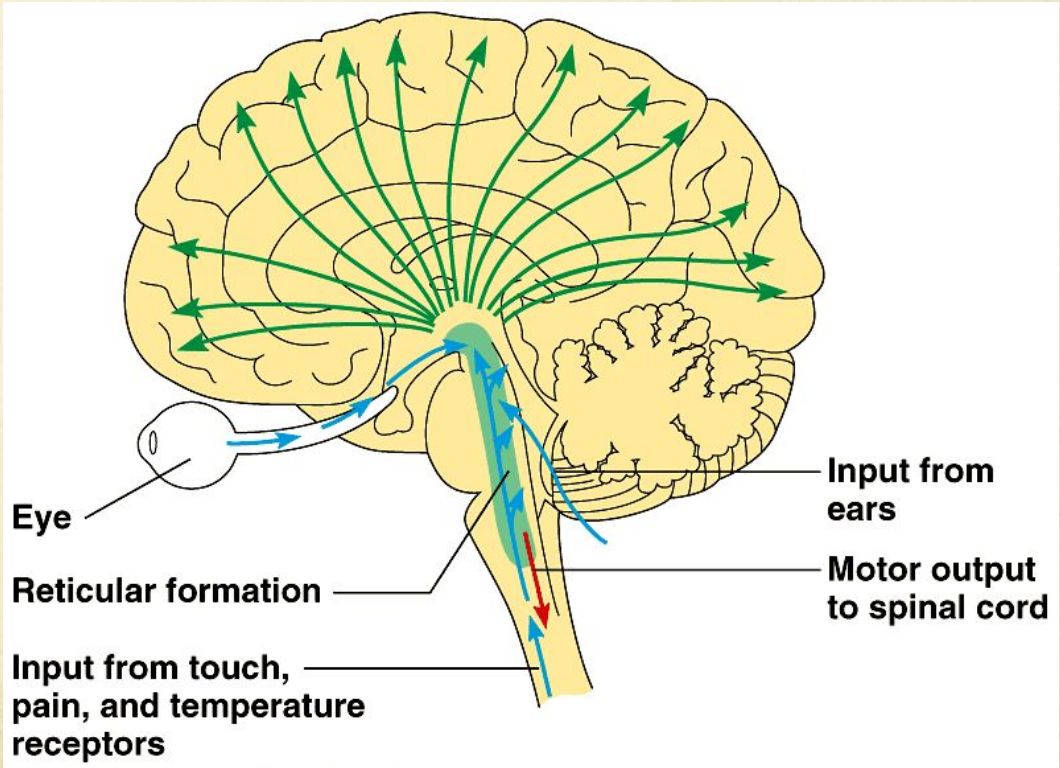
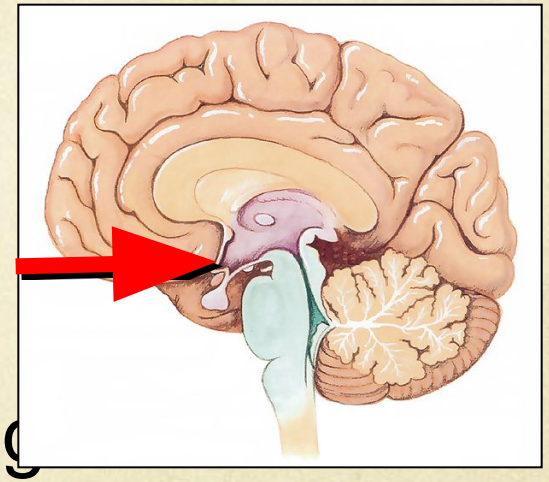


Fig. 48.21

Hypothalamus

autonomic control center- blood pressure, rate and force of heart contraction, center for emotional response and behavior

- body temperature
- water balance and thirst
- sleep/wake cycles
- appetite
- sexual arousal
- control of endocrine functioning

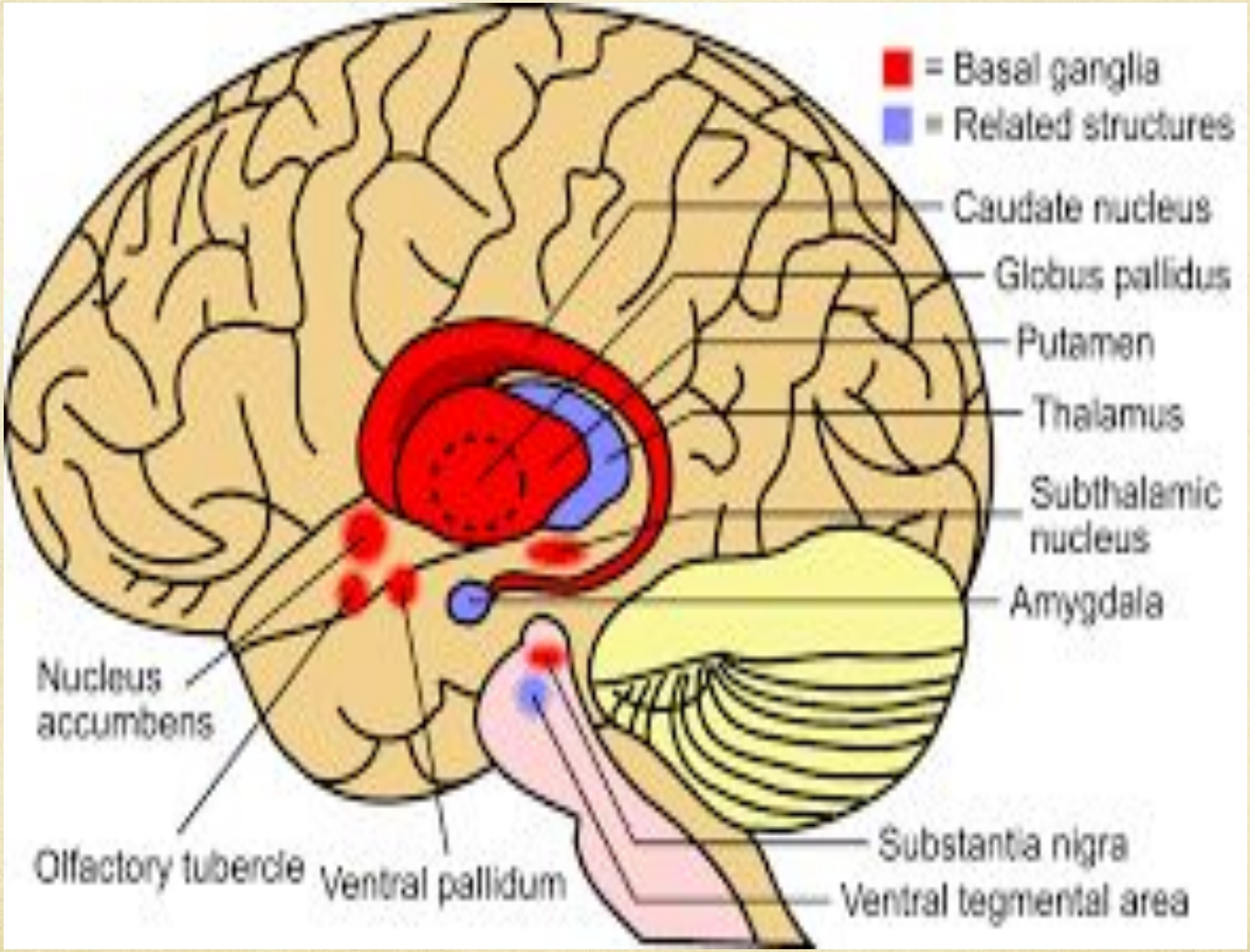


Acts on the pituitary gland through the release of neurosecretions.

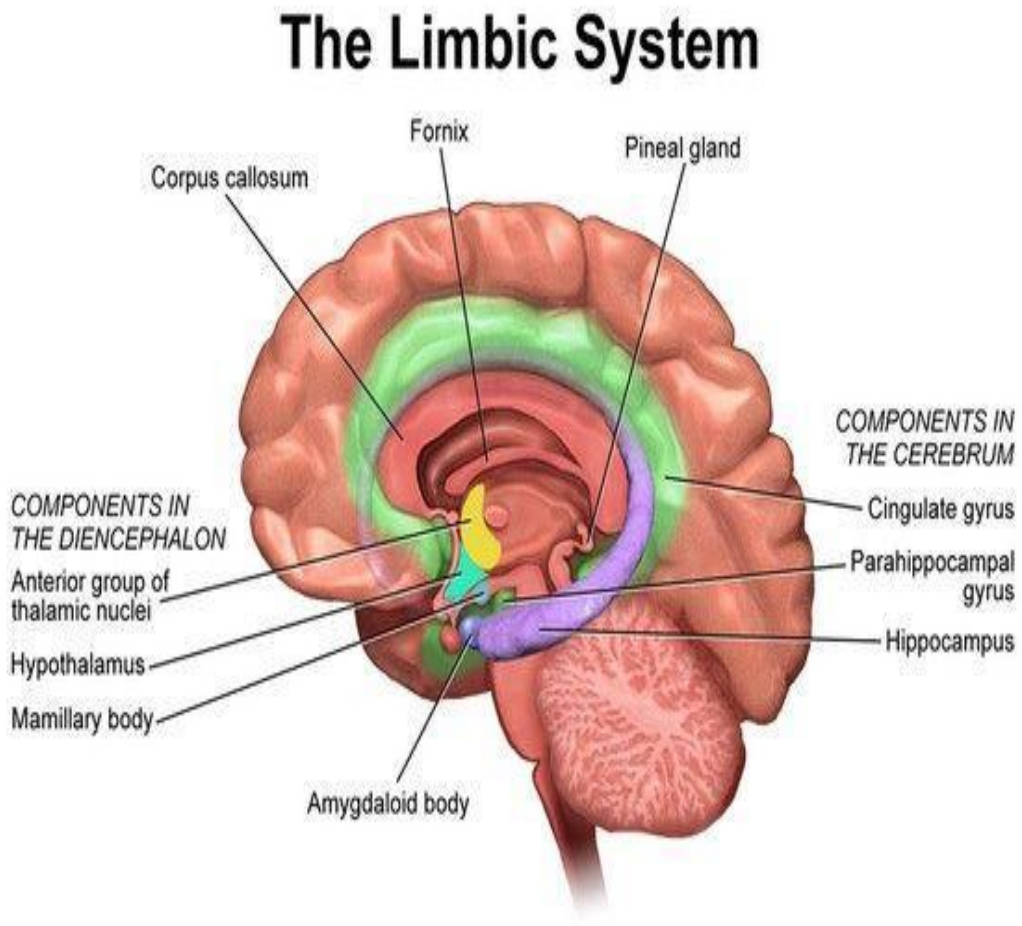
Basal Ganglia

- Caudate Nucleus
- Putamen
- Striatum

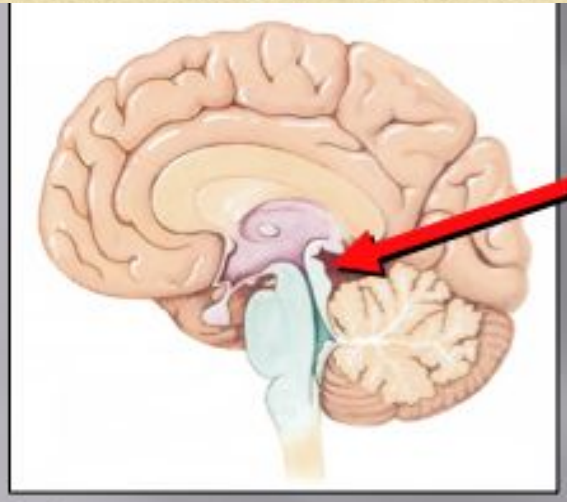
- Motor control- voluntary motor behavior & extrapyramidal motor behavior- Parkinson's
- Inhibitory motor respones
- Connected to Thalamus and Motor Association cortex of Frontal Lobe


= Basal ganglia
= Related structures
Caudate nucleus
Globus pallidus
Putamen
Thalamus
Subthalamic nucleus
Amygdala
Nucleus accumbens
Olfactory tubercle
Ventral pallidum
Substantia nigra
Ventral tegmental area

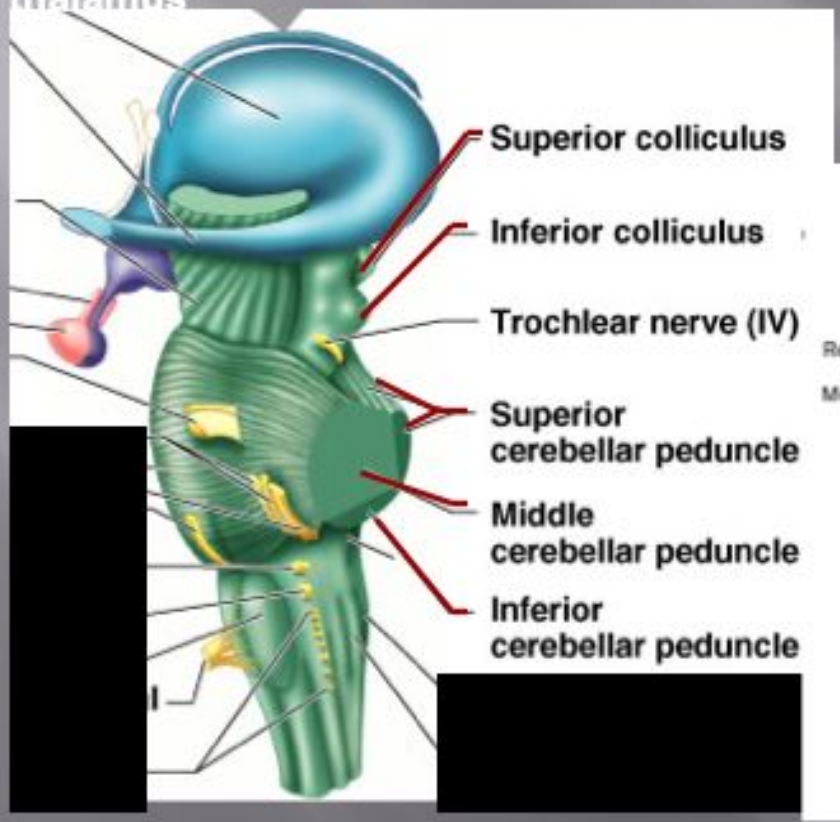
Limbic System

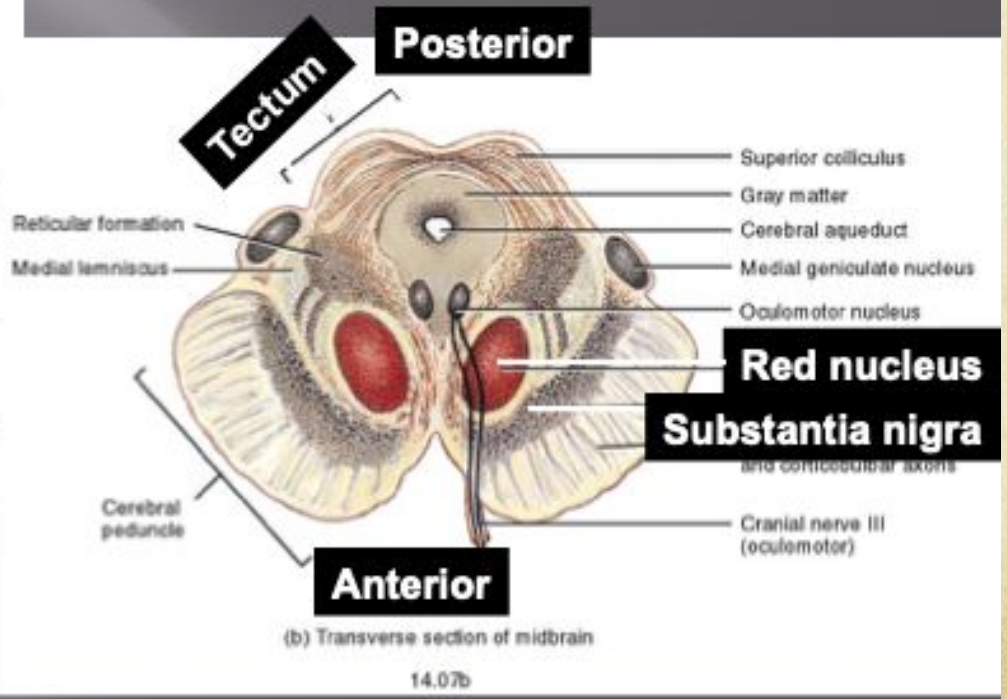


Midbrain



- Cerebellar peduncles
- Tectum
- Superior colliculi
- Inferior colliculi
- Substantia nigra
- Red nuclei





Midbrain functions

- Motor Movement
- Eye movement /Visual Processing
- Auditory Processing

Midbrain

- Contains ascending and descending tracts to the cerebrum and thalamus.
- Reflex center for eye muscles.
- Also involved with processing visual and auditory information (connects head movements with visual and auditory stimuli).

Hindbrain

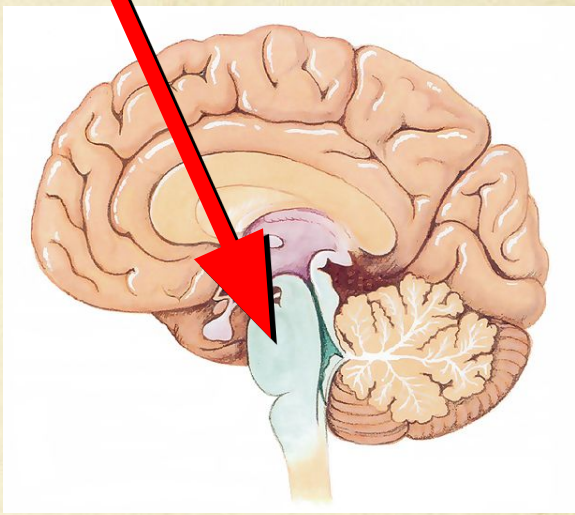
Cerebellum

Little brain

- Motor structure
- Balance
- Voluntary Motor movements including speech

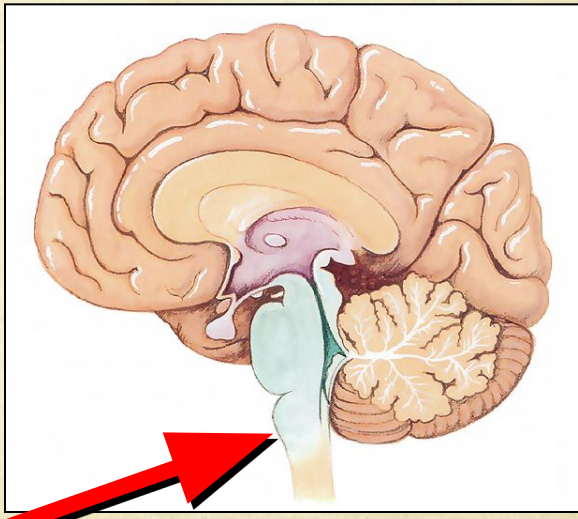
Pons

- Connects the two halves of the cerebellum.
- Regulates breathing.



Medulla Oblongata

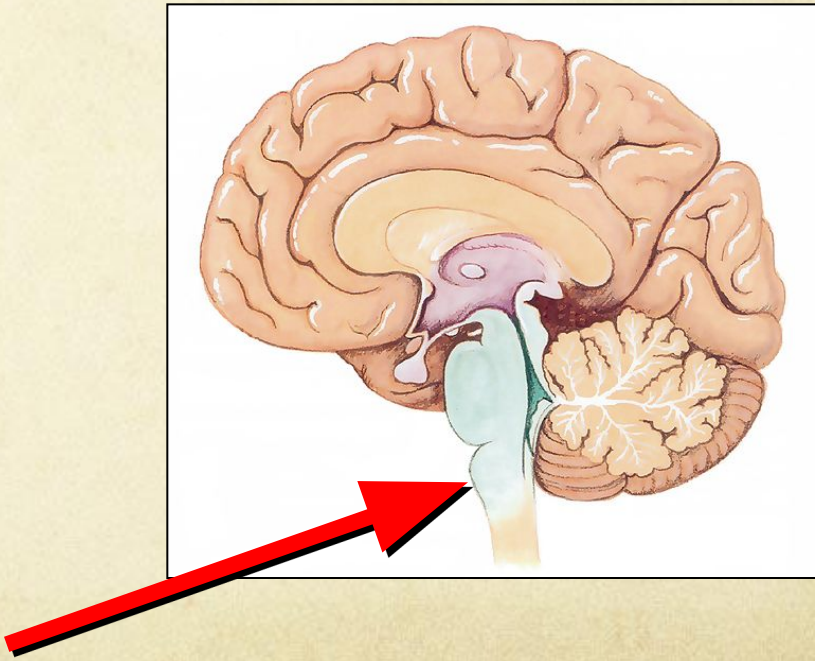
- Composed of nerve tracts to and from the brain (these tracts cross over left to right and right to left)
- May be regarded as an extension of the spinal cord
- Almost all of the cranial nerves arise from this region



Medulla Oblongata

Contains control centers for many subconscious activities

- Respiratory rate
- Heart rate
- Arteriole constriction
- Swallowing
- Hiccupping
- Coughing
- Sneezing

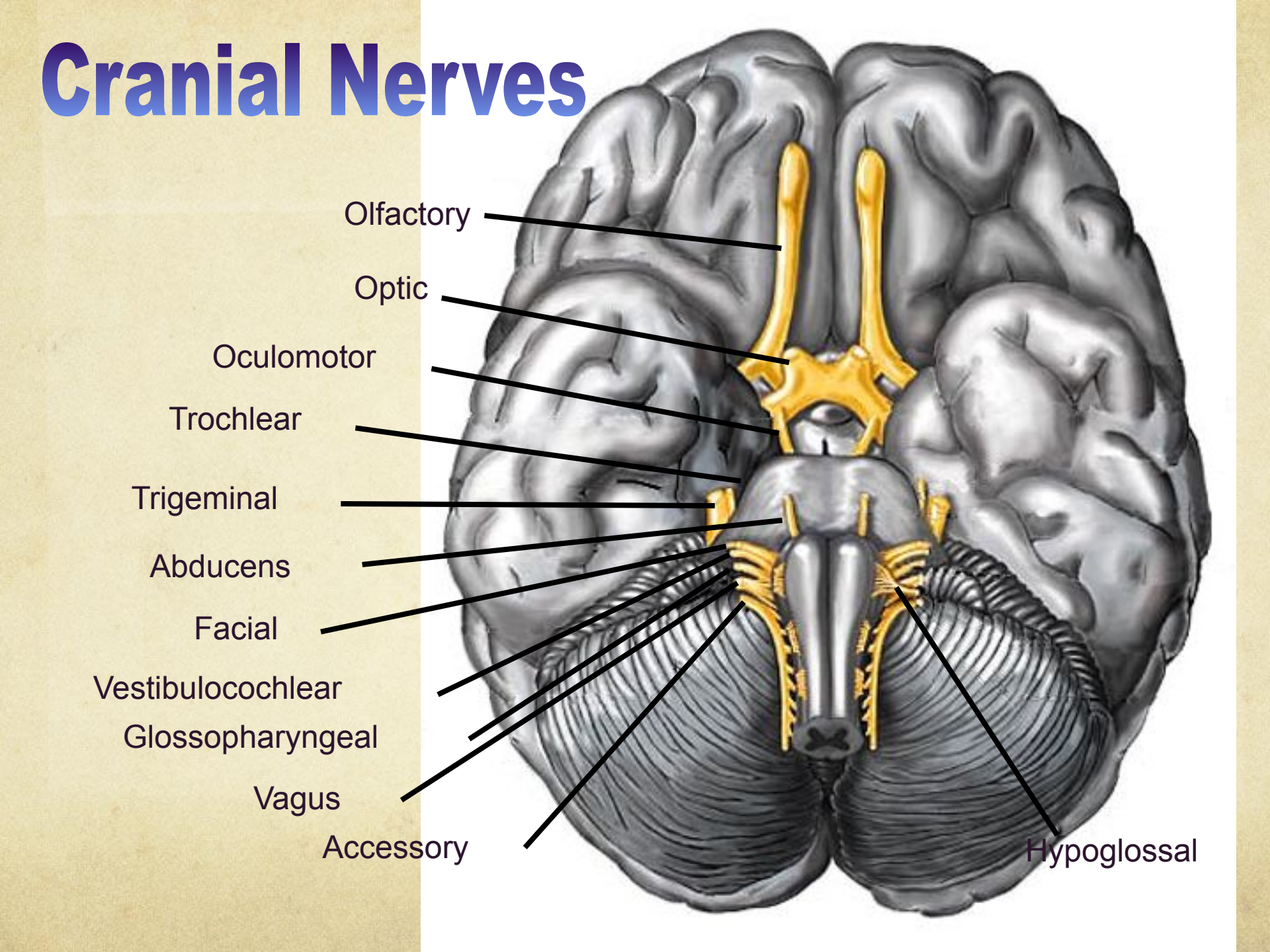


Cranial Nerves

On Old Olympus Towering Tops A Fat Voracious German Viewed A Hop

1. **Olfactory-** smell
2. **Optic-** vision
3. **Oculomotor-** 4 of the 6 extrinsic eye muscles
4. **Trochlear-** extrinsic eye muscles
5. **Trigeminal-** sensory fibers to the face and motor fibers to the chewing muscles
6. **Abducens-** controls eye muscles that turn the eye laterally
7. **Facial-** facial expression
8. **Vestibulocochlear-** hearing and balance
9. **Glosopharyngeal-** tongue and pharynx
10. **Vagus-** parasympathetic control of heart, lungs & abdominal organs
11. **Accessory-** accessory part of vagus nerve, neck & throat muscles
12. **Hypoglossal-** moves muscles under tongue

Cranial Nerves



Protection of the Central Nervous System

- Scalp and skin
- Skull and vertebral column
- Meninges

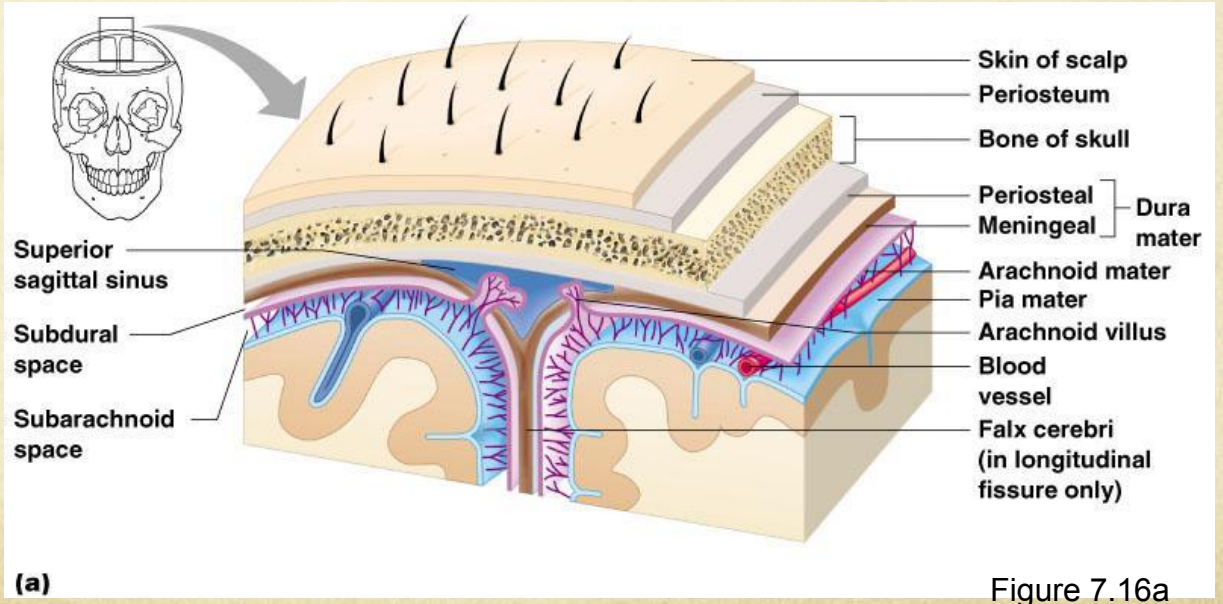
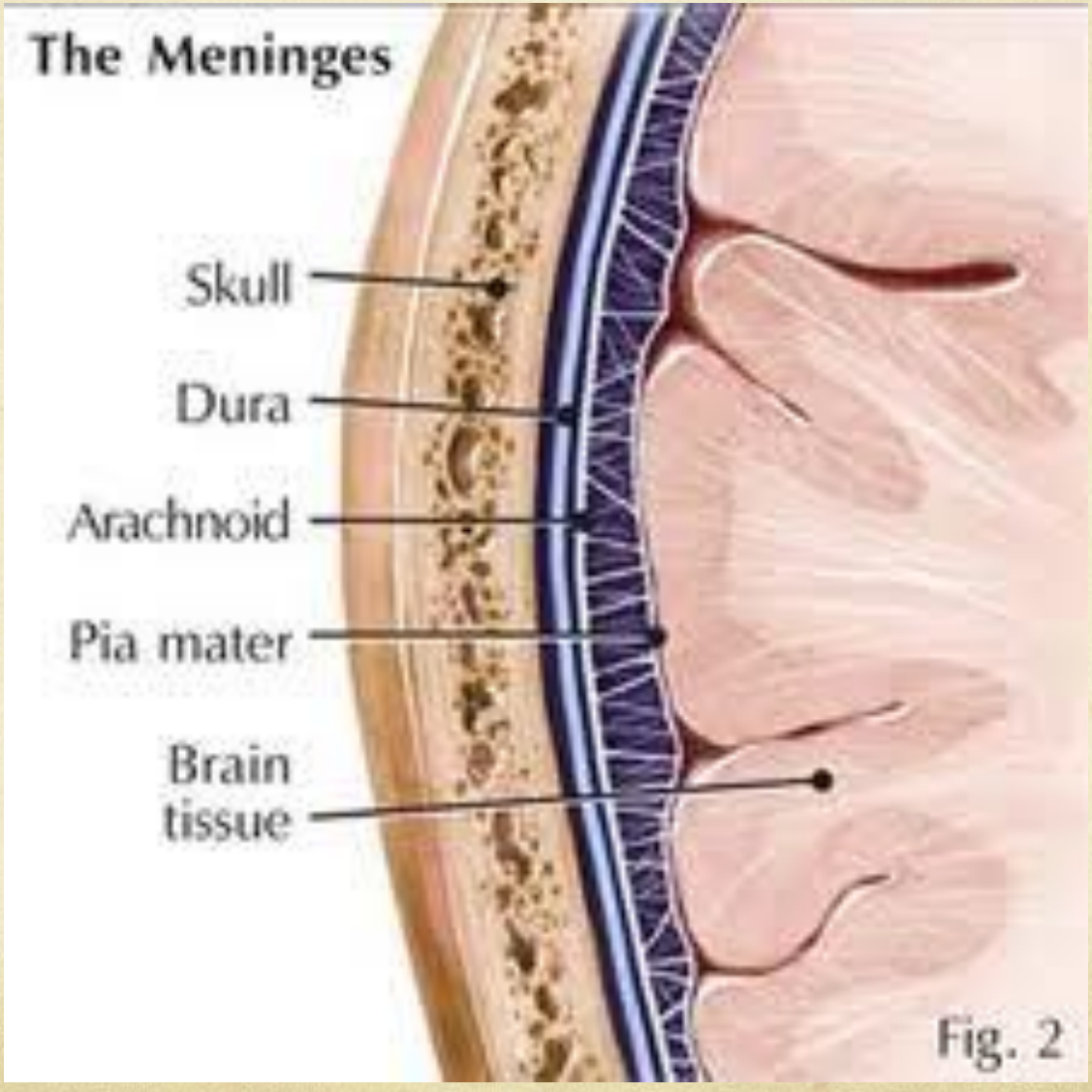


Figure 7.16a

Meninges

- Dura Matter
- Arachnoid Matter
- Pia Matter


The Meninges
Skull
Dura
Arachnoid
Pia mater
Brain tissue
Fig. 2

Cerebrospinal Fluid

- Similar to blood plasma composition
- Forms a watery cushion to protect the brain
- Circulated in arachnoid space, ventricles, and central canal of the spinal cord

Ventricles and Location of the Cerebrospinal Fluid

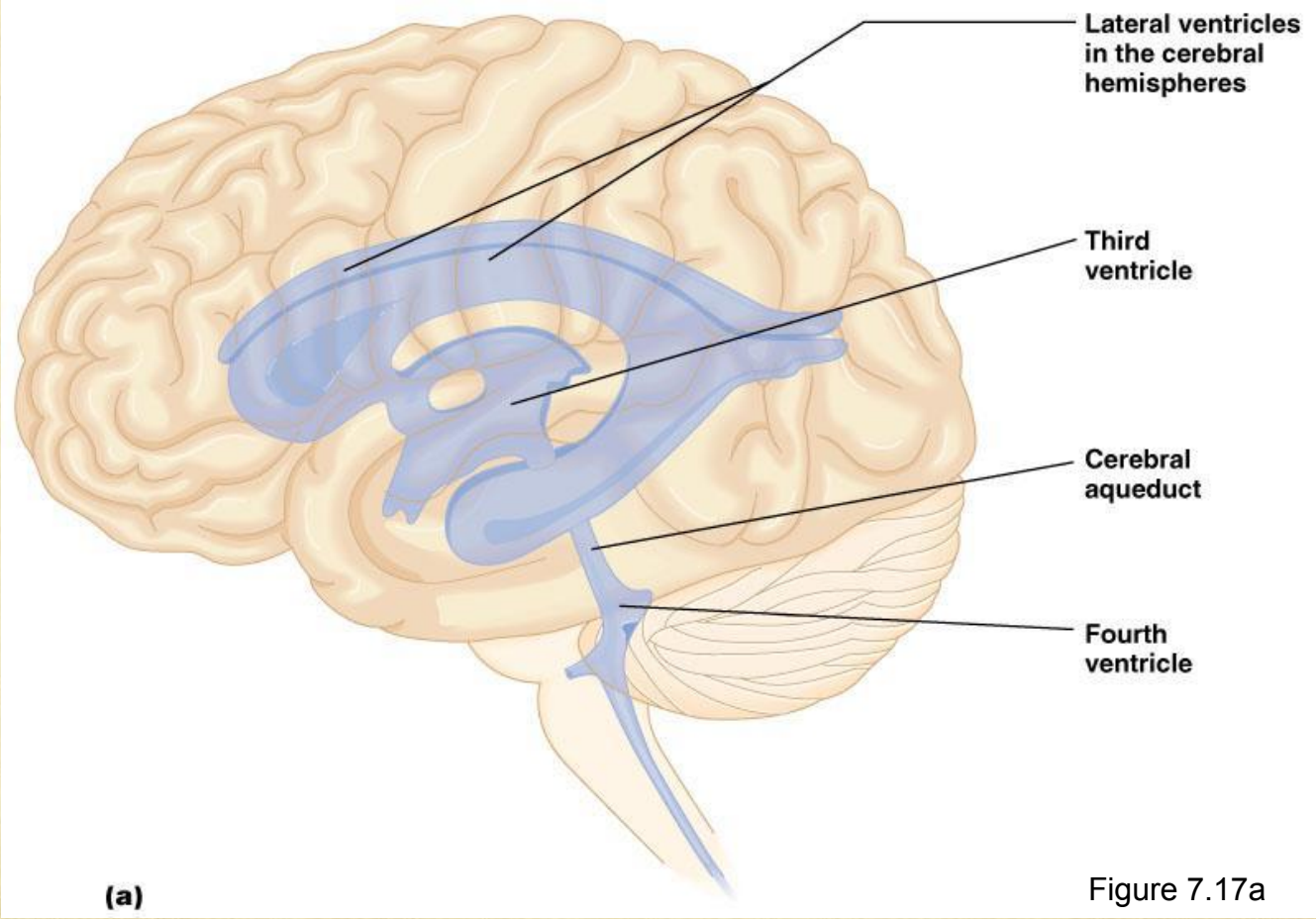


Figure 7.17a

Ventricles and Location of the Cerebrospinal Fluid

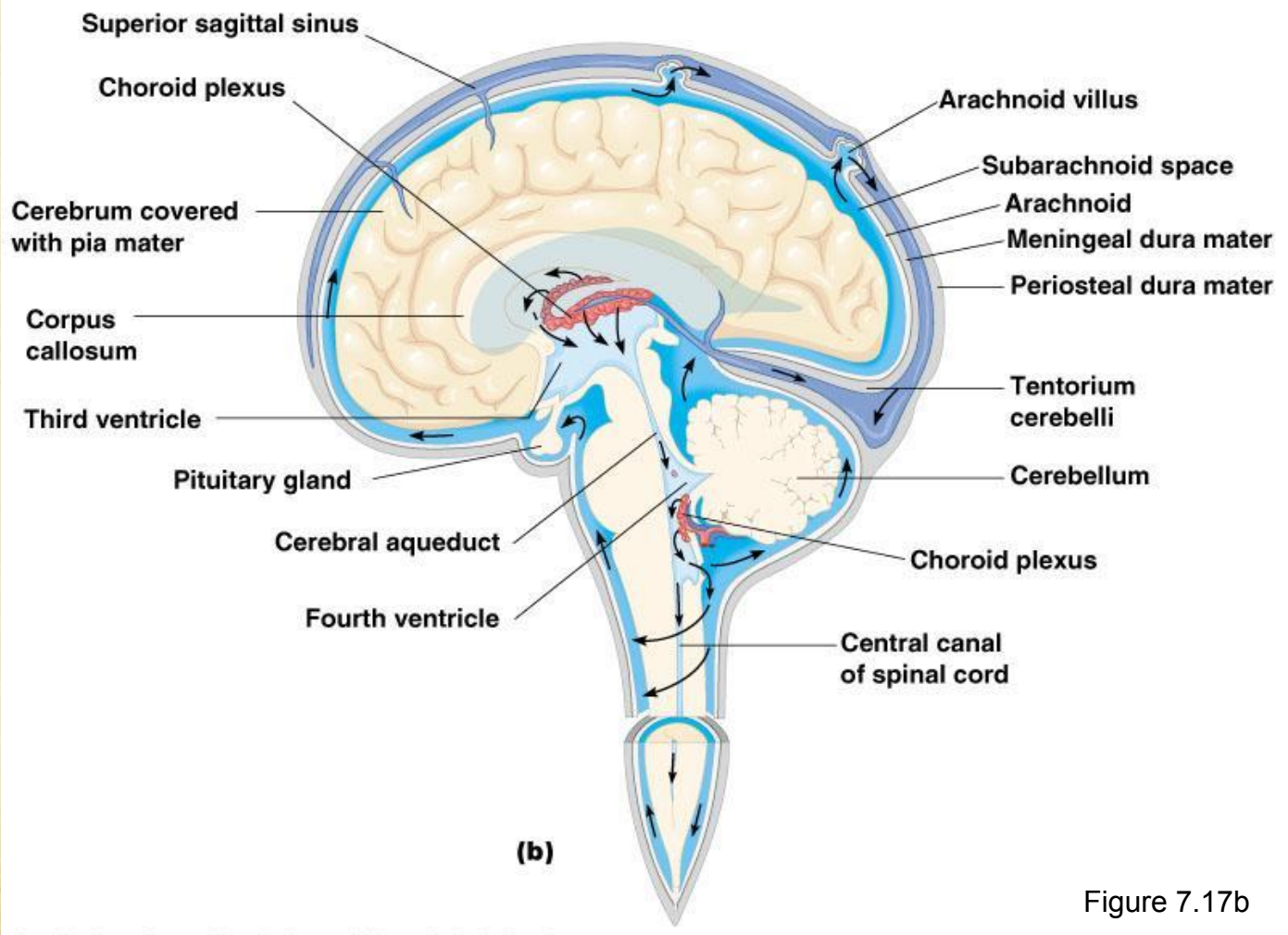
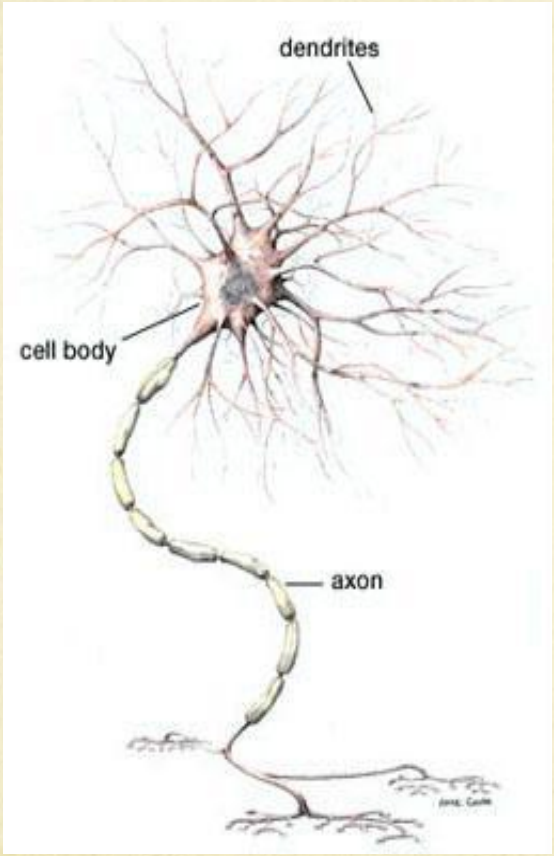


Figure 7.17b

Blood Brain Barrier

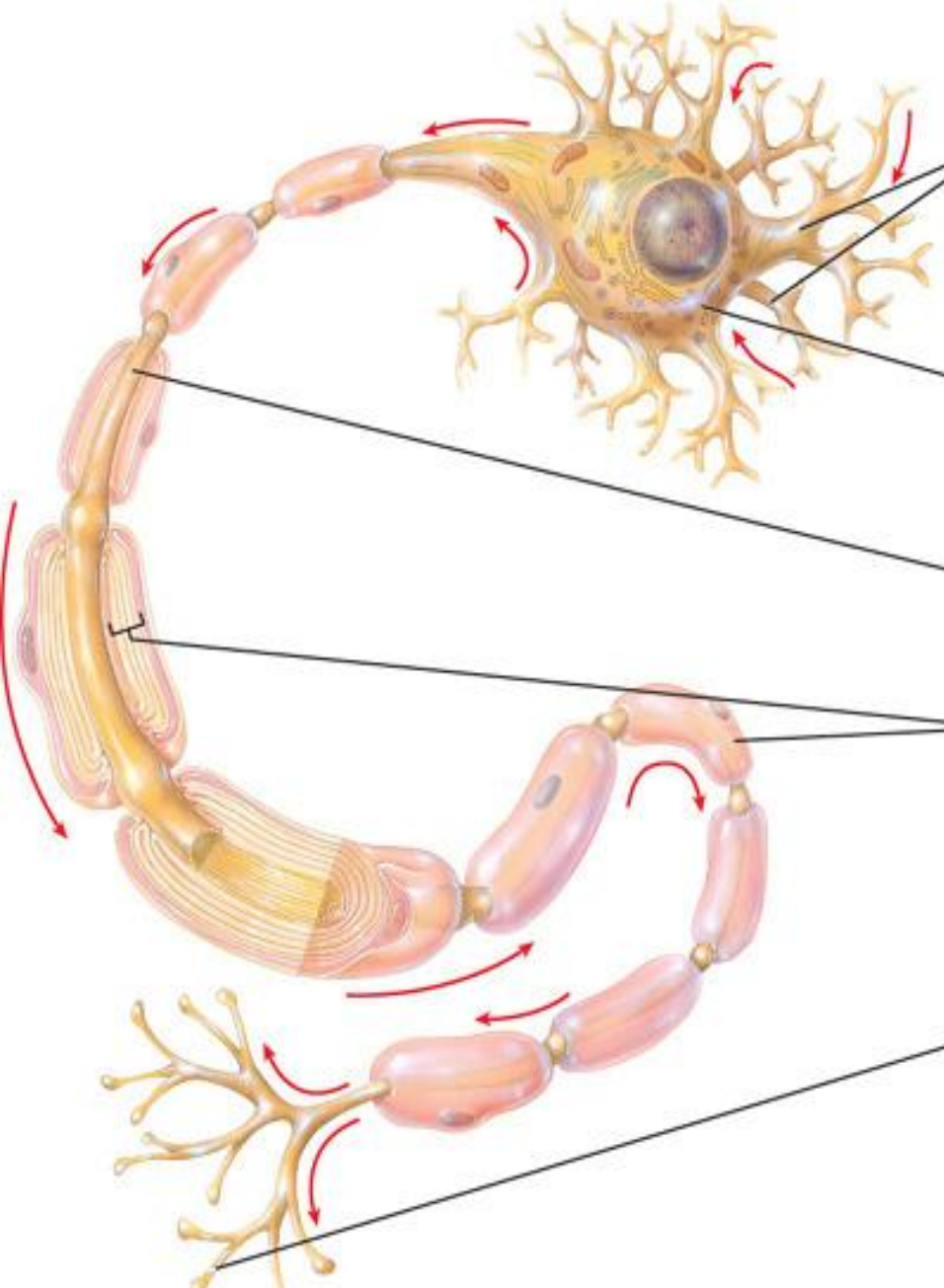
- Includes the least permeable capillaries of the body
- Excludes many potentially harmful substances
- Useless against some substances
  - Fats and fat soluble molecules
  - Respiratory gases
  - Alcohol
  - Nicotine
  - Anesthesia

1.2 Neurons




EFF JOHNSON
BIOLOGICAL & MEDICAL VISUALS

Let's Review!



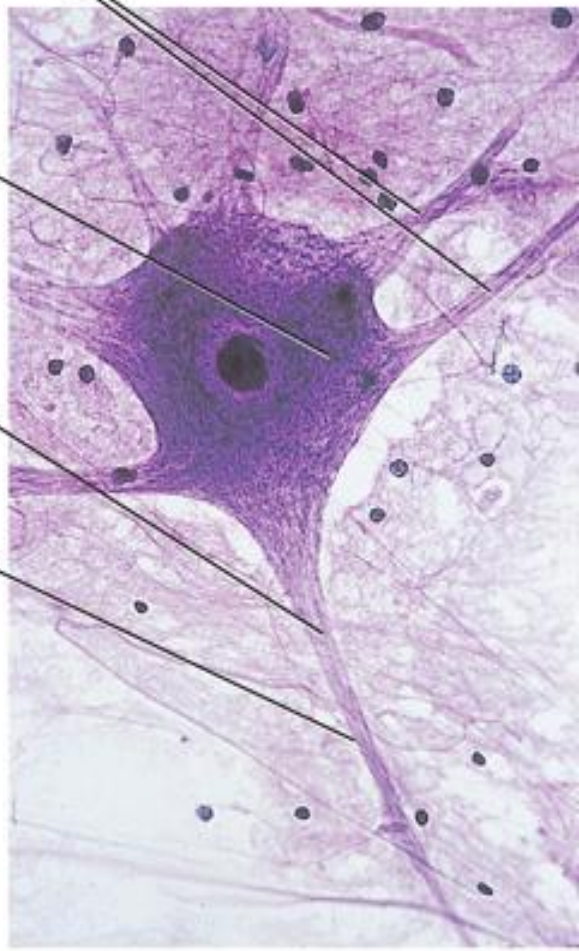
Dendrites receive information from other neurons and sensory receptors.

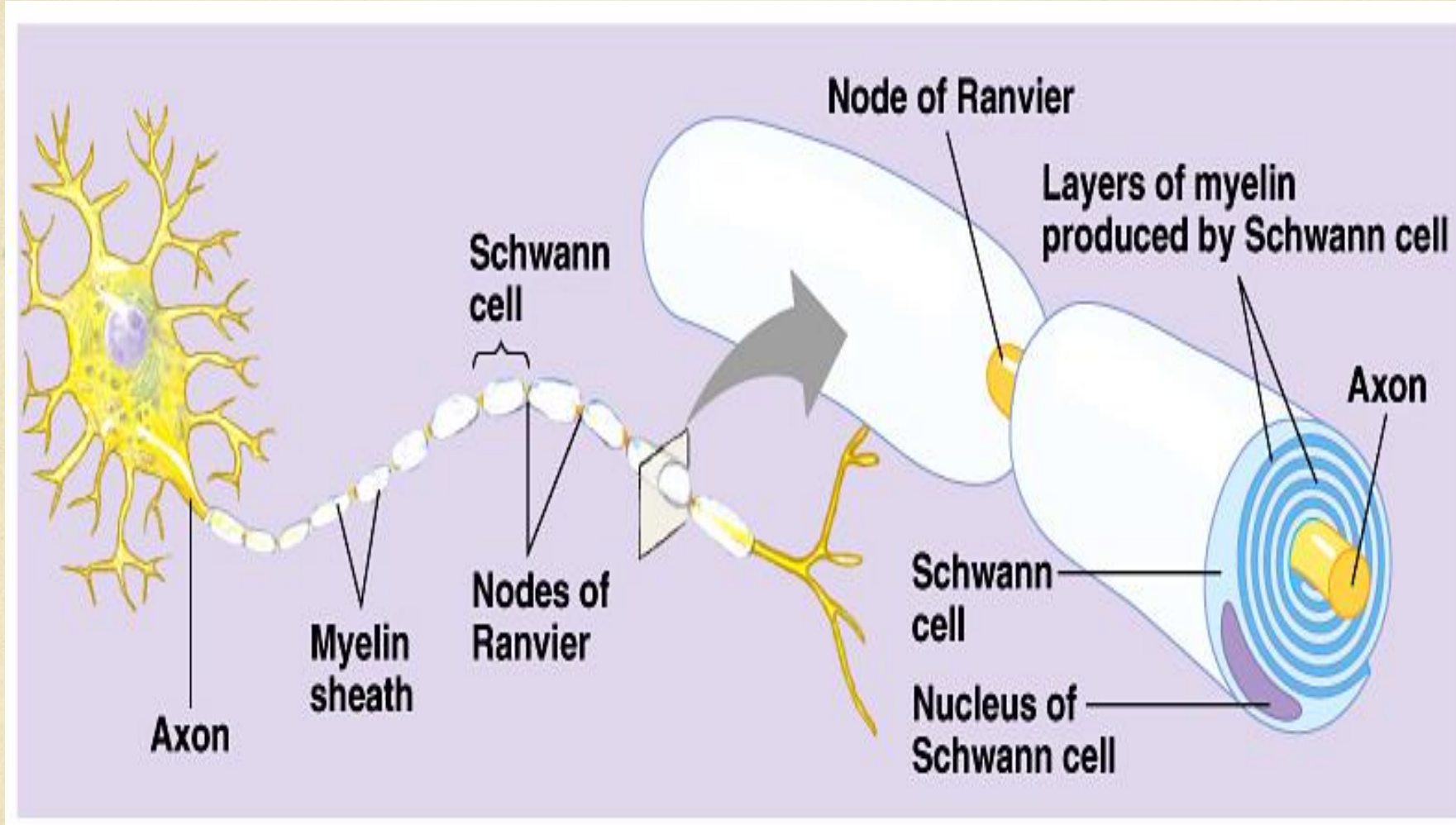
Cell body receives information from dendrites, and if enough stimulation is received the message is passed on to the axon.

Axon carries neuron's message to other body cells.

Myelin sheath covers the axon of some neurons to insulate and help speed neural impulses.

Terminal buttons of axon form junctions with other cells and release chemicals called neurotransmitters.




Node of Ranvier
Layers of myelin produced by Schwann cell
Schwann cell
Axon
Nodes of Ranvier
Myelin sheath
Schwann cell
Axon
Nucleus of Schwann cell

Main Parts of a Neuron

- Soma
- Axon
- Dendrites
- Terminal Buttons
- Myelin Sheath
- Nodes of Ranvier

Types of Neurons

unipola
r

Dorsal root ganglion cells

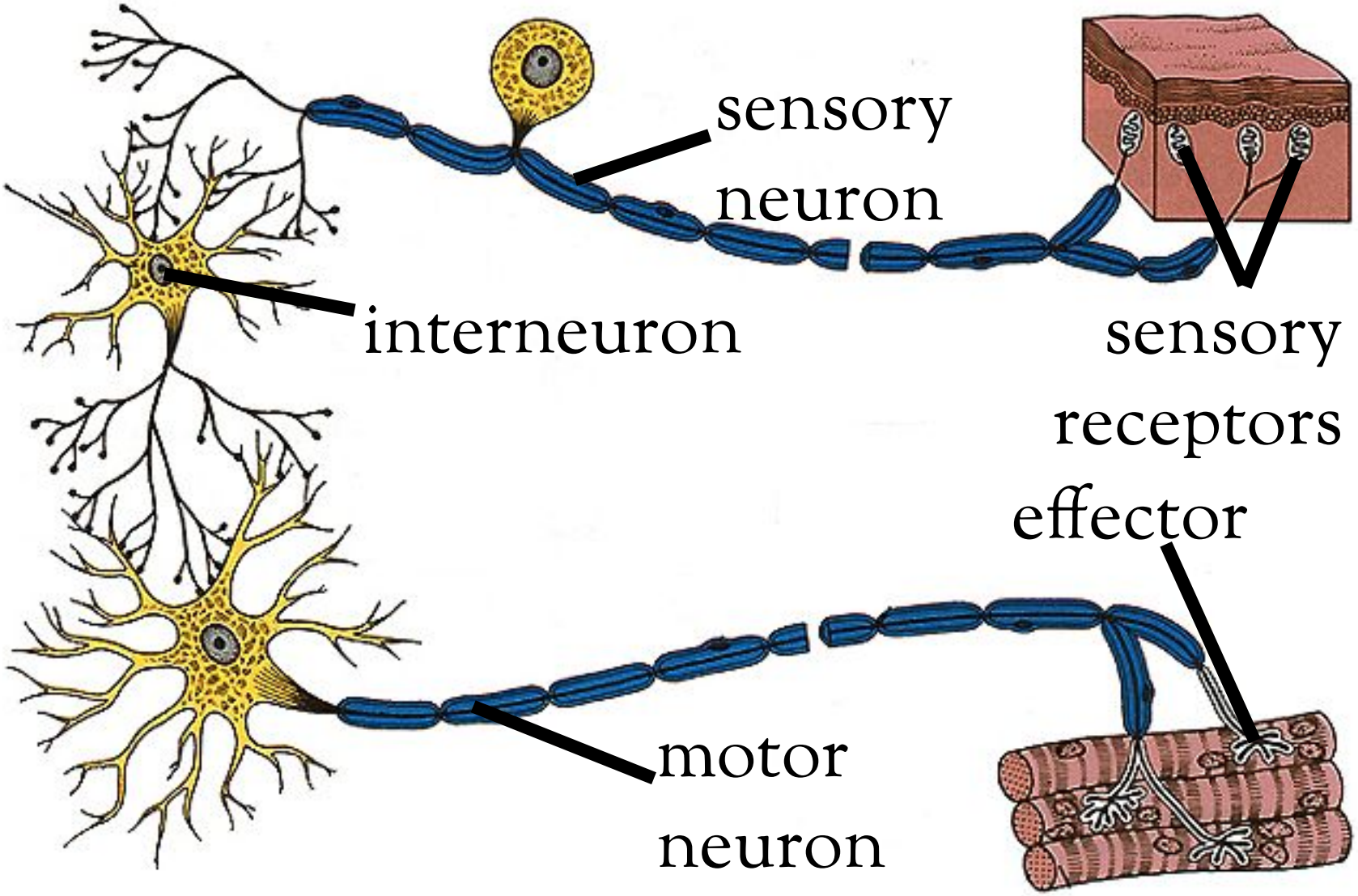
bipolar

eye, ear, & olfactory

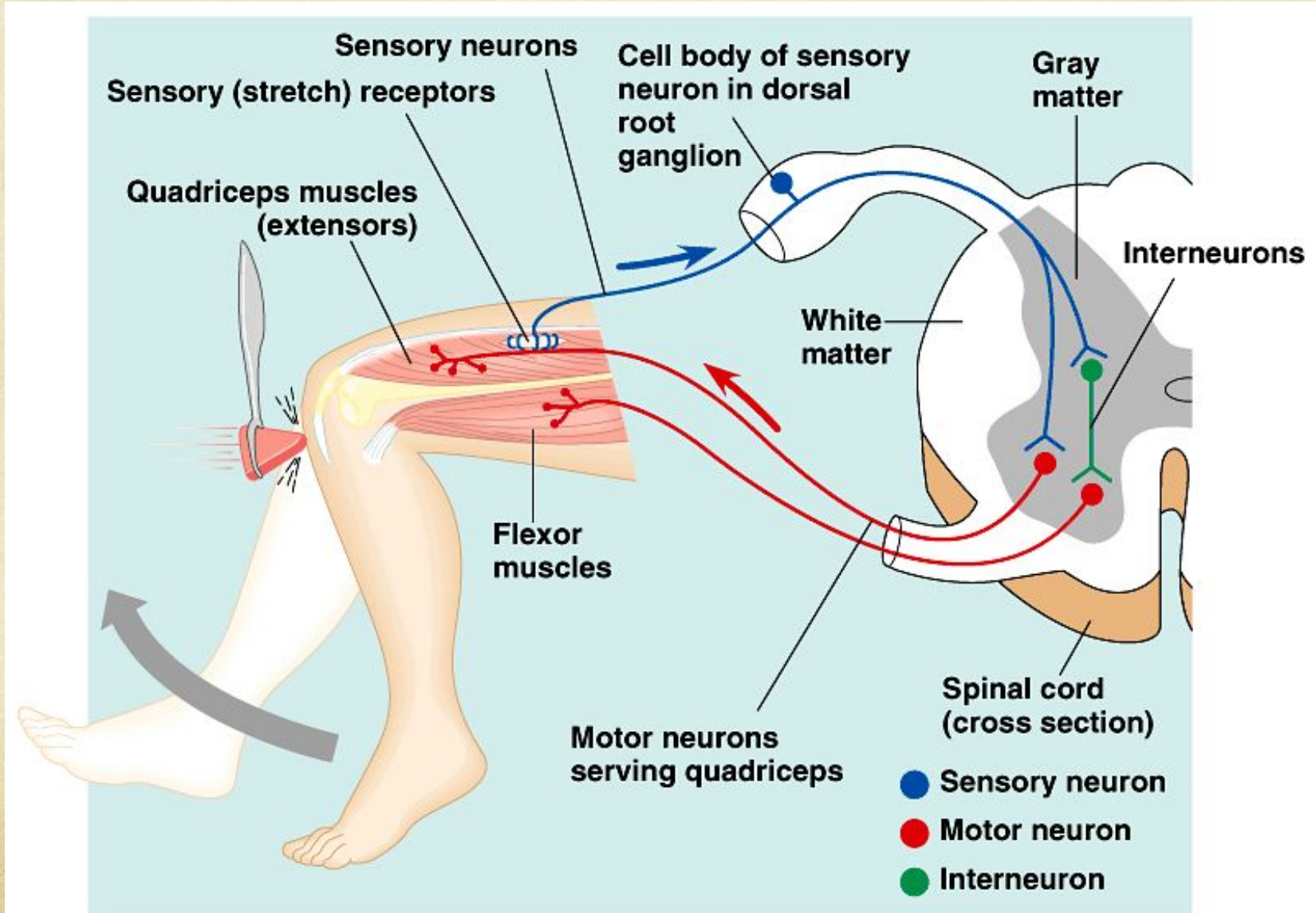
multipolar

most abundant type in CNS

Neuron Interaction & Integration



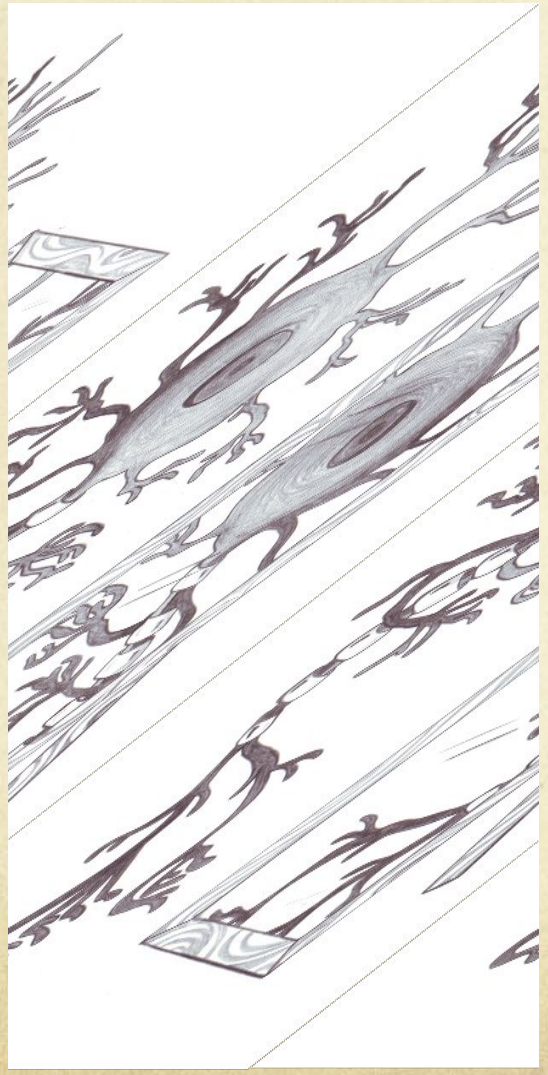
- A Simple Nerve Circuit – the Reflex Arc.
  - A **reflex** is an autonomic response.



Afferent and efferent are terms used to describe the direction of neural impulses in the peripheral nervous system (PNS)

Afferent neurons carry information from sensory receptors throughout the body to the CNS, which includes the brain and spinal cord. The CNS then processes the information- ie. Sensory Neurons - Afferent fibres/ nerves

Efferent neurons carry motor information from the CNS to the body's muscles and glands to initiate an action. For example, efferent impulses can cause muscles to move. ie. Motor Neurons - Efferent fibres/ nerves



Mirror Neurons

Giocomo Rizzolati identified these in late 1990s

Published paper 2002

Inferior Frontal Lobe and Parts of Parietal –Occipital cortex

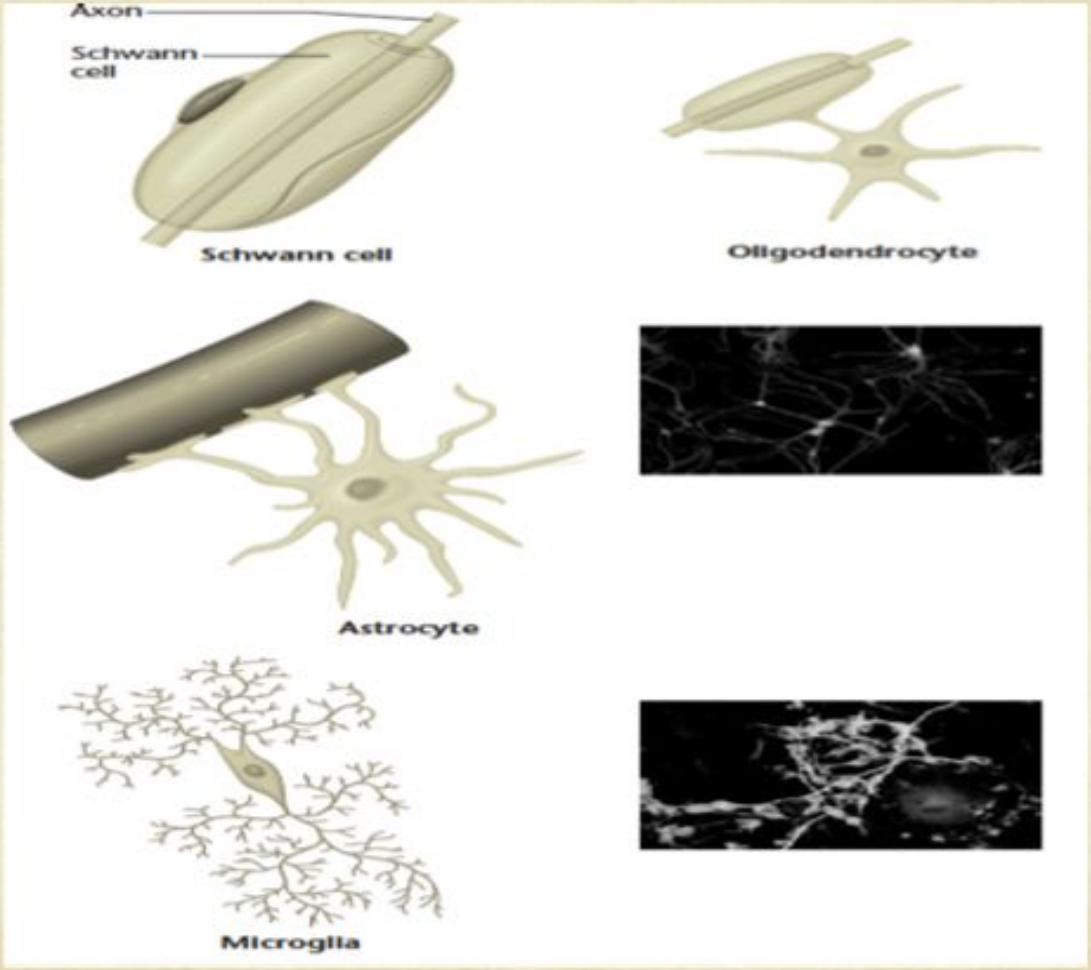
Broken Mirror Hypothesis – Autism

Very Controversial Topic

Glial Cells

- Myelin Sheath is made up of Oligodentrocytes in CNS
- And Schwann Cells in the PNS
- Much Smaller than neurons
- 10 times more Glial cells or Neuroglia than neurons
- Parents, Servants – Housekeepers
- Provide nutrients – As Neurons cannot store their own
- Remove dead neurons –hence, housekeepers

- CNS has 3 glial cells –Oligodentrocytes , Astrocytes, Microglia
- Microglia Deal with dead neurons
- Astrocytes- form blood brain barrier and provide nutrients
- Oligodentrocytes/ Schwann Cells – help in increasing speed of electrical impulse


Axon
Schwann cell
Schwann cell
Oligodendrocyte
Astrocyte
Microglia

Dendrites are specialized to receive signals from neighboring neurons and carry them back to the cell body

Thin, bushy-like structures that receive information from outside the neuron

Relays the information into the *cell body*

Axon: A thin, long structure that transmits signals from the cell body to the *axon terminal*.

Axon Terminal is the last step for the relay of information inside the neuron.

The cell body is covered with Axon Terminals

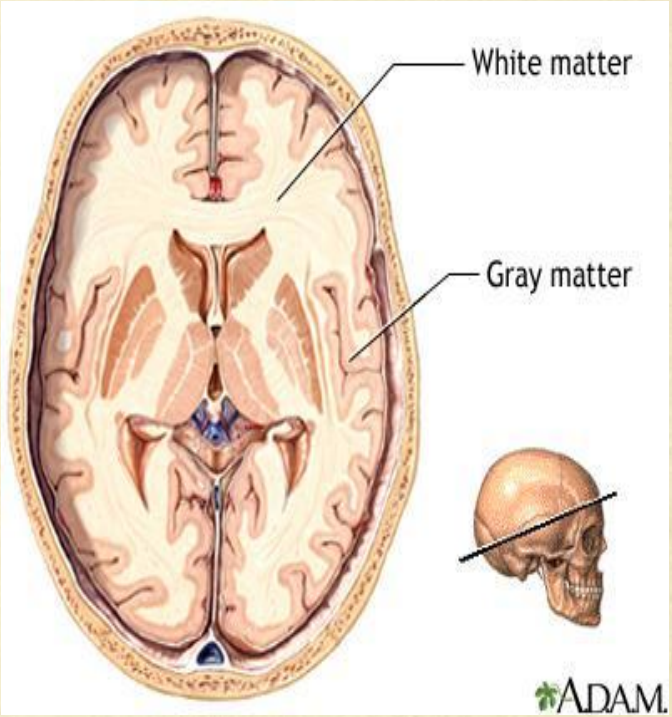
Once the information hits the terminal, it is transmitted outside the cell by *neurotransmitters*, which reside in the axon terminal.

Grey Matter vs. White Matter

The central nervous system - CNS - has two kinds of tissue:

- Grey matter: has a pinkish-grey color in the living brain and is a major component of the central nervous system,

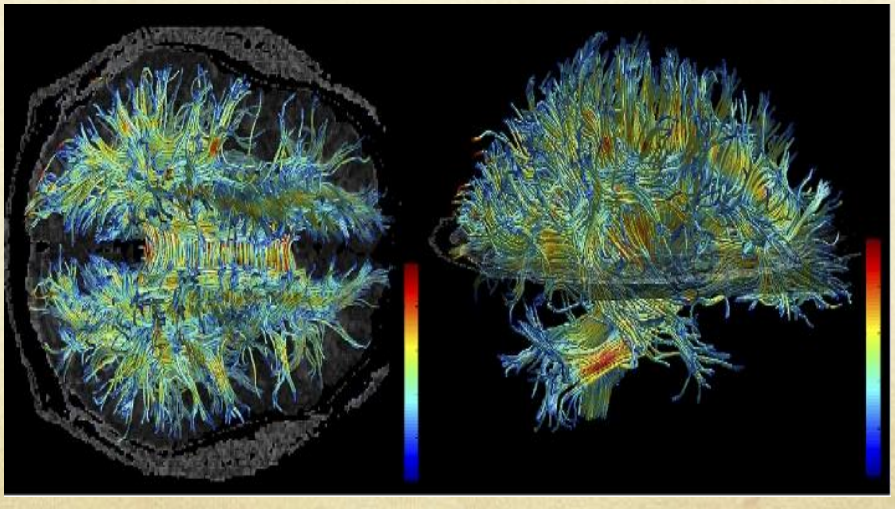
- White matter: is made of axons connecting different parts of grey matter to each other.



Gray and White Matter Functions

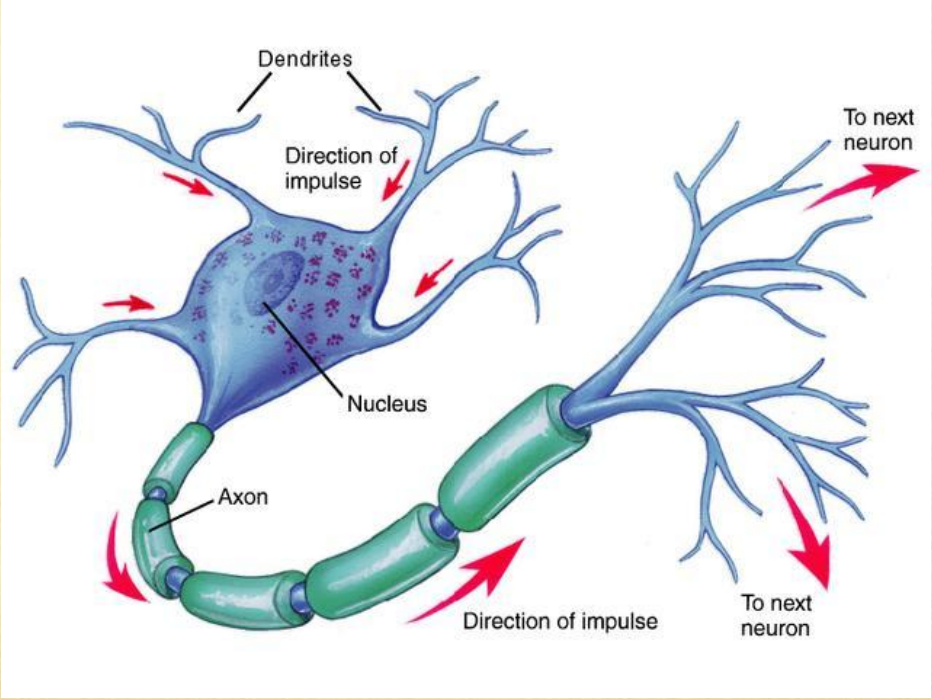
- The grey matter includes regions of the brain involved in muscle control, and sensory perception such as seeing and hearing, memory, emotions, speech, decision making, and self-control. Grey matter makes up 40% of brain matter. white matter comprises the other 60%.

- White matter is composed of bundles of myelinated nerve cell projections (or axons), which connect various grey matter areas (the locations of nerve cell bodies) of the brain to each other, and carry nerve impulses between neurons.



How do Neurons Communicate?

- Electrical Communication
- Chemical Communication



The Electrical Part

- **Action potential** is an electrical current sent down the axon.

- The activity **within** the neurons is electrical. This current causes the neuron to "fire"

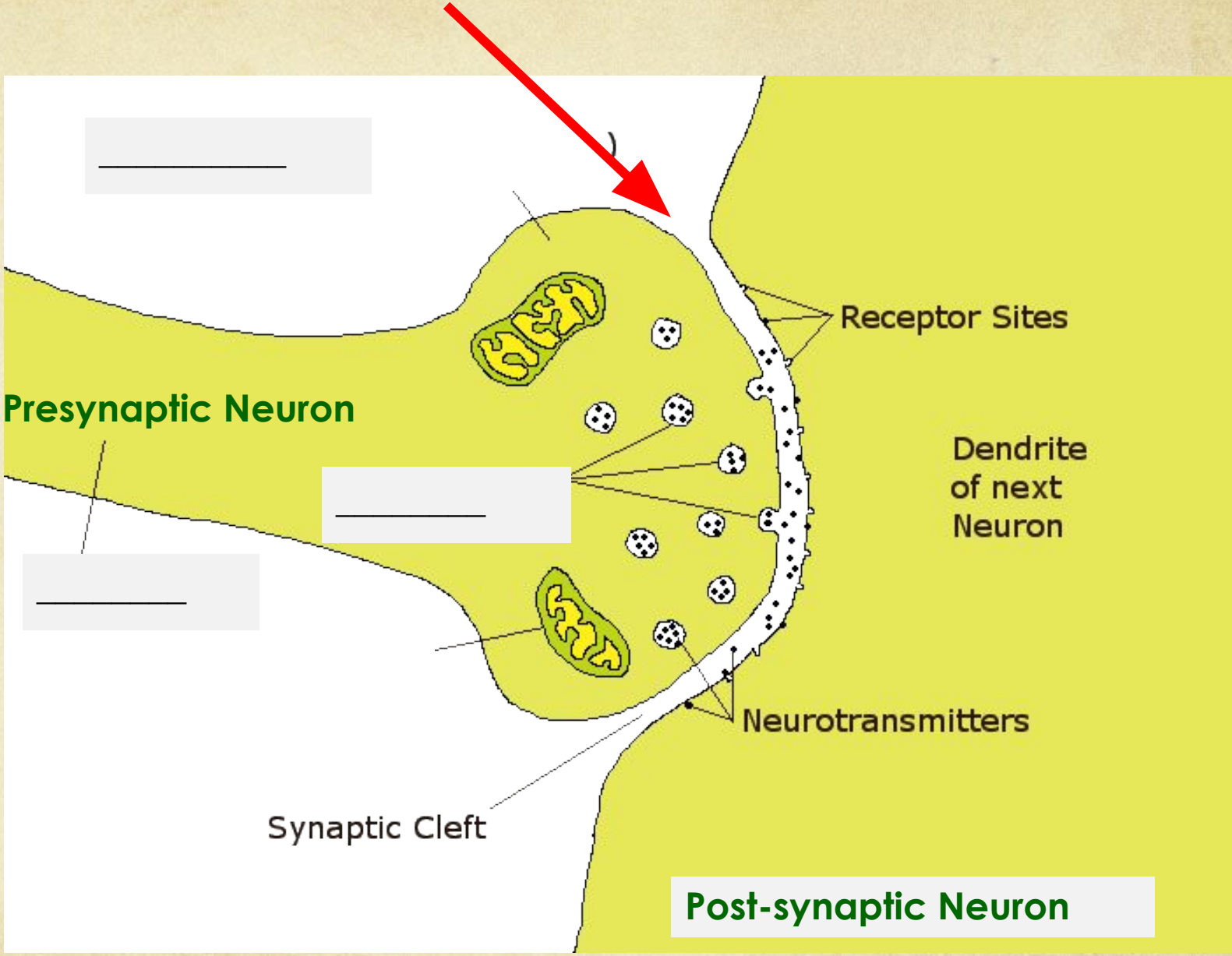
  - This is an "all-or-none" process

Action potentials travel down the axon like a wave of energy

The *Synapse* is the space between neurons
The synaptic gap or cleft

•Information must be transmitted across the synapse to other neurons via the *neurotransmitters*.

•This is an *electrochemical process*


Receptor Sites
Presynaptic Neuron
Dendrite
of next
Neuron
Neurotransmitters
Synaptic Cleft
Post-synaptic Neuron

Chemical Communication

- The communication between neurons is **chemical**

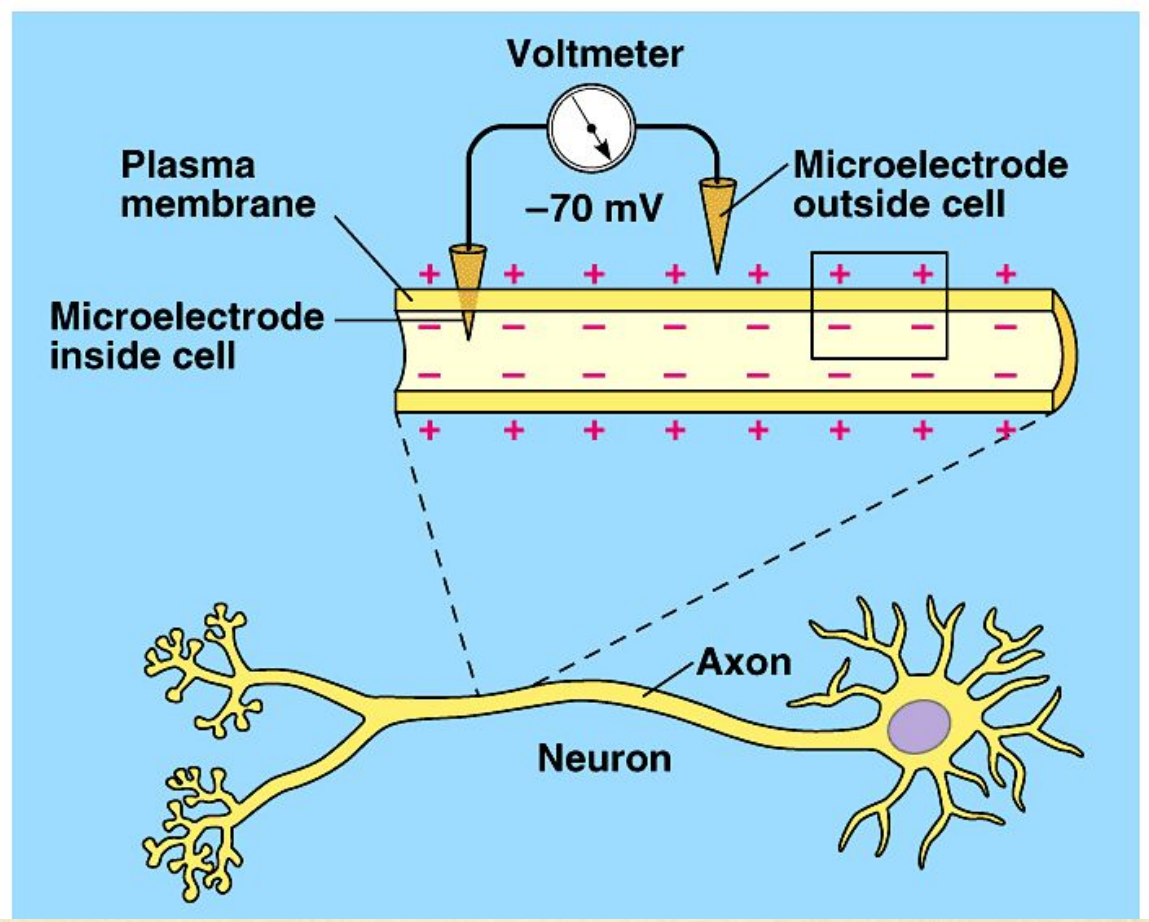
Selective permeability

- Neurotransmitter are either neutralized by an enzyme or taken back up by the neuron that released it in **reuptake.**

    - At least 50 different types of neurotransmitters have been identified

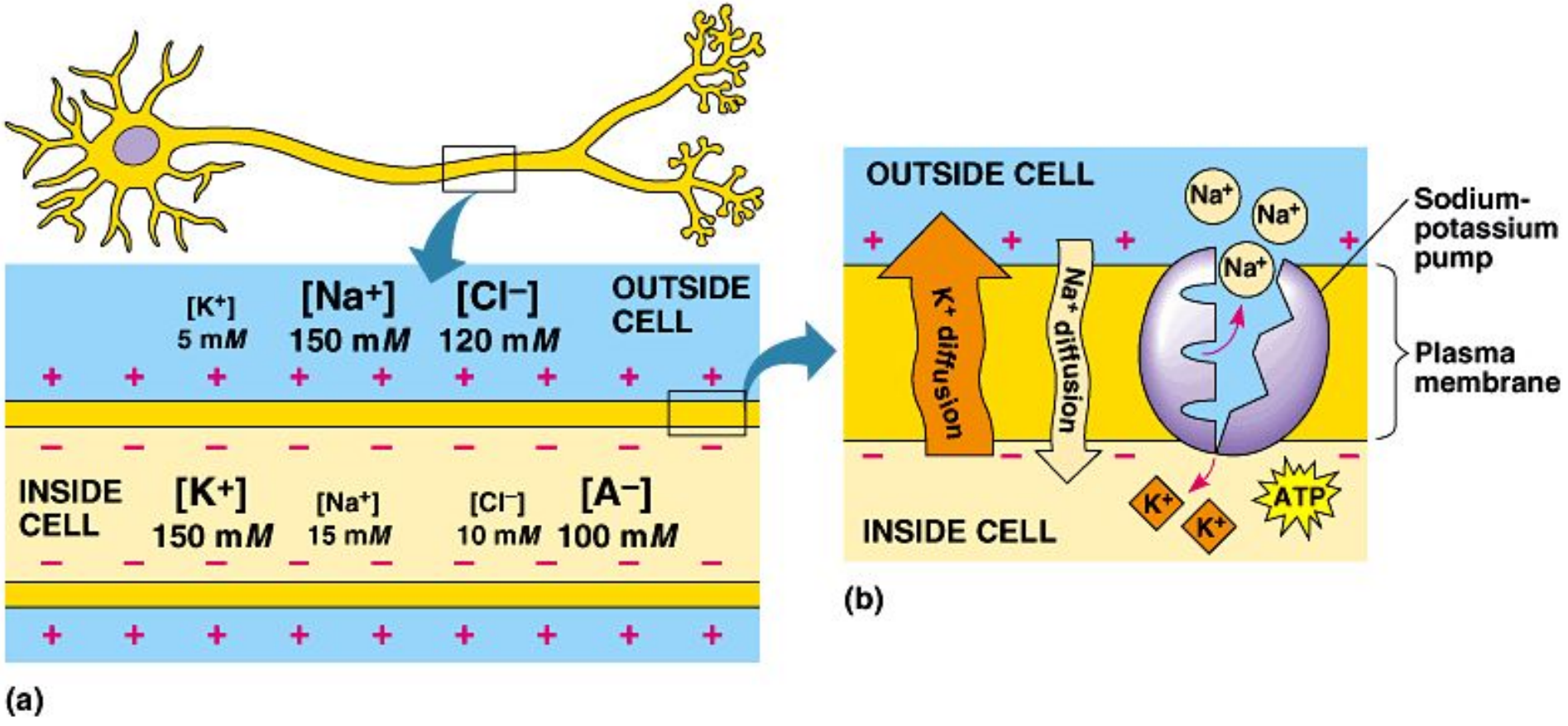
- The neurotransmitters are released from the vesicles and then attach to receptors located on the postsynaptic neuron.
- These neurotransmitters are in contact with the dendrite of the postsynaptic neuron only briefly.
- The chemical is almost immediately destroyed or reabsorbed

- Measuring Membrane Potentials.



  - An unstimulated cell usually have a **resting potential** of -70mV.

- **Ungated ion channels** allow ions to diffuse across the plasma membrane.
  - These channels are always open.



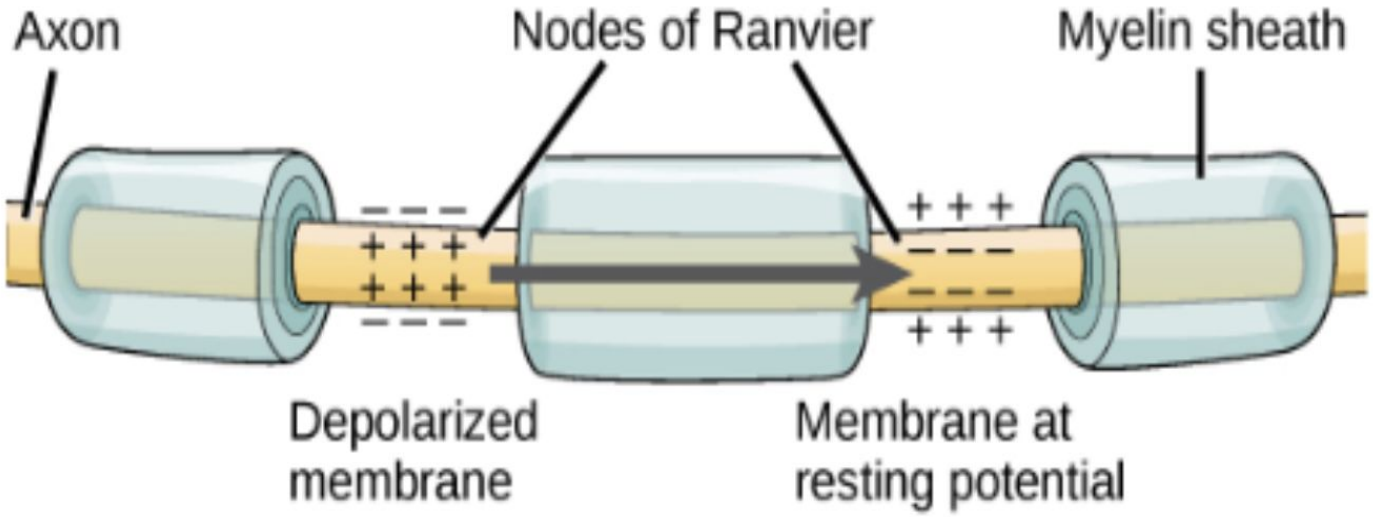


Figure 5. The Nodes of Ranvier are gaps in the myelin sheath along the length of the axon. Nodes of Ranvier contain voltage-gated sodium and potassium channels. Action potentials travel down the axon by jumping from one node to the next.

Saltatory Conduction- **action potential is propagated along a myelinated axon.. electrical activity jumping from node to node**

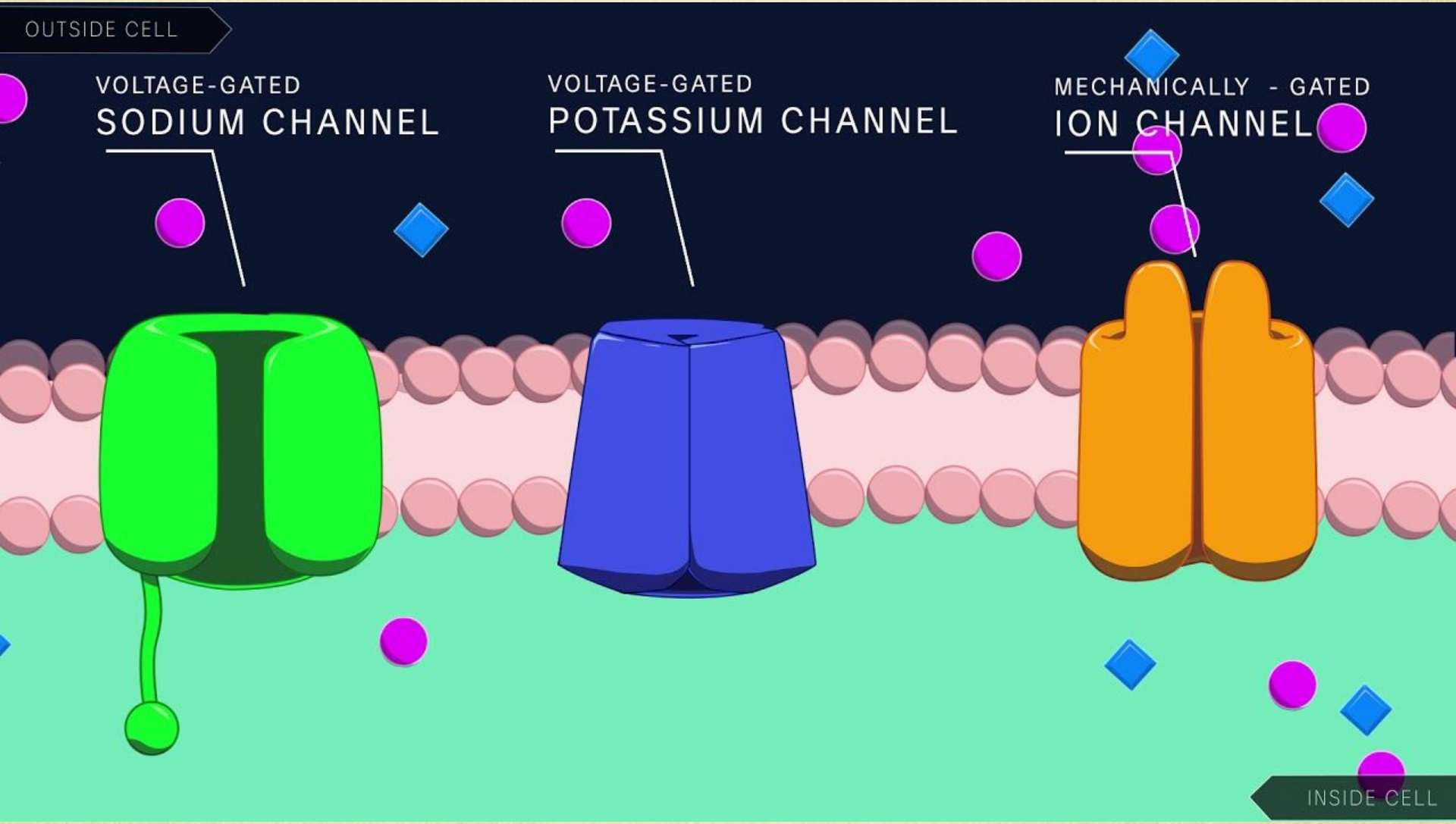
The chemical activity is primarily due to Sodium ion flow- Hodgkin-Huxley sodium channels

Alan **Hodgkin** and Andrew **Huxley** - Nobel Prize In Biophysics for mathematical model of Action Potential in 1963- Hodgkin-Huxley Model

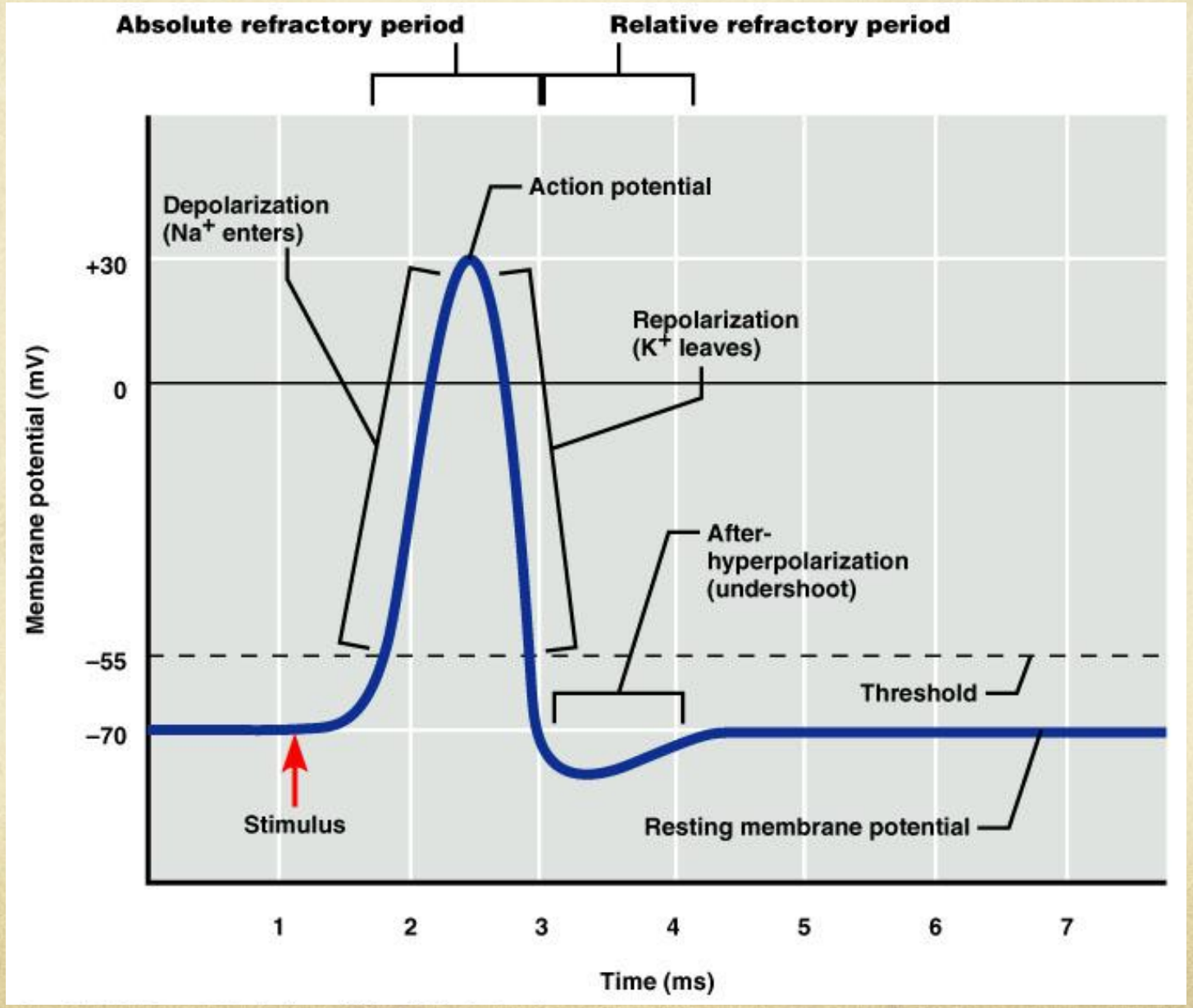
Adenosine triphosphate (ATP)

A large membrane-associated *enzyme* uses ATP to transport sodium and potassium ions across the cell membrane. This process is critical for neurons to fire action potentials, which are the basis of electrical signaling in neurons.

Adenosine triphosphate (**ATP**) is a nucleotide(made up of nitrogen , sugar and phosphate) that provides energy to drive and support many processes in living cells, such as muscle contraction, nerve impulse propagation, and chemical synthesis. Found in all known forms of life, it is often referred to as the "molecular unit of currency" for intracellular energy transfer.


OUTSIDE CELL
VOLTAGE-GATED
SODIUM CHANNEL
VOLTAGE-GATED
POTASSIUM CHANNEL
MECHANICALLY - GATED
ION CHANNEL
INSIDE CELL

Refractory Period



- NT binds to receptor

  NT = key

  Receptor = lock

determines if EPSP(excitatory) or IPSP(inhibitory)

Excitatory postsynaptic potential vs Inhibitory postsynaptic potential

Dopamine	Developmental Problems Schizophrenia Psychosis Possible increased testosterone production	Lack of Motivation Focus Memory Addictions and Cravings Low Libido/ decreased testosterone Poor motor control/ Tremors
Noradrenaline	Stress and Anxiety Hyperactivity Increased Blood Pressure Pain	Lack of Focus/Energy/Motivation Depression with Apathy
Adrenaline	Insomnia Anxiety Stress Blood Sugar Imbalance Insulin Resistance Allergic reactions	Poor Methylation Lack of Focus Lack of Energy Poor Blood Sugar Control
Glutamate	Neurotoxicity Anxiety Stress Decreased Mood Sleep disturbances	Fatigue Low Brain Function Poor Memory
Serotonin	Headache, mental confusion Sweating, shivering Hypertension, tachycardia	Depression/Low Mood Hot Flashes Sleep Difficulties/Anxiety

Areas of Interest !

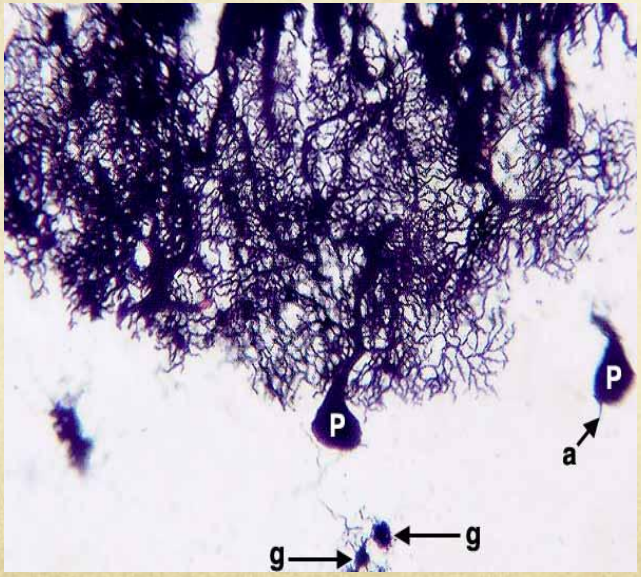
Peri aquaductal Gray
Interneurons
Role of Glial Cells- Angels and Assasins
Glial Cells , Gut Health and Immune
Vagus Nerve- intestinal system ,hear , lungs- Polyvagal theory
neuroscience and emotion- mindfulness and trauma , attention in face of trauma

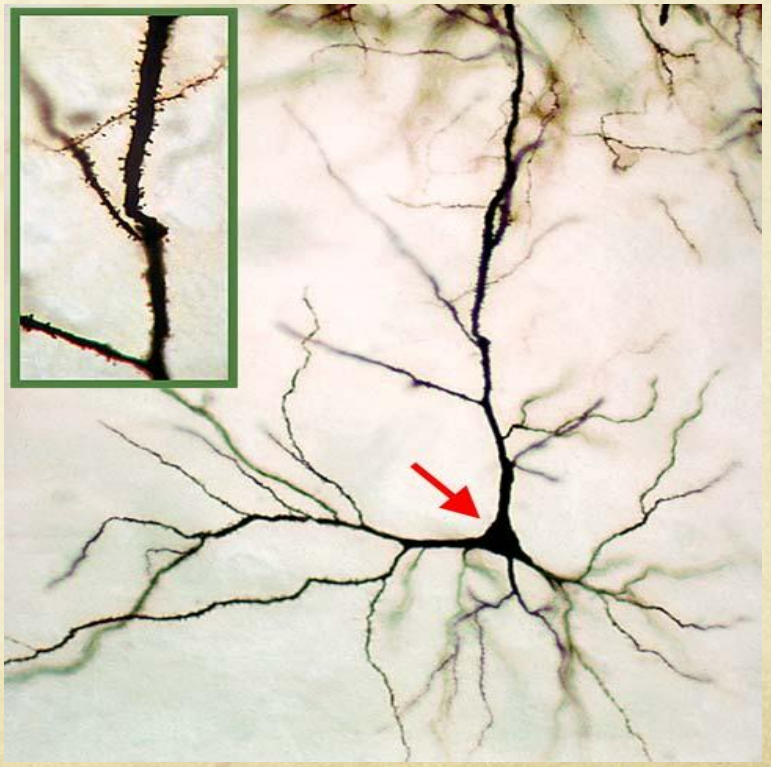
Integration of brain- Left right - 3 levels- hindbrain-midbrain- forebrain

Methods of Investigating the Brain

Neuro-Histology(Staining Techniques)

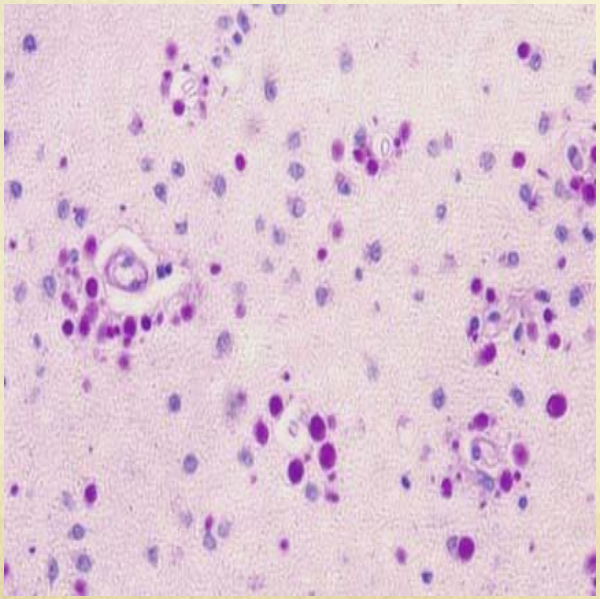
- Golgi Staining
  - Select Neurons
  - Golgi Type I Neurons
  - Golgi Type II Neurons

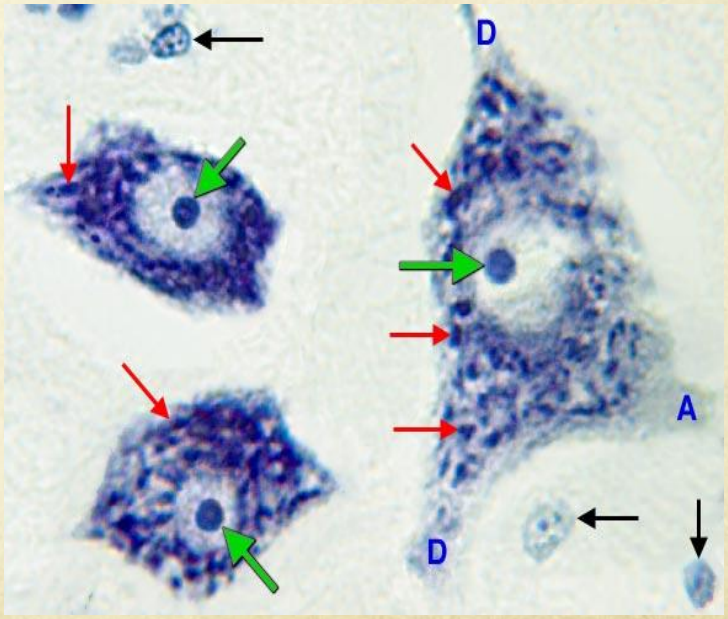




Neuro-Histology

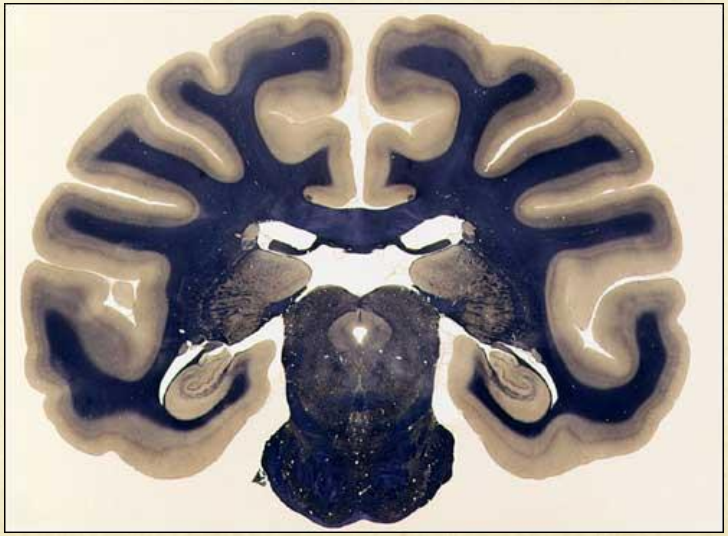
- Nissl Stain
  - Select for Cell Body and organelles





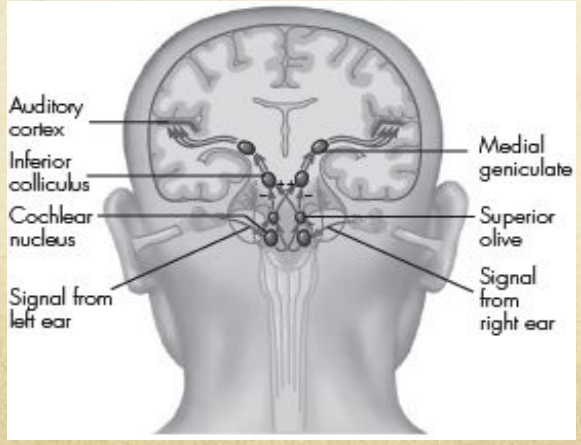
Neuro-Histology

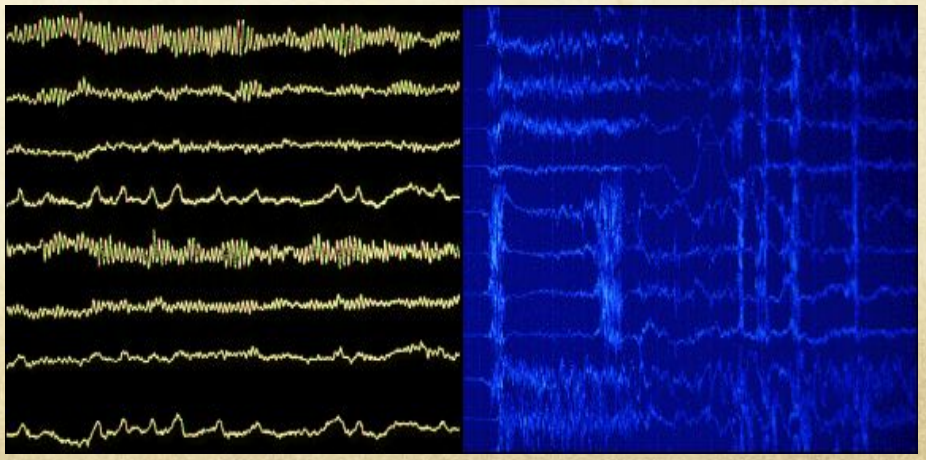
- Myelin Staining
  - White Matter –Axons
  - Gray Matter- Cell Bodies



Electrical Scanning

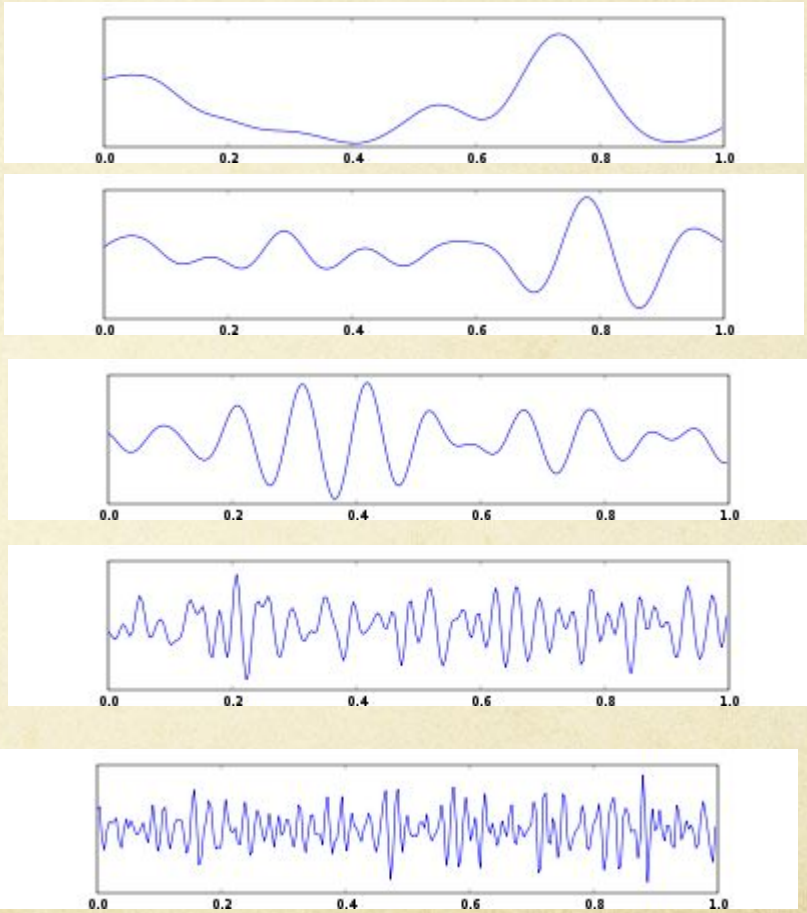
- Electroencephalogram (EEG)
  - Evoked Potentials
    - Brainstem Auditory Evoked Response (BAER)
    - Visual Evoked Potential
    - Somatosensory Conduction





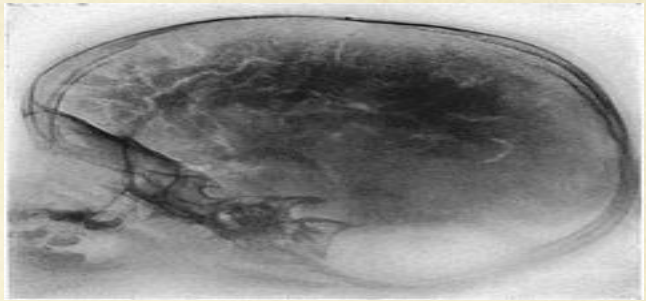
EEG Patterns

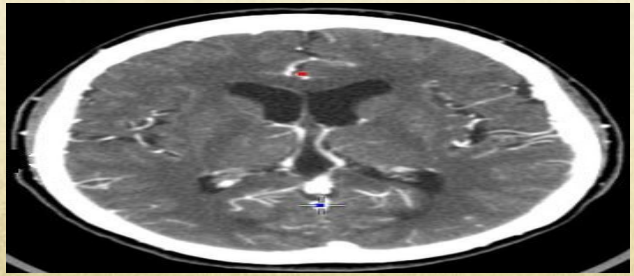
- Delta Wave
  - <0.5-4 Hz Deep Sleep
- Theta Wave
  - 4-7 Hz Drowsy and Sleep
- Alpha Wave
  - 8-12 Hz Awake and restful
- Beta Wave
  - 12-35 Hz Focused and Active
    - High, Mid, Low
- Gamma Wave
  - 35+ Hz Peak Hyperarousal

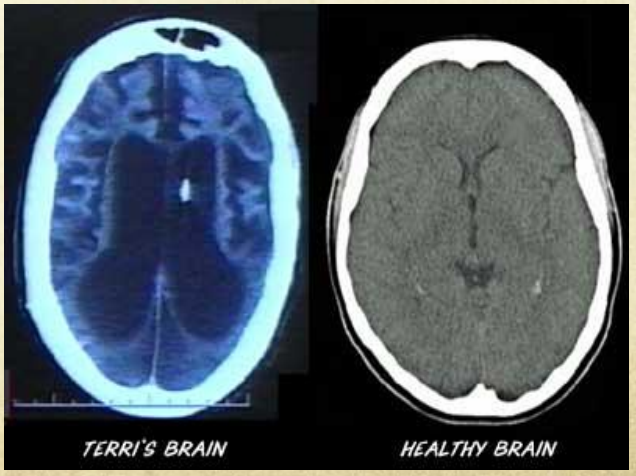


Radiological Scanning

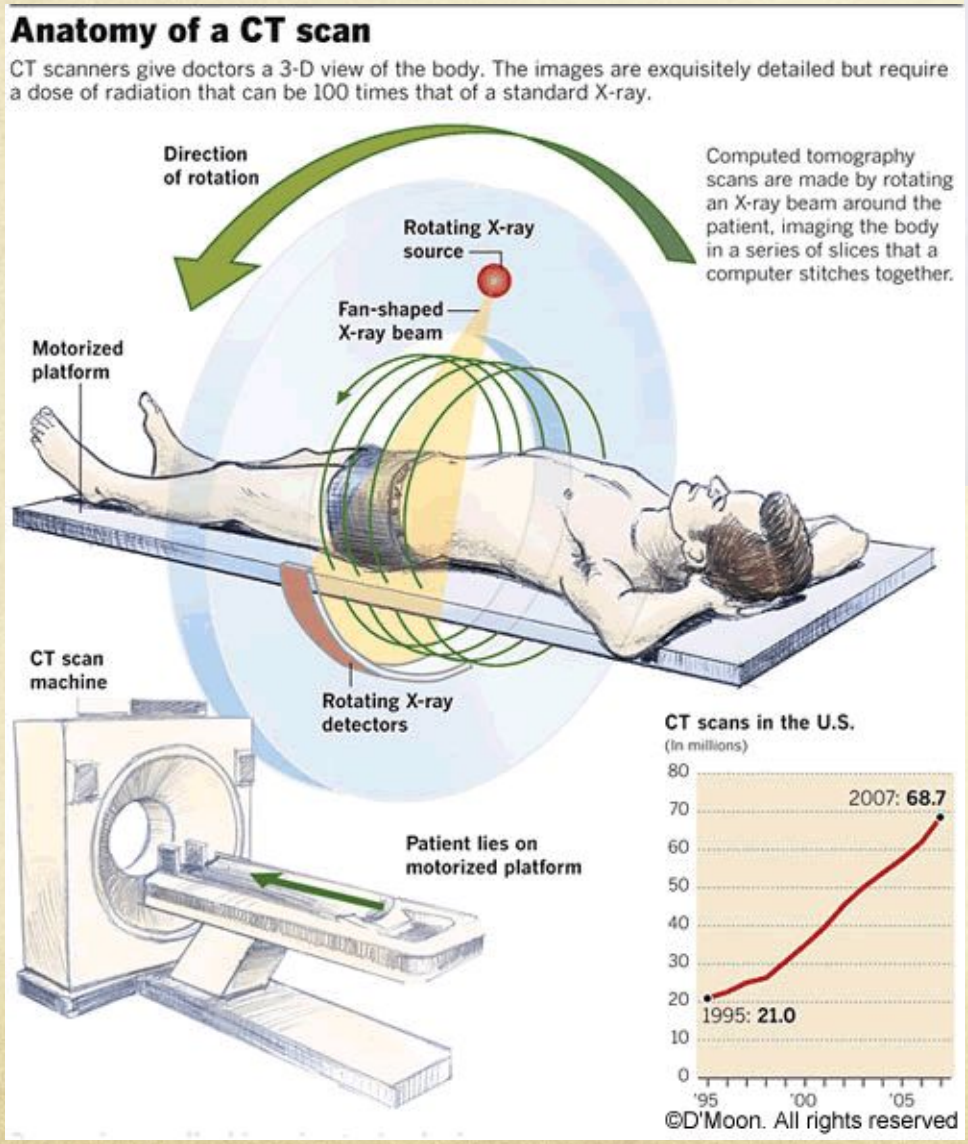
- Pneumoencephalography
  - Drain CSF through Lumbar Puncture
  - Inject sterile air/gas into space
  - Take x-ray
- CT Scan
  - Take multiple x-ray slices
  - Reconstruct slices into 3-D image





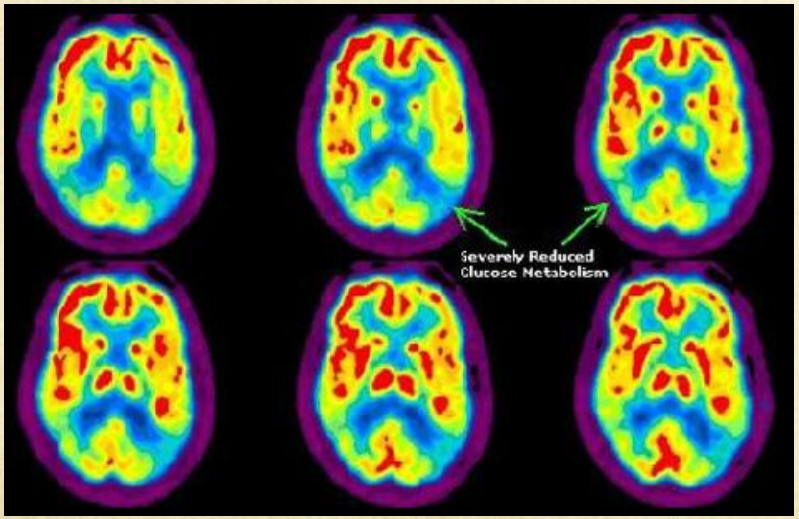


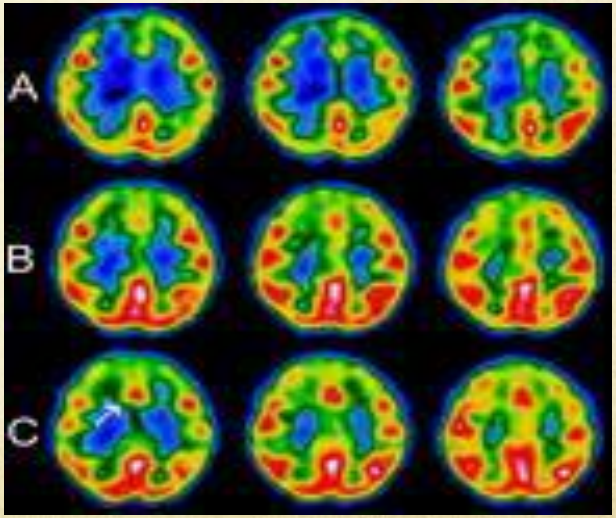
CT Scanner


Anatomy of a CT scan
CT scanners give doctors a 3-D view of the body. The images are exquisitely detailed but require a dose of radiation that can be 100 times that of a standard X-ray.
Direction of rotation
Rotating X-ray source
Fan-shaped X-ray beam
Motorized platform
Computed tomography scans are made by rotating an X-ray beam around the patient, imaging the body in a series of slices that a computer stitches together.
CT scan machine
Rotating X-ray detectors
Patient lies on motorized platform
CT scans in the U.S.
(In millions)
80
70
60
50
40
30
20
10
0
2007: 68.7
1995: 21.0
'95
'00
'05
©D'Moon. All rights reserved

Radiological Scanning

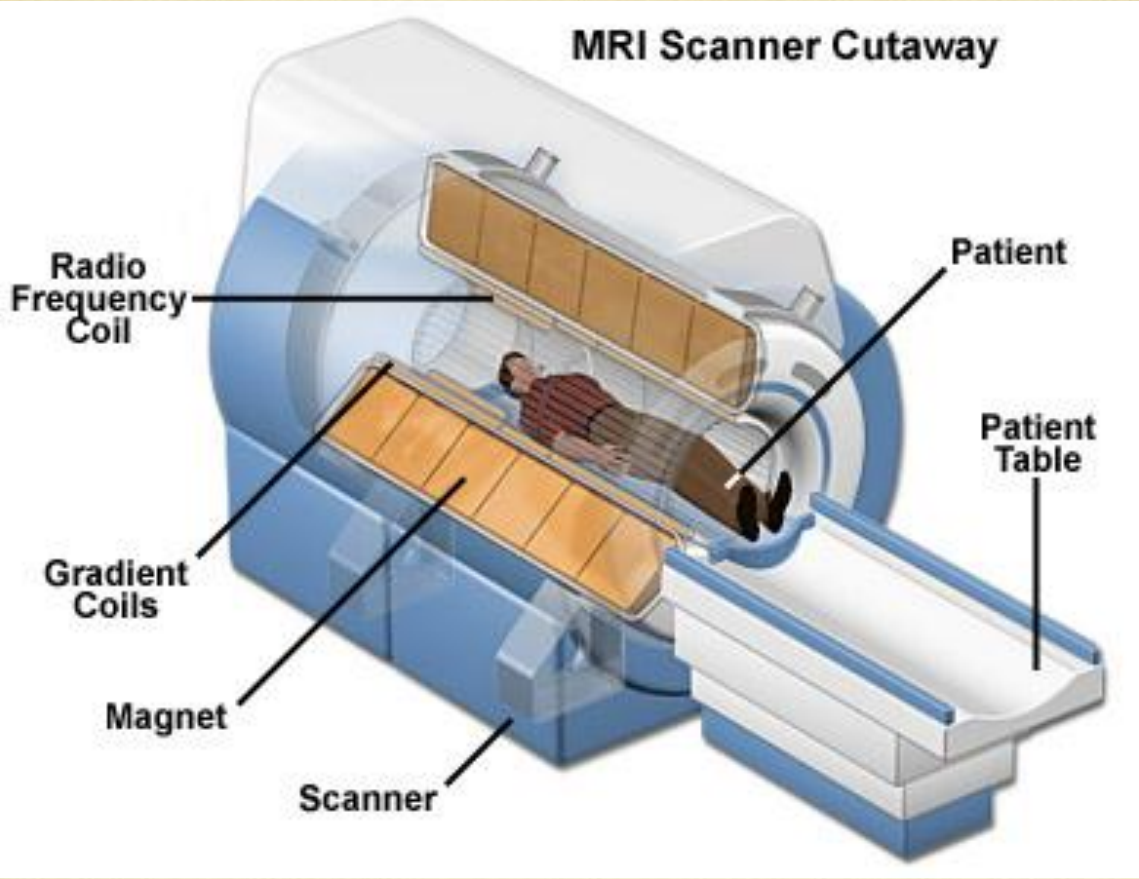
- SPECT Glucose Metabolism
- PET Glucose Metabolism





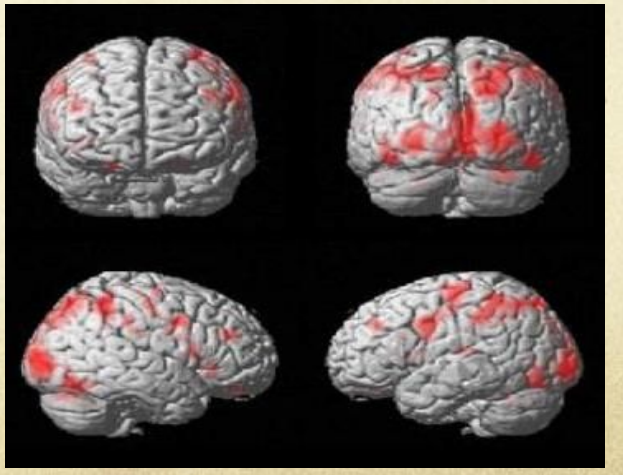
Radiological Scanning

- Magnetic Resonance Imaging
  - July 3, 1977 the first MRI performed on a human
  - Hydrogen nuclei (protons) spinning randomly
  - A strong magnetic field is applied causing the protons to line up
  - A radio pulse applied causing the protons to flip their spin (resonate)
  - When the signal is removed, the protons return to their natural alignment with the magnetic field and release excess stored energy
  - Coils pick up the released energy which is transformed into images.
  - Different types of tissues (normal and abnormal) give off different signals and are easily differentiated


MRI Scanner Cutaway
Radio Frequency Coil
Patient
Patient Table
Gradient Coils
Magnet
Scanner

Radiological Scanning

- Functional MRI (*f*MRI)
  - Hydrogen protons emit a different resonance signal in blood depending on level of oxygenation
  - Difference in signals (Blood Oxygen Level Dependent-BOLD)
  - Superimpose images on a structural MRI during activity



WADA testing

sodium amobarbital (typically 100-500mg) into the internal carotid artery

one side is then made “ numb” - all tests then done with active hemisphere

Neuropsychological Tests

- Stand Alone- specific tests for speech, memory, perception, executive functioning
- Neuropsychological Batteries - Halstead-Reitan, Luria Nebraska , NIMHANS