Nervous system structure and organization

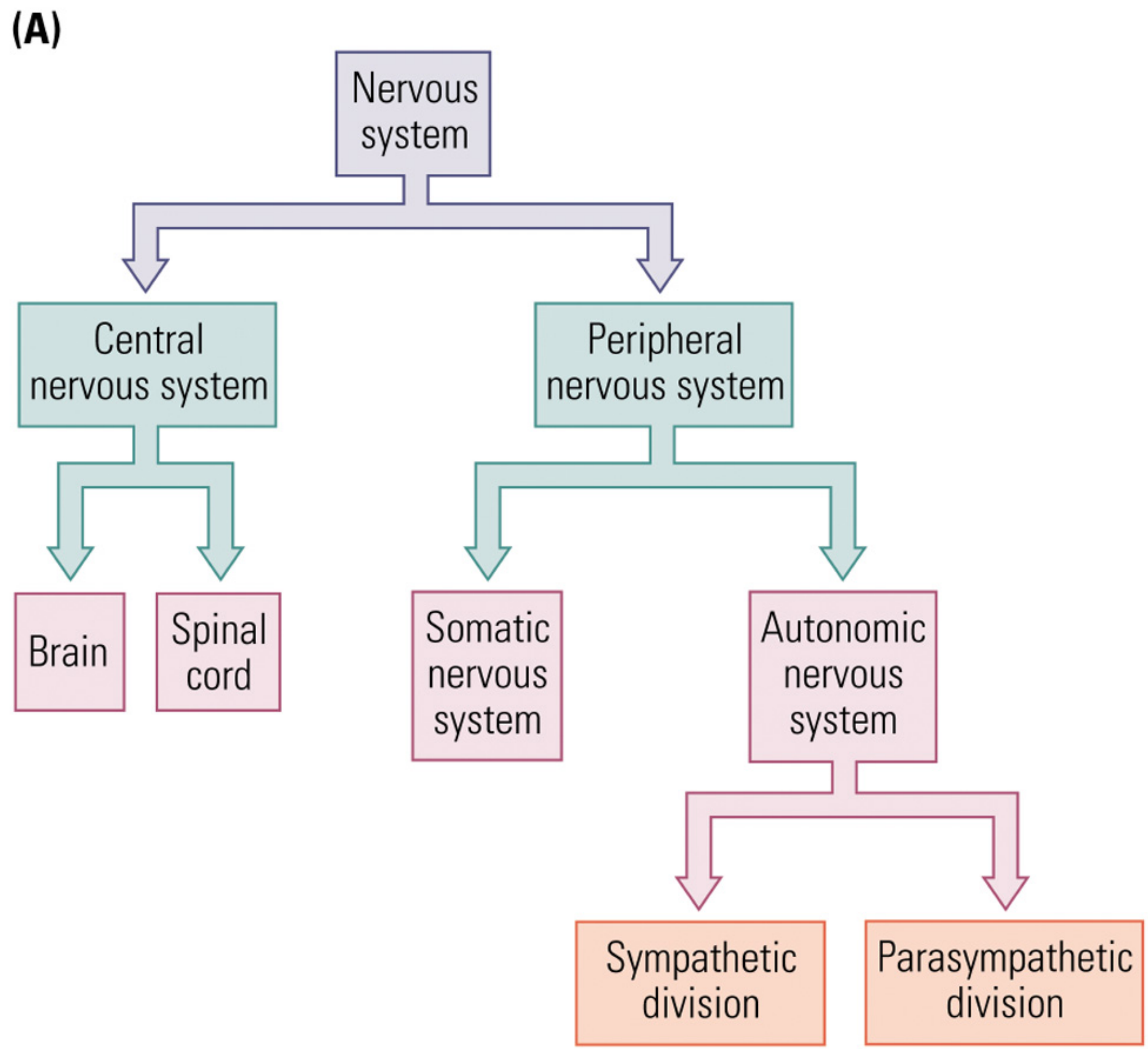
Nervous system arrangement

Central

- brain & spinal cord

Peripheral

- somatic
- autonomic



Kolb and Whishaw, 2005

Organization of the nervous system

CENTRAL NERVOUS SYSTEM

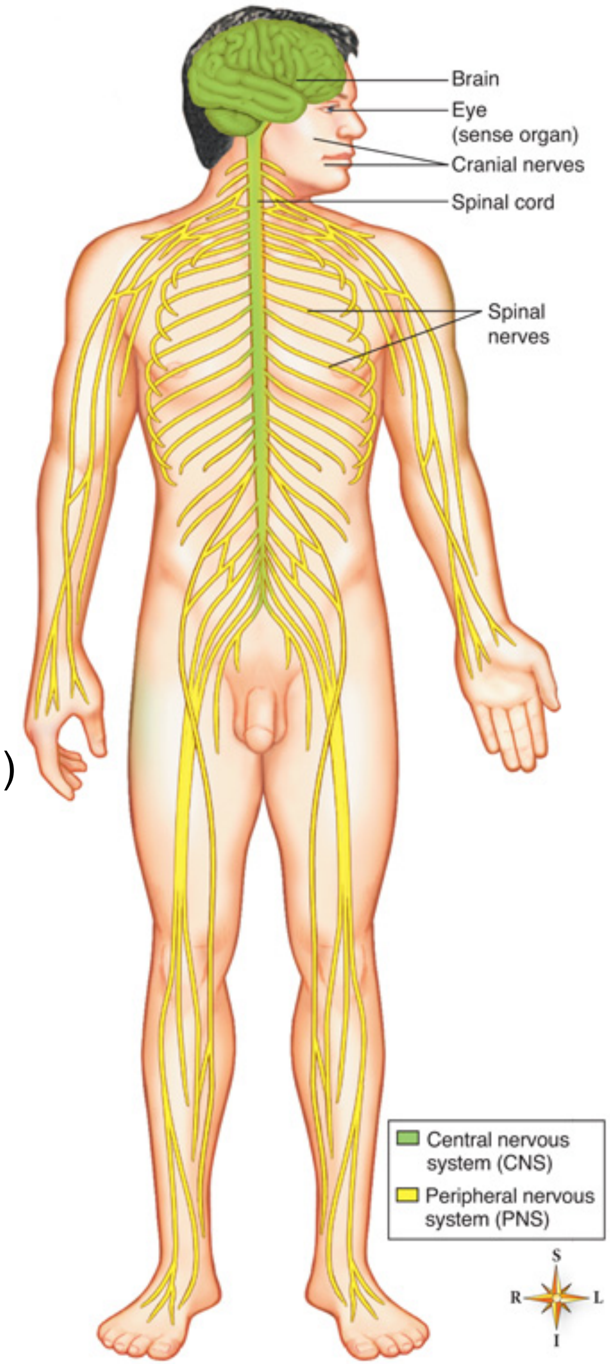
Brain

Spinal cord

PERIPHERAL NERVOUS SYSTEM

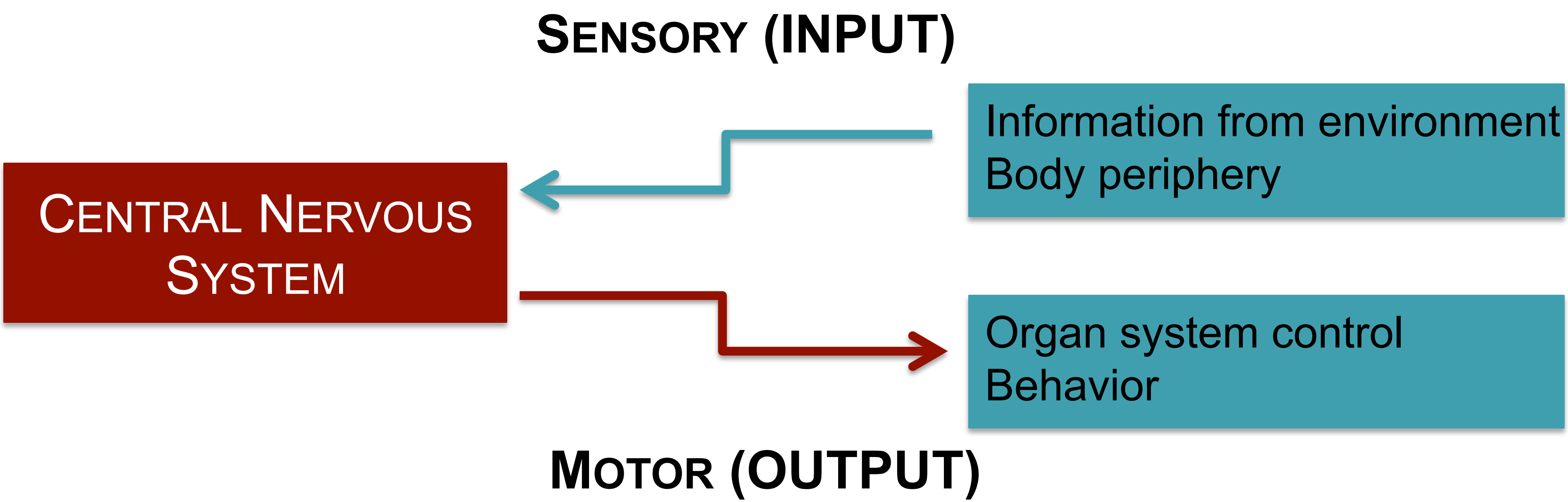
Cranial nerves (except cranial nerve II)

Spinal nerves



Thibodeau and Patton, 2013

Input and output pathways across the nervous system



Defining directions

Anterior (Rostral)-
Posterior (Caudal)

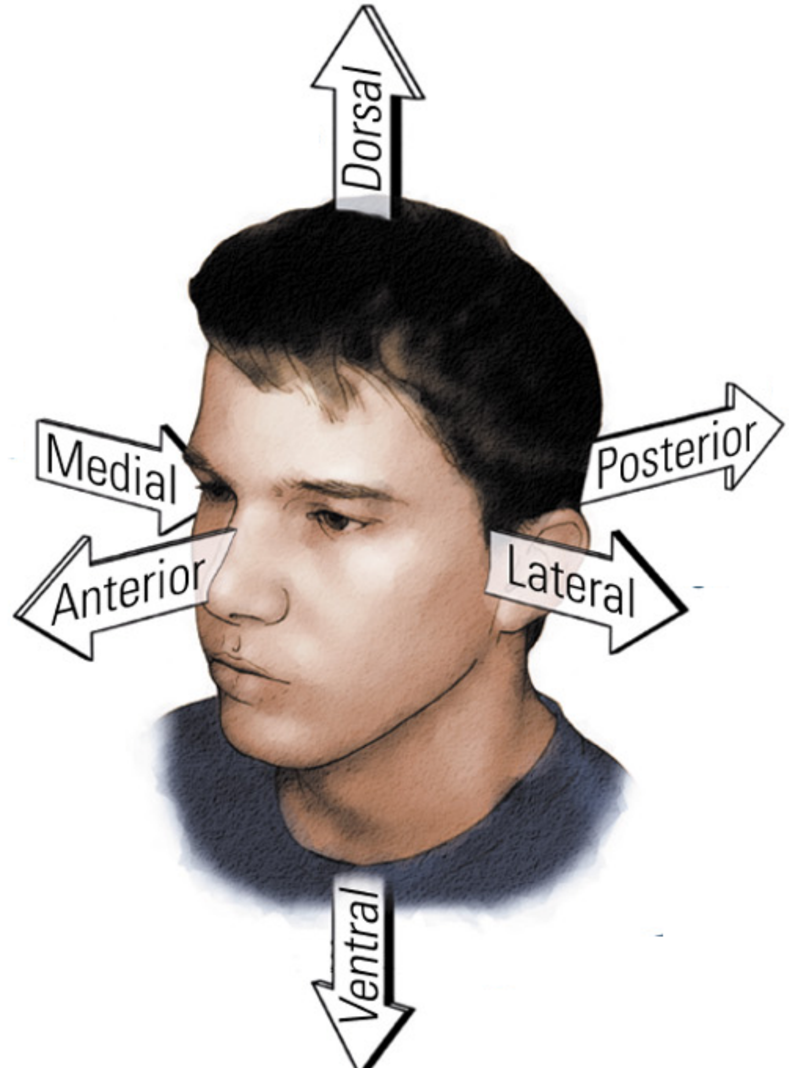
- front vs. back

Ventral-Dorsal

- bottom vs. top

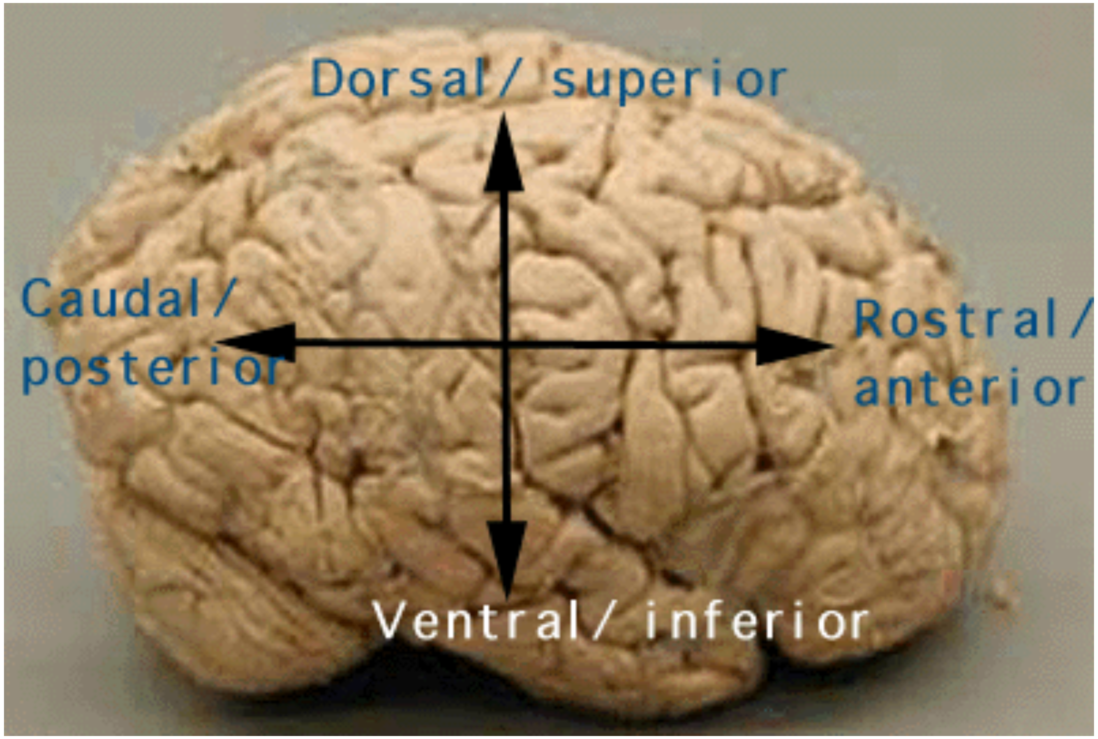
Medial-Lateral

- middle vs. side



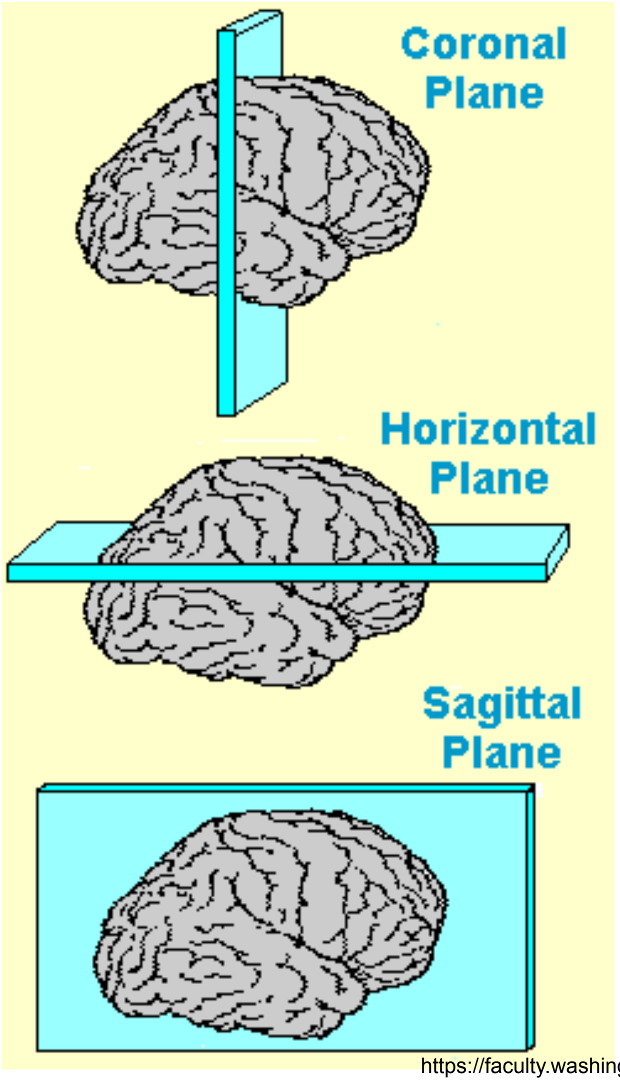
Kolb and Whishaw, 2005

Directions



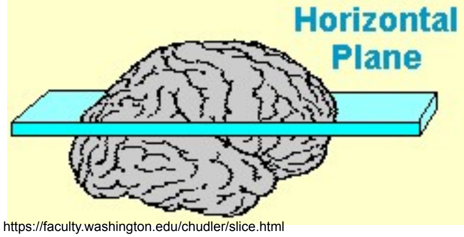
http://serendip.brynmawr.edu/bb/kinser/BrainInfo.html

Brain sections



https://faculty.washington.edu/chudler/slice.html

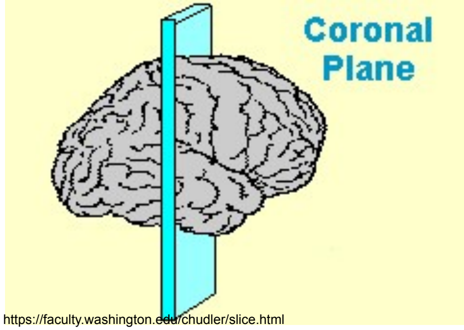
Horizontal section



https://faculty.washington.edu/chudler/slice.html

Parallel to the ground

Coronal section



https://faculty.washington.edu/chudler/slice.html

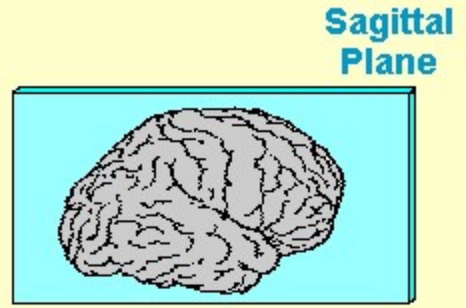
Perpendicular to the ground, front-to-back

Also known as:

– transverse
– cross-sections


http://accweb.itr.maryville.edu/myu/Bio321/321lab1.html

Sagittal section



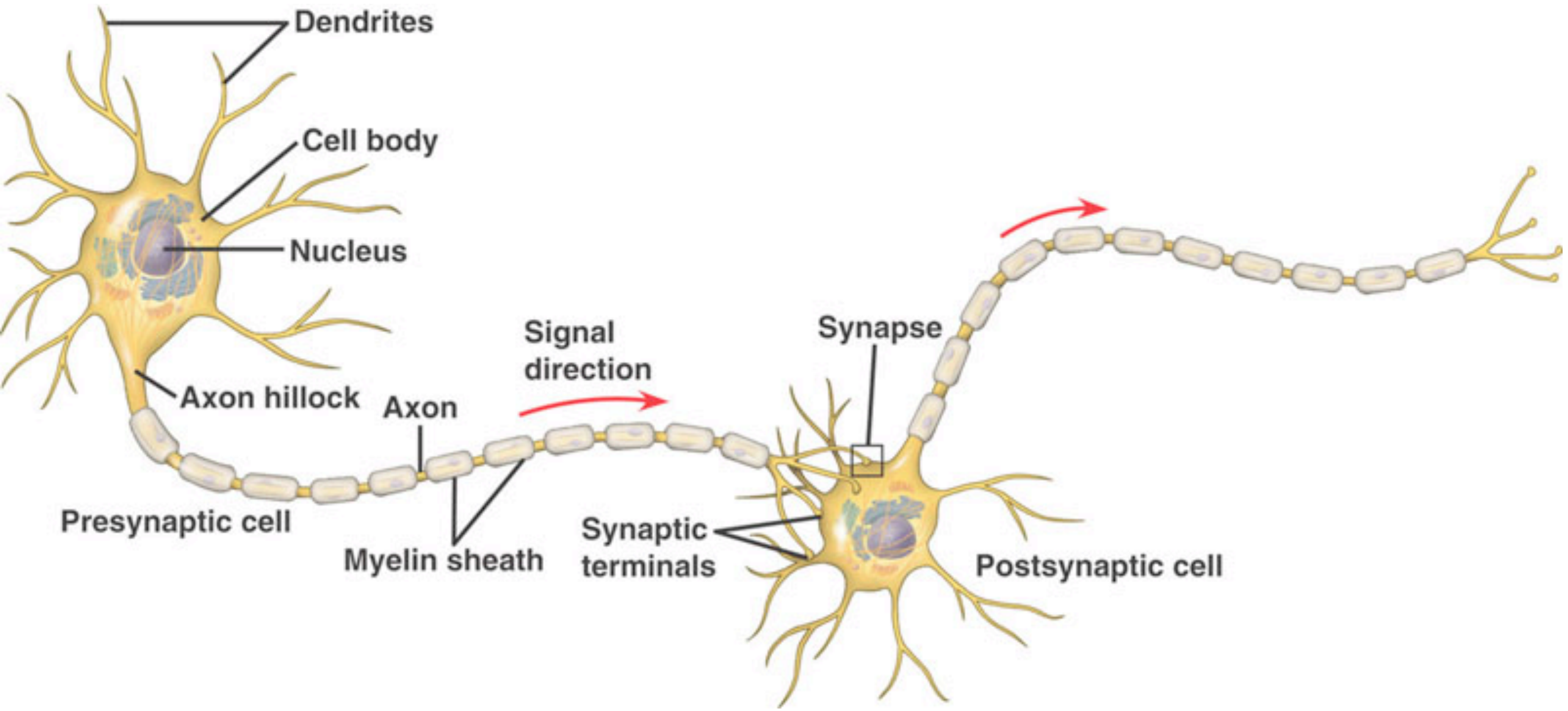
https://faculty.washington.edu/chudler/slice.html

Perpendicular to the ground, side-to-side

Special section: midsagittal (right on the mid-line)

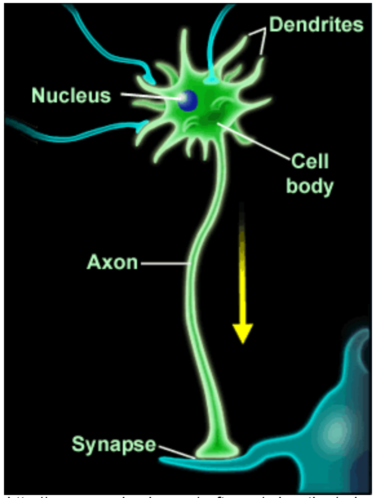
http://anatomy-diagram.net/wp-content/uploads/2015/11/sagittal-section-brain-sagittal-section-anatomy.jpg

The structure of the neuron

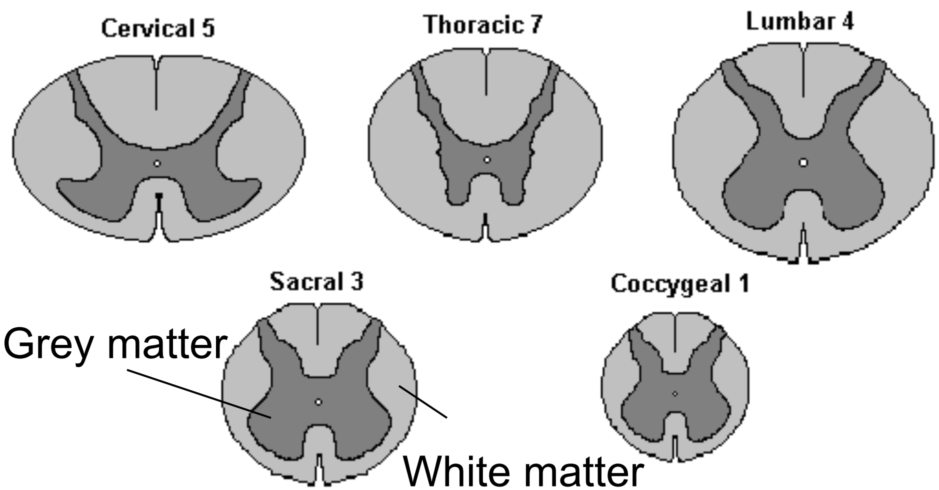


http://kvhs.nbed.nb.ca/gallant/biology/neuron_structure.html

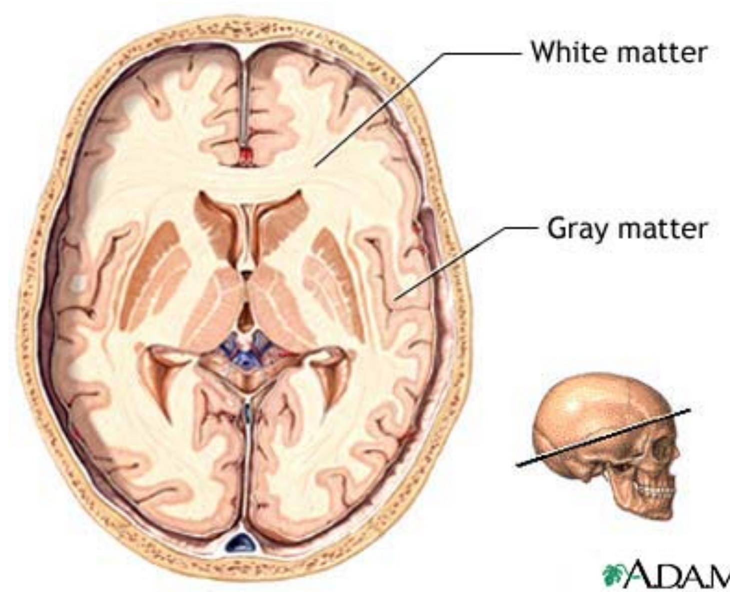
Gray vs white matter



http://www.morphonix.com/software/education/science/brain/game/specimens/images/neuron_parts.gif



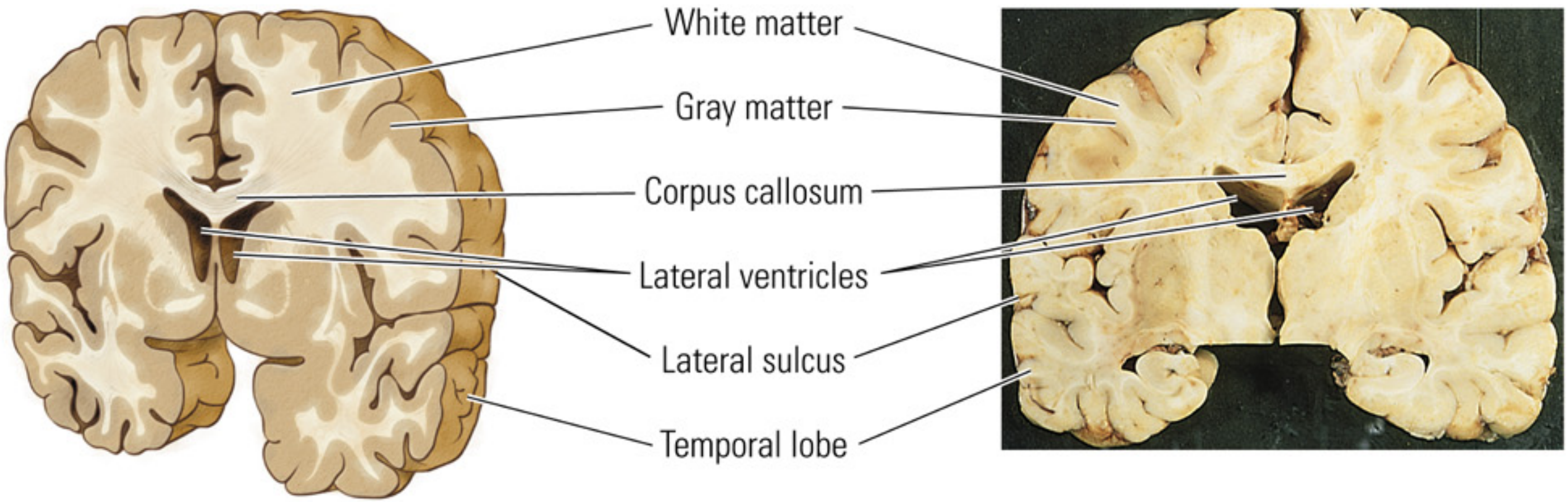
https://faculty.washington.edu/chudler/spinal.html



Spinal cord

Brain

Cell bodies vs processes

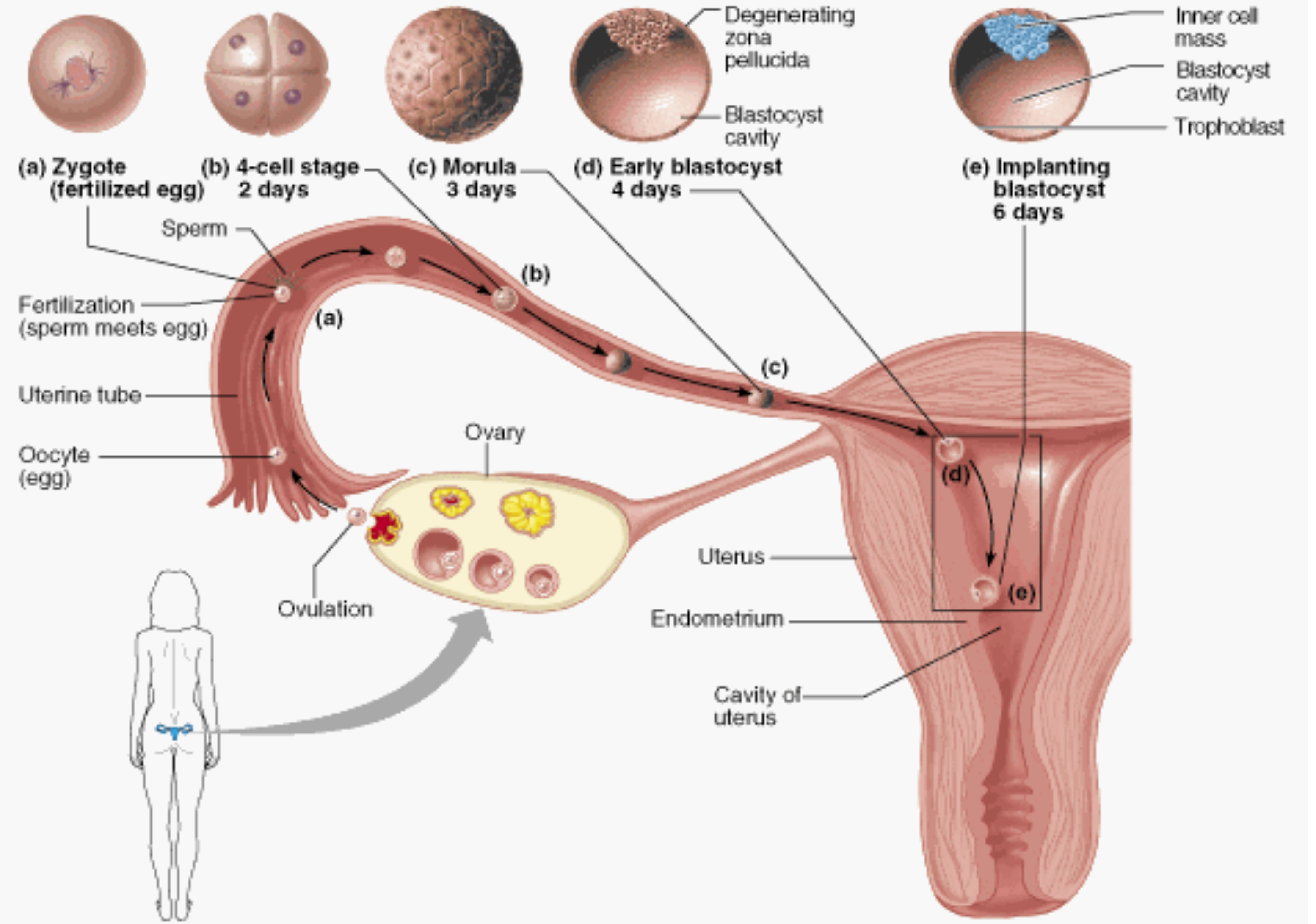


Gray matter refers to cell bodies

White matter refers to axons of passage

Kolb and Whishaw, 2005

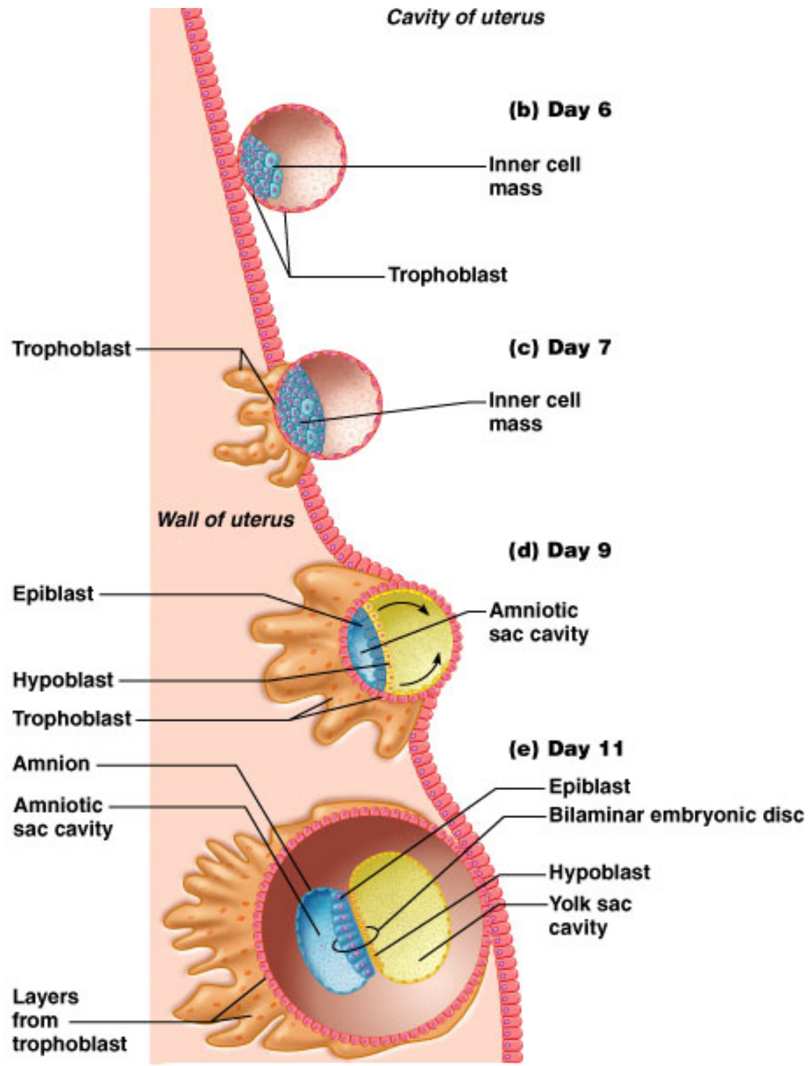
Organization of the nervous system:
Learning about anatomy through development



Degenerating zona pellucida
Blastocyst cavity
Inner cell mass
Blastocyst cavity
Trophoblast
(a) Zygote (fertilized egg)
(b) 4-cell stage 2 days
(c) Morula 3 days
(d) Early blastocyst 4 days
(e) Implanting blastocyst 6 days
Sperm
(b)
Fertilization (sperm meets egg)
(a)
(c)
Uterine tube
Ovary
Oocyte (egg)
(d)
Uterus
Ovulation
(e)
Endometrium
Cavity of uterus

Inner cell mass of the blastocyst divides into **epiblast** and **hypoblast**

- Amniotic sac comes from epiblast
- Yolk sac comes from hypoblast

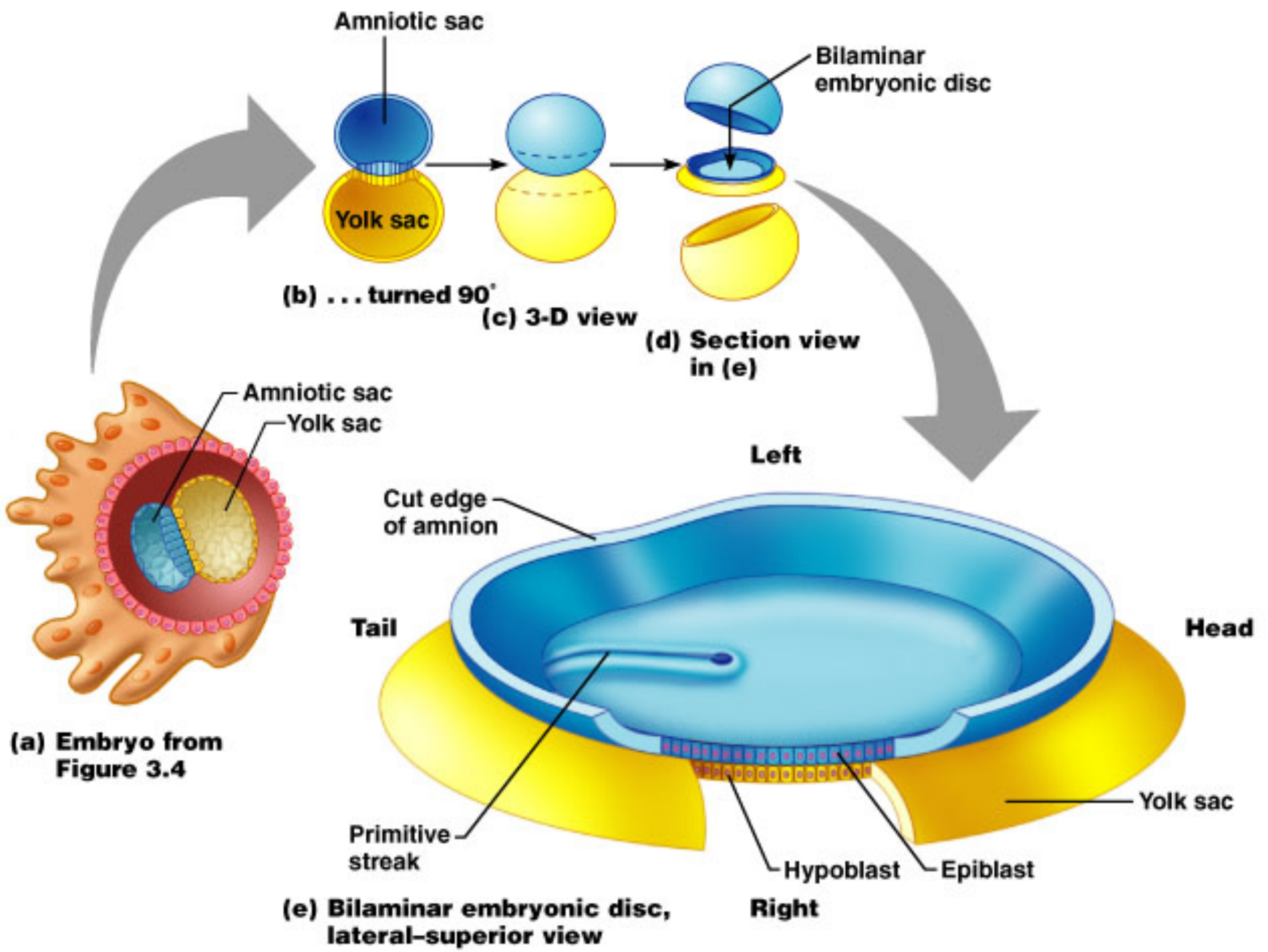


BILAMINAR EMBRYONIC DISC

Formed at the site the epiblast and hypoblast come in contact

Occurs at 2 weeks post-fertilization

The bilaminar embryonic disc



(a) Embryo from Figure 3.4

(e) Bilaminar embryonic disc, lateral–superior view

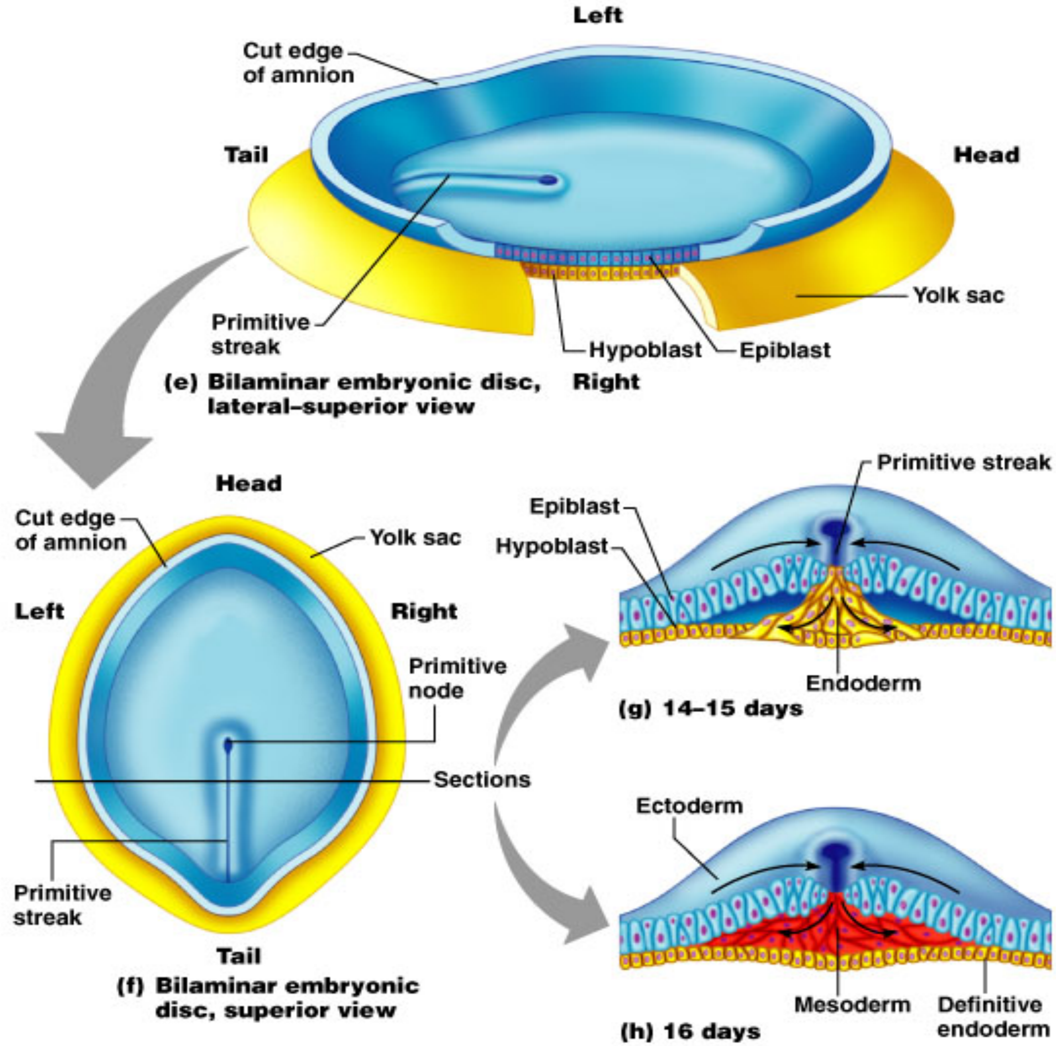
At Week 3, bilaminar disc develops into three layers

Ectoderm

Mesoderm

Endoderm

All tissues of the body arise from these germ layers



GASTRULATION

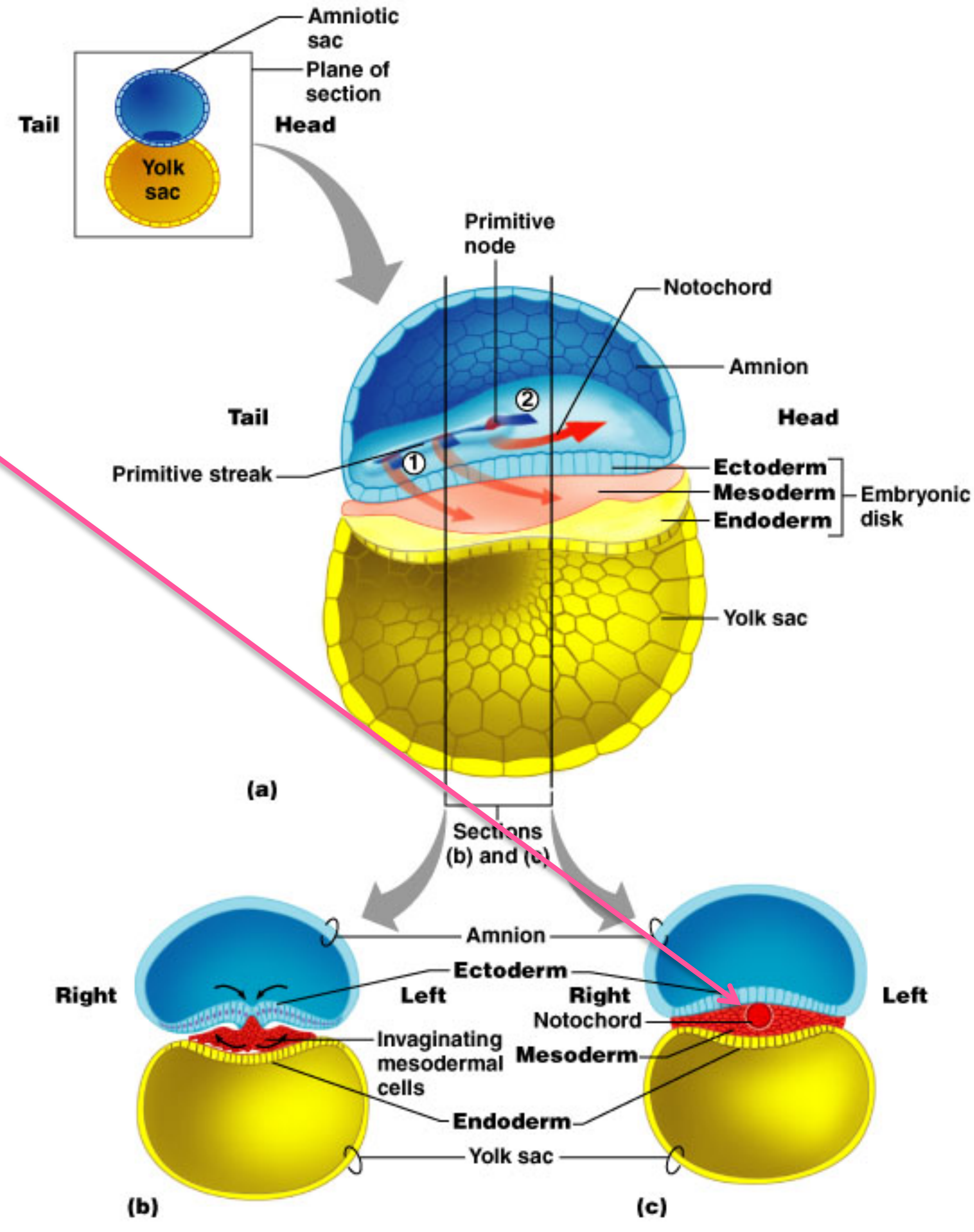
Pearson Education, Inc. 2008

ECTODERM	MESODERM	ENDODERM
• Epidermis of skin and its derivatives (including sweat glands, hair follicles) • Epithelial lining of mouth and anus • Cornea and lens of eye • Nervous system • Sensory receptors in epidermis • Adrenal medulla • Tooth enamel • Epithelium of pineal and pituitary glands	• Notochord • Skeletal system • Muscular system • Muscular layer of stomach and intestine • Excretory system • Circulatory and lymphatic systems • Reproductive system (except germ cells) • Dermis of skin • Lining of body cavity • Adrenal cortex	• Epithelial lining of digestive tract • Epithelial lining of respiratory system • Lining of urethra, urinary bladder, and reproductive system • Liver • Pancreas • Thymus • Thyroid and parathyroid glands

Notochord

Forms between 2-3 wks post fertilization

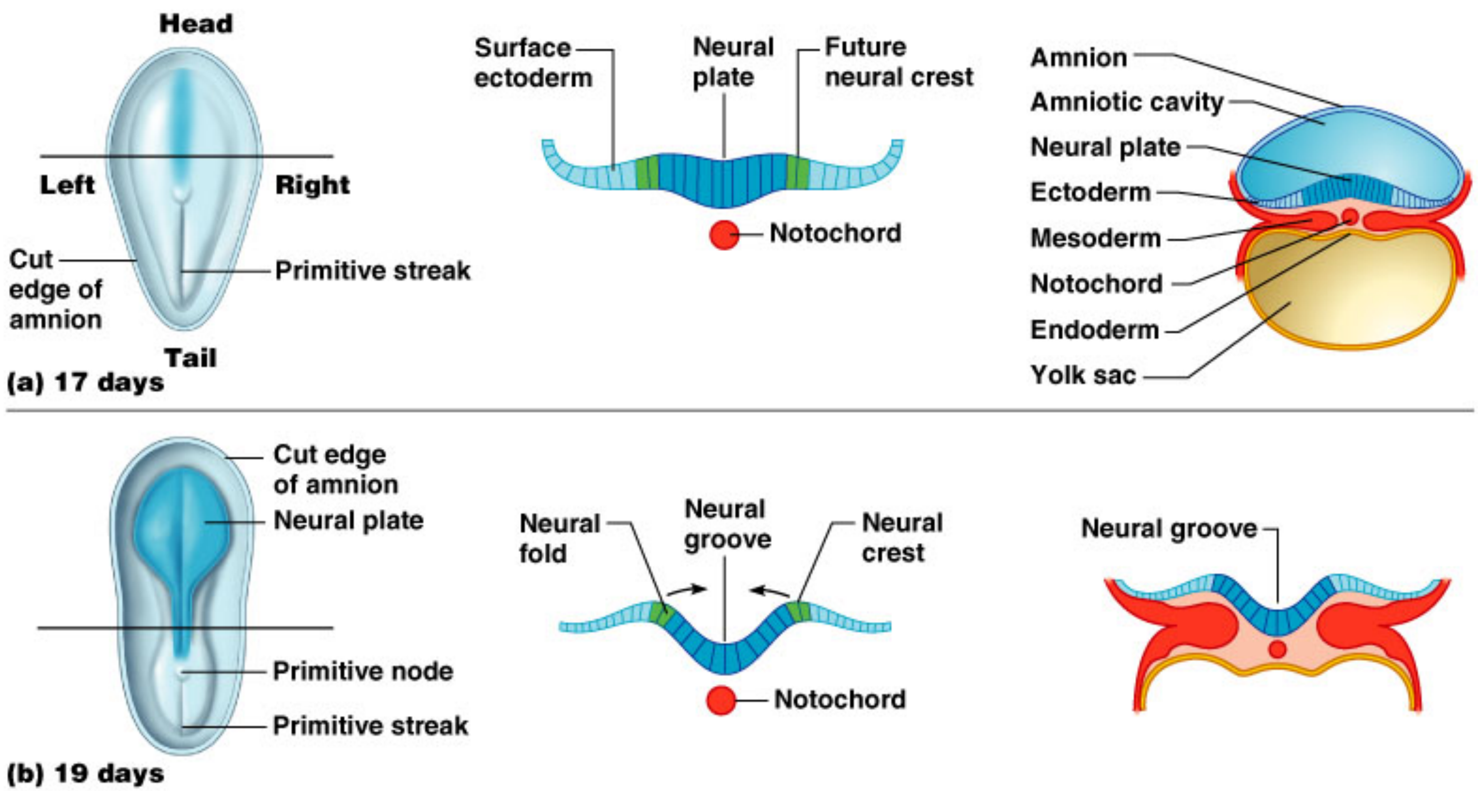
Will become part of the vertebral column



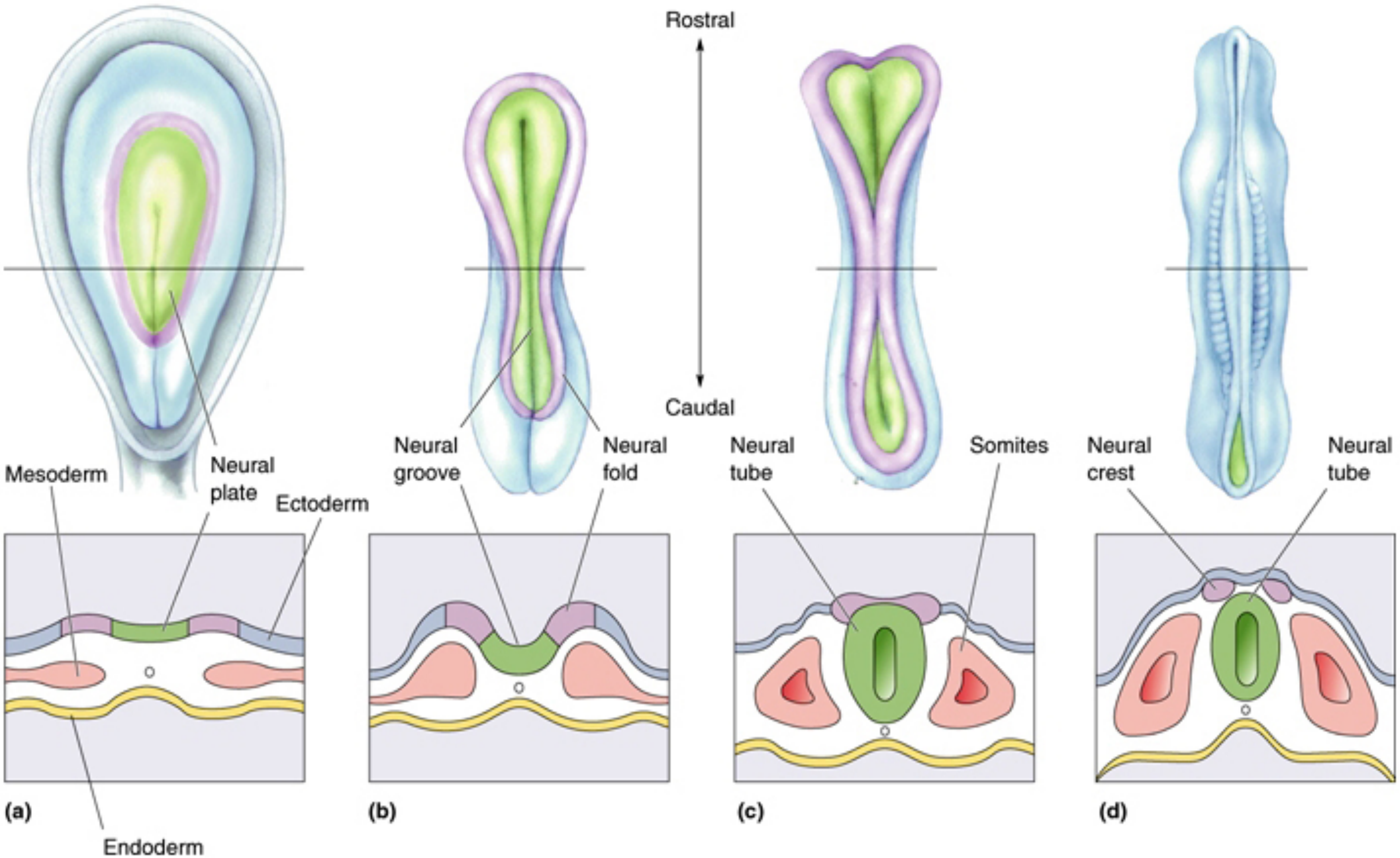
Neurulation: the formation of a neural tube (will become CNS)

Notochord send signals to ectoderm

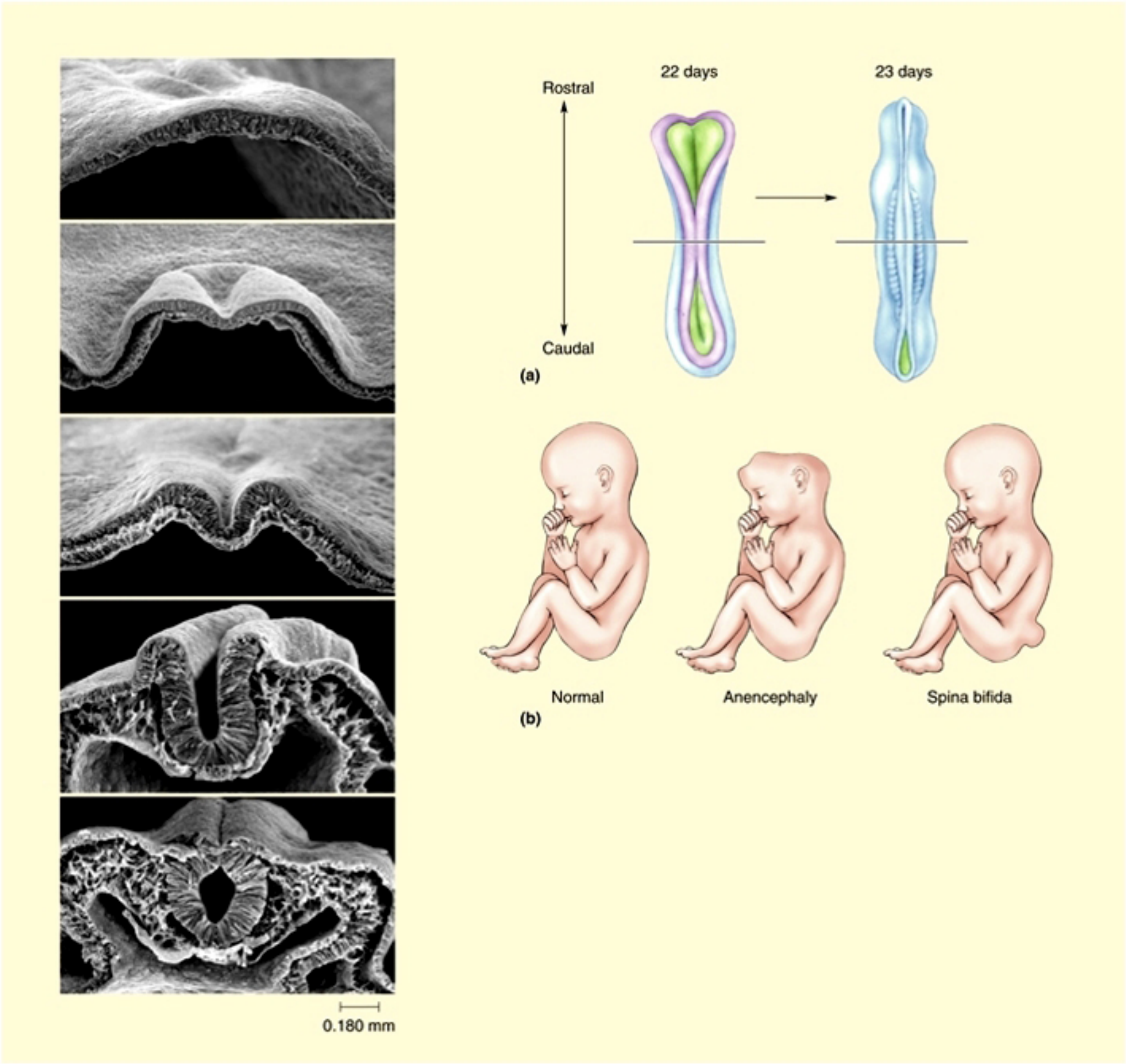
Neural plate transforms into neural groove which then transforms into neural tube



Another look at neurulation



Neural tube defects



Everything You Need to Know About Prenatal Vitamins

Yes, you need to take them. But do you know exactly why, when or how?

By Anna Medaris Miller | June 18, 2015 | 4:24 p.m. EDT

Folic acid (a B vitamin) helps to prevent neural tube defects

CDC Centers for Disease Control and Prevention
CDC 24/7: Saving Lives. Protecting People™

SEARCH

CDC A-Z INDEX

Folic Acid

Folic acid fortification continues to prevent neural tube defects.

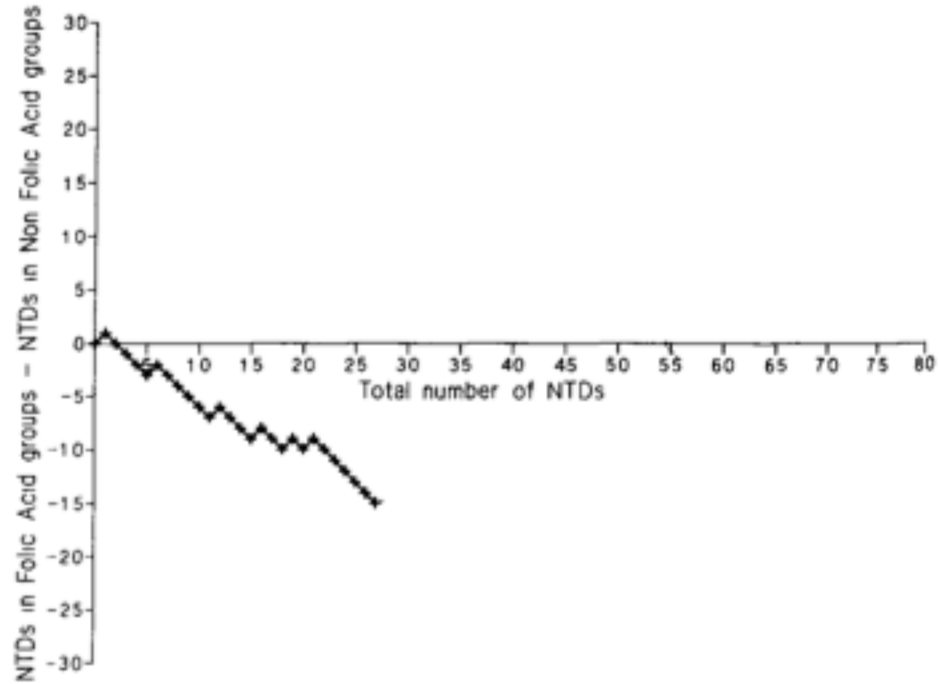
Language: English

Folic acid is a B vitamin. If a woman has enough folic acid in her body before and during pregnancy, it can help prevent major birth defects of the baby's brain and spine. Women need 400 micrograms (mcg) of folic acid every day.

Folic acid fortification mandate by the FDA

Starting January 1, 1998, all enriched cereal and grain products must be fortified with **folic acid**

Based in part on available data demonstrating a 71% reduction in neural tube defects associated with folic acid supplementation (MRC Vitamin Study Research Group. Lancet 1991)



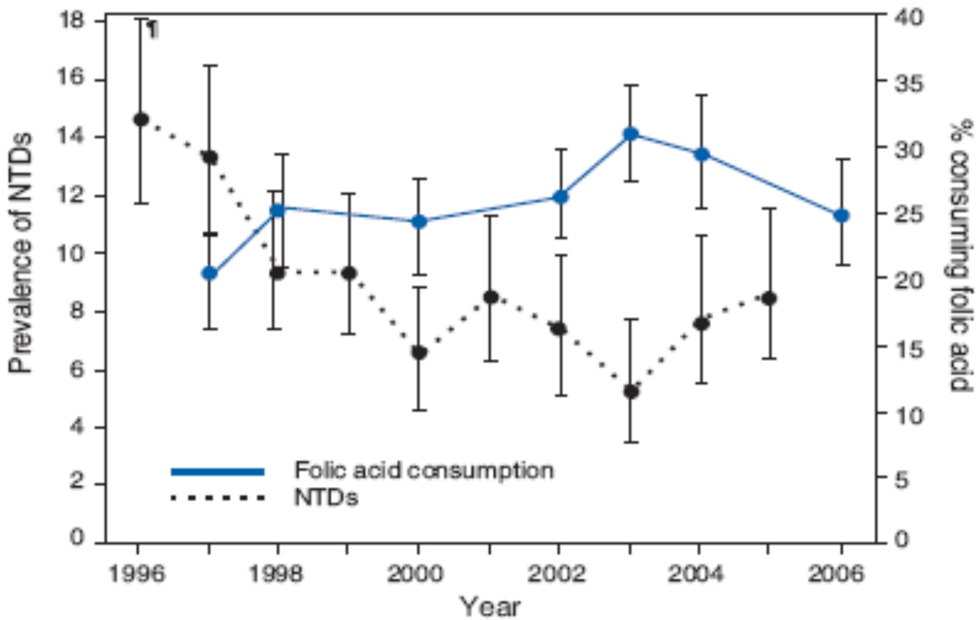
Sequential analysis, showing cumulative difference between number of neural tube defects (NTDs) in the folic acid and non-folic-acid groups plotted against total number of NTDs.

The boundaries of the diagram define the stopping points of the study. Upper and lower boundaries of the figure were constructed by use of approximation that number of events in the folic acid groups minus number in the groups without folic acid follows a gaussian distribution with mean $N(1-r)/(1+r)$ and variance N, where r is the relative risk and N is the total number of neural tube defects in the study.[22] By taking the parameters of this gaussian distribution, equations given by Armitage[23] can be used to specify the upper and lower boundaries of the figure.

(MRC Vitamin Study Research Group. Lancet 1991)

Increases in folic acid consumption associated with decreases in neural tube defects

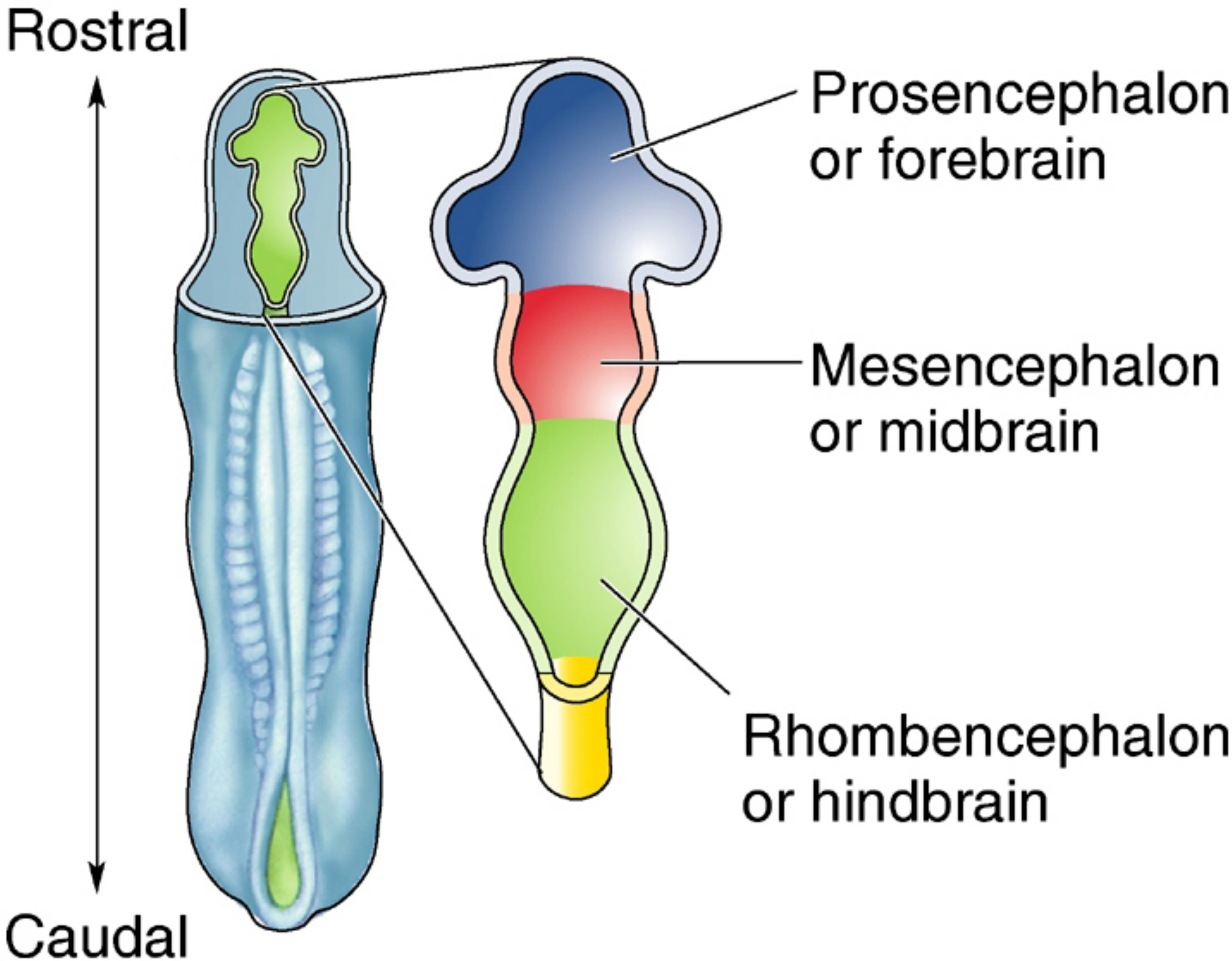
FIGURE. Prevalence* of neural tube defects (NTDs)† and estimated folic acid consumption§ among nonpregnant women aged 18–44 years — Birth Defects Surveillance System and Behavioral Risk Factor Surveillance System, Puerto Rico, 1996–2005 and 1997–2006



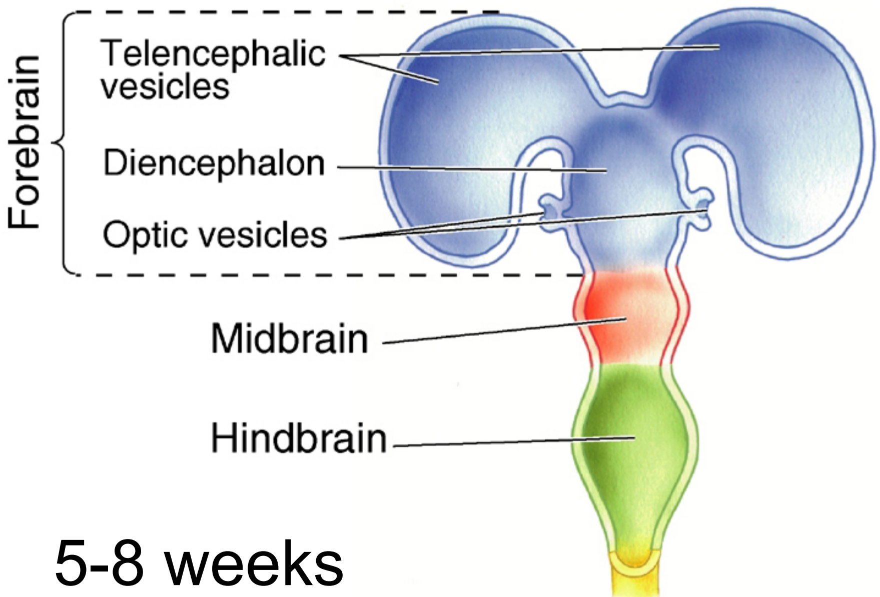
* Per 10,000 live births.
† Anencephaly and spina bifida.
§ Defined as reported daily consumption of a vitamin pill or supplement containing folic acid.
¶ 95% confidence interval.

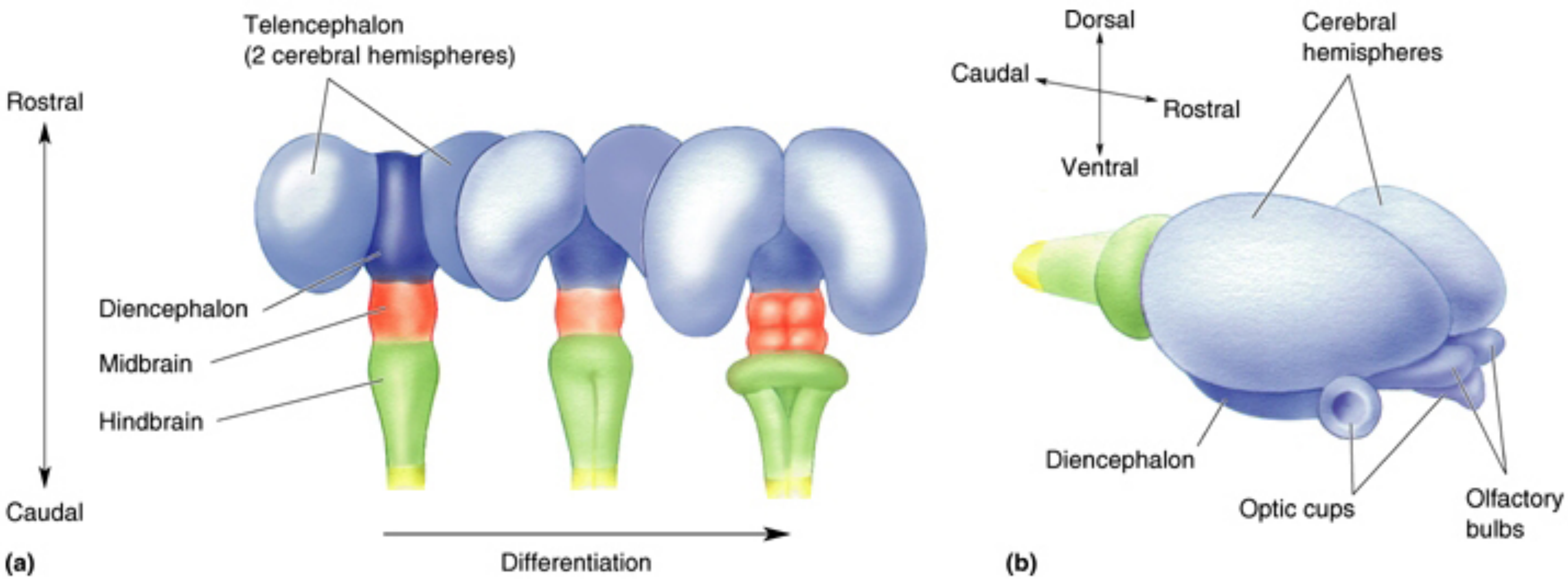
http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5701a5.htm

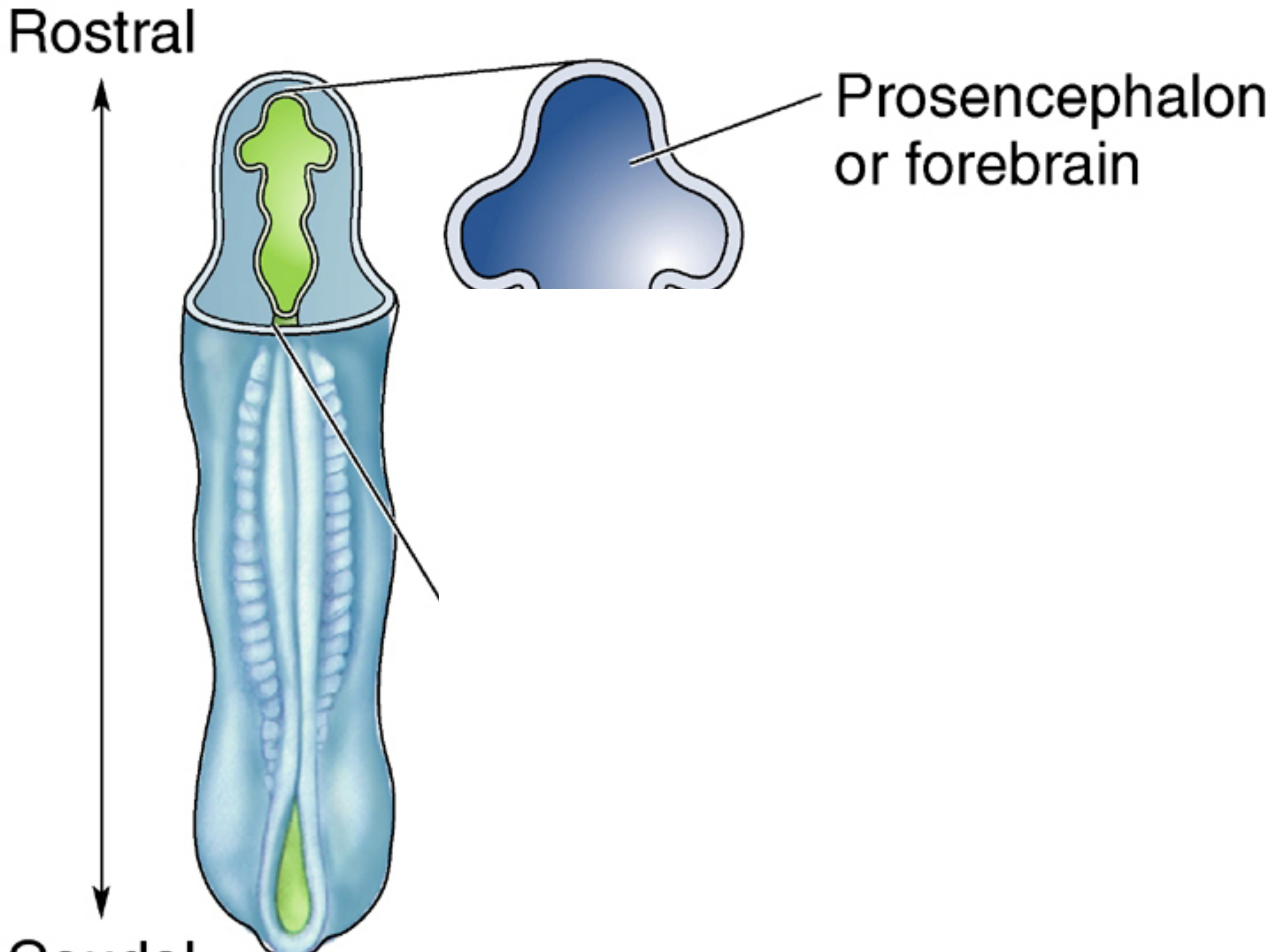
After neural tube formation, the brain begins to develop with the formation of the **primary brain vesicles**

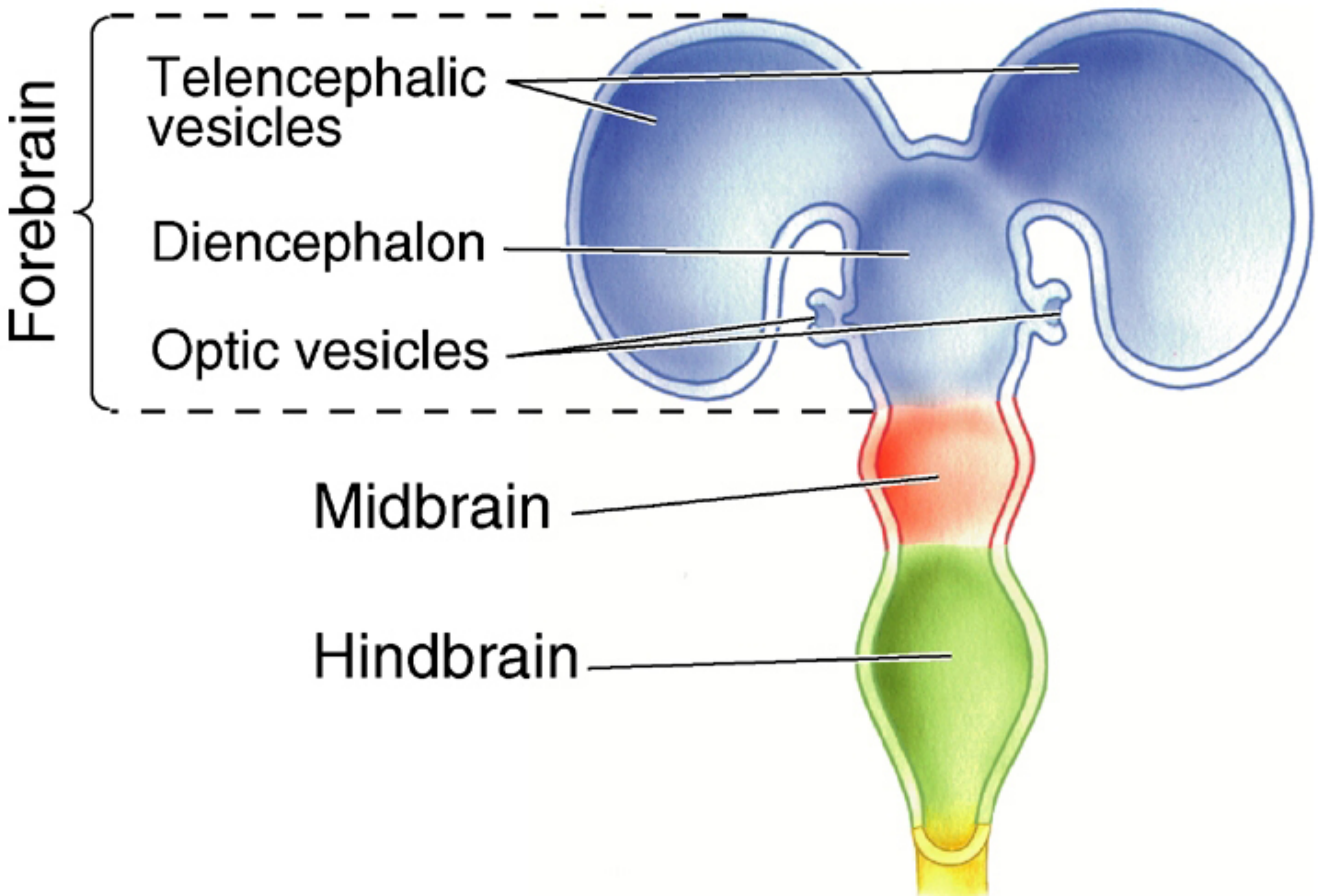


The forebrain, midbrain, and hindbrain regions continue to differentiate and change shape



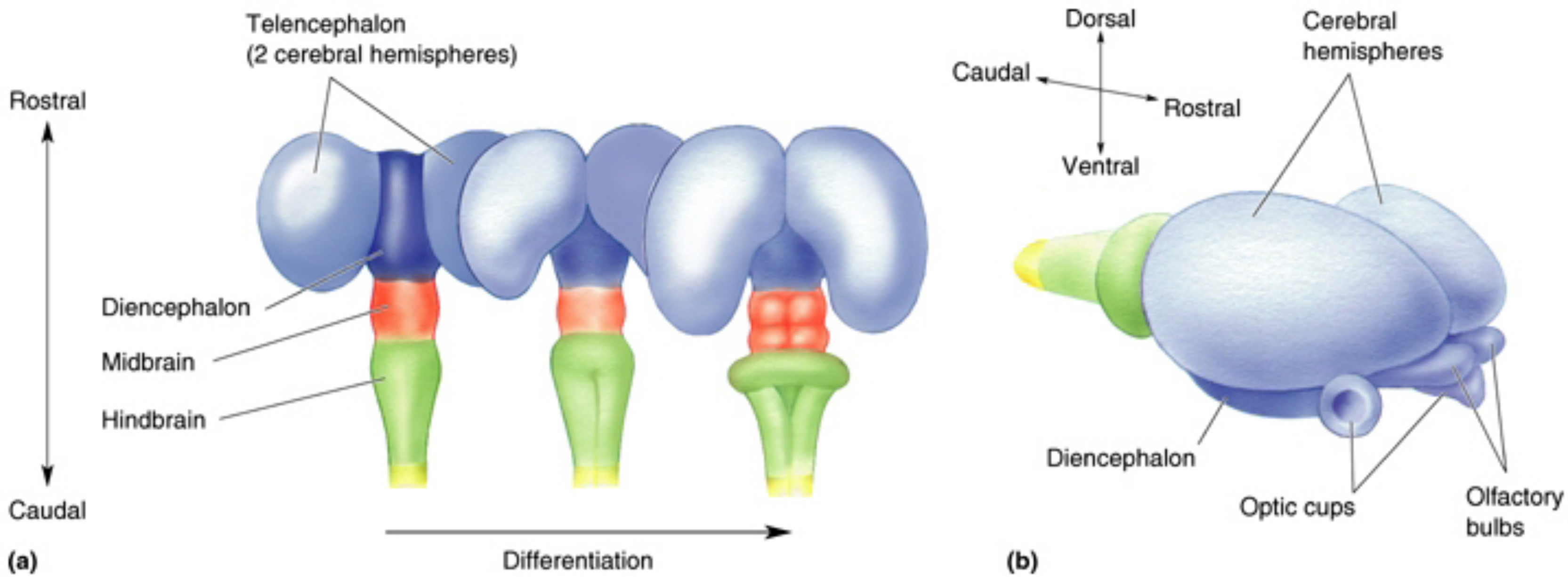



Rostral
Prosencephalon
or forebrain
Caudal

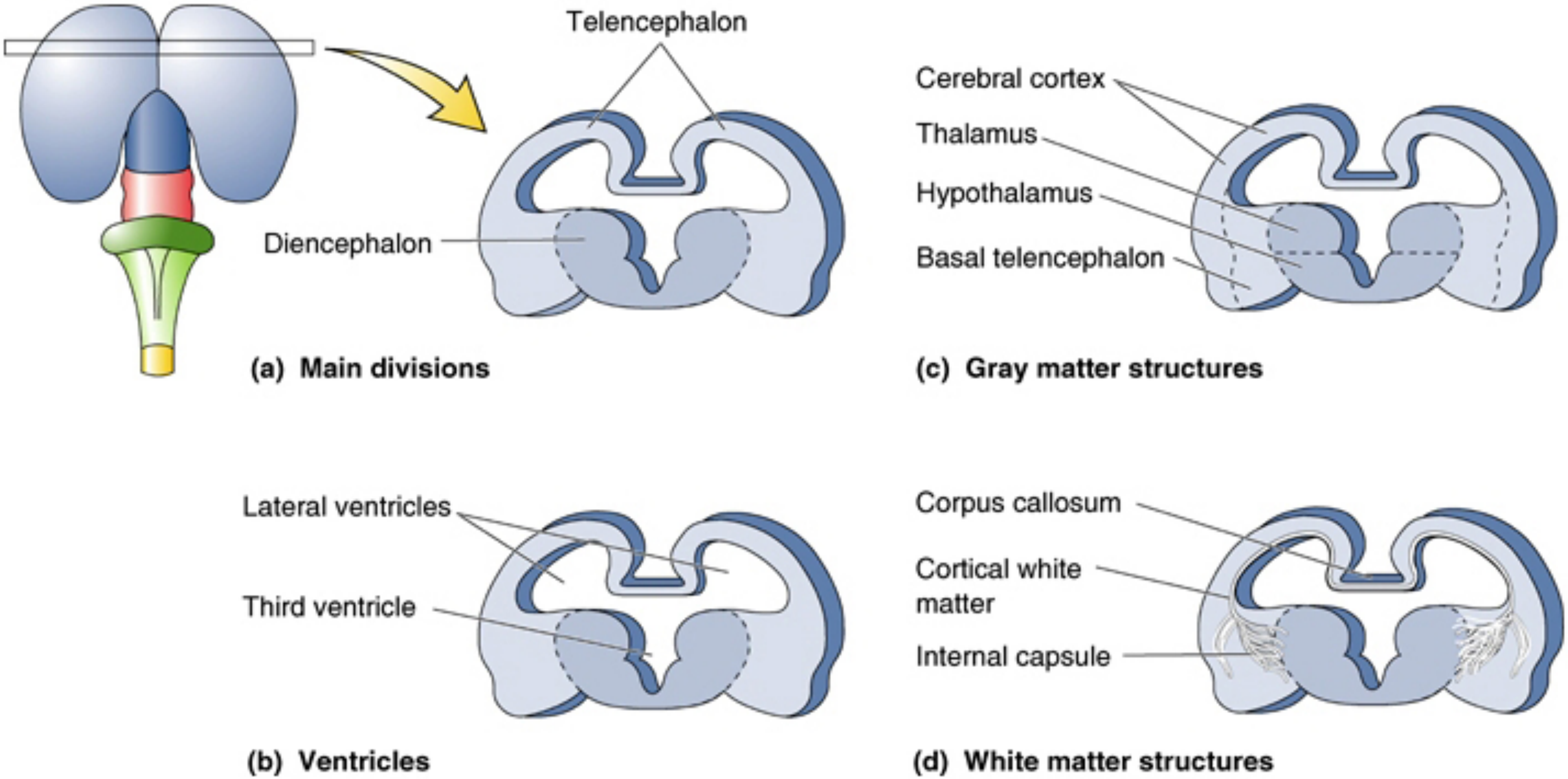

Forebrain
Telencephalic vesicles
Diencephalon
Optic vesicles
Midbrain
Hindbrain

Secondary Brain Vesicles

- Telencephalon → Two cerebral hemispheres
- Diencephalon → Thalamus and hypothalamus
- Optic Vesicles → Eyes

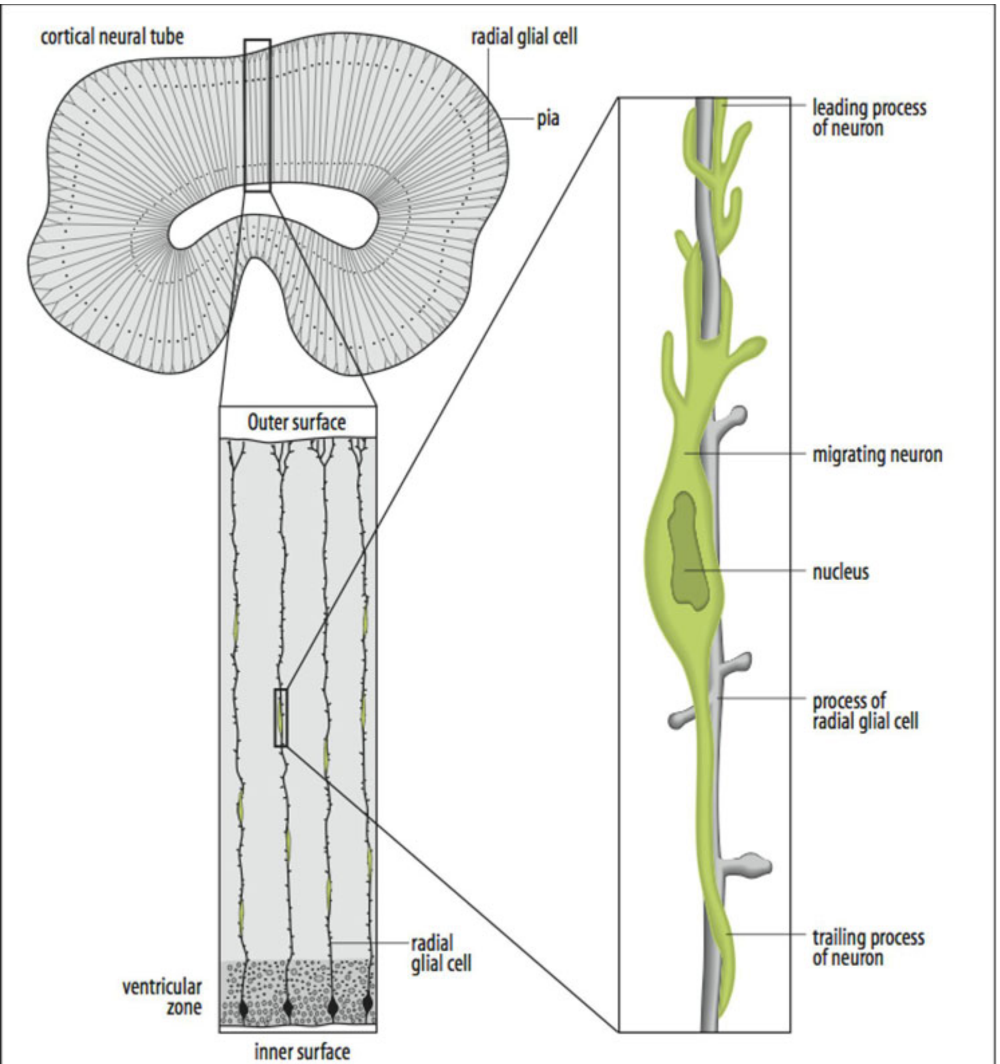


Telencephalon
(2 cerebral hemispheres)
Rostral
Diencephalon
Midbrain
Hindbrain
Caudal
Differentiation
(a)
Dorsal
Caudal
Rostral
Ventral
Cerebral
hemispheres
Diencephalon
Optic cups
Olfactory
bulbs
(b)



Telencephalon
Diencephalon
(a) Main divisions
Cerebral cortex
Thalamus
Hypothalamus
Basal telencephalon
(c) Gray matter structures
Lateral ventricles
Third ventricle
(b) Ventricles
Corpus callosum
Cortical white matter
Internal capsule
(d) White matter structures

There is a high rate of neurogenesis as the brain continues to expand and change shape



New cells born in **ventricular zone**

Some cells then migrate away from this zone

All neurons (100 billion in total) are produced pre-natally

Rate of proliferation extremely high; thousands/minute

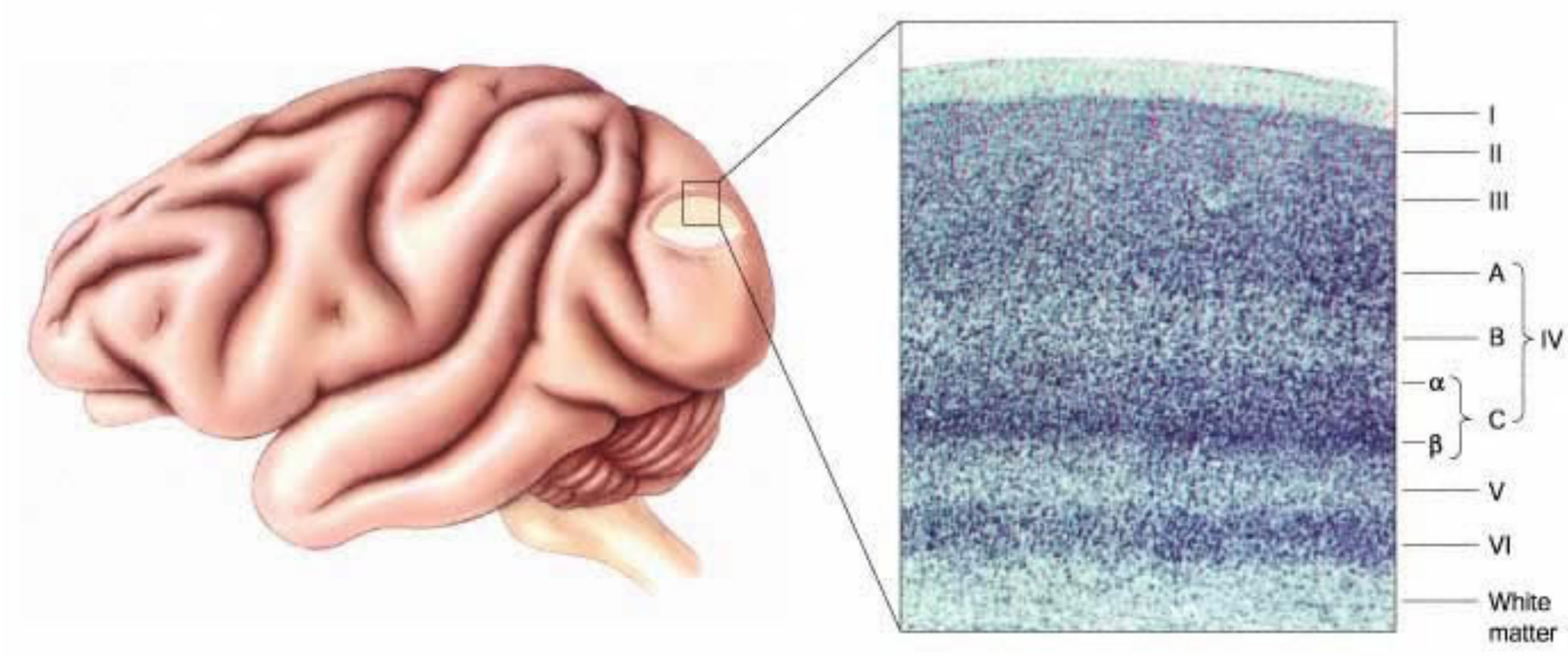
Radial glial cells provide the framework for the migrating cells

~ 67% migrate up while 33% migrate horizontally; leads to the formation of the layered cortex

http://www.mun.ca/biology/desmid/brian/BIOL3530/DB_10/fig10_10.jpg

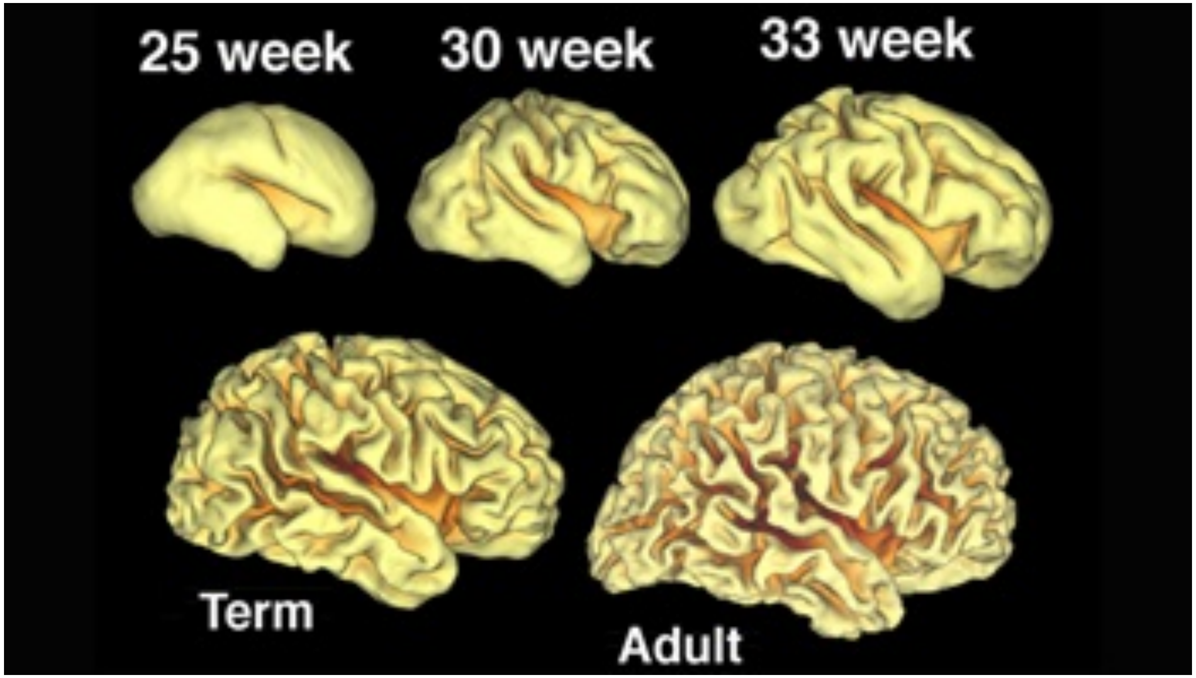
Resulting cortical layers: Cerebral cortex is striated

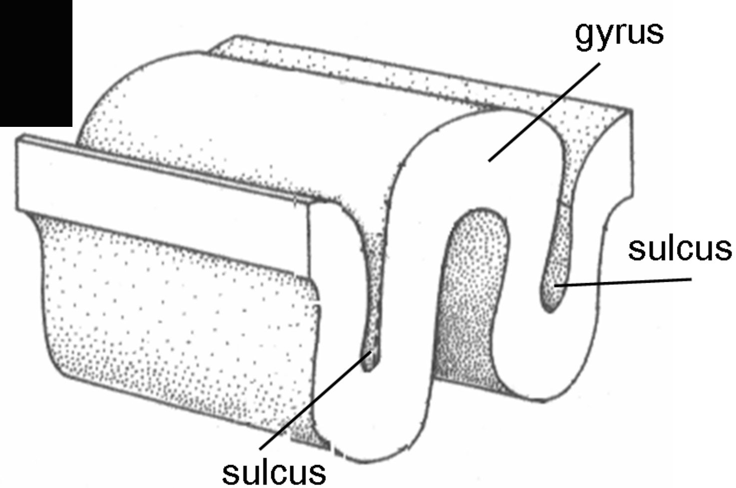
Each layer has different cell density and type



http://fourier.eng.hmc.edu/e180/lectures/v1/node4.html

Over time, the cerebral hemispheres expand and become "wrinkled"

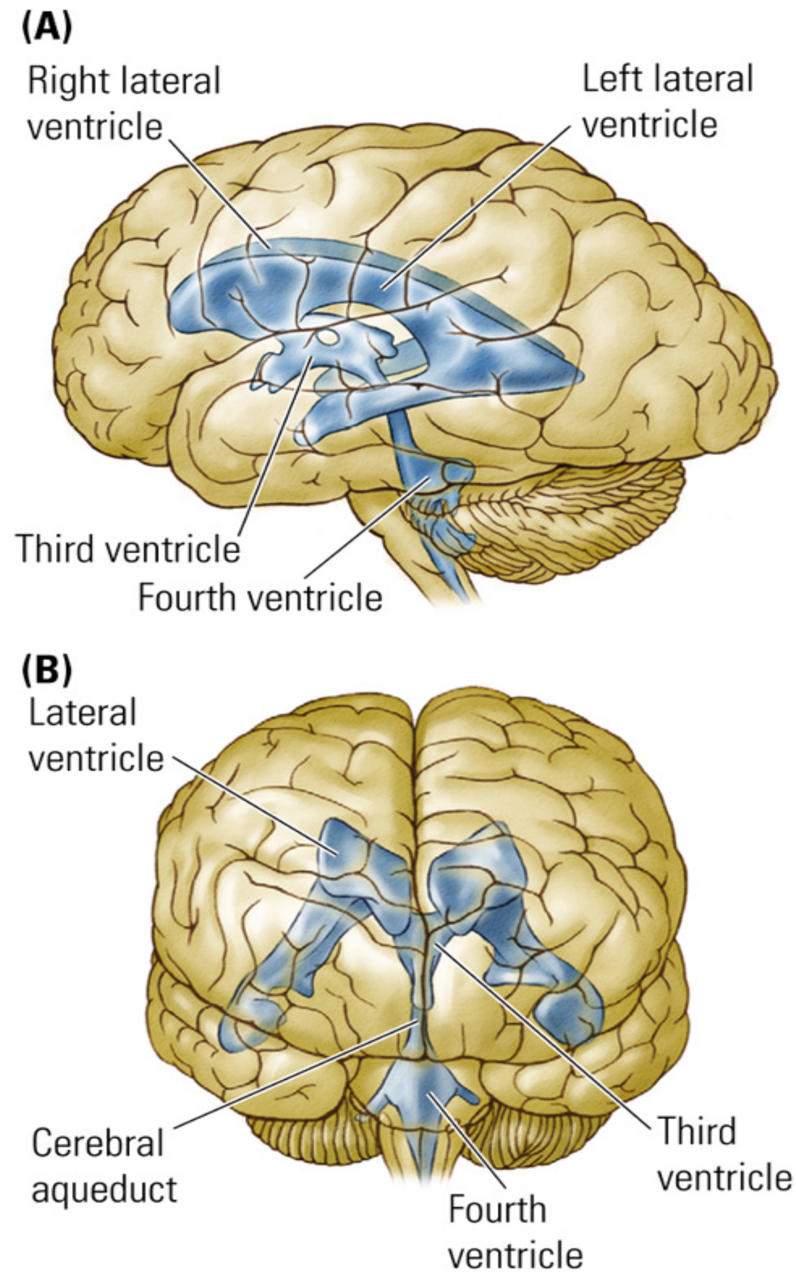




http://www.brainfacts.org/about-neuroscience/technologies/articles/2009/brain-atlases/

Keeping the central nervous system hydrated

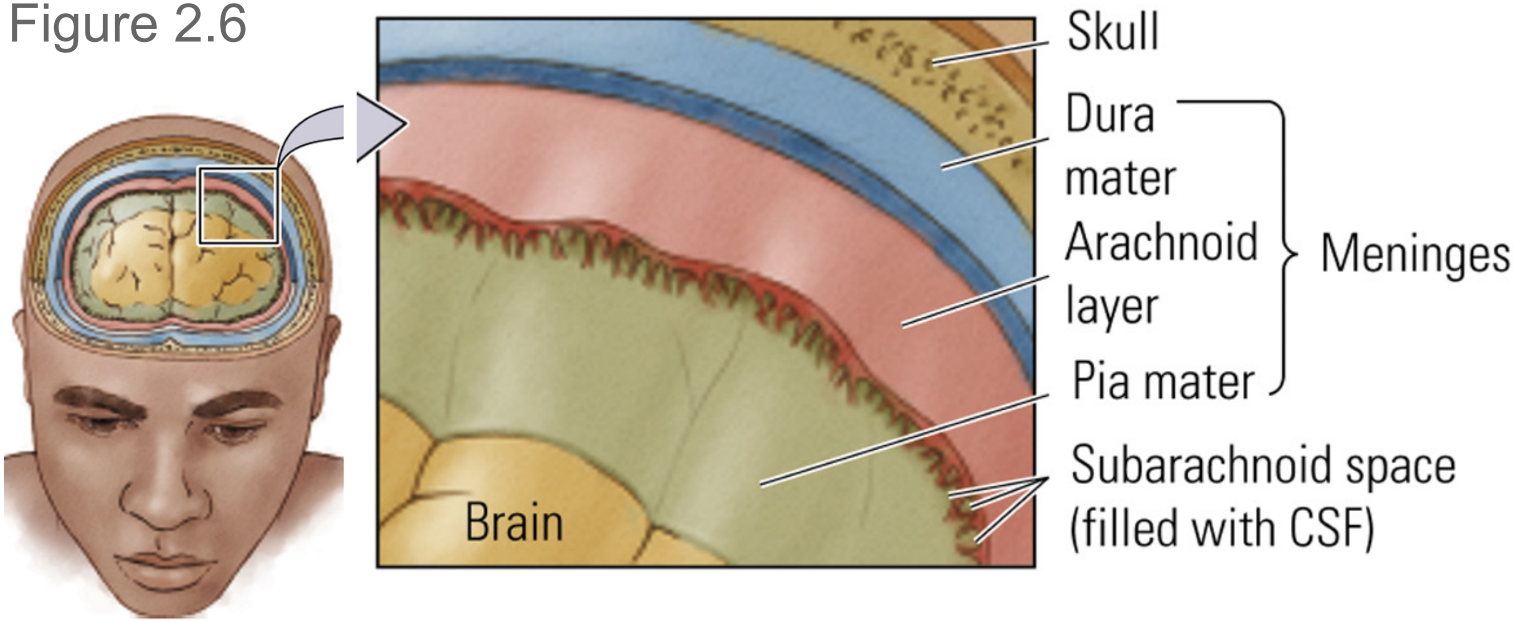
Cerebral spinal fluid is produced by choroid plexus cells (in the ventricles) and circulates through the ventricular cavities and in spaces surrounding the brain and spinal cord



Kolb and Whishaw, 2005

Cerebral spinal fluid flows between two layers of the meninges

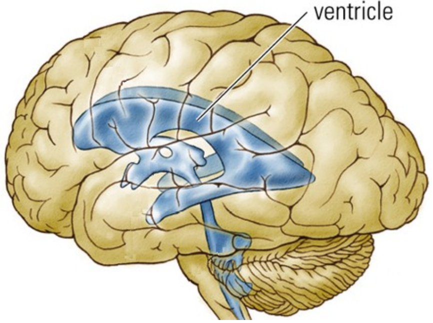
Figure 2.6



DURA MATER: thick, tough, flexible, but unstretchable
ARACHNOID: soft and spongy
PIA MATER: Thin and closely attached

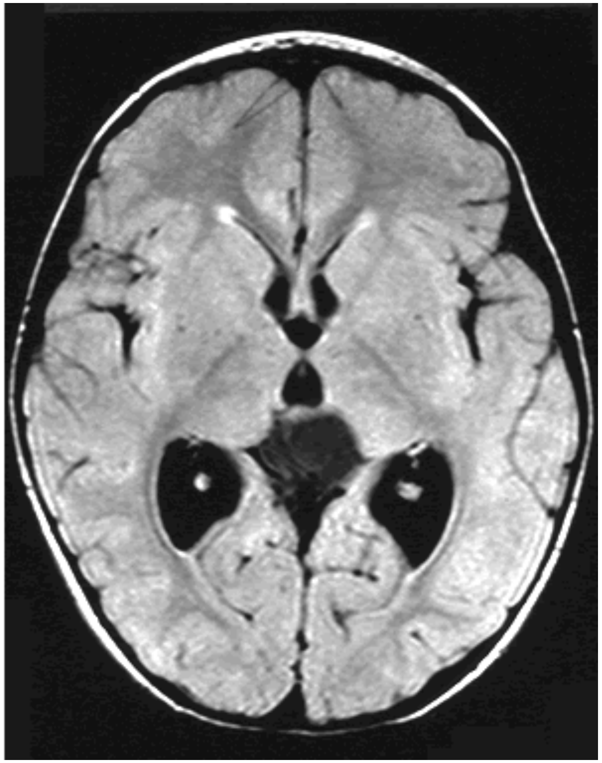
CSF flows between the arachnoid and pia layers (i.e. the subarachnoid space)

Kolb and Whishaw, 2005

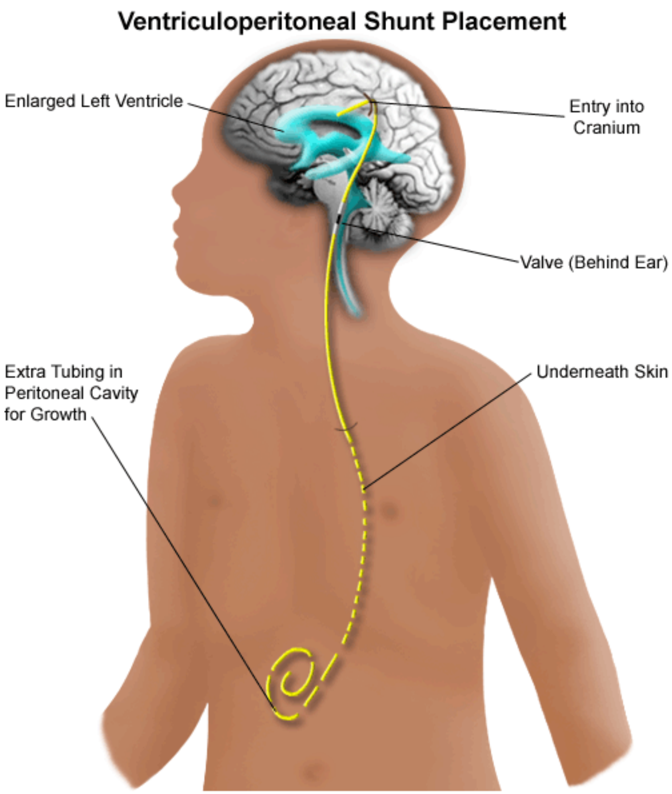


Hydrocephalus

Hydrocephalus



Normal Ventricles



A shunt can be inserted to drain excess fluid

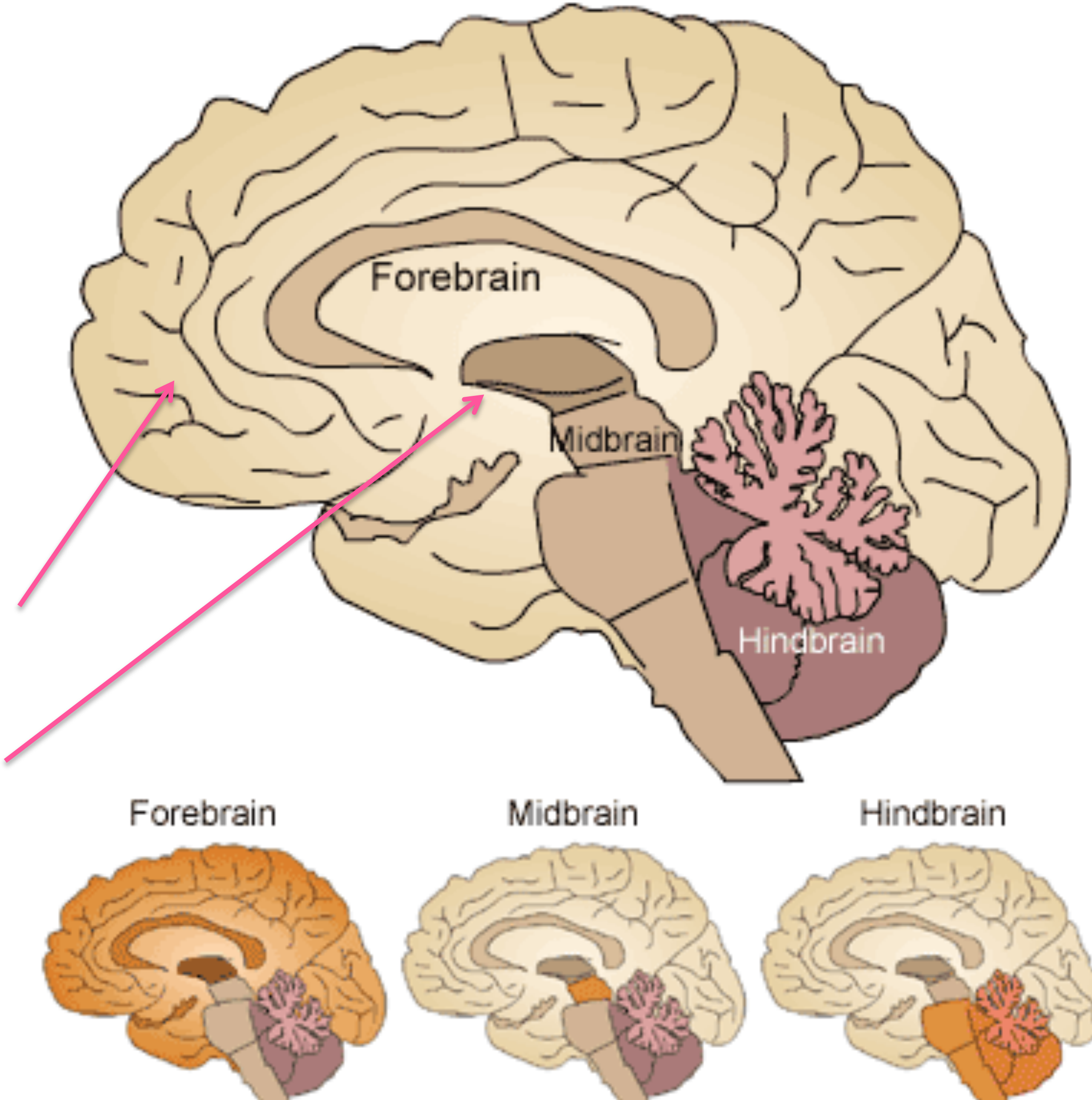
http://www.seattlechildrens.org/uploadedimages/Seattle_Childrens/cmsassets/Images/hydrocephalus-normal-non-normal-ct-scans_large.gif

http://ecs.utdallas.edu/research/researchlabs/QoLT/projects.html

Overall brain structure

Forebrain = Telencephalon + Diencephalon

Figure AB-7: Forebrain / Midbrain / Hindbrain

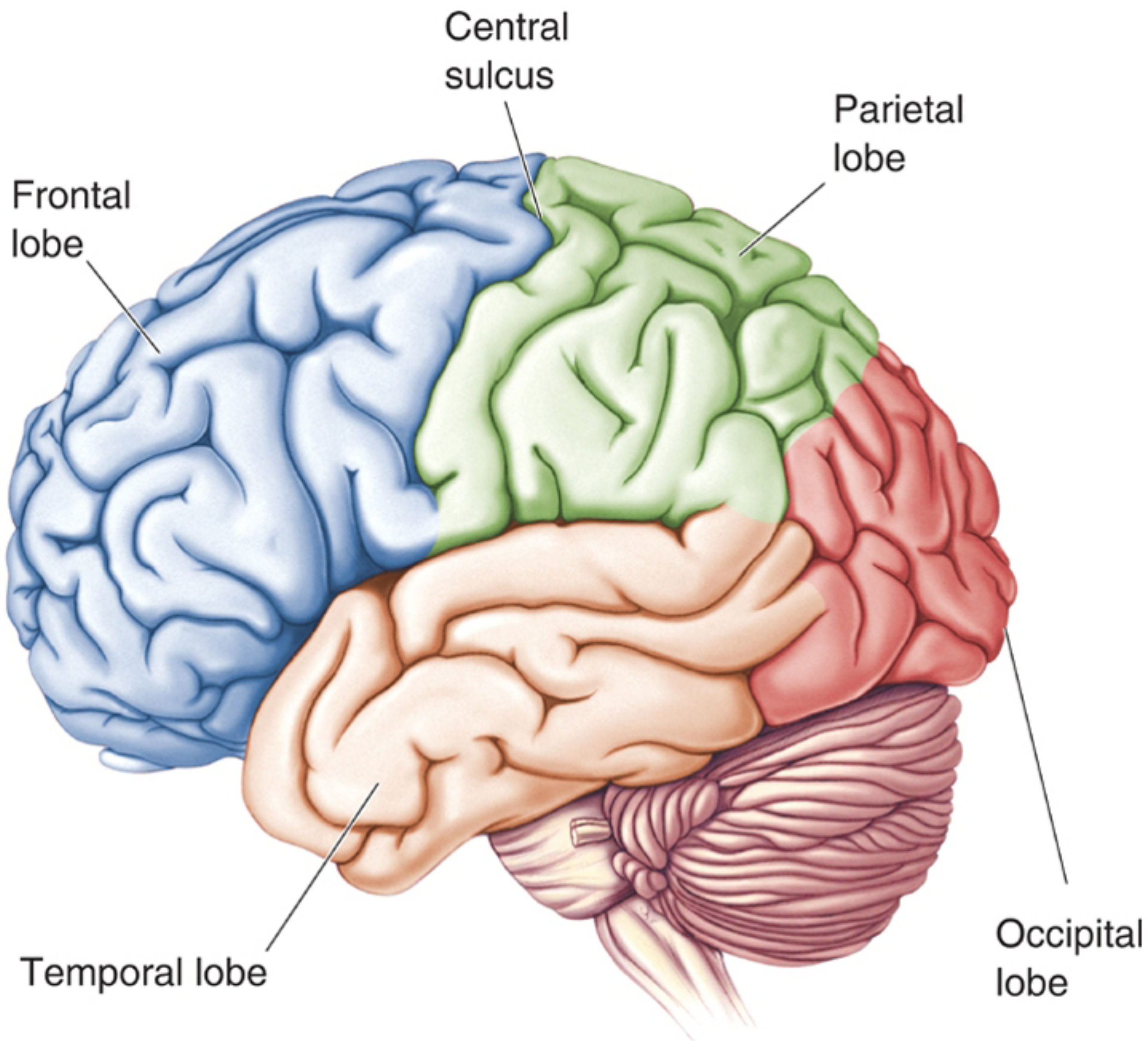


Forebrain: Telencephalon (cerebral cortex + basal telencephalon)

Cerebral cortex = cerebrum

Divided into four major lobes

FRONTAL
PARIETAL
TEMPORAL
OCCIPITAL

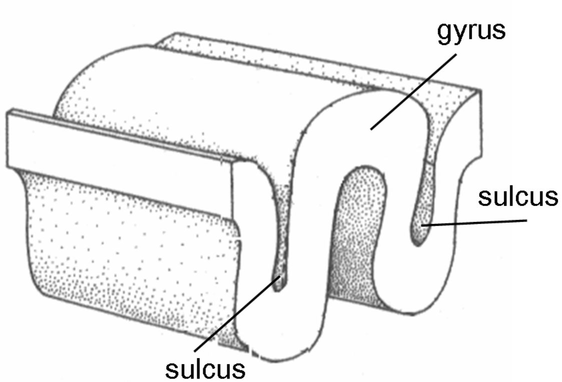


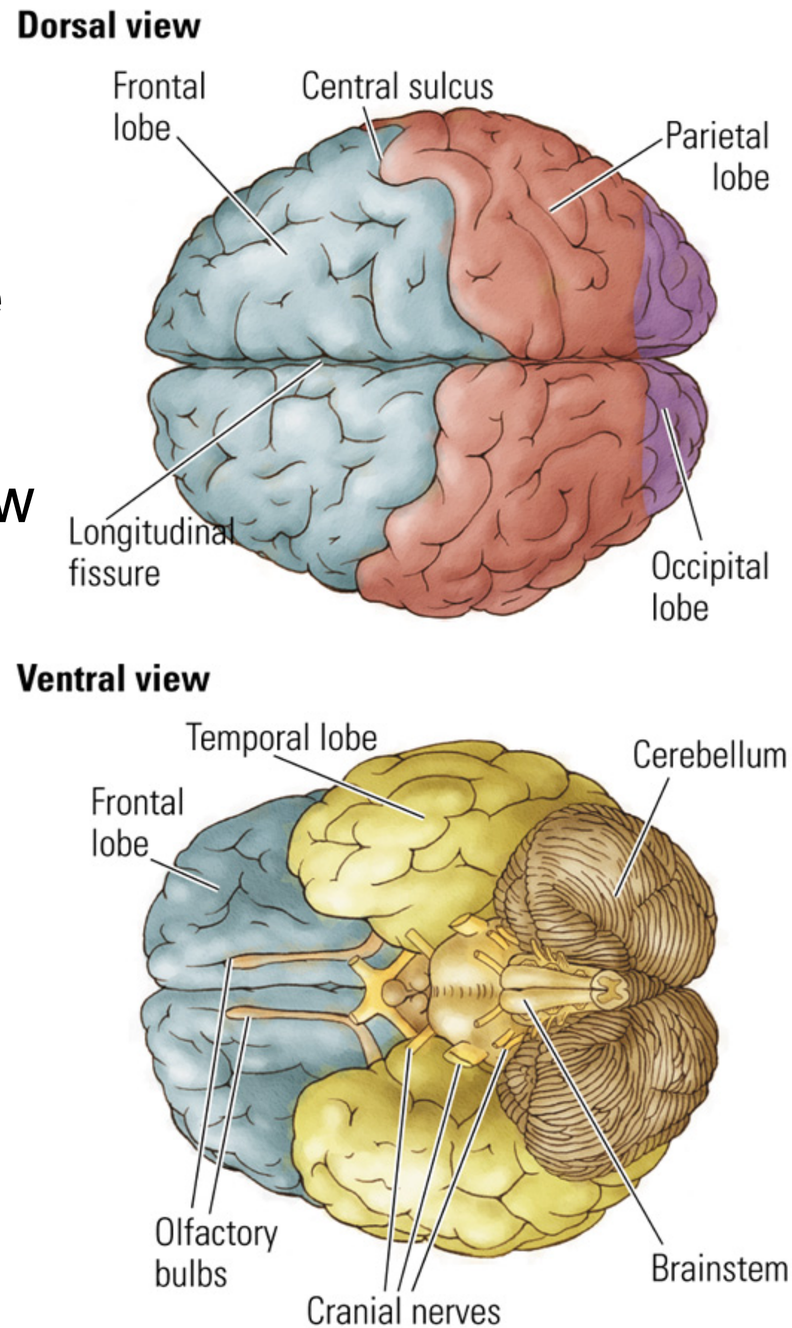
That wrinkled brain

GYRUS (pl. gyri) is a bump or ridge
Latin for ‘circle’

SULCUS (pl. sulci) is a crack/ furrow
Latin for ‘furrow’
big sulcus is called a fissure

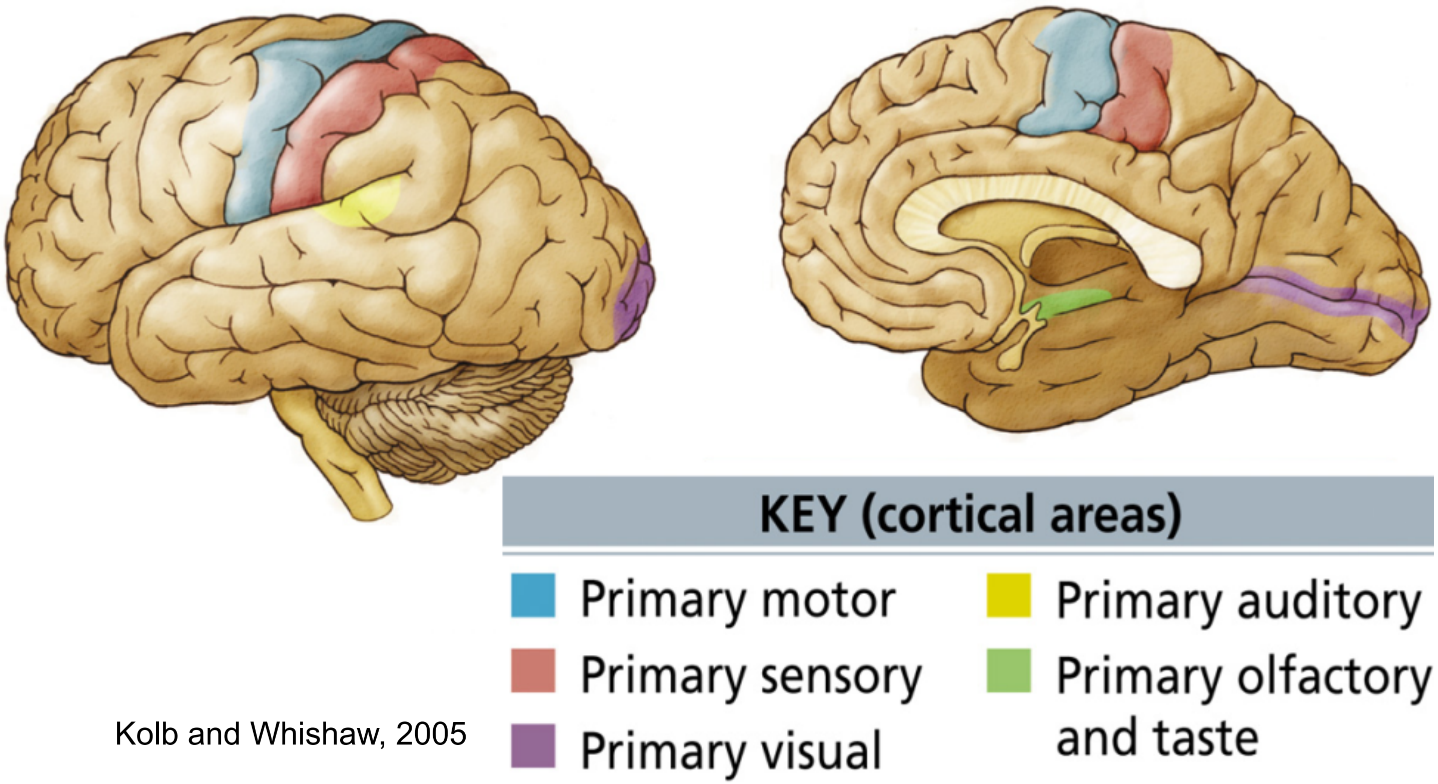
Major gyri and sulci have names





Kolb and Whishaw, 2005

Primary vs association cortex



Kolb and Whishaw, 2005

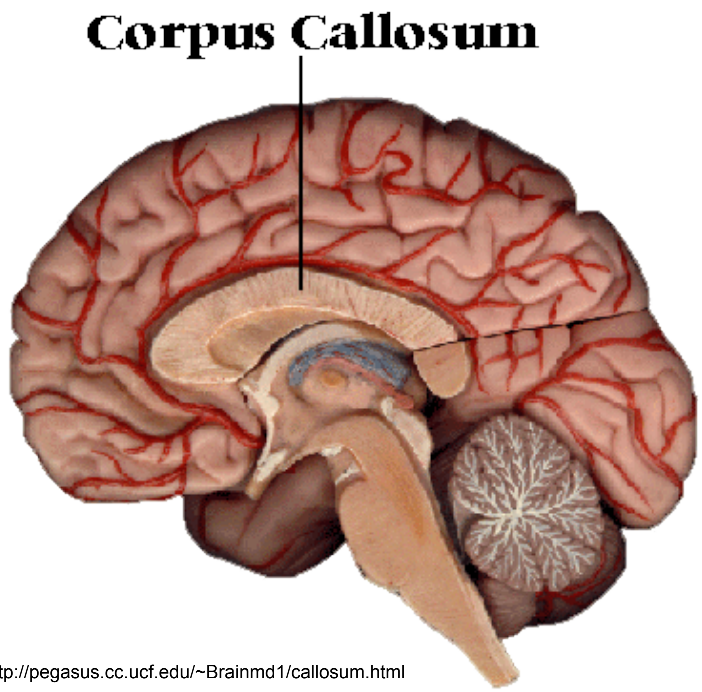
Anything that is not primary cortex is association cortex

- majority of cortical area

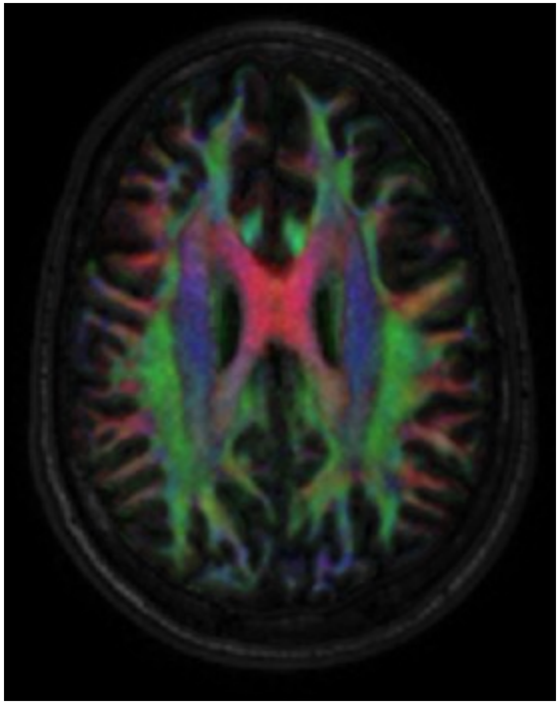
Receives highly processed information

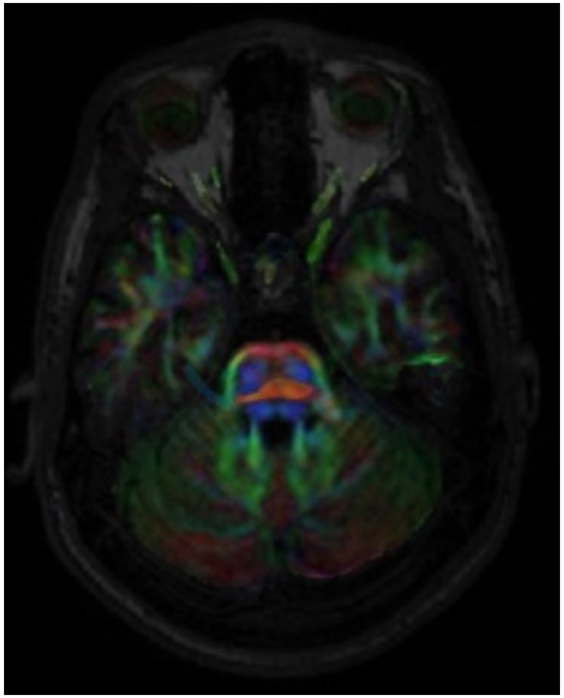
- very different than simplified info in primary sensory cortices (V1)

Corpus callosum – network of fibers that connects the two cerebral hemispheres



http://pegasus.cc.ucf.edu/~Brainmd1/callosum.html





http://phineasgage.files.wordpress.com/2007/06/070606dti2.png

Forebrain:
<u>Basal telencephalon</u>

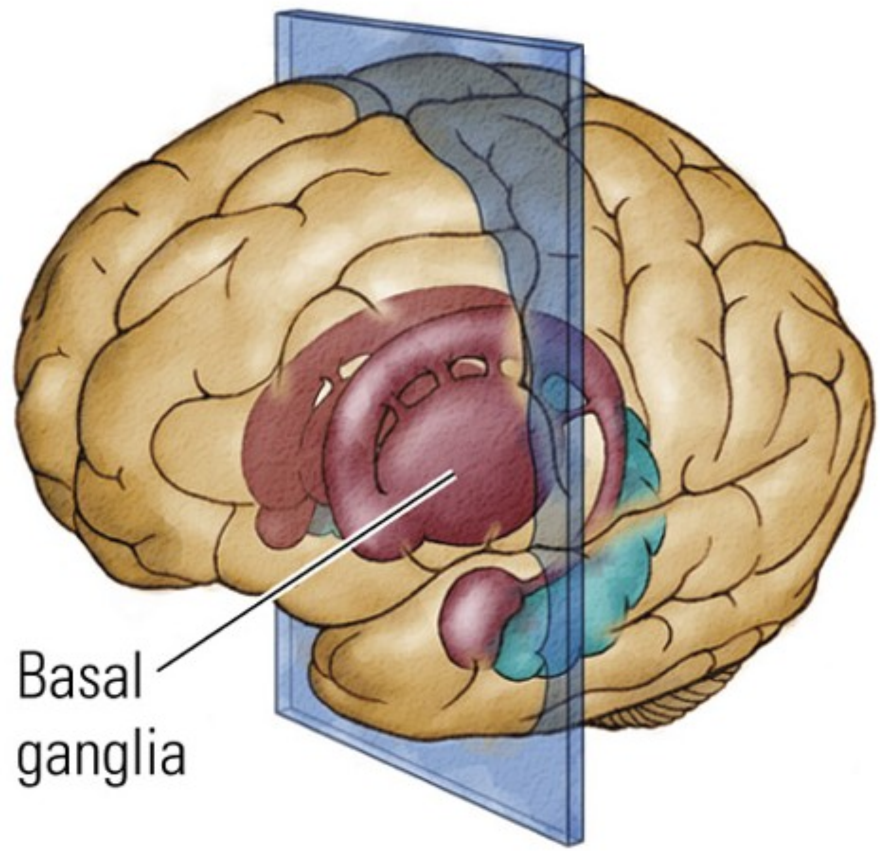
Includes the following:

- Basal ganglia
- Limbic system

Forebrain: basal ganglia

Involved in aspects of voluntary motor control

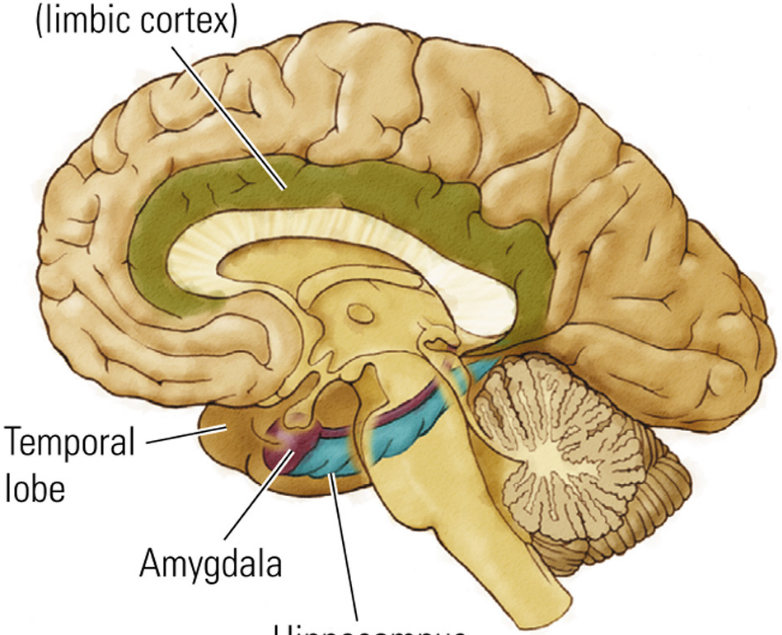
Major structures include globus pallidus, caudate nucleus, and putamen



Kolb and Whishaw, 2005

Forebrain: limbic system

- Cingulate gyrus
  - coordinates sensory input with emotions
- Amygdala
  - best known as fear center, but involved in other forms of emotion and emotion-associated behavior
- Hippocampus
  - key in learning & memory



Kolb and Whishaw, 2005

Figure AB-17: Limbic System
(Cross-Coronal Section)

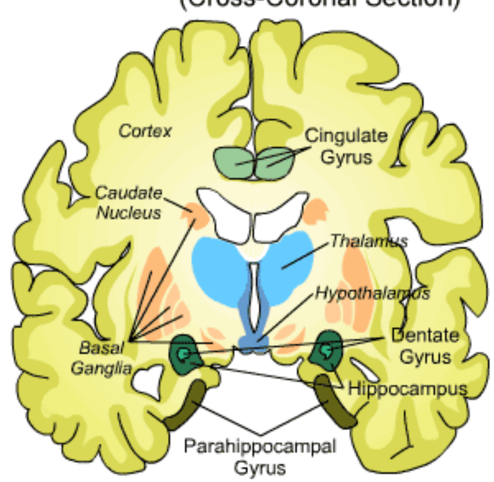
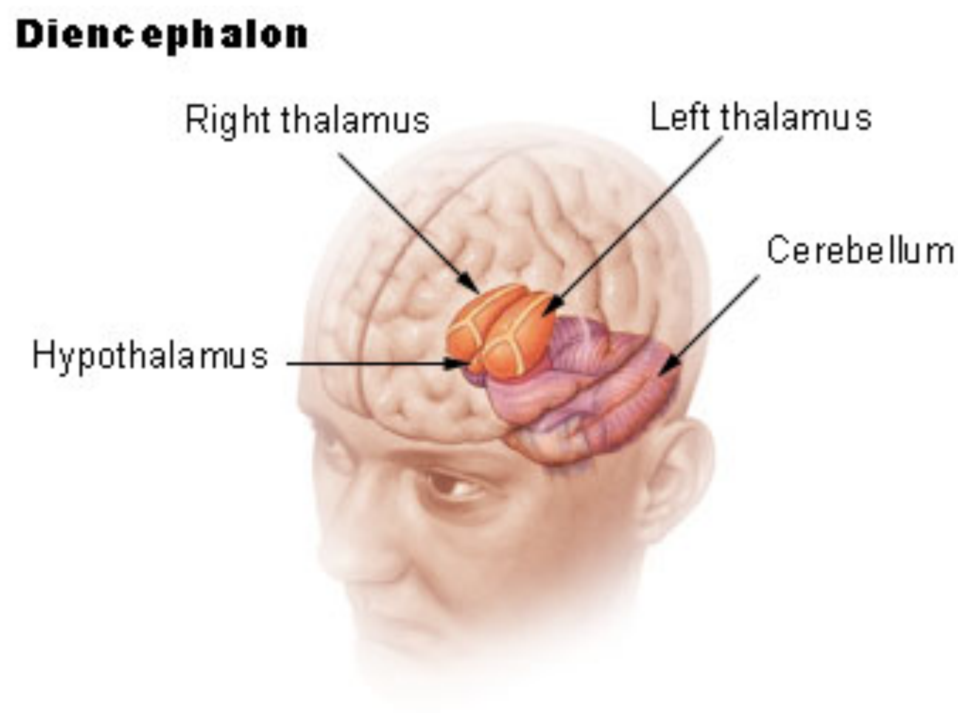


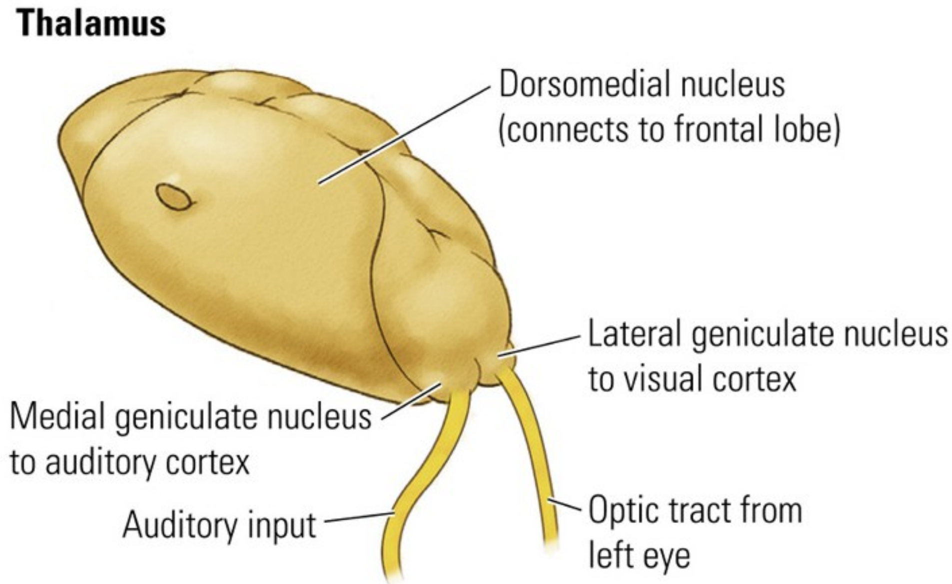
Diagram colors are consistent with Figure AB-16.

Forebrain: Diencephalon

Diencephalon (thalamus and hypothalamus) is the posterior end of the forebrain



Diencephalon: thalamus



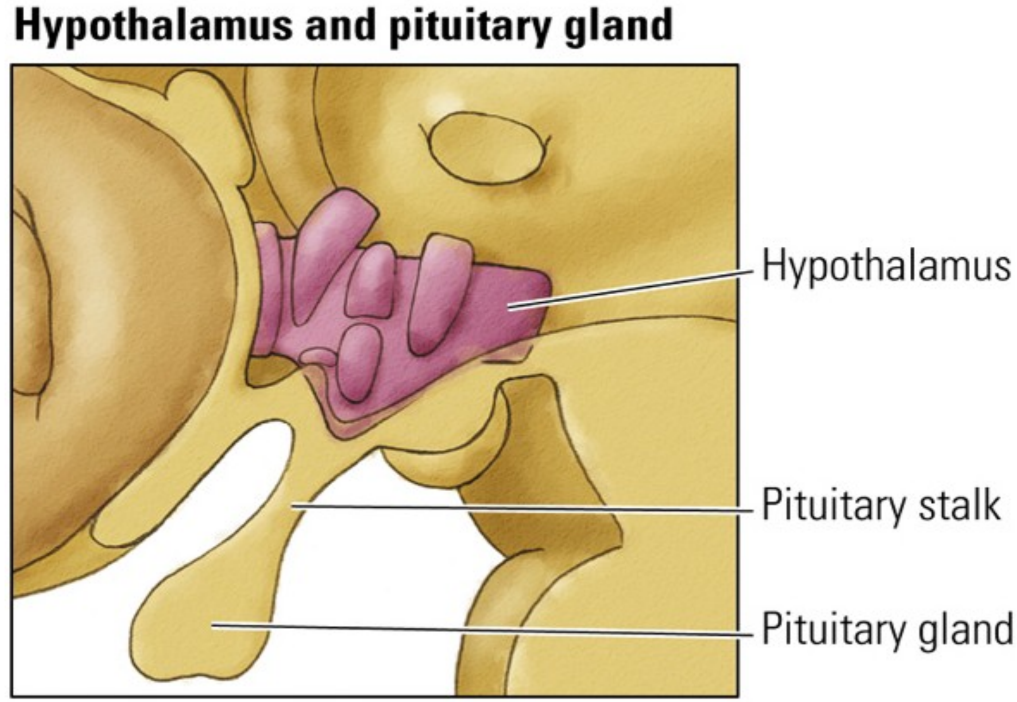
Kolb and Whishaw, 2005

Major processing center

- integration of sensory information and relay to correct cortical areas

Recent data suggest thalamus also helps different areas of cortex talk to each other

Diencephalon: hypothalamus



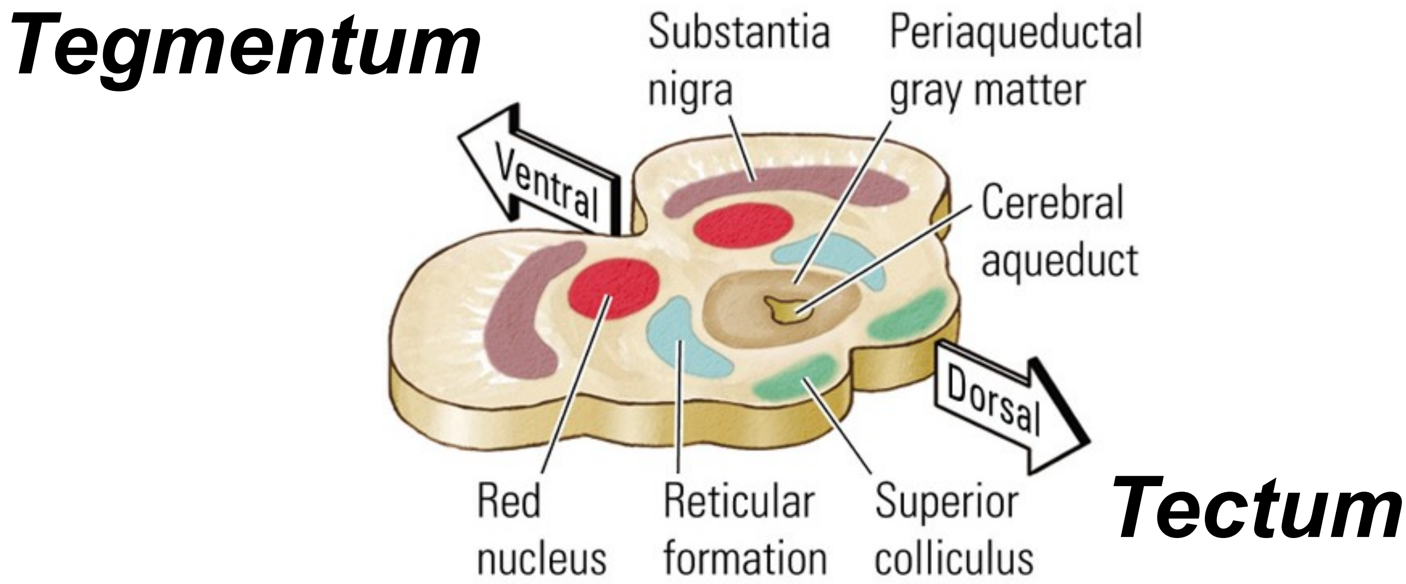
Kolb and Whishaw, 2005

Hypothalamus

- ~22 nuclei involved in many behaviors
  - feeding, sleep, sexual behavior, urination, etc.
  - gender diffs. In hypo.
- controls pituitary gland

Pituitary gland

- release hormones that affect target tissues far from the brain



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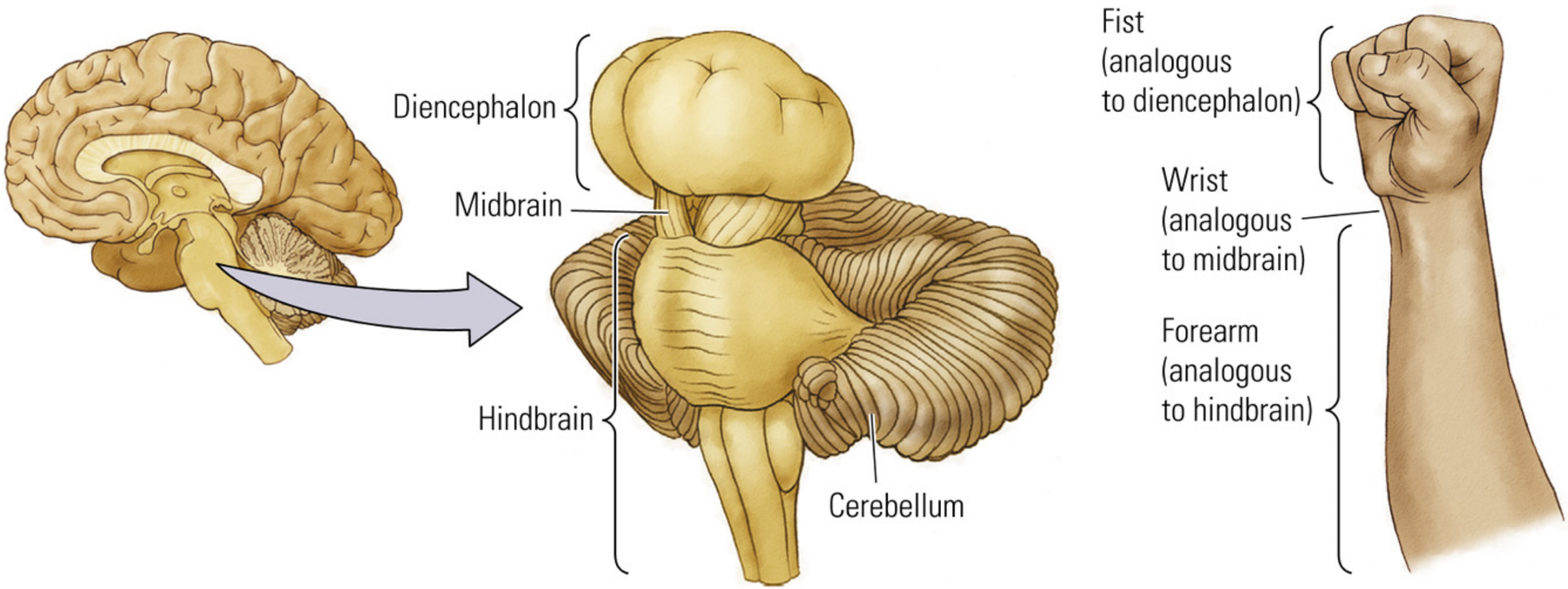
Midbrain

Tectum
- sensory nuclei for head-orientation

Tegmentum
- largely motor nuclei
  - substantia nigra (key in Parkinson's disease)
- ventral tegmental area (motivation/addiction)

Diencephalon, midbrain and hindbrain



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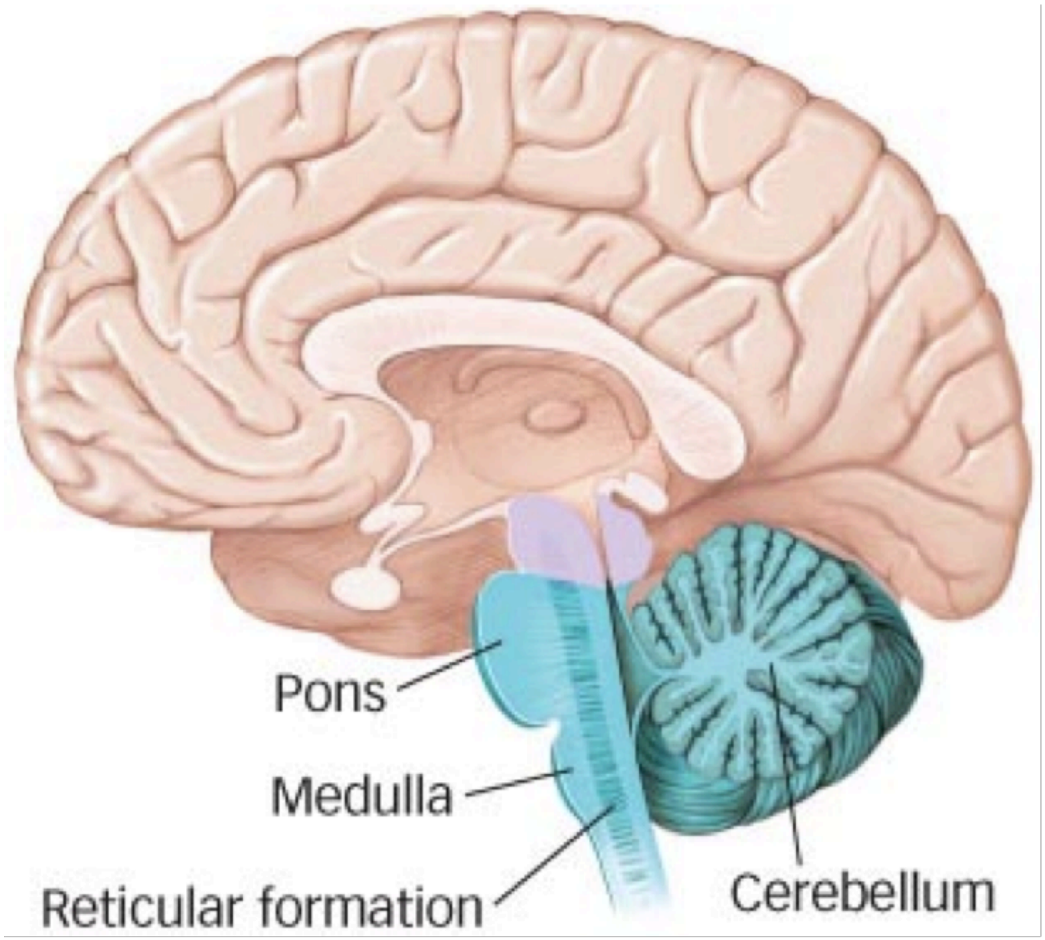
Receives nearly all sensory input and sends outputs directly to motor neurons, controlling almost every movement; sends information to cerebral cortex

Hindbrain

Medulla (oblongata)
- controls vital functions (breathing center, etc.)

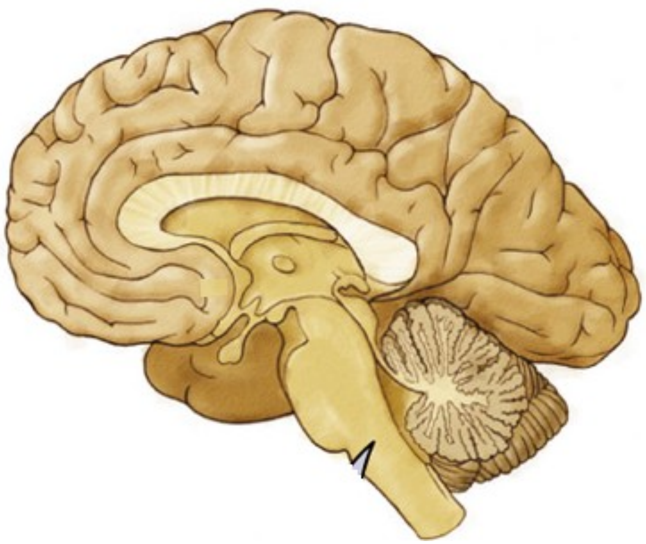
Pons
- many fibers passing though
- w/ medulla, control of homeostasis

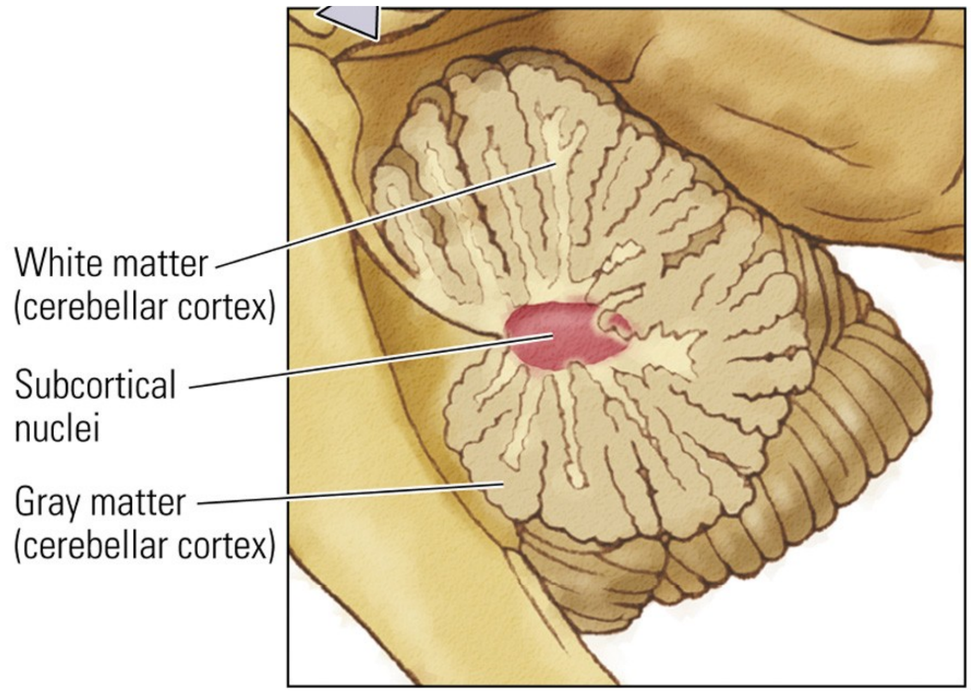
Cerebellum



https://sites.google.com/site/biologyandbehaviortoc/major-divisions-of-the-brain/hindbrain

Cerebellum





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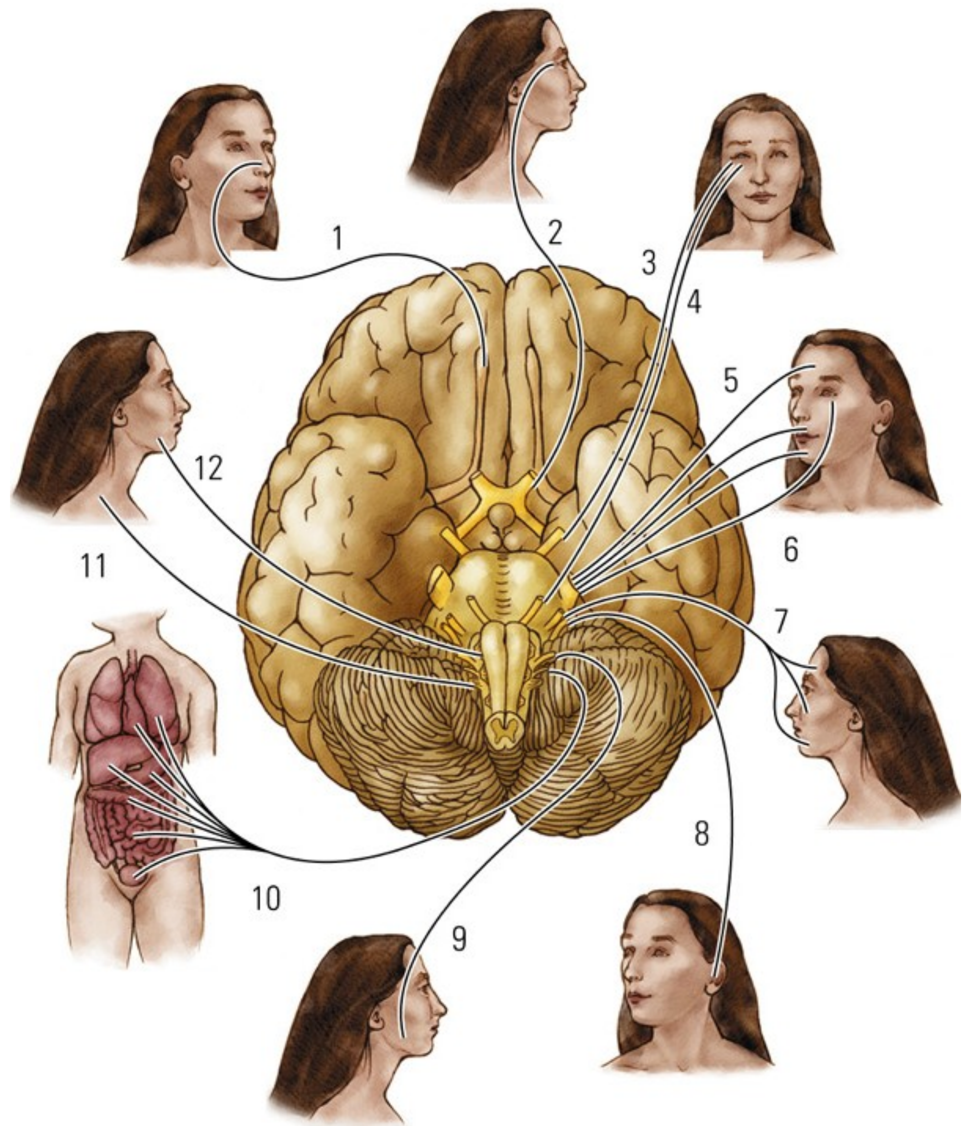
Involved in movement control center (and other functions)

extensive connections with both the cerebral cortex and the spinal cord

Cranial nerves

12 pairs of nerves (axons)
- mostly deal with head & neck, but also visceral control



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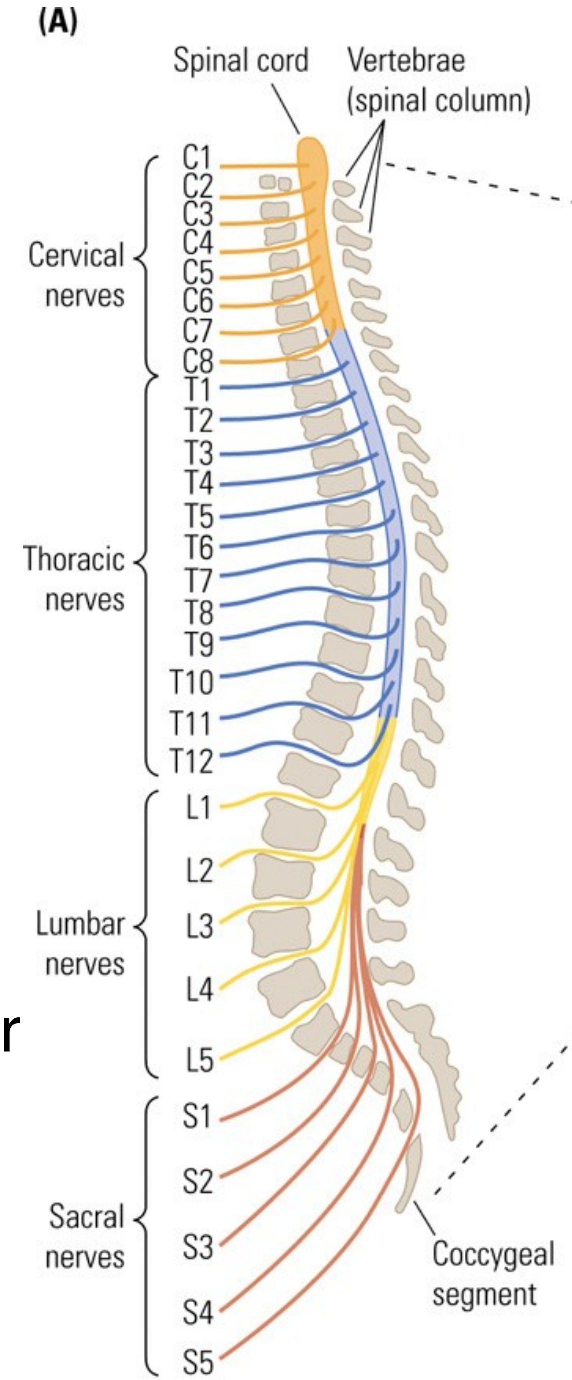
Spinal cord

31 spinal vertebrae

- 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, 1 coccygeal

Each segment of spine gets sensory input from the corresponding body parts

cervical sections get info from arms, lower lumbar and high sacral sections get input from legs



Kolb and Whishaw, 2005

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http://www.tulane.edu/~embryo/labsyllabus.htm