Topic 6: ANATOMY OF THE NERVOUS SYSTEM
Part A

<u>CNS (Chapt.11: pp.389-397;Chapt.12:p.432-455)</u>

- connected as a single unit, but anatomically divided into 2 parts:

  (i) **Central Nervous System**: brain + spinal cord; integrating & command centre

  (ii) **Peripheral Nervous System**: cranial & spinal nerves; pathway of communication between CNS & all parts of body

  A. *Sensory division*: somatic & visceral fibers; **from** receptors **to** CNS (incoming information transmitted to CNS)

  B. *Motor division:* motor nerve fibers **from** CNS **to** effectors (outgoing)

  B1. Somatic ns: voluntary; **from** CNS **to** skeletal muscle (moving consciously)

  B2. Autonomic ns: involuntary; (visceral motor); **from** CNS **to** cardiac muscle, smooth muscle, glands

  a) *Sympathetic division*: “fight or flight”

  b) *Parasympathetic division:* conserve energy at rest

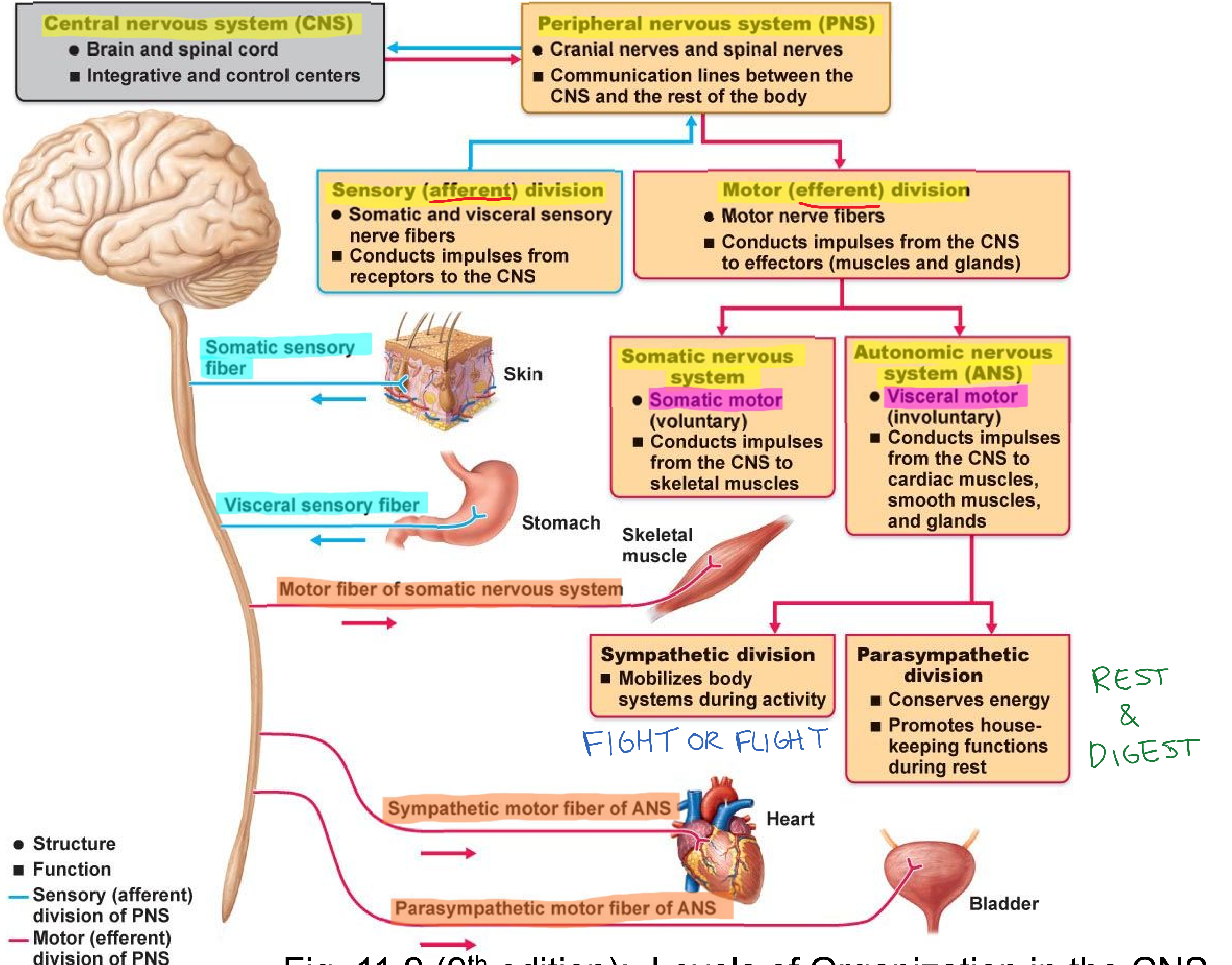


Fig. 11.2 (9th edition): Levels of Organization in the CNS

Histology of Nervous Tissue

- very cellular; minimal extracellular matrix
- 2 principal types of cells:

Fig. 11.4

(i) neurons

(ii) supporting cells

A. Supporting cells: (6 types)

CNS: (4 types – neuroglia)

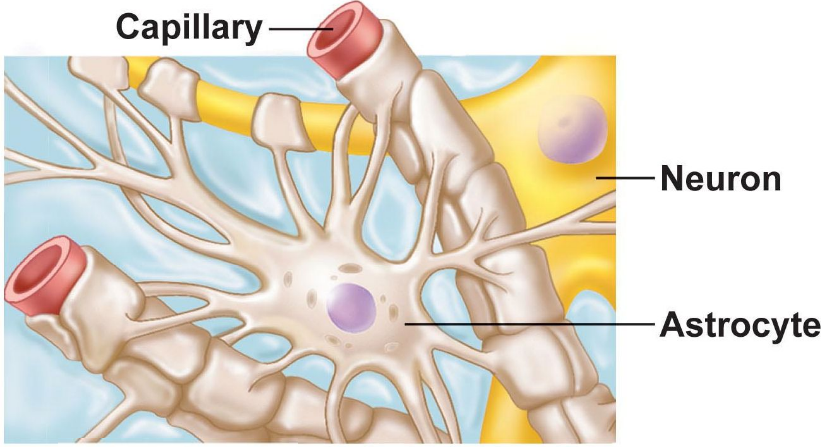
(1) Astrocytes: star-shaped, most abundant; anchor neurons close to capillaries

- roles in nutrient exchange, antigen presentation, control of environment

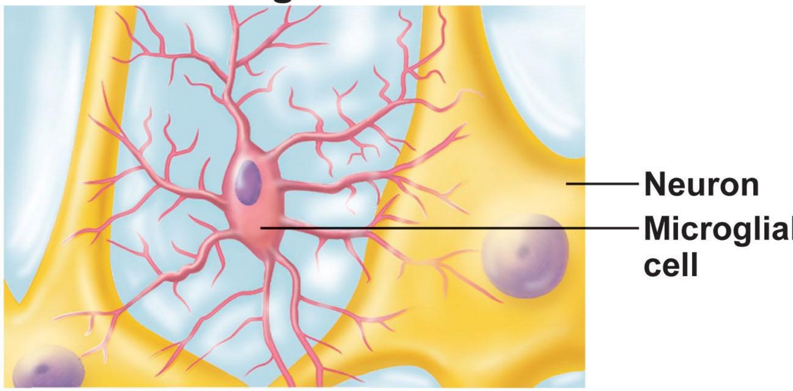
(2) Microglia: protective; touch neurons to monitor well-being; can transform into macrophages if necessary

(3) Ependymal cells: line cavities of brain & spinal cord as barrier between CSF & fluid bathing cells of CNS; cilia circulate CSF

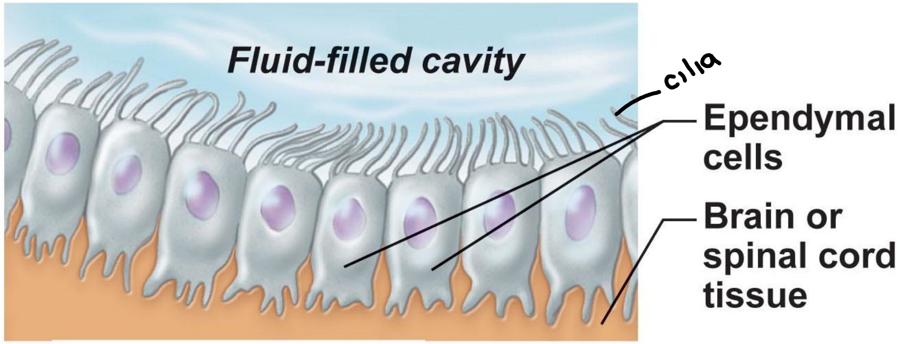
(4) Oligodendrocytes: "few branches"; provide myelin sheaths to CNS neurons



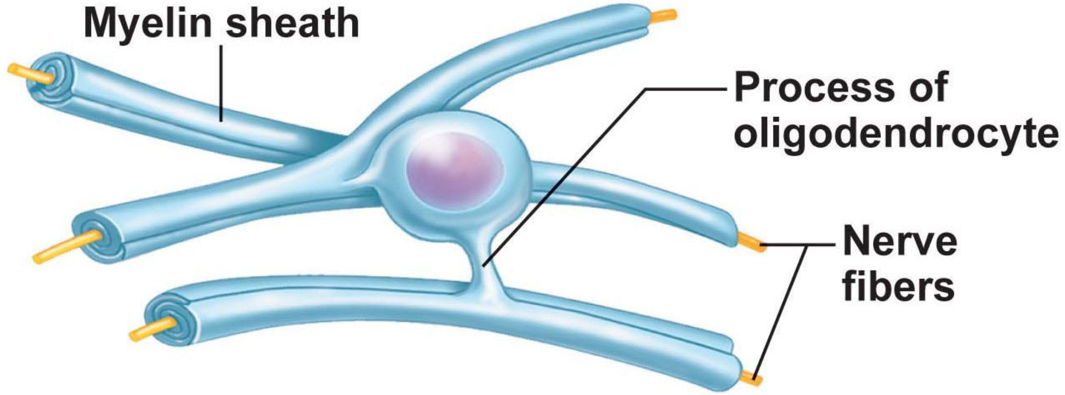
(a) Astrocytes are the most abundant CNS neuroglia.



(b) Microglial cells are defensive cells in the CNS.



(c) Ependymal cells line cerebrospinal fluid–filled cavities.

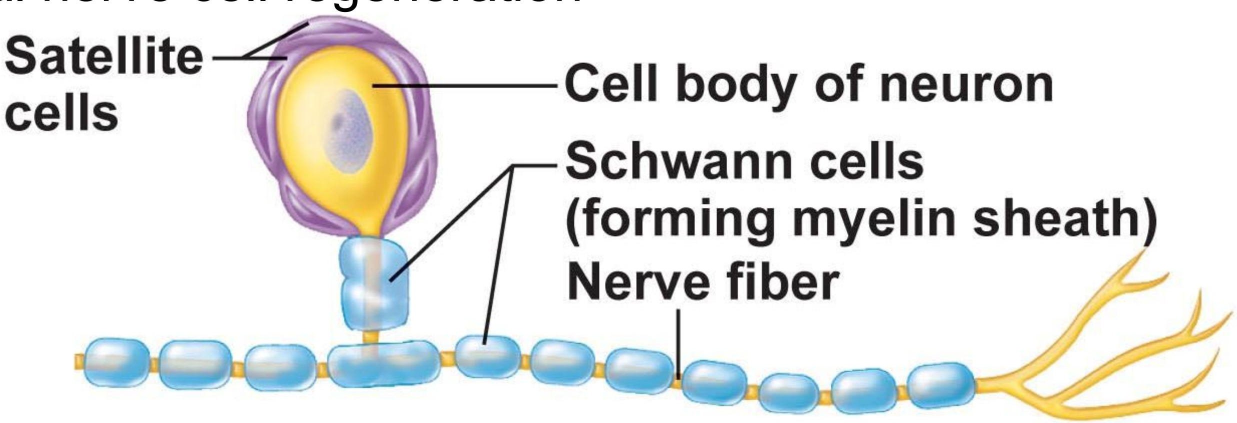


(d) Oligodendrocytes have processes that form myelin sheaths around CNS nerve fibers.

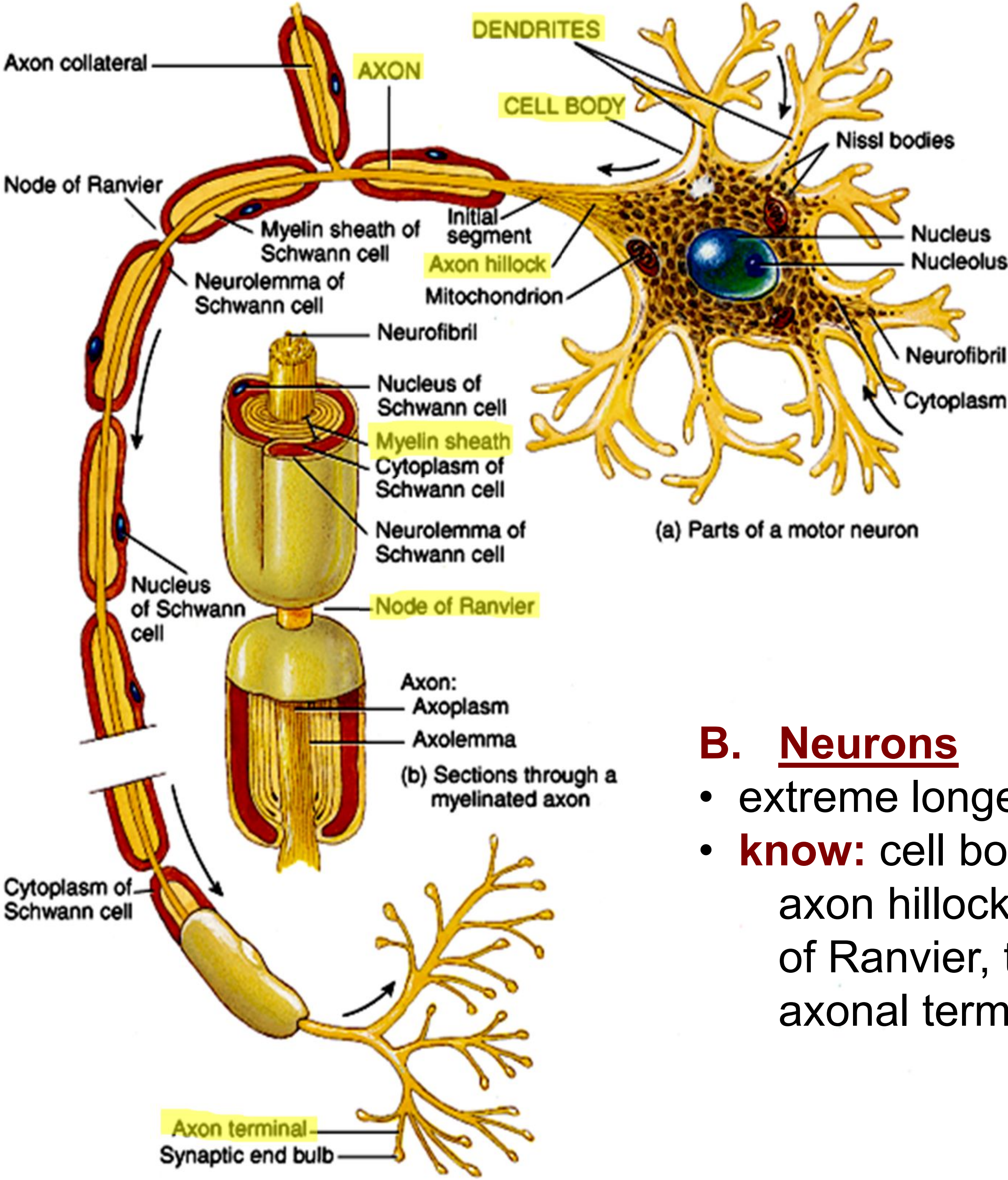
PNS:

(1) Satellite cells: surround neuron cell bodies in ganglia (cluster) – influence chemical environment of these neurons (?), protect neuron cell bodies

(2) Schwann cells: form myelin sheaths around larger neurons in PNS; vital to peripheral nerve cell regeneration



(e) Satellite cells and Schwann cells (which form myelin) surround neurons in the PNS.



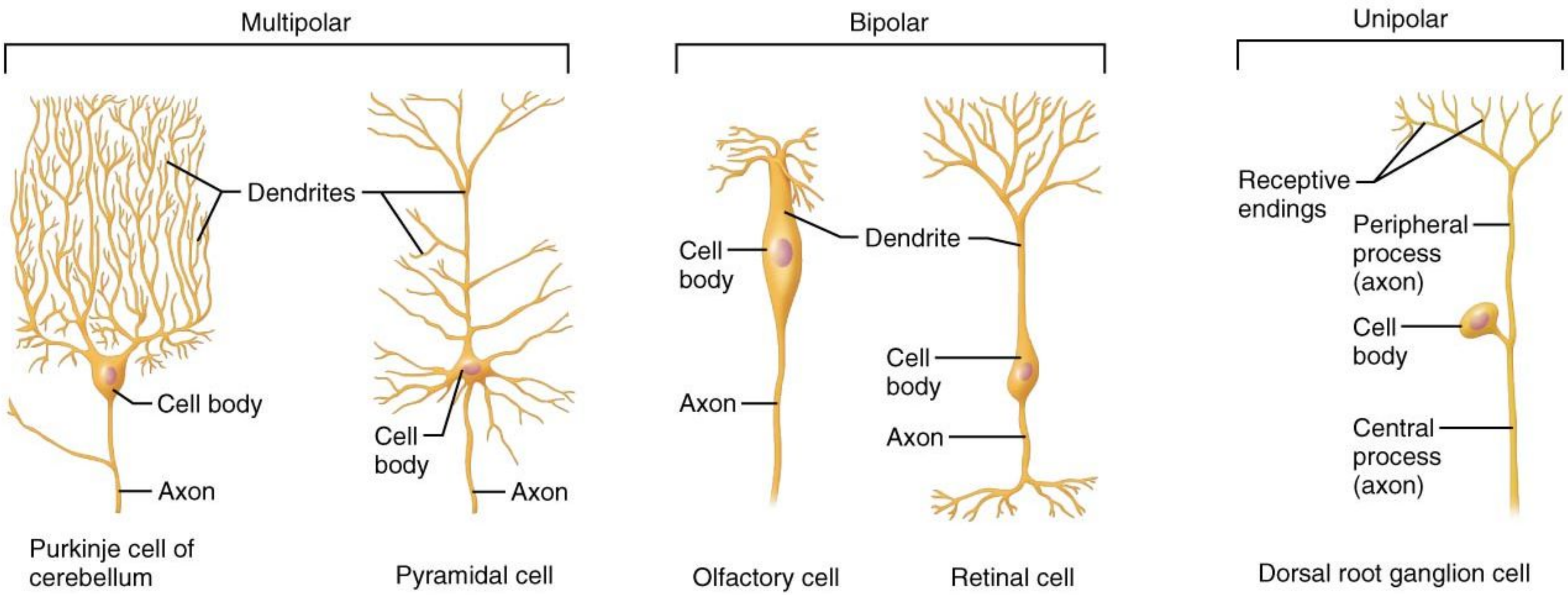
B. Neurons

- extreme longevity, amitotic, high MR
- **know:** cell body, dendrites, axon, axon hillock, myelin sheath, node of Ranvier, terminal branches, axonal terminals

C. Structural Classification of Neurons

Table 11.1 Comparison of Structural Classes of Neurons *(continued)*

	NEURON TYPE	
MULTIPOLAR	**BIPOLAR**	**UNIPOLAR (PSEUDOUNIPOLAR)**
Relative Abundance and Location in Human Body		
Most abundant in body. Major neuron type in the CNS.	Rare. Found in some special sensory organs (olfactory mucosa, eye, ear).	Found mainly in the PNS. Common only in dorsal root ganglia of the spinal cord and sensory ganglia of cranial nerves.
Structural Variations		



D. Functional Classification of Neurons

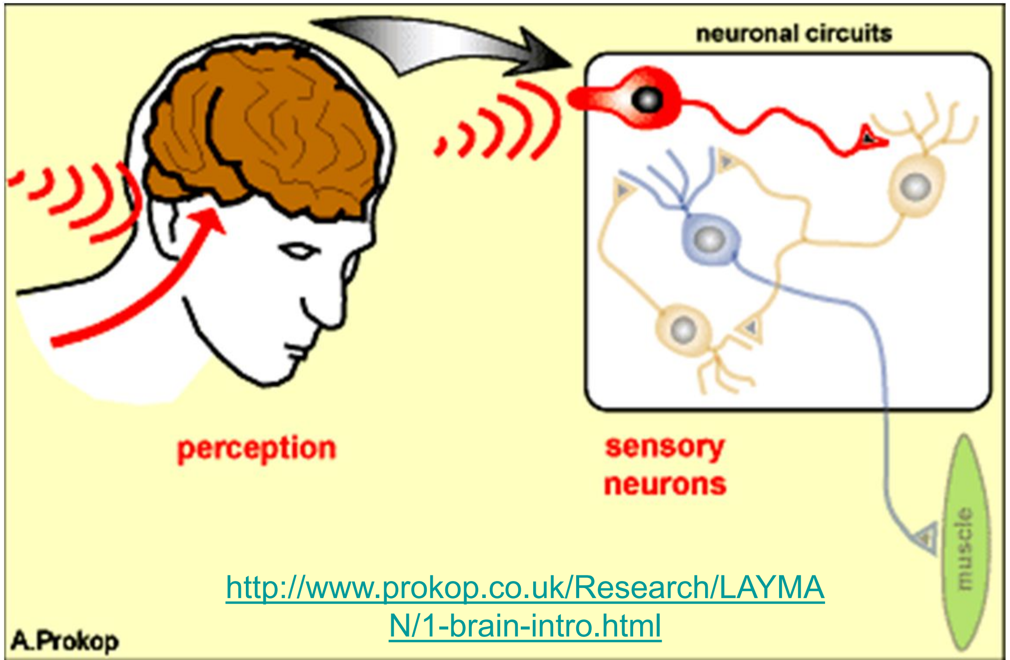
- according to ***direction*** nerve impulse travels with respect to CNS
- sensory, motor & association neurons

(i)sensory: **toward** CNS; primary, secondary, tertiary

- except bipolar neurons in some special sense organs, virtually all **primary** sensory neurons are **unipolar** & cell bodies located in ganglia **outside** CNS
- higher order sensory neurons all multipolar & reside entirely within CNS – conduction to higher brain centers for interpretation

(ii)motor: **away** from CNS to effector organs like muscle & glands; multipolar; most cell bodies reside in CNS

(iii)association (interneurons): **between** sensory & motor neurons – integration of info; multipolar; most entirely within CNS; 99% of neurons of the body



http://www.prokop.co.uk/Research/LAYMAN/1-brain-intro.html

The Brain (jump to chapter 12 here)

- complexity of wiring rather than size is what matters

subdivisions:

cerebral hemispheres

diencephalon (thalamus, hypothalamus, epithalamus)

brain stem (midbrain, pons, medulla)

cerebellum

each subdivision has a different level of awareness

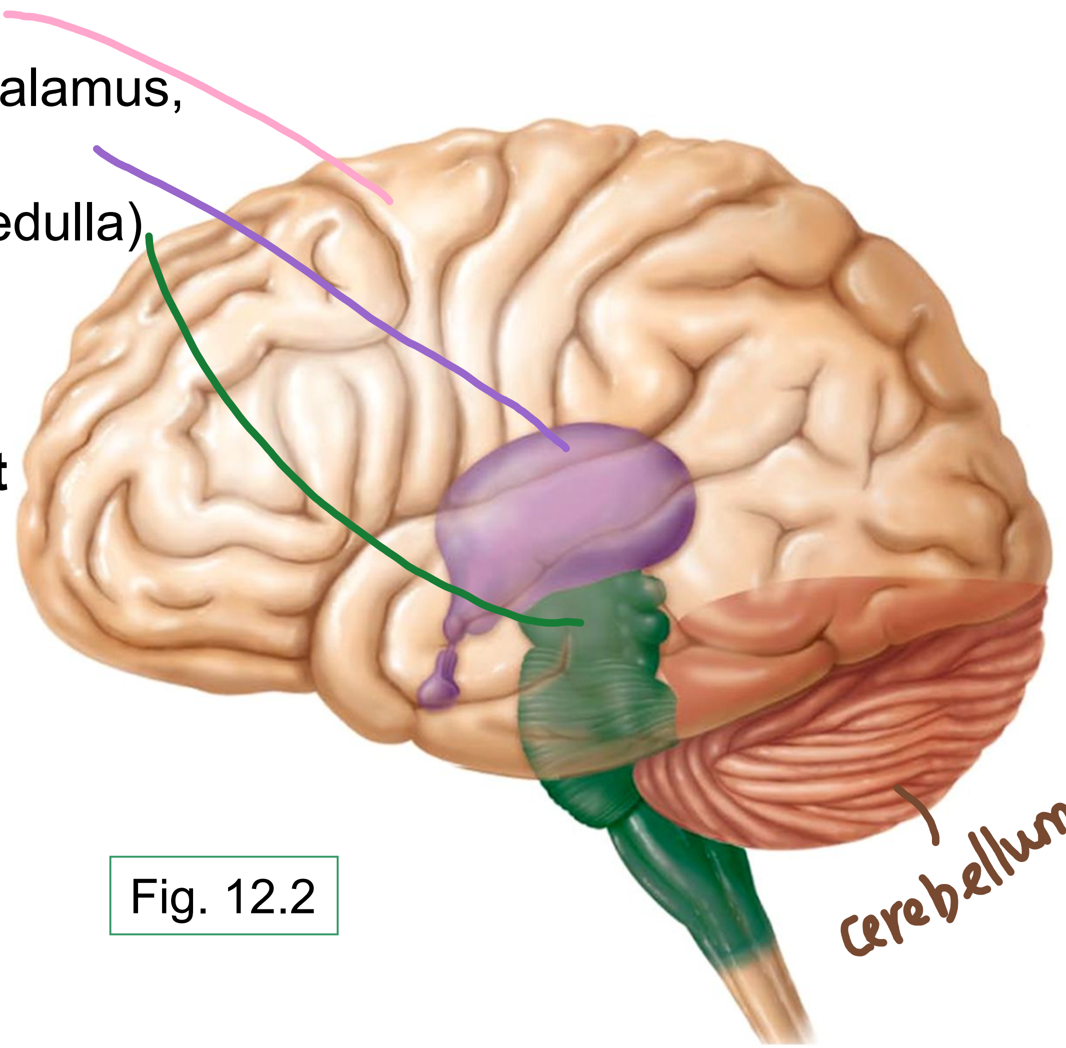


Fig. 12.2

Arrangement of gray & white matter:

Spinal cord has central cavity surrounded by gray matter (neuron cell bodies and anything not myelinated) & white matter (primarily myelinated axons)
Brain has same design, but with additional regions of gray matter (**nuclei**); cerebral hemispheres & cerebellum have outer "bark" of gray matter (**cortex**)

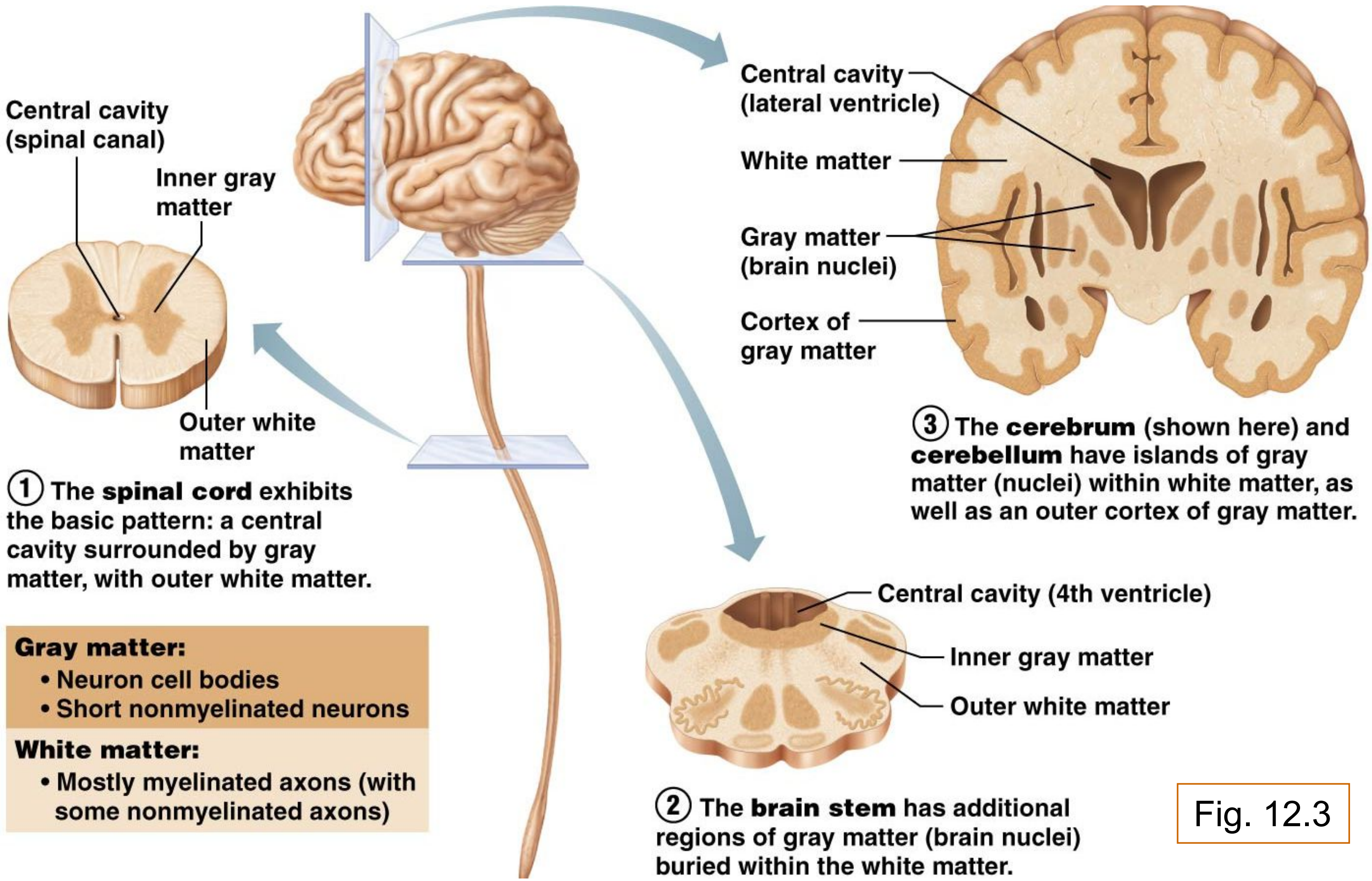


Fig. 12.3

Ventricles of Brain:

continuous with one another and with central cavity of spinal cord; filled with **cerebral spinal fluid** & lined by **ependymal** cells

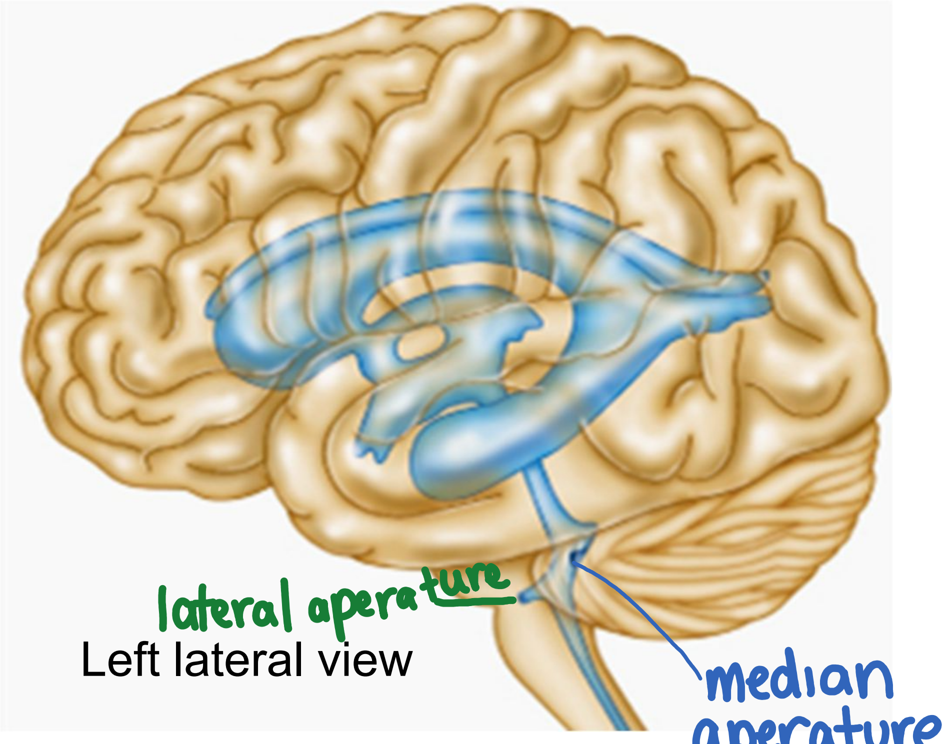
(i) Paired **lateral ventricles** separated by narrow septum pellucidum

(ii) Each communicates with narrow **3rd ventricle** in diencephalon via interventricular foramen

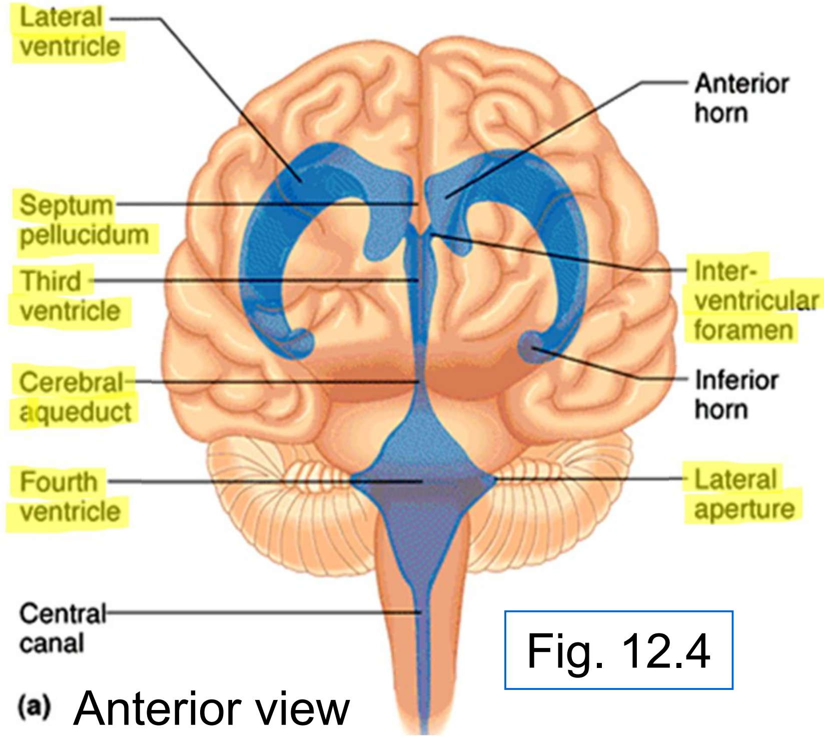
(iii) 3rd ventricle to **4th ventricle** (dorsal to pons) via cerebral aqueduct

(iv) 4th ventricle continuous with central canal

(v) 3 **apertures** (paired lateral apertures & median aperture) connect ventricles to **subarachnoid space** (surrounds brain)

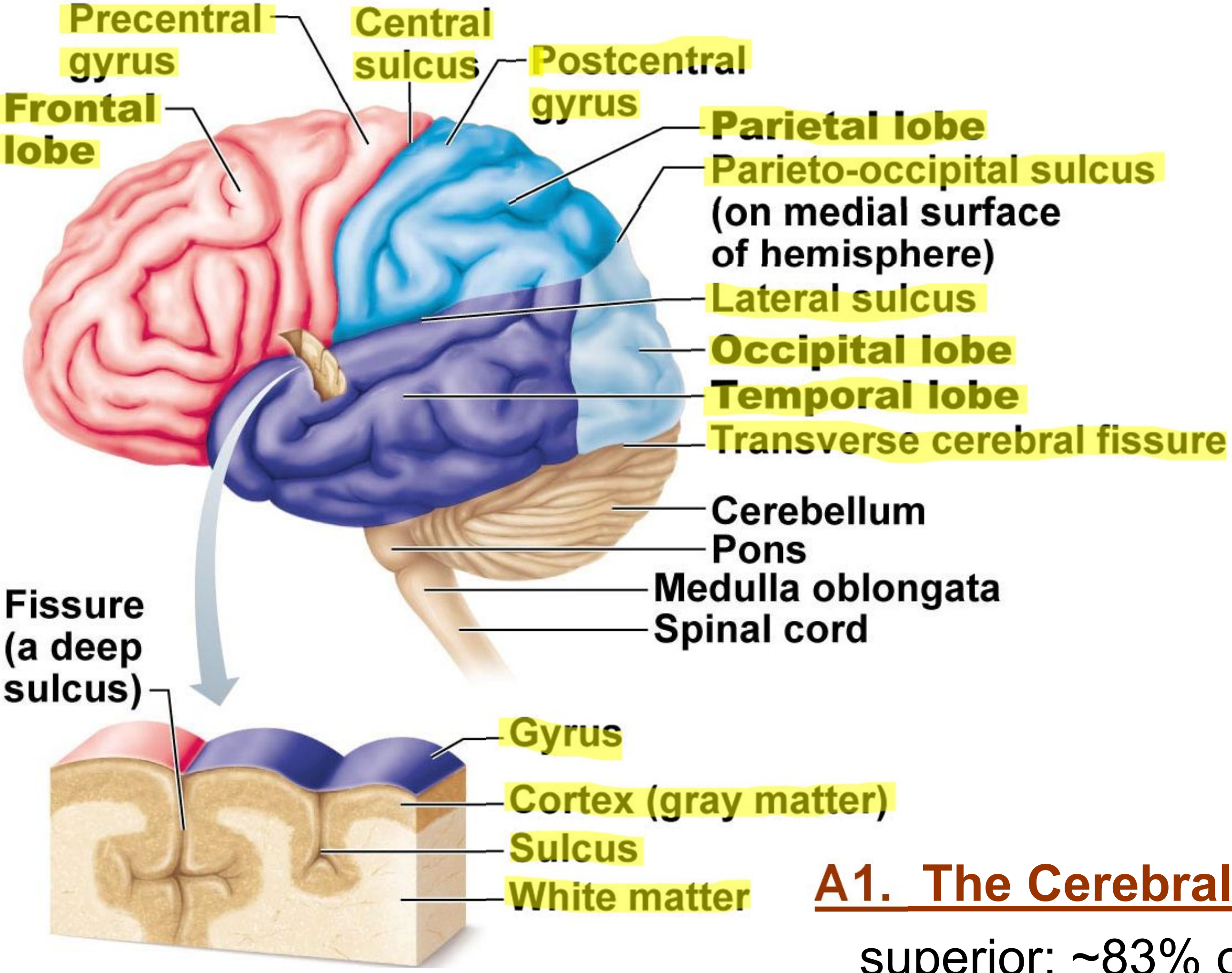


Left lateral view



(a) Anterior view

Fig. 12.4



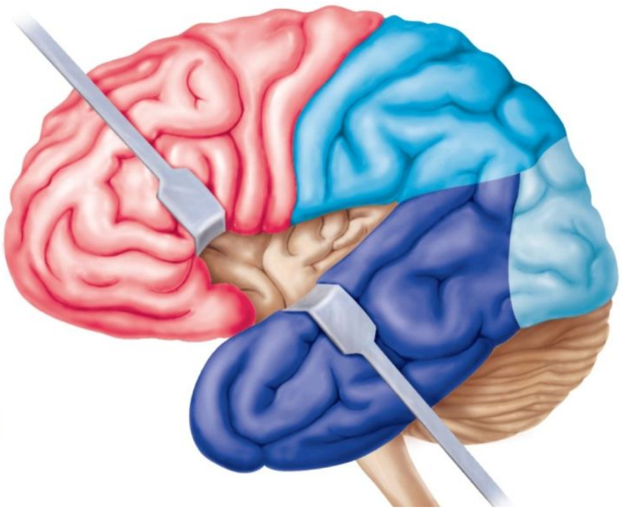


Fig. 12.5c

A1. The Cerebral Hemispheres

superior; ~83% of brain mass

gyri separated by **sulci**; anatomical landmarks

longitudinal fissure; transverse cerebral fissure

Lobes: frontal, parietal, occipital, temporal, insular

central sulcus: precentral/postcentral gyrus

parieto-occipital sulcus, lateral sulcus

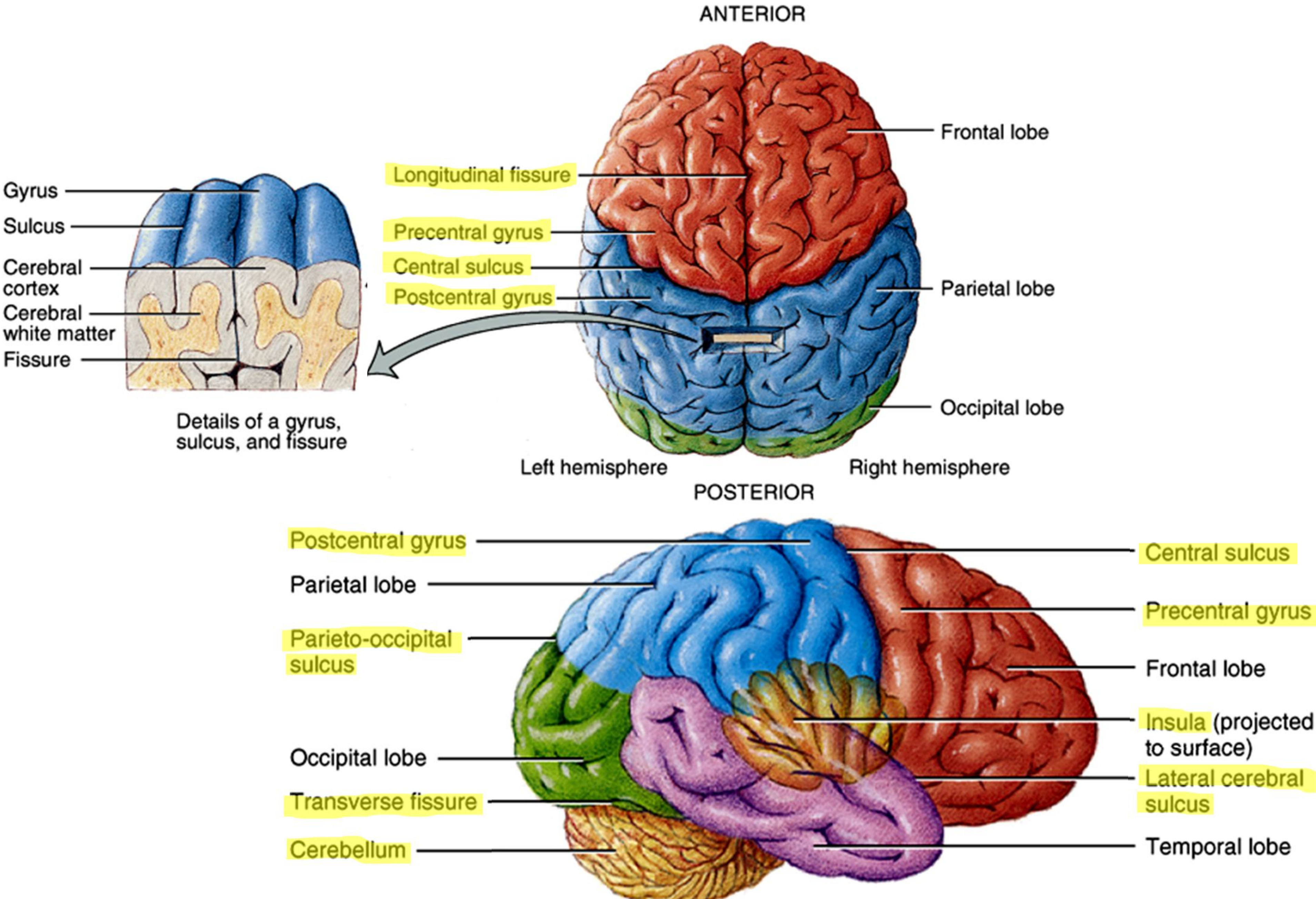


Fig. 14.11 (T&G)

(b) Right lateral view

Cerebral cortex:

- allows us to perceive, communicate, remember, understand, appreciate, initiate voluntary movements -- **conscious behaviour**
- cell bodies, dendrites & unmyelinated axons; only 2-4 mm thick, but many convolutions triple surface area
- **Brodmann** areas: numbered according to subtle differences in thickness, structure of contained neurons; some areas link with particular functions; other functions (memory & language) have overlapping domains; more diffusely organized

(i) 3 functional areas: **motor**, **sensory** & **association**

(ii) each hemisphere handles sensory & motor functions of opposite side of body

(iii) largely symmetrical, but not 100% equal in function (lateralization)

(iv) no functional area of cortex acts alone; all conscious behaviour involves entire cortex in some way

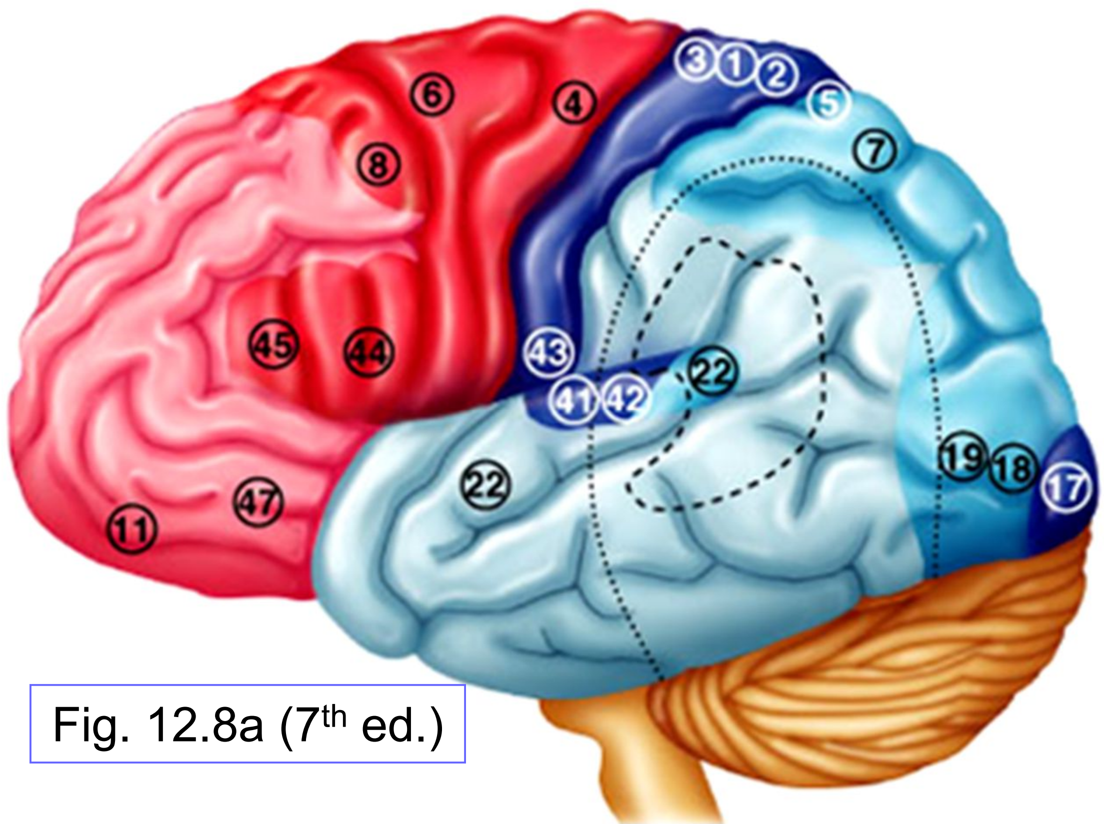


Fig. 12.8a (7th ed.)

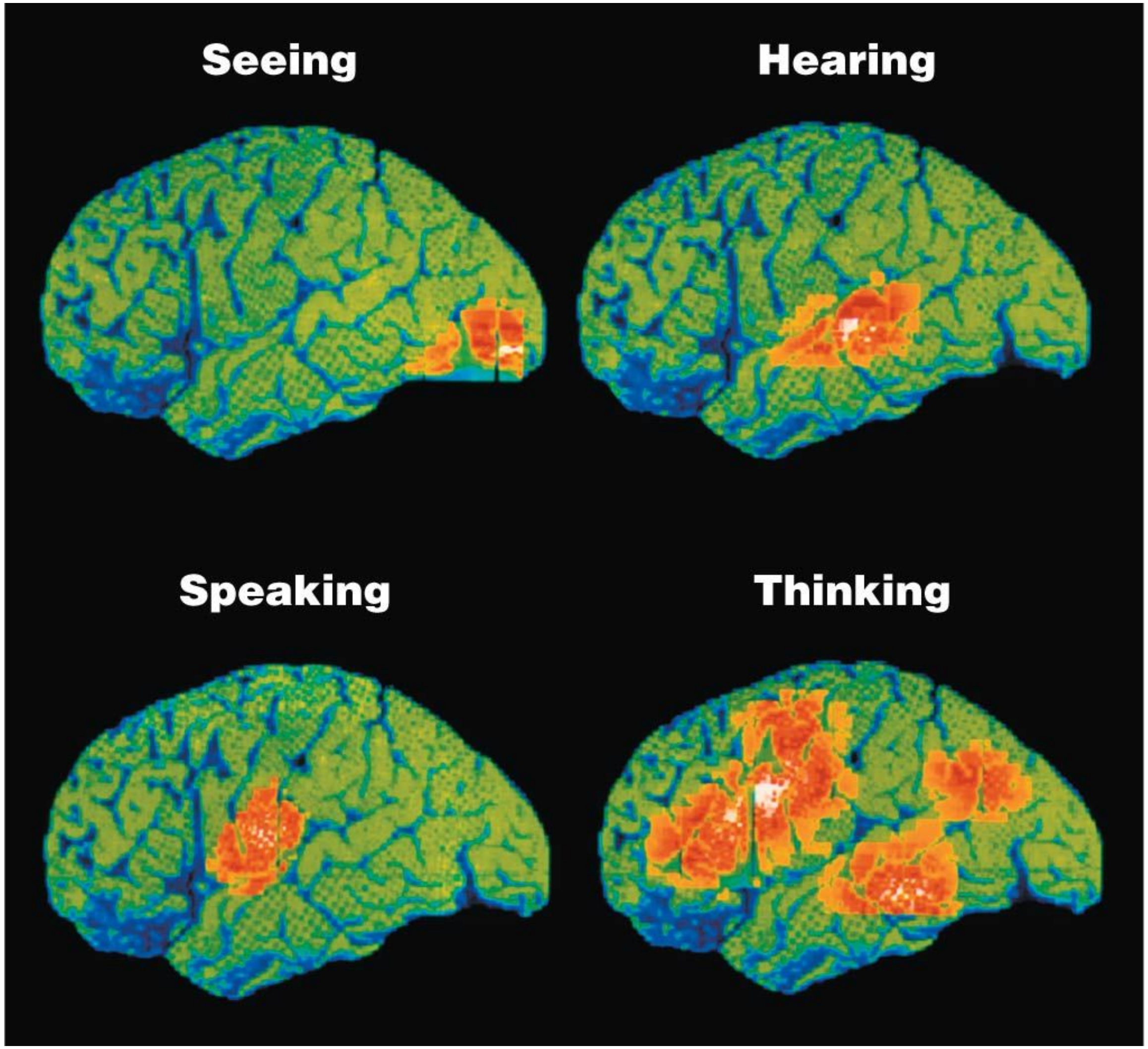
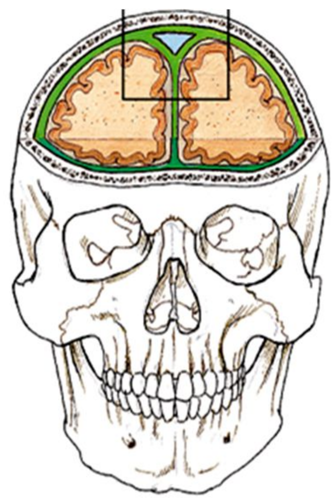


Fig. 12.6. Functional neuroimaging of cerebral cortex. Red & orange areas show increased blood flow when cortex involved in various activities.

(i) Motor Areas:

- posterior part of frontal lobes: primary motor cortex, premotor cortex, Broca's area & frontal eye field

1) **Primary motor cortex (area 4):** - precentral gyrus of frontal lobe of each hemisphere; **pyramidal cells** allow control of skeletal muscles; axons project to spinal cord as pyramidal/corticospinal tracts



- entire body represented spatially in primary motor cortex of each hemisphere – **somatotopy**
- which areas require most precise motor control?
- motor innervation is **contralateral**

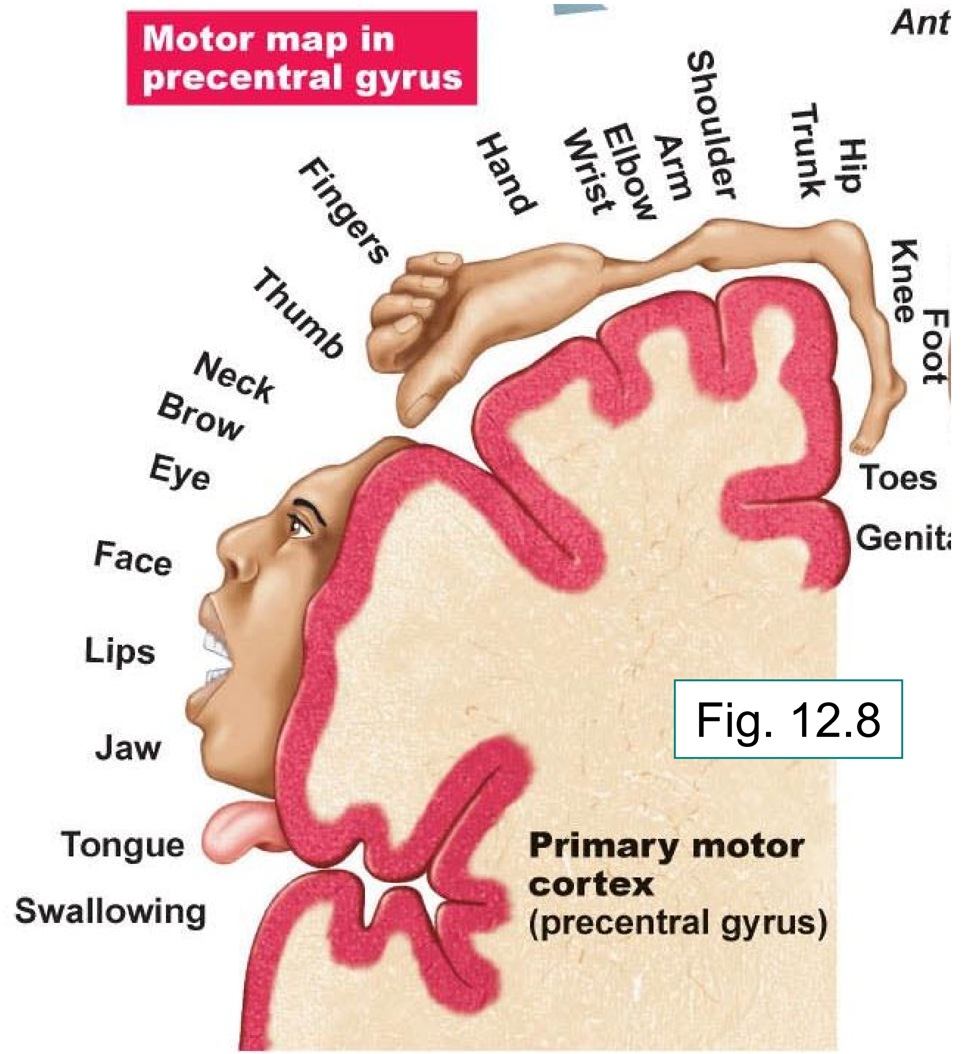


Fig. 12.8

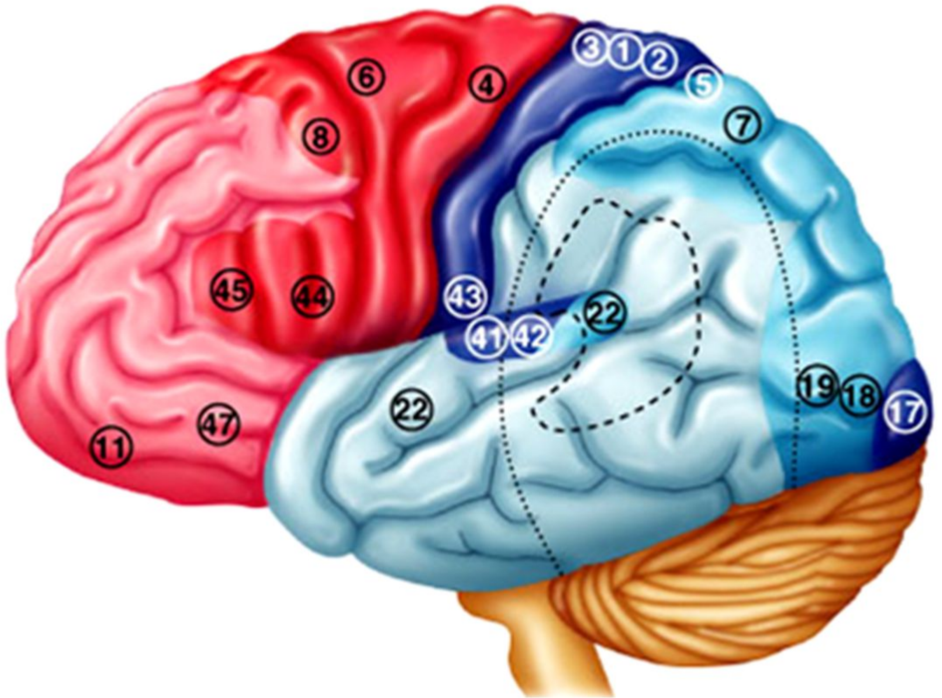
Penfield Homunculus

Wilder Penfield

control not as simple as in diagram – some neurons send impulses to more than one muscle – think about coordinated movement of arm, drawing from a bunch of different areas

no overlap between muscles involved in unrelated movements

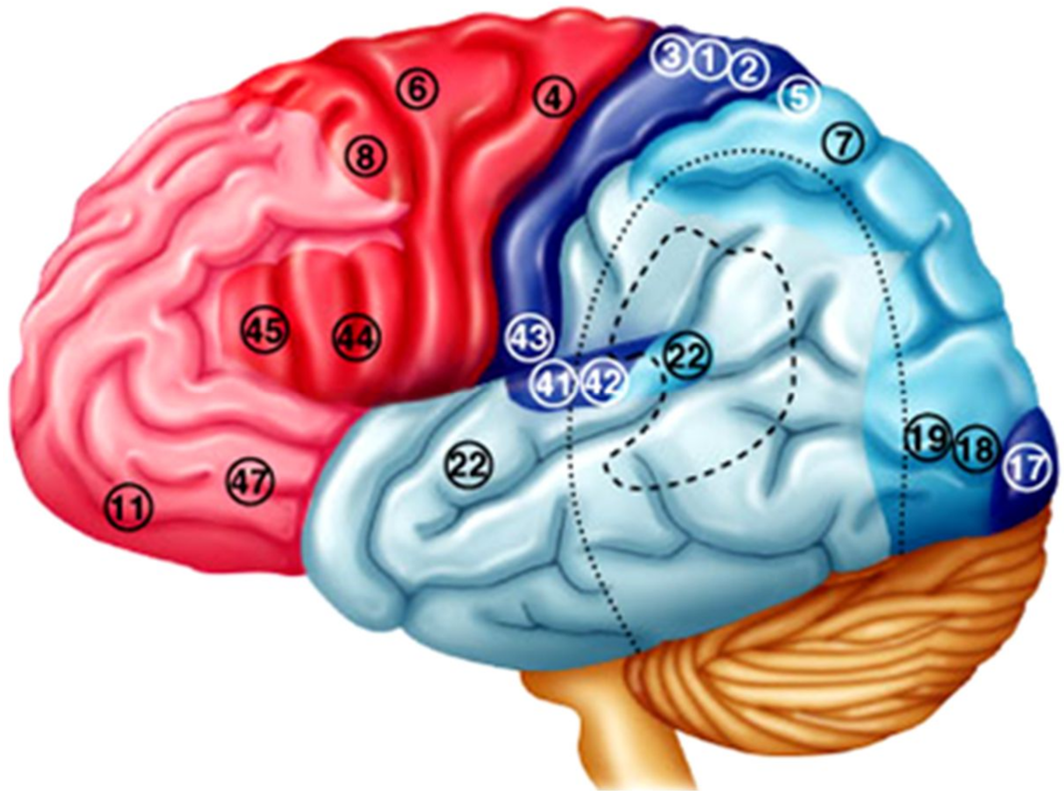
stroke: damage to area of right hemisphere paralyzes body muscles on left – only voluntary movement lost; reflex contraction still possible



2. Premotor cortex (around area 6):

- anterior to precentral gyrus
- helps plan movements by selecting and sequencing basic motor movements into more complex tasks (e.g. playing musical instrument, keyboarding, ie. practice)
- coordinates movement of several muscle groups simultaneously/sequentially by activating motor cortex
- can control voluntary actions that depend on sensory feedback – e.g. feeling for light switch in a dark room

What if there is damage to the area of premotor cortex regulating keyboarding?
-> you can still type the letters because primary motor cortex is okay, but have to relearn patterns

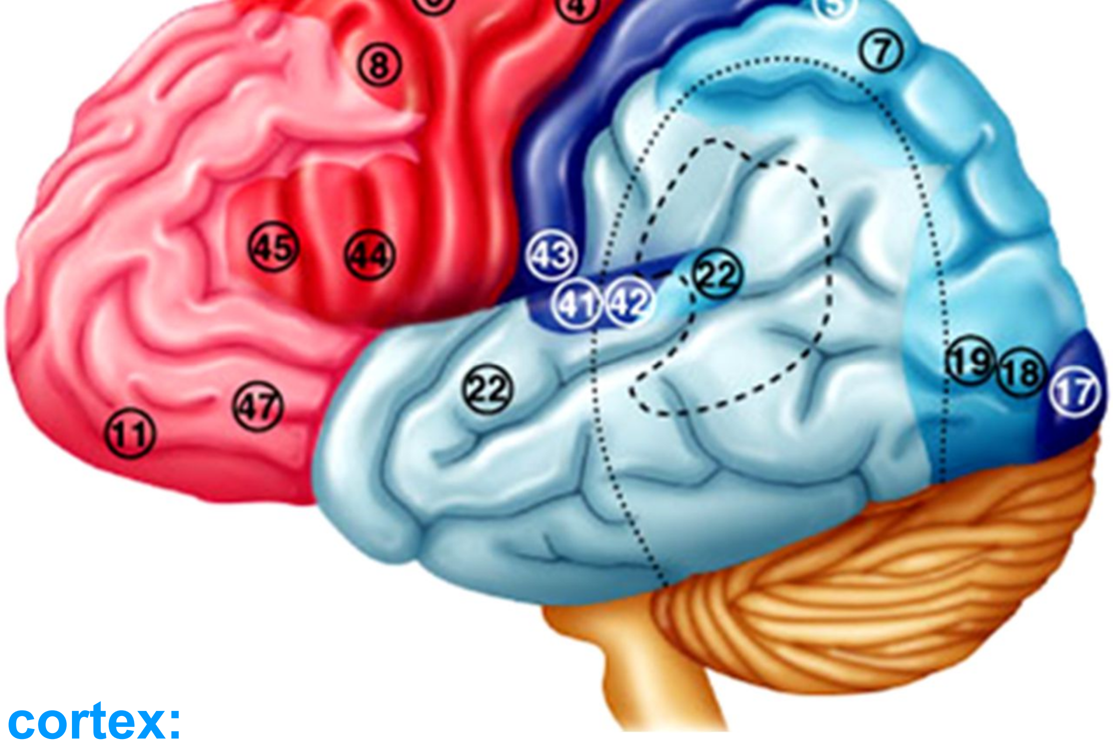


3. Broca's area:

- overlaps Brodmann areas 44 & 45
- present in one hemisphere only – usually the left
- originally thought to be <u>only</u> a motor speech area
- newer studies: Broca's area is active when we prepare to speak and plan voluntary activities other than speech, getting READY to do things

4. Frontal eye field:

- Brodmann area 8; controls voluntary movements of the eyes (nothing to do with visual information), control activity of muscles that control eye movement



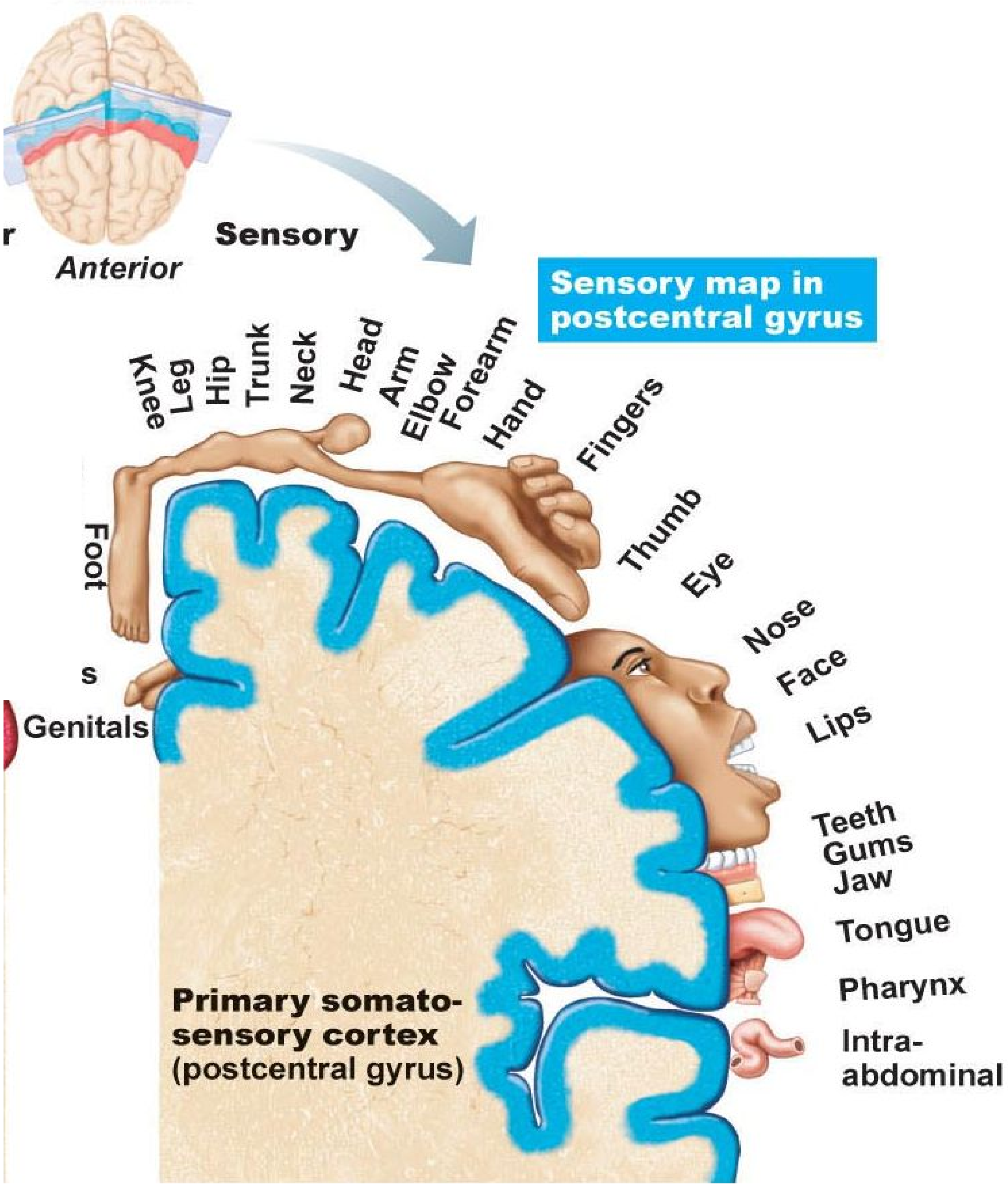
(ii) *Sensory Areas*

1. **Primary somatosensory cortex:**

- in postcentral gyrus of parietal lobe (Brodmann areas (BA) 1-3) (dark blue)
- receives info from somatic sensory receptors (skin (touch, pressure, pain receptors)) & proprioreceptors (skeletal muscle) (what area of the body the touch is)
- **spatial discrimination**

2. **Somatosensory association cortex:**

- posterior to PSC (BA 5-7) - many connections with it
- integrate/analyze somatic inputs (temp, pressure, ..) – interpret wrt size, texture, relationship of parts based on prior experience (put hand in pocket and determine what object you're touching; drawing on memory)



r
Anterior
Sensory
Sensory map in postcentral gyrus
Knee
Leg
Hip
Trunk
Neck
Head
Arm
Elbow
Forearm
Hand
Fingers
Thumb
Eye
Nose
Face
Lips
Teeth
Gums
Jaw
Tongue
Pharynx
Intra-abdominal
Foot
s
Genitals
Primary somato-sensory cortex (postcentral gyrus)

Fig. 12.8

3. Visual areas:

primary visual cortex (17)-> posterior tip occipital lobe

- largest cortical area; contains map of visual space on retina (opposite sides)

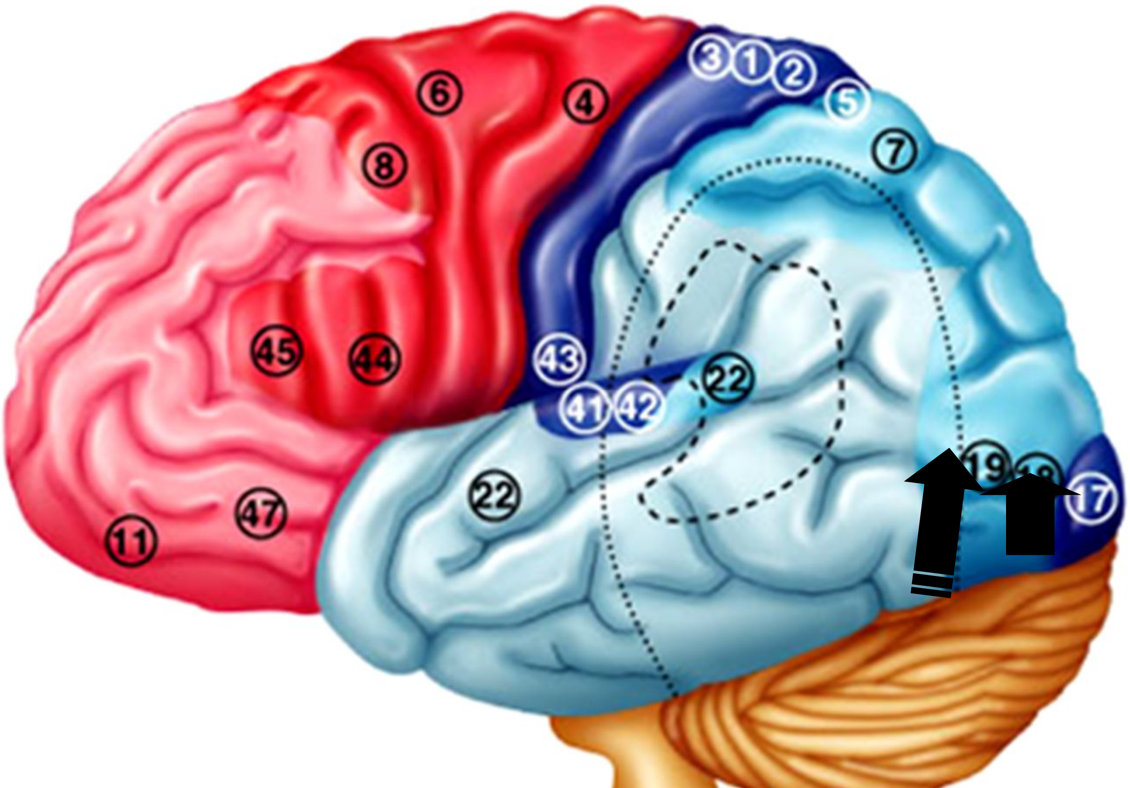
visual association area (18,19 area)-> surrounds PVC

- interprets visual image based on prior experience – eg: recognition of a face, letter (also movement!), words on a sign, ie. make sense of what you're seeing

What is the result of damage to the primary visual cortex? To the visual association area?

PVC: you can't see

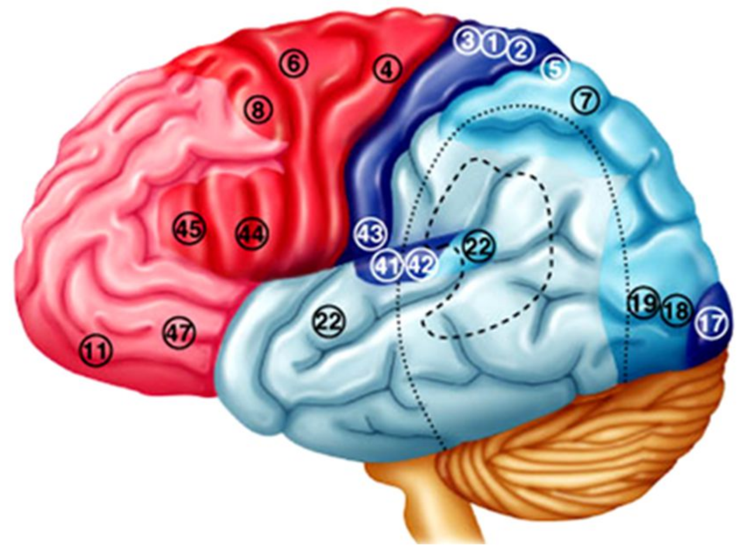
VAA: you can see but it won't make sense to you (won't know what things are called)



4. Auditory areas:

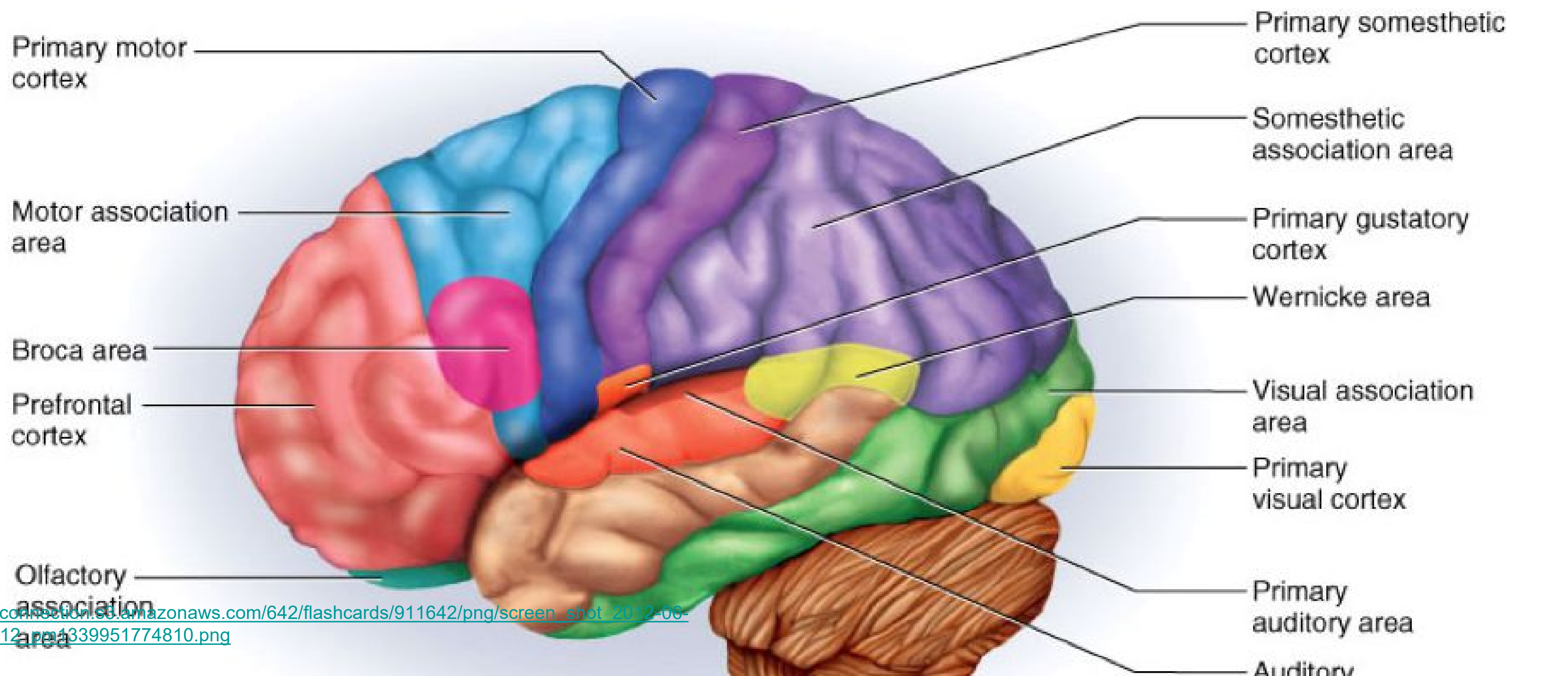
primary auditory cortex (~ BA 42) sound evaluated wrt pitch, rhythm, loudness

auditory association area (~ BA 22) interpretation based on memory – speech, words, music, thunder, etc. -> recognition



5. Vestibular (equilibrium) cortex:

- awareness of balance – posterior part of insula & adjacent parietal cortex
- (not on diagram because deep)



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6. Olfactory cortex:

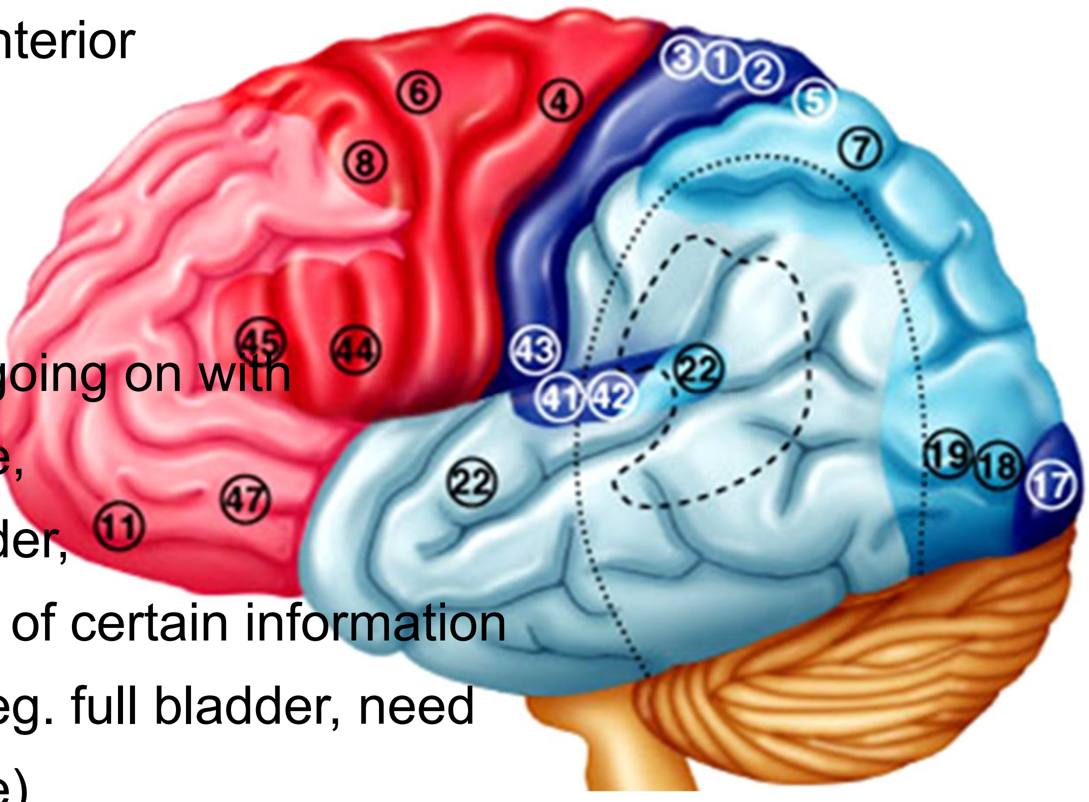
- medial aspects of temporal lobes = **uncus**
- small in humans; most of surrounding tissue now forms limbic system (emotions, memory)
- conscious awareness of different odors

7. Gustatory cortex:

- sense of taste
- insula; ~ BA 43 and a bit anterior

8. Visceral sensory area:

- posterior to gustatory cortex
- not aware of most of what's going on with visceral organs (blood pressure, intestinal information, low bladder, nausea), but makes you aware of certain information when conditions are extreme (eg. full bladder, need to vomit, high af blood pressure)



THE MAN WHO READS FACES

Elm Street (Oct/2002)

(post on web site)

When he was 29 years old, Kevin Chappell figured that he could use his formidable brain to accomplish just about anything. He had an IQ of 147 and a ton of drive. He had just been accepted at medical school. He was researching his master's thesis on the trial of King Charles I, with most of the texts in Latin.

He had always mastered whatever task he gave himself, whether it was playing lead guitar in his hard-rock band, graduating at the top of his class with a 94 per cent average from Trent University or keeping fit for soccer, his lifelong passion.

Then, in an instant, his life was transformed. It was a drizzly, dark evening on January 30, 1988. Chappell had just finished a long day studying at Queen's University in Kingston, Ont., when he stepped outside for a run. He ran up to an intersection and jogged on the spot, taking his pulse. The light turned and he started across the street. Suddenly, a car hit his right hip and threw him into the air. His head slammed against the windshield. Chappell fell to the ground, tried to get up to yell at the driver and then collapsed. For a moment, he felt serene, almost peaceful. From then on, his world would never look the same.

Chappell has one of the strangest brain injuries you can imagine. In fact, there may be only two or three humans on the planet like him. There is nothing the matter with his eyes, although his peripheral vision was impaired by the accident. Chappell can see, but he cannot recognize things. Put a pair of sunglasses in front of him and he sees them. He can describe what they look like. Although he knows what sunglasses are used for, he can't tell what they are just by examining them. It's as if he's living in a world of unidentifiable objects.

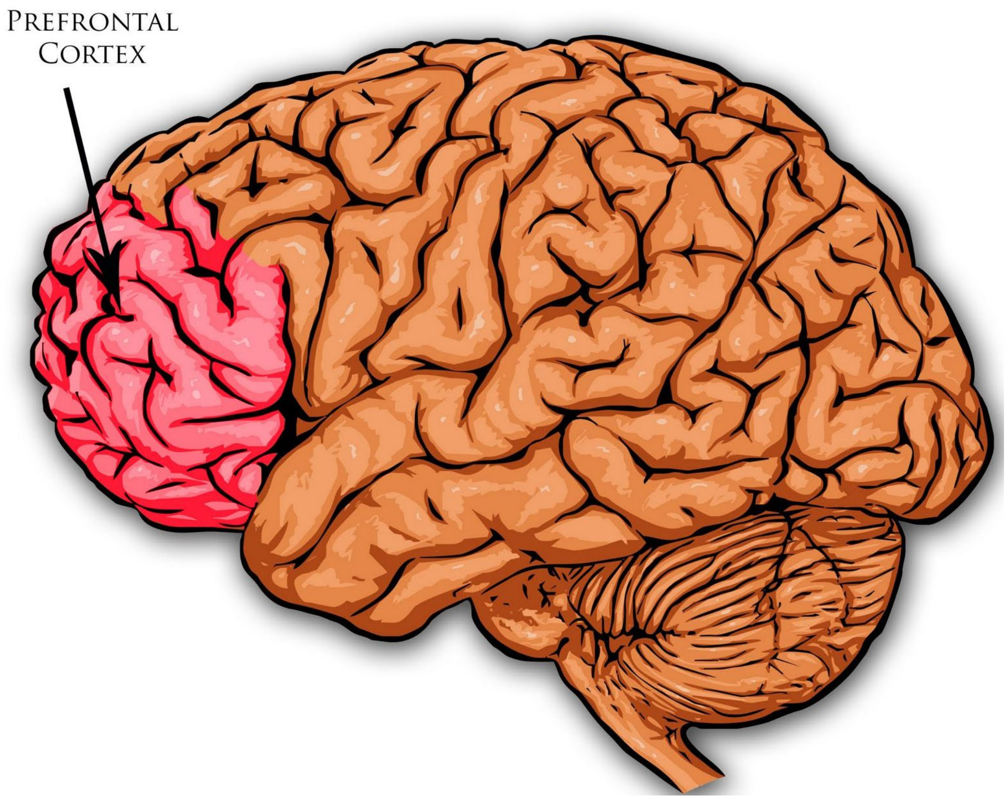
Scientists call Chappell's condition visual agnosia, the inabil-

Visual Agnosia – the inability to recognize/understand things that you see

(iii) Multimodal Association Areas:

any cortical area that is not "primary"

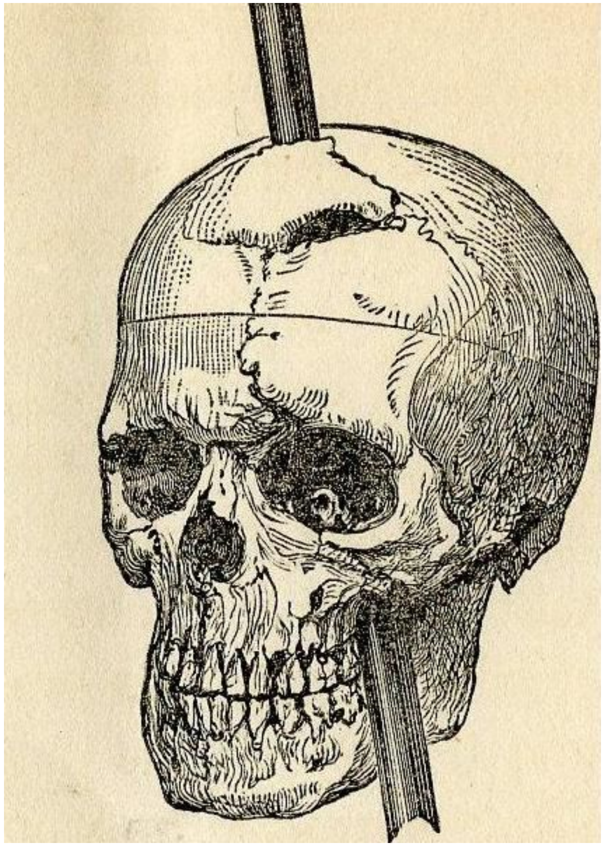
sensory receptors
↓
primary sensory cortex
↓
sensory association cortex
↓
multimodal association cortex



http://mind.in/images/easyblog_images/637/prefrontal_cortex.jpg

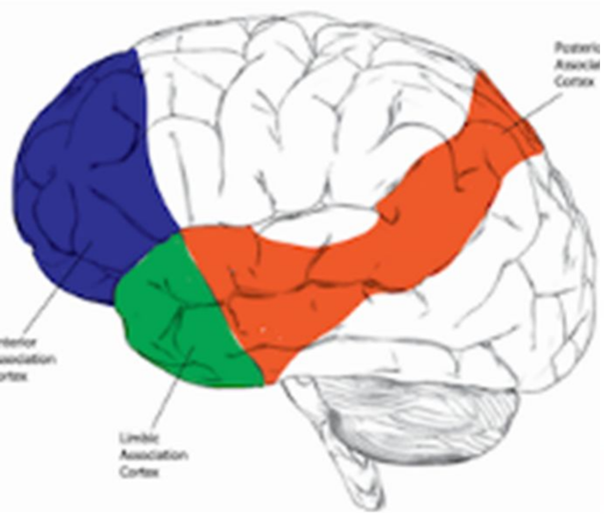
1. Anterior Association Area (Prefrontal Cortex):

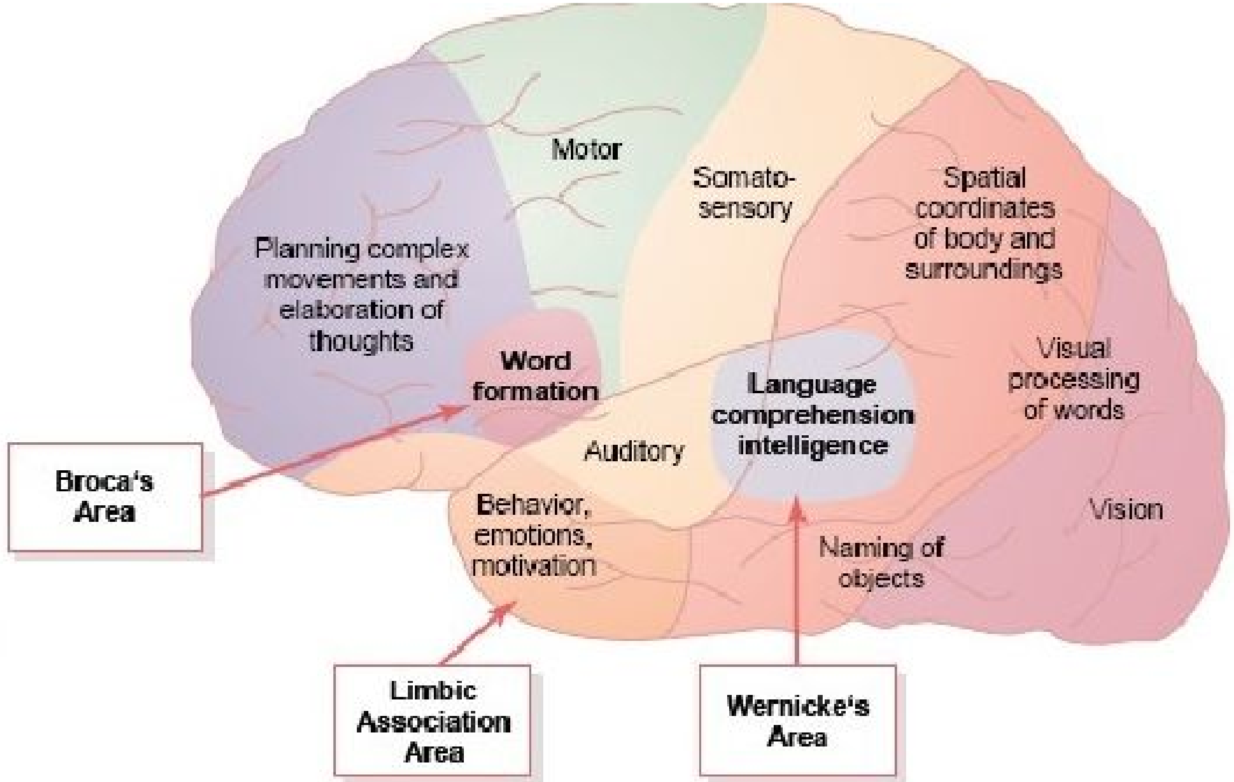
- intellect, complex learning (cognition) & personality (working memory is here)
- abstract ideas, judgment, reasoning, persistence, planning, concern, conscience
- matures slowly; dependent on feedback from social environment
- closely linked to limbic system; involved in mood



Phineas Gage

- Railway worker injured in 1848 by a tamping bar during an explosion
- Sensory, motor OK – but dramatic personality changes
- Autopsy revealed damage to some parts of the anterior association area (prefrontal cortex)





2. Posterior Association area: parts of temporal, parietal & occipital lobes

- input from all sensory association areas – storage of complex memories linked to sensation – put info together to understand what see, feel etc
- localization of self and surroundings in space
- recognition of patterns, faces
- some parts for understanding written & spoken language (Wernicke's area)

3. Limbic Association area:

- provides emotional impact – e.g. be aware of the danger associated with a particular situation and to remember it, etc. ex. looking before crossing

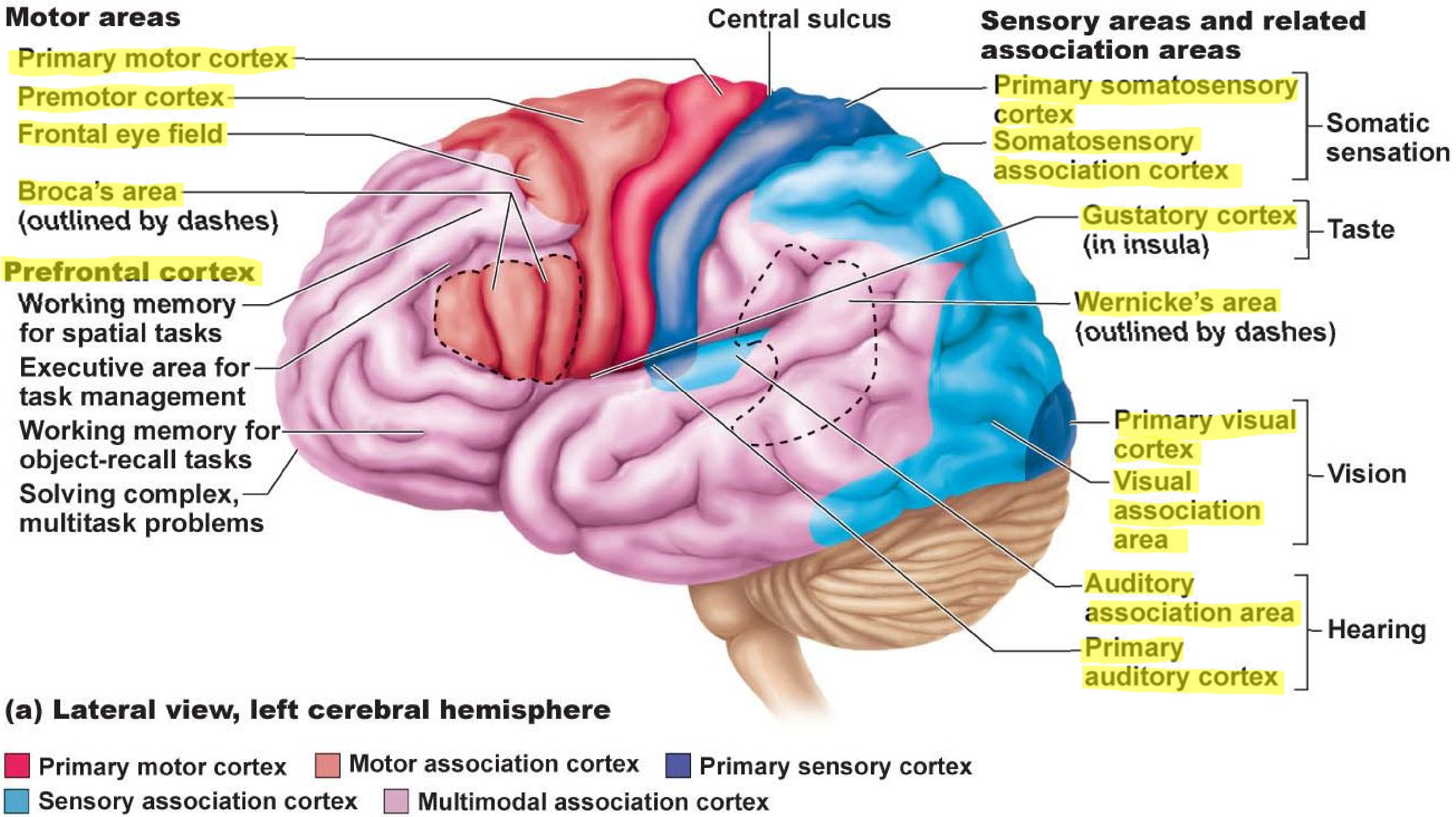
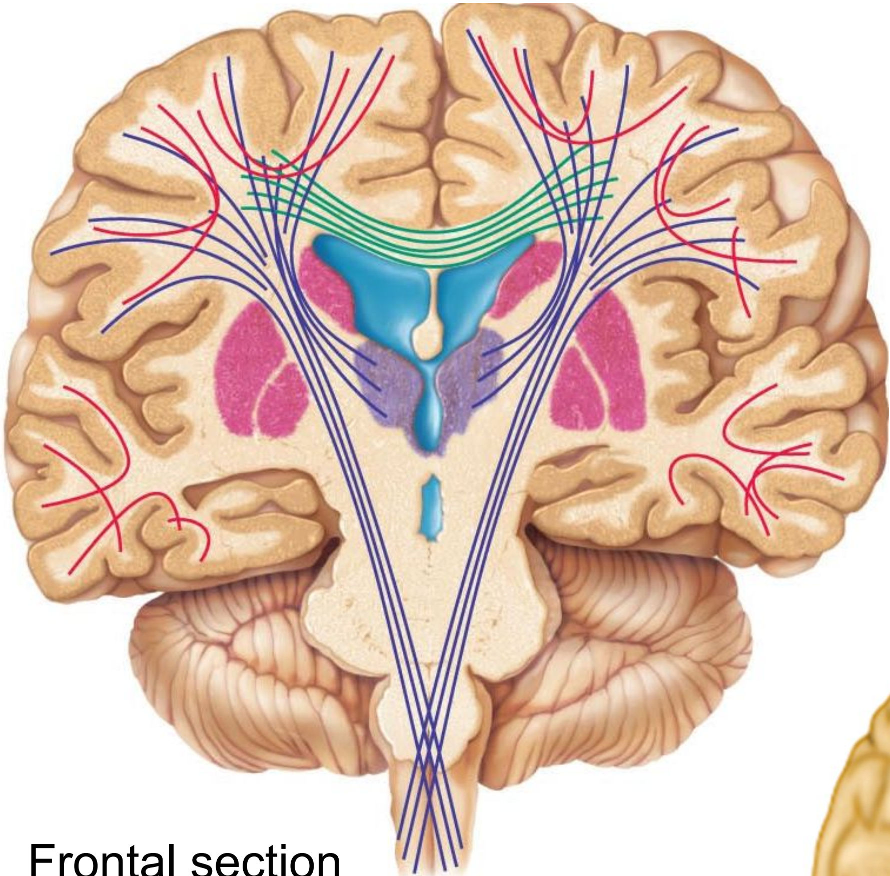


Fig. 12.7a: Lateral view – left cerebral hemisphere

Lateralization of Cortical Functioning

- each cerebral hemisphere has some abilities not completely shared by other hemisphere
- cerebral dominance = hemisphere that is dominant for **language**
- 90% of people: **left** hemisphere dominant for language, math, logic
- other hemisphere dominates for visual-spatial skills, intuition, emotion, appreciation of art & music – creative side, better at recognizing faces
- most individuals with **left** cerebral dominance are **right-handed**
- in remaining 10%, roles reversed or shared equally

A3. Cerebral White Matter



Frontal section

communication between cerebral areas, between cortex & lower CNS centres

commissural fibers (left to right): connect corresponding areas **between** the 2 hemispheres – largest is **corpus callosum**

association fibers: connections **within** a hemisphere (connect gyri, lobes)

projection fibers: to or from cortex and **rest** of nervous system; these ones run vertically

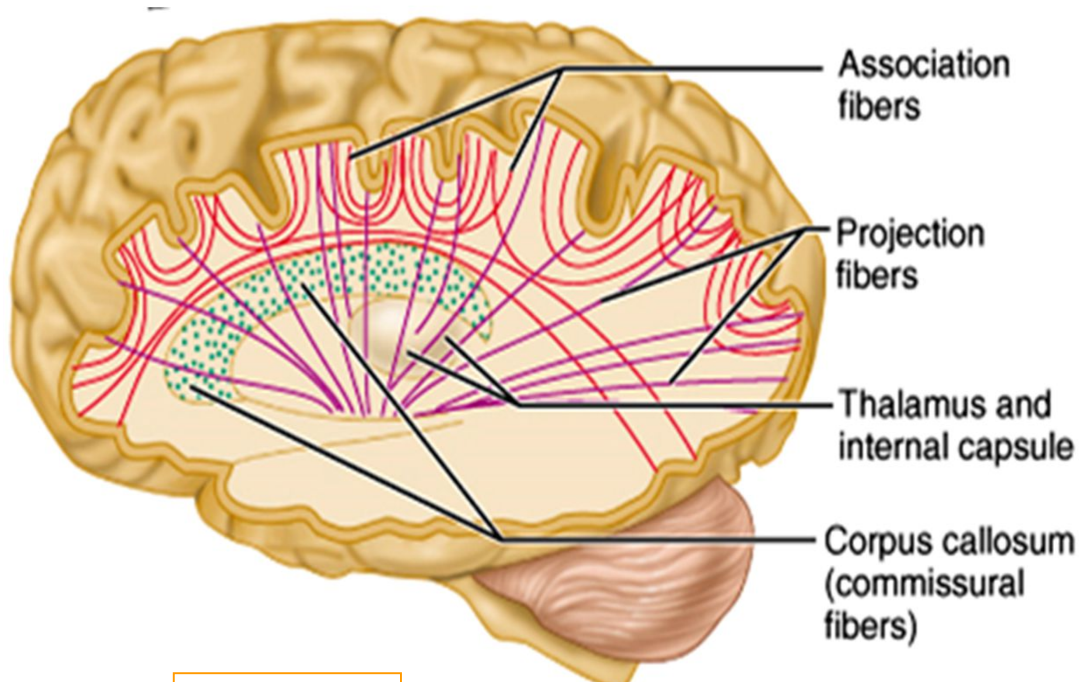


Fig. 12.9

Midsagittal section

Basal Nuclei

- **caudate nucleus +[putamen & globus pallidus = lentiform nucleus]**
- inputs from entire cerebral cortex, other subcortical nuclei & each other
- project to premotor & prefrontal cortices to influence muscle movements directed by primary motor cortex – have no direct access to motor pathways
- precise roles elusive (difficult to access and some roles overlap with cerebellum) – roles in starting, stopping, monitoring intensity of movements executed by cortex, especially if slow, sustained, stereotyped; also inhibit antagonistic and/or unnecessary actions
- disorders can result in too much movement (e.g. Huntington's disease) or too little movement (Parkinson's disease)

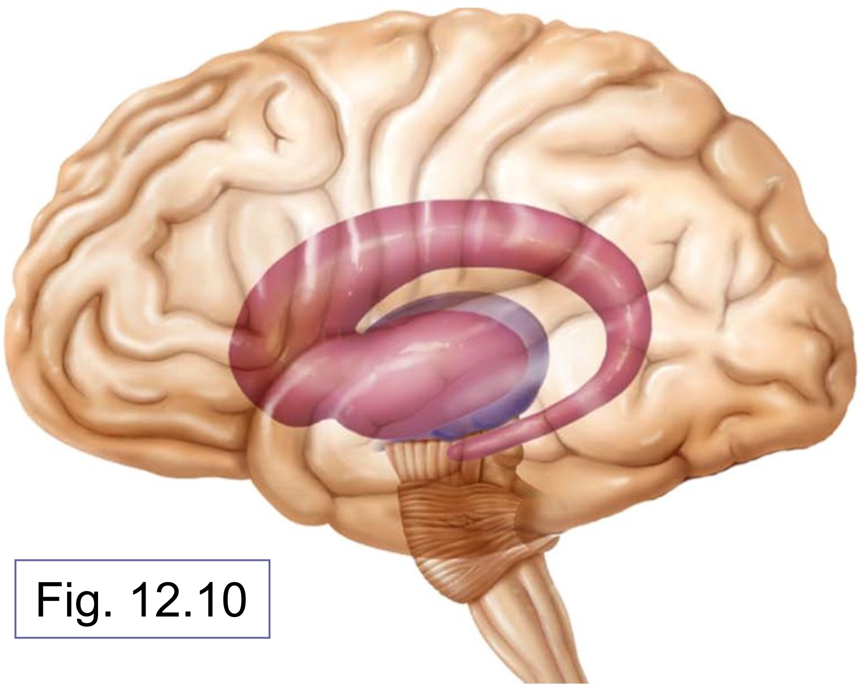
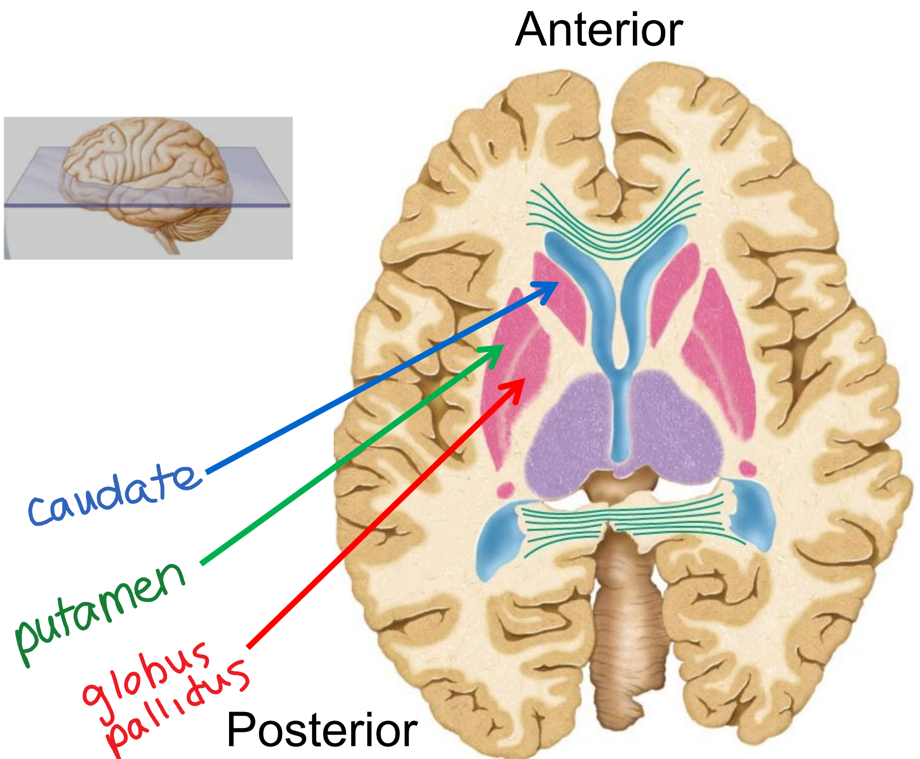
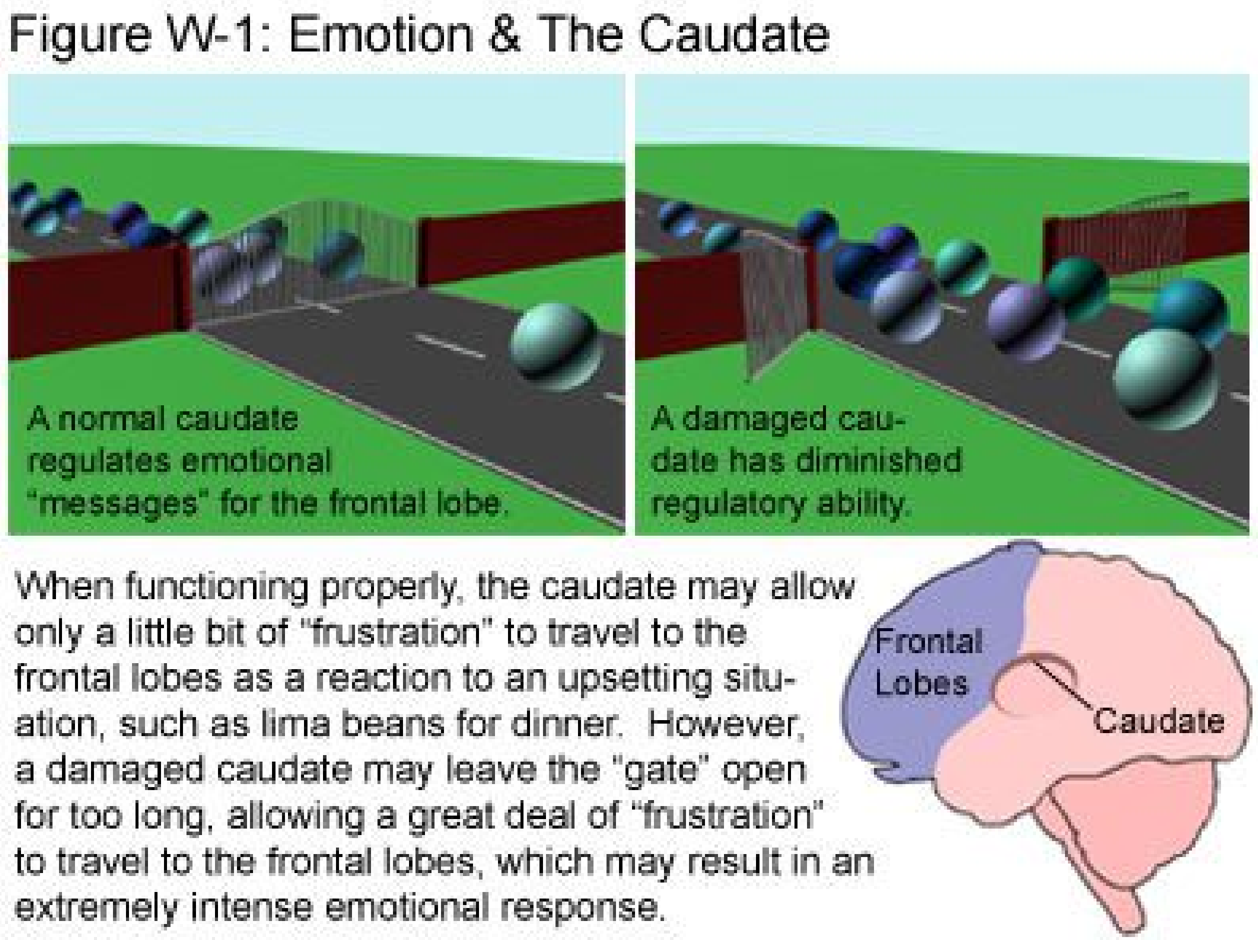


Fig. 12.10



Huntington's Disease

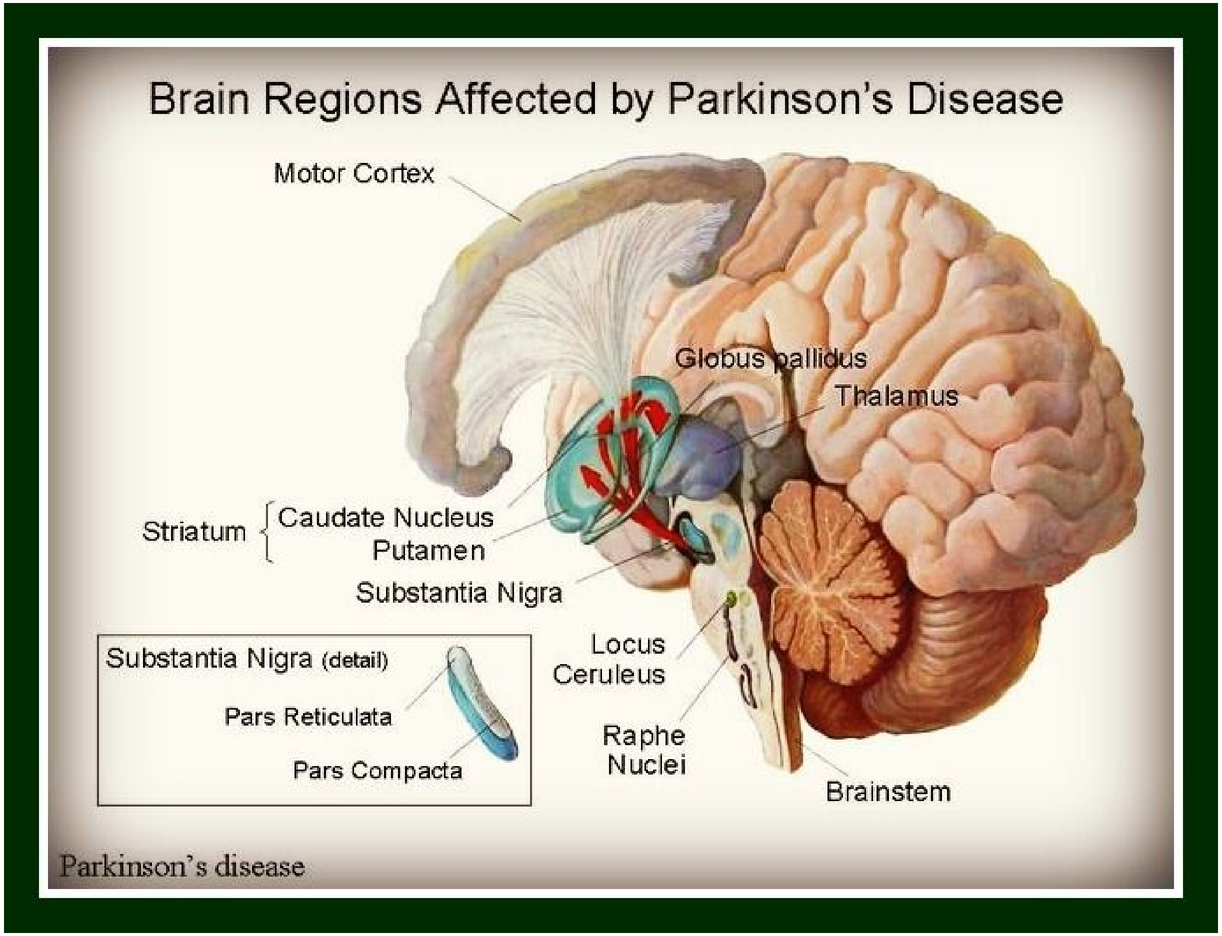
- hereditary disorder in which mutant *huntingtin* protein accumulates in brain cells $\rightarrow$ degeneration of the basal nuclei and eventually of the cortex
- as caudate deteriorates, connections to frontal lobe become lost so that the affected individual in unable to control feelings, thoughts or movements



http://web.stanford.edu/group/hopes/cgi-bin/wordpress/2010/06/the-behavioral-symptoms-of-huntingtons-disease/

Parkinson's Disease

- degeneration of dopamine-releasing neurons of **substantia nigra** (midbrain)
- causes basal nuclei usually targeted by substantia nigra to become overactive → persistent tremor at rest; muscles become rigid leading to difficulty walking, loss of facial expression, difficulty writing, etc.



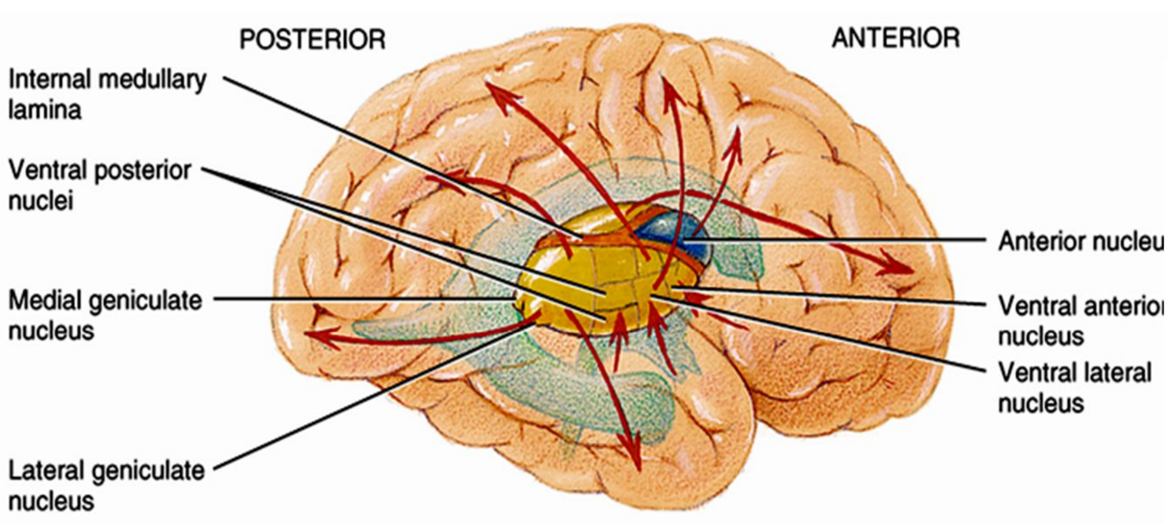
http://parkinsons-tmj.com/the-shaking-palsy-a-review-on-parkinsons-disease/

The Diencephalon

- **thalamus, hypothalamus, epithalamus –** enclose the **3rd ventricle**

Thalamus: 80%; bilateral masses of gray matter held together by midline commissure called the **intermediate mass**

- consists of many different nuclei, named for their position in thalamus – afferent impulses from all senses & all parts of body converge on thalamus
- sorting & editing of information; group like impulses to send to appropriate region of cortex – crude awareness of sensation at level of thalamus
- also input pertaining to emotions & viscera from hypothalamus
- key roles in mediating sensation, motor activities, cortical arousal, learning, memory = **"gateway to cerebral cortex"**



(a) Right lateral view showing thalamic nuclei

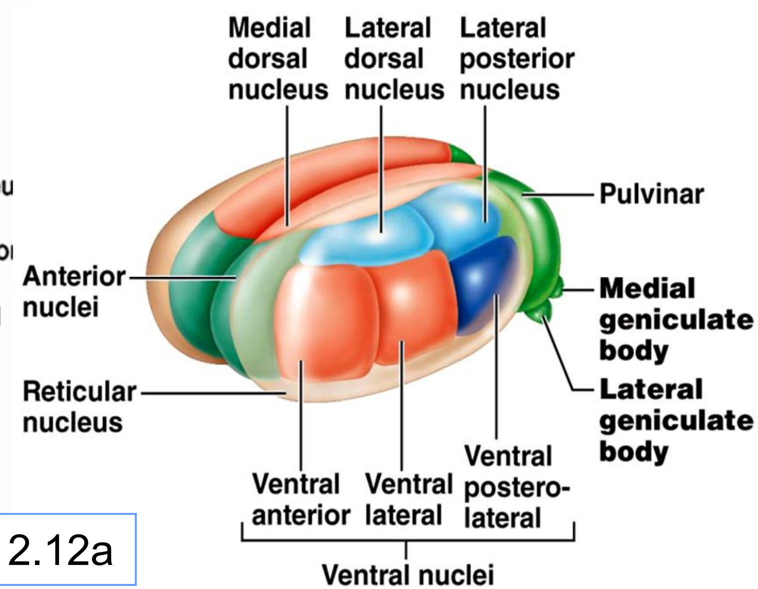
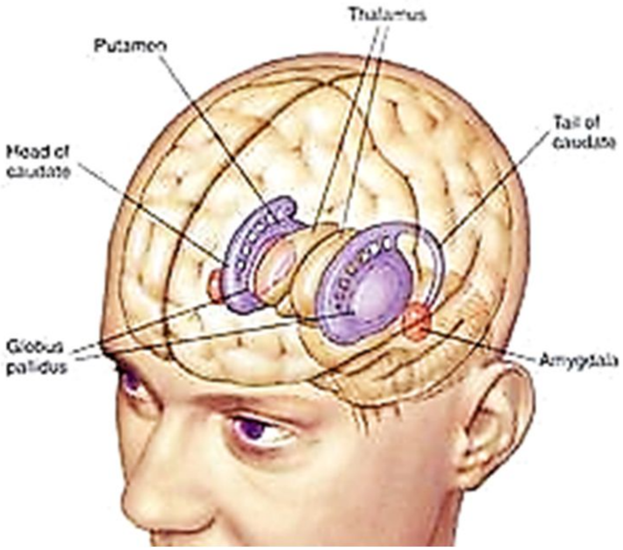
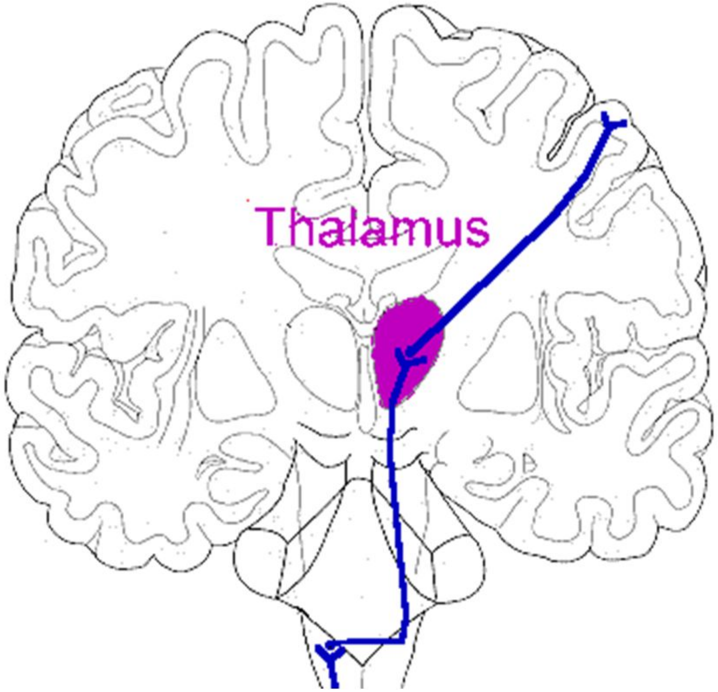


Fig. 12.12a





http://idealab.ucdavis.edu/IST/ISTF08/lectures/F08Lecture3vhtml_files/image007.gif

Hypothalamus: "below" thalamus

(i) **Autonomic control centre:** centres for bp, heart, GI, respiration, etc

(ii) **Centre for emotional response & behaviour:** heart of limbic system

(iii) **Body temperature regulation:**

(iv) **Regulation of food intake:** hunger, satiety

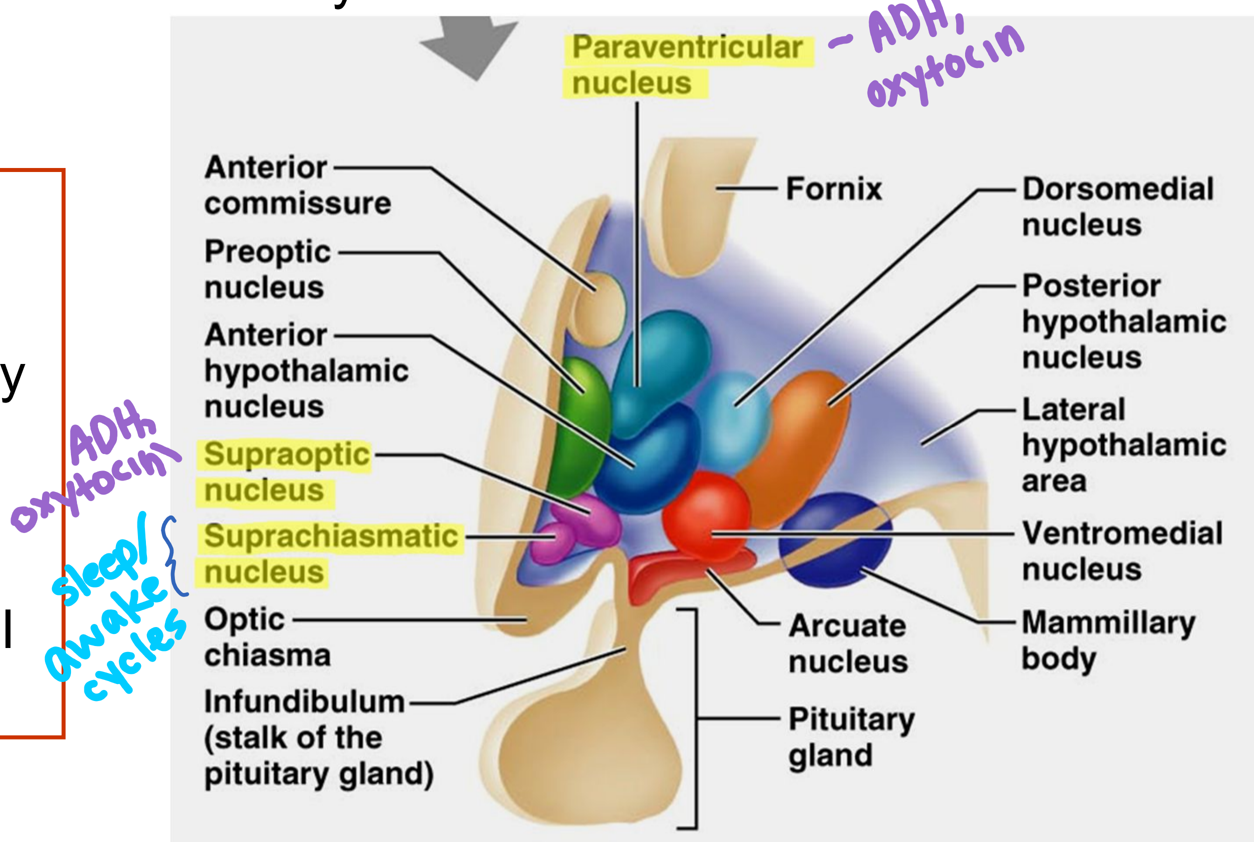
(v) **Regulation of water balance & thirst:** release of ADH; thirst centre

(vi) **Regulation of sleep-awake cycles:** suprachiasmatic nucleus

(vii) **Control of endocrine system:** releasing factors plus 2 nuclei (supraoptic & paraventricular) produce ADH & oxytocin

Hypothalamic disturbances:

cause disorders in body homeostasis such as body wasting, obesity, sleep disturbances, dehydration, emotional imbalances



Epithalamus: most dorsal part of diencephalon & forms roof of 3rd ventricle; **pineal gland** (melatonin) extends from its dorsal border

- **choroid plexus** (CSF-forming/producing structure) also part of epithalamus -> network of blood capillaries

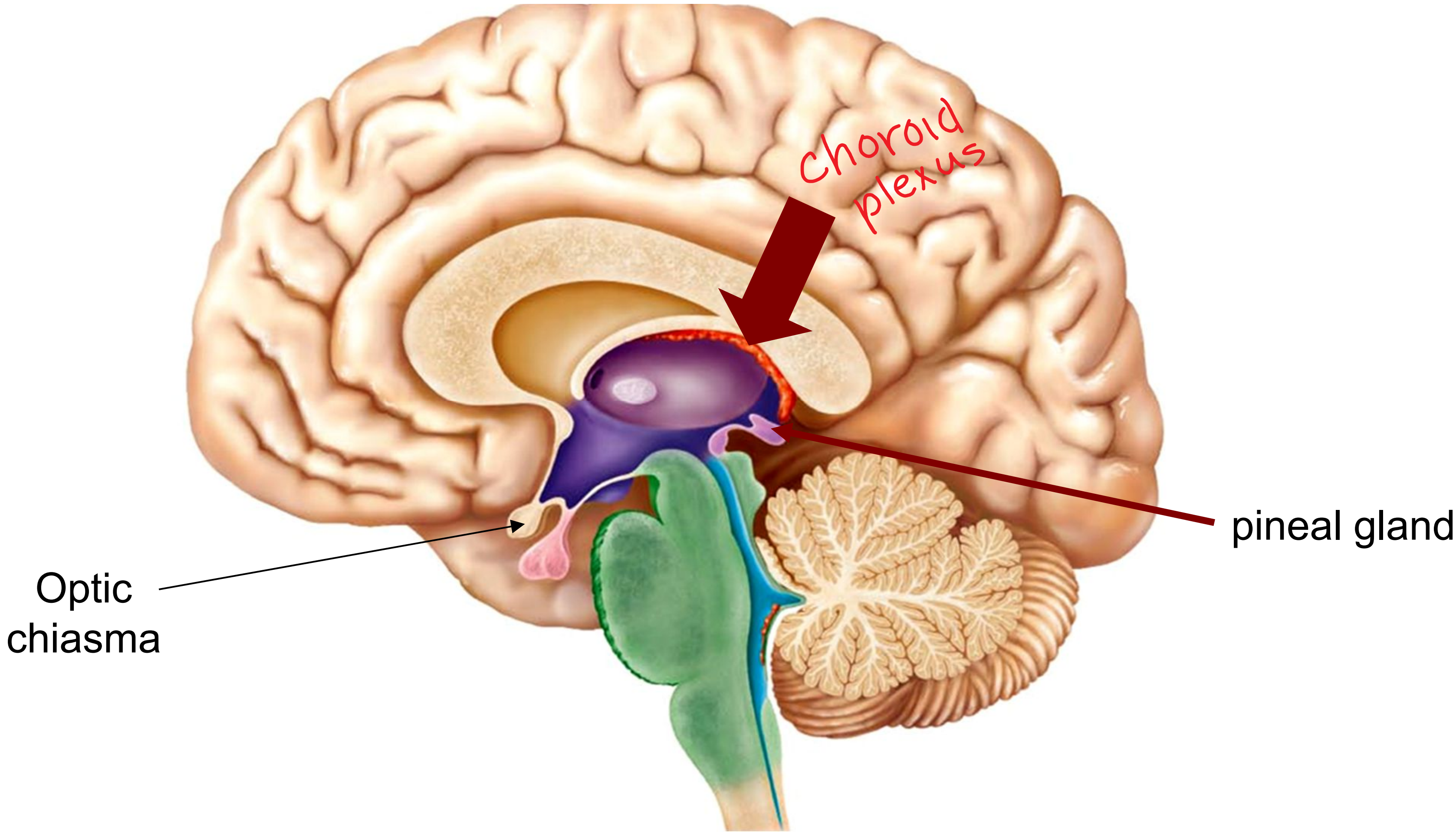


Fig. 12.11: Midsagittal section

The Brain Stem: consists of midbrain, pons, medulla oblongata

(i) rigidly programmed, automatic behaviours necessary to survival (regulating blood pressure, heart, breathing rates)

(ii) pathway between higher & lower neural centers

(iii) associated with 10 pairs of cranial nerves (yellow)

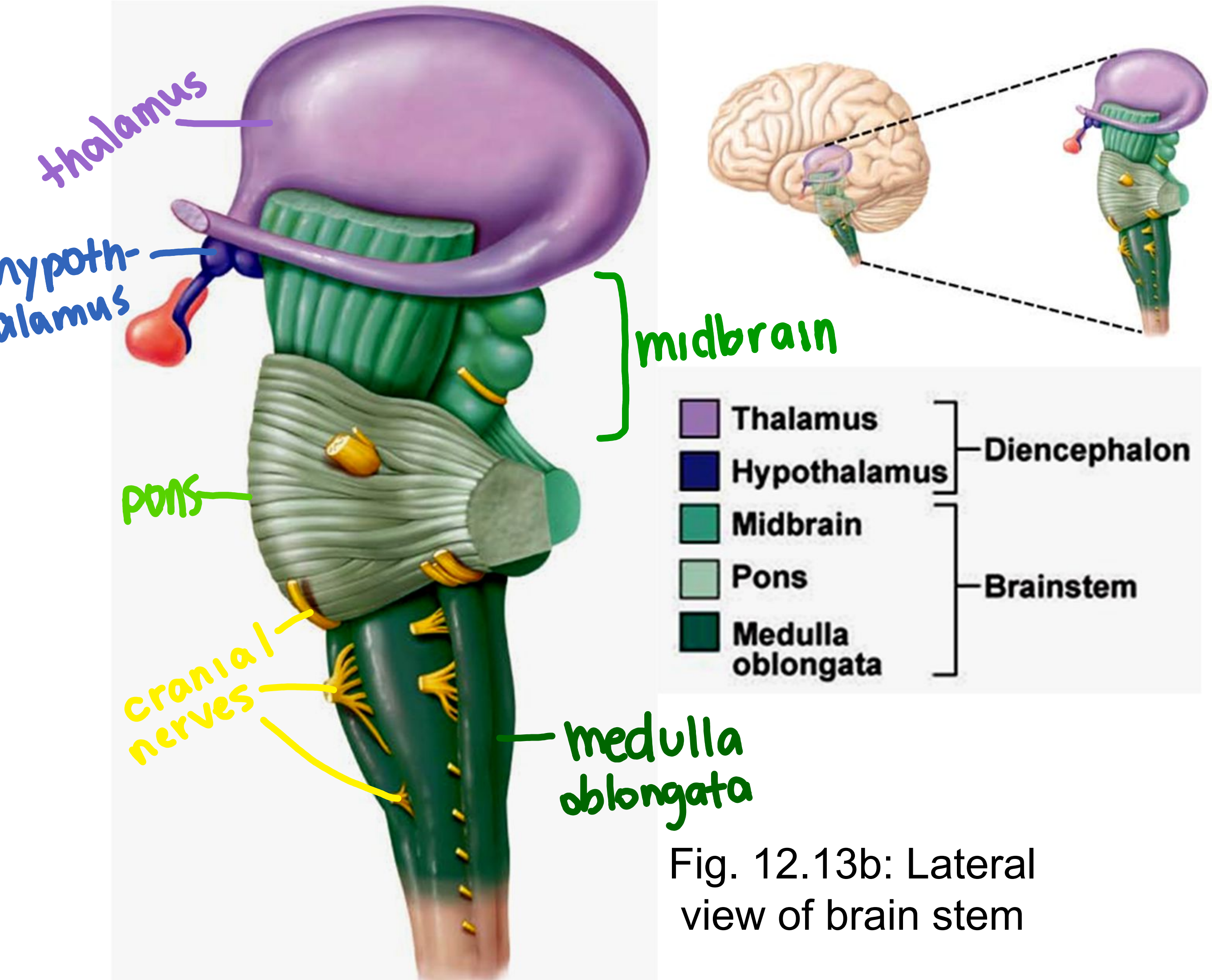


Fig. 12.13b: Lateral view of brain stem

Midbrain:

2 cerebral peduncles that contain large pyramidal (corticospinal) motor tracts
hollow cerebral aqueduct runs through midbrain
periaqueductal gray matter involved in pain suppression
Corpora quadrigemina: superior colliculi are visual reflex centres; inferior colliculi are part of auditory relay (*also startle reflex*)

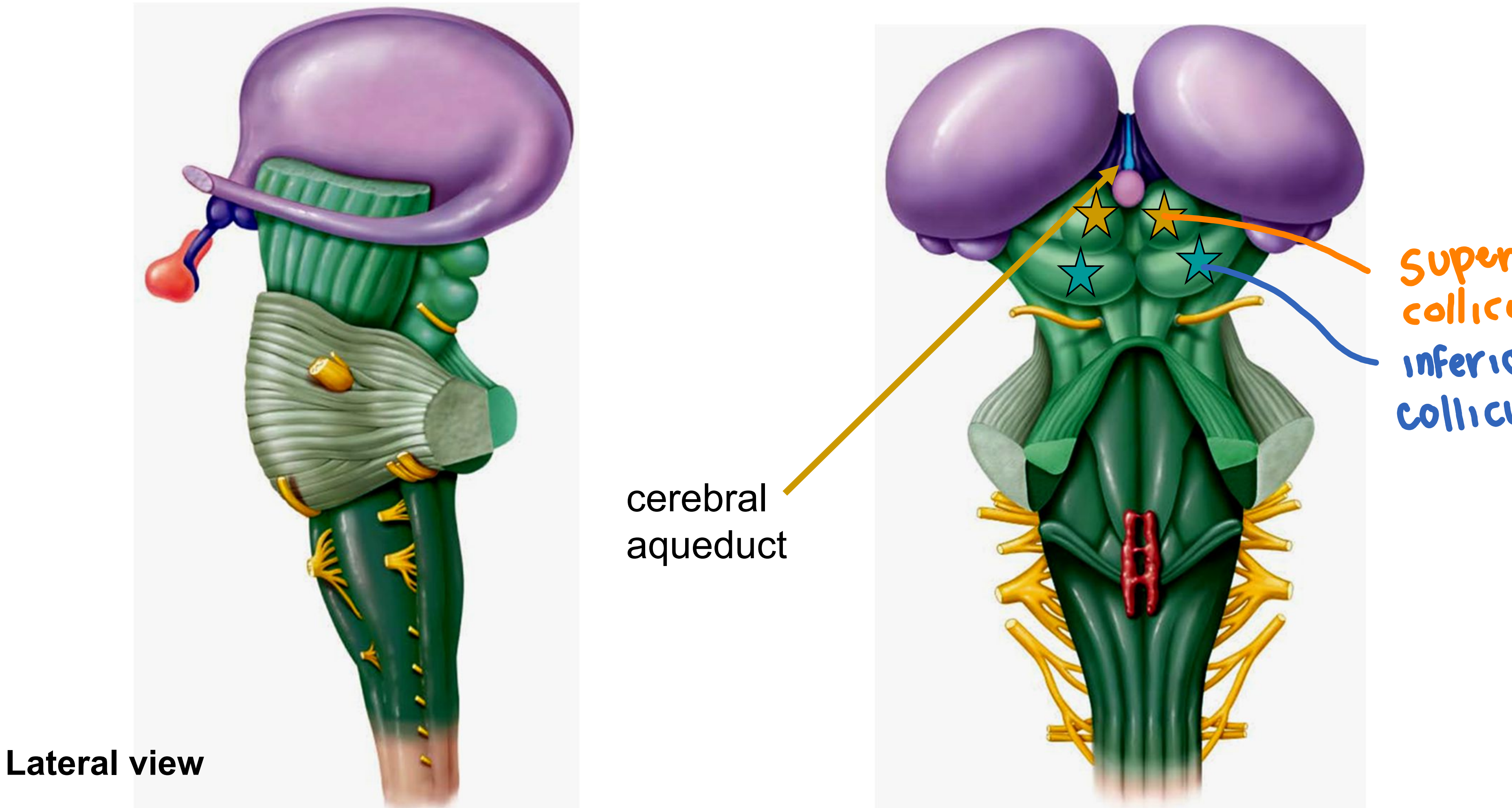


Fig. 12.13c: relationship of brain stem to diencephalon; dorsal view

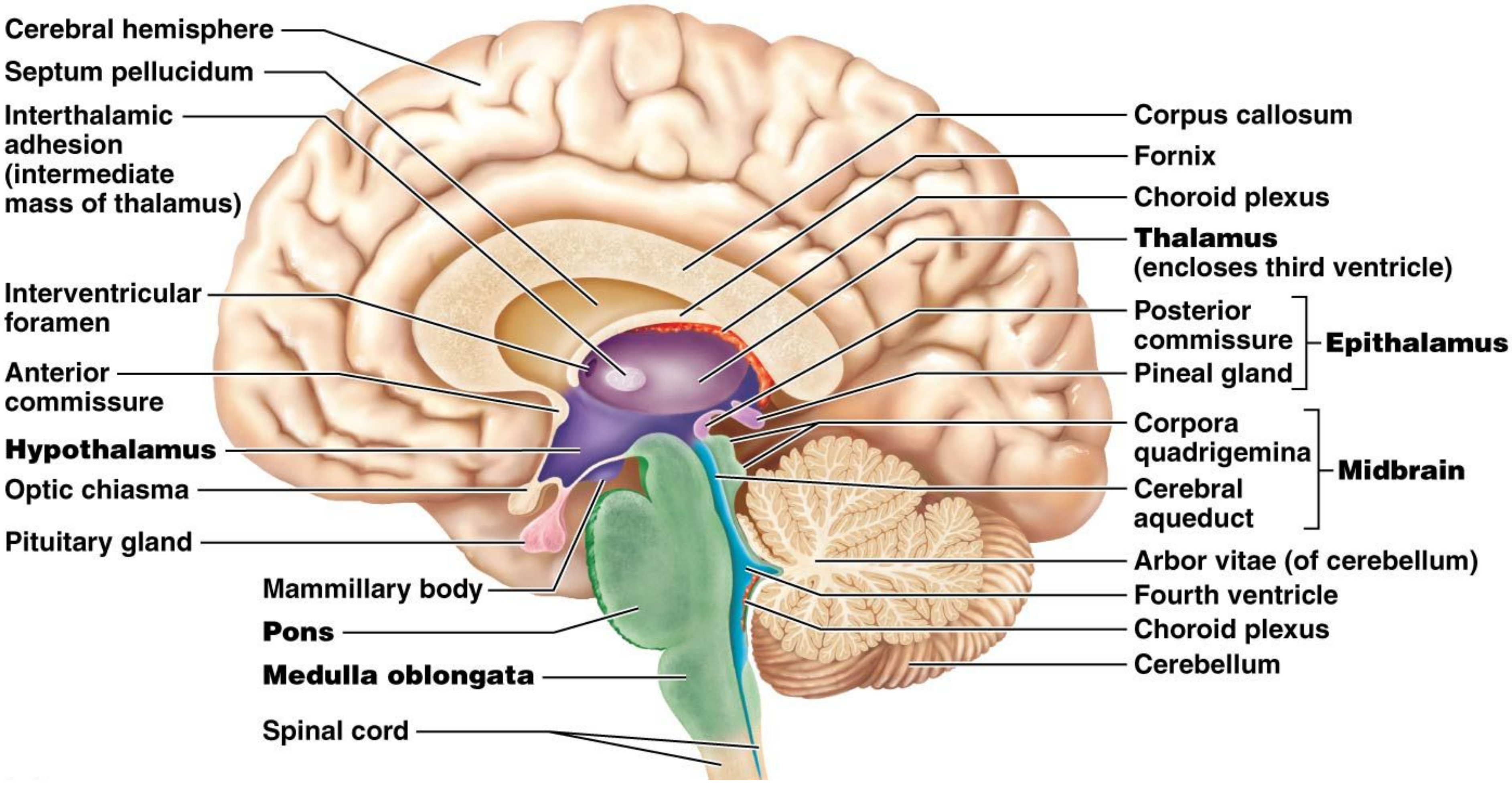
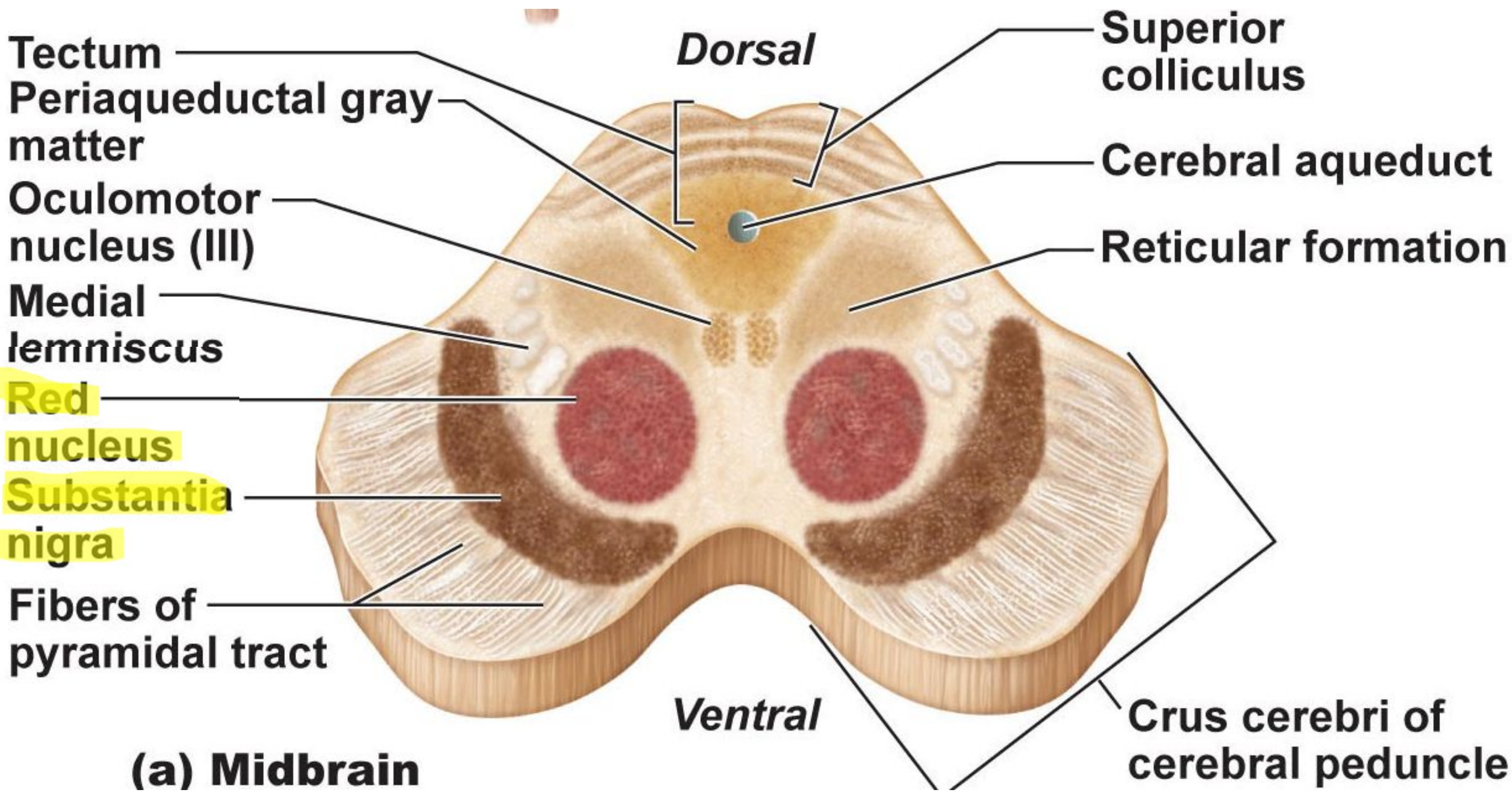


Fig. 12.11a: Midsagittal section of brain

Midbrain (cont):

- **substantia nigra**: band-like nucleus; high melanin content (precursor • dopamine); linked to basal nuclei of cerebral hemispheres (Parkinson's disease)
- **red nucleus**: rich vascular supply, iron pigment in neuron cell bodies; relay nuclei for descending pathways influencing limb flexion
- also some nuclei associated with reticular formation

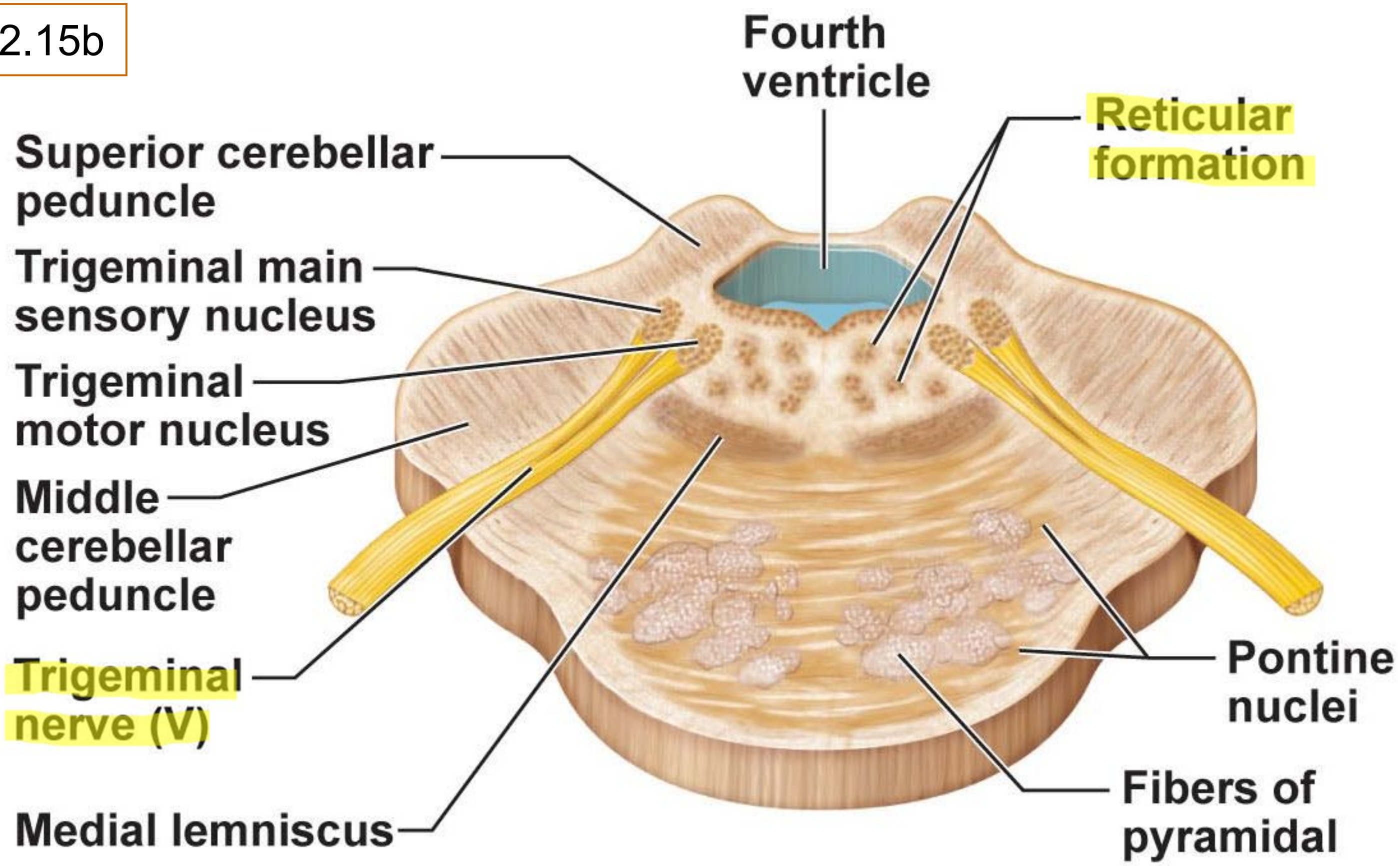
Fig. 12.15a



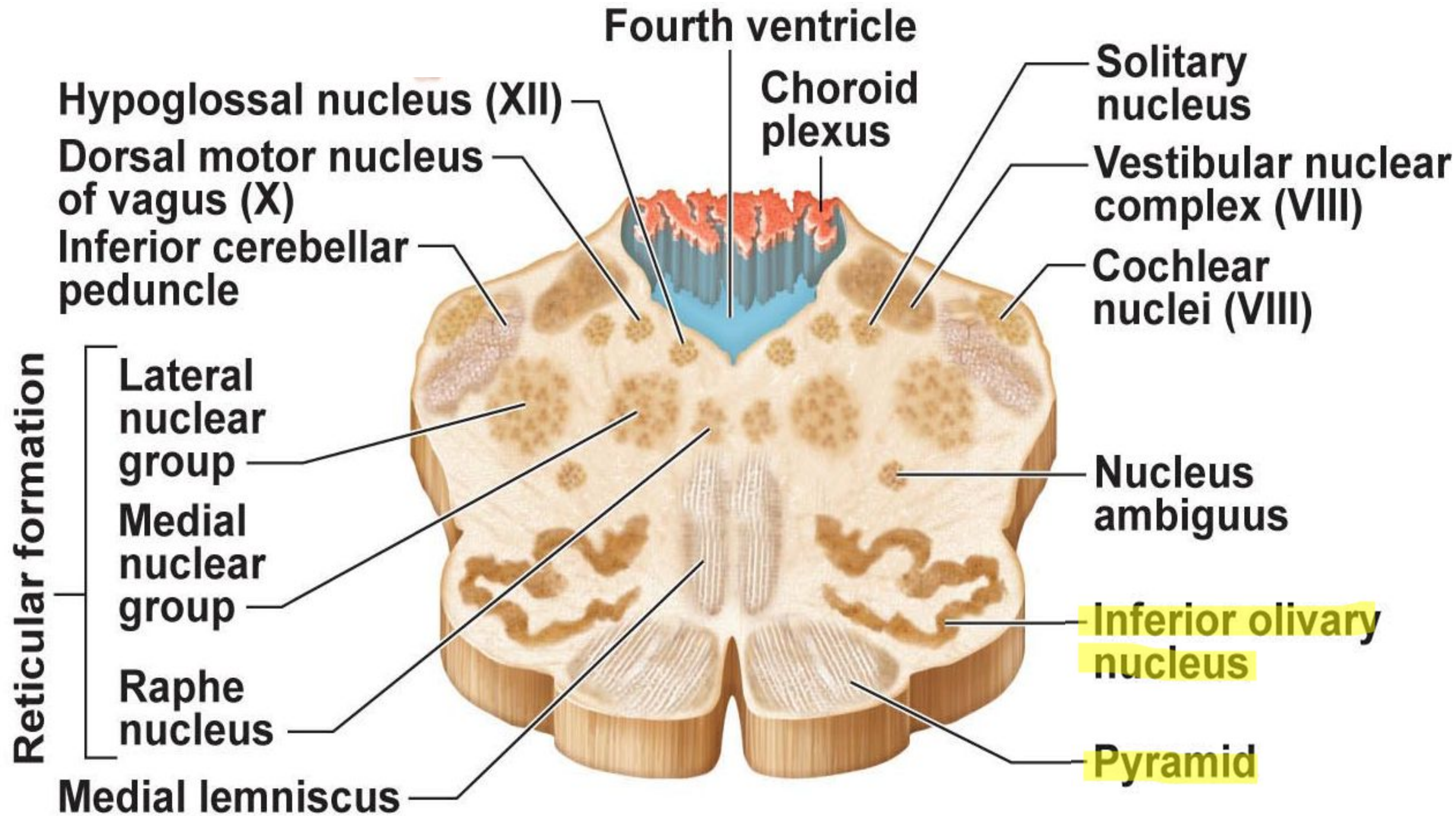
Pons: dorsally, forms part of anterior wall of 4th ventricle

- primarily conduction tracts ("bridge"); some run longitudinally; others oriented transversely to communicate with cerebellum
- **cranial nerves V** (trigeminal), **VI** (abducens) & **VII** facial; other pons nuclei are part of reticular formation and others are involved in respiration)

Fig. 12.15b



(b) Pons



(c) Medulla oblongata

Fig. 12.15c

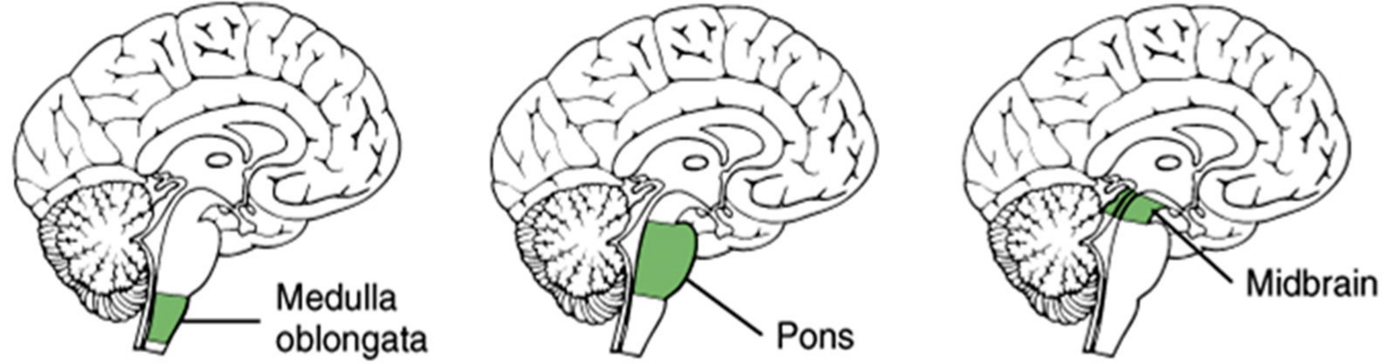
Medulla oblongata: from pons to spinal cord

- **pyramids, decussation** (significance of this?)

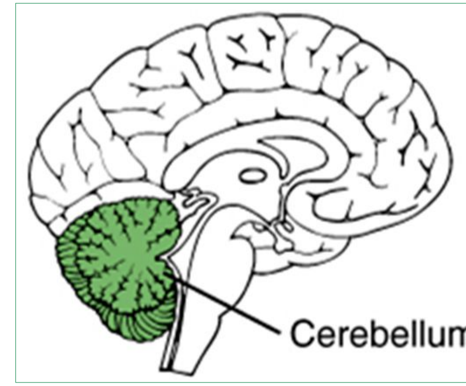
inferior **olivary nuclei**: relay sensory info re muscles & joints to cerebellum

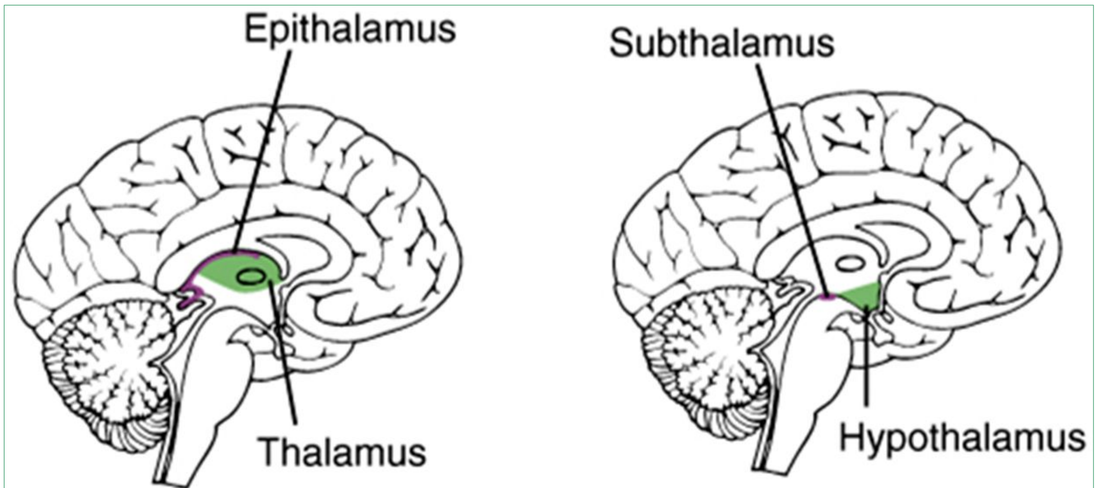
cranial nerves XII (hypoglossal), **IX** (glossopharyngeal), **X** (vagus), **XI** (accessory)

vestibulocochlear nerve fibers (**VIII**) synapse with cochlear nuclei (***functions?***)



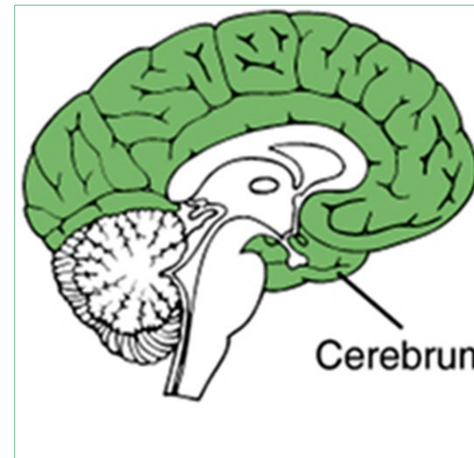
(a) Brain stem





(c) Diencephalon

See also Table 12.1



(d) Cerebrum

Table 14.1 (T&G)

Medulla oblongata: crucial role as autonomic reflex centre for homeostasis

(i) Cardiovascular centre: cardiac & vasomotor centres

(ii) Respiratory centres: rate & depth of breathing

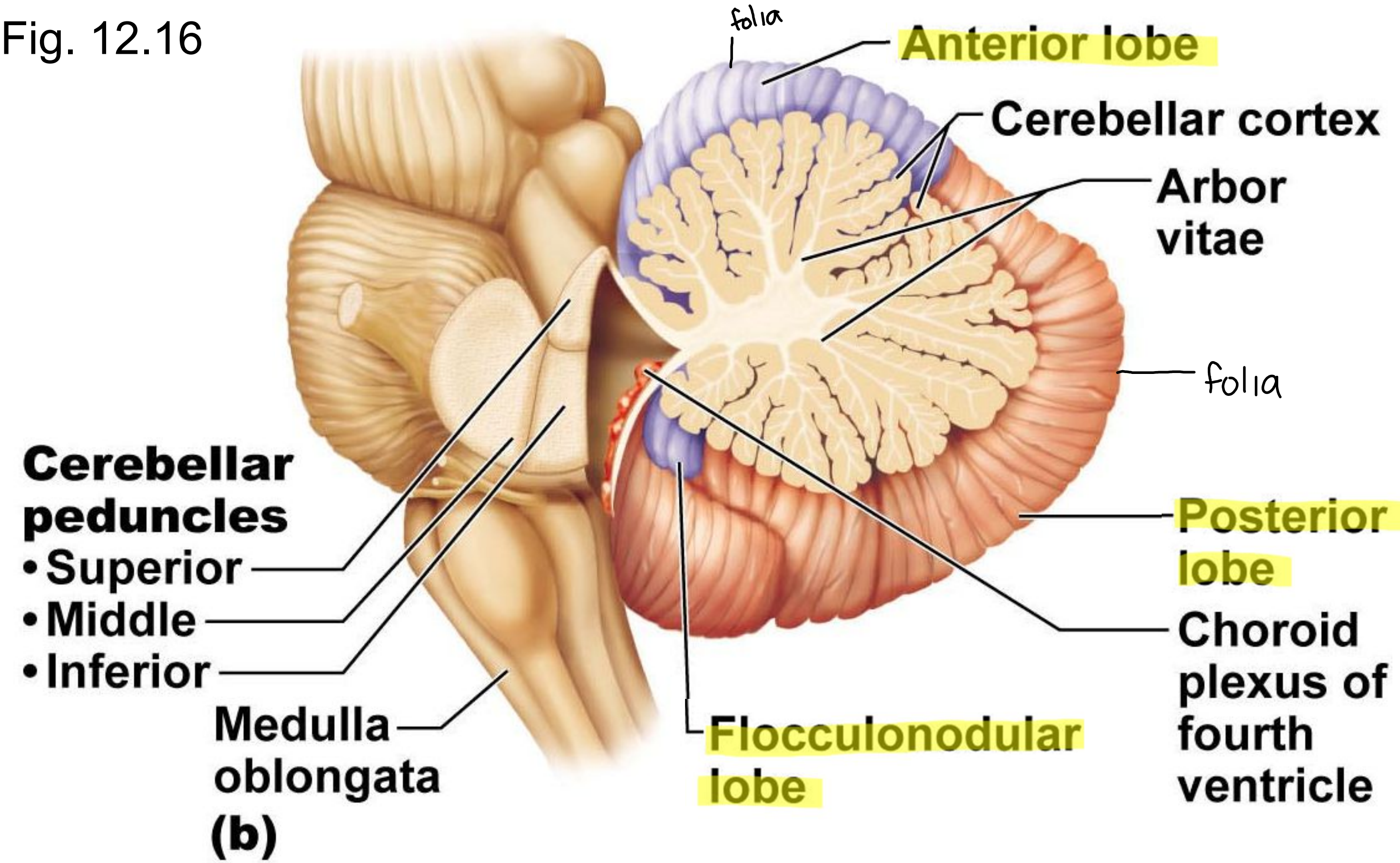
(iii) Other centres: eg: vomiting, hiccupping, swallowing coughing, sneezing

- overlap with hypothalamus: hypothalamus controls most visceral functions by relaying instructions through medullary centres which carry them out

The Cerebellum:

- processes inputs from cerebral motor cortex, brainstem nuclei & sensory receptors -> timing & patterns of skeletal muscle contraction for smooth, daily movements – eg: driving, typing, playing a musical instrument, etc (not under conscious control)
- bilaterally symmetrical; connected by **vermis**; fine transverse fissures called **folia**; each hemisphere divided into 3 lobes: anterior, posterior, flocculonodular

Fig. 12.16



4. The Cerebellum (cont):

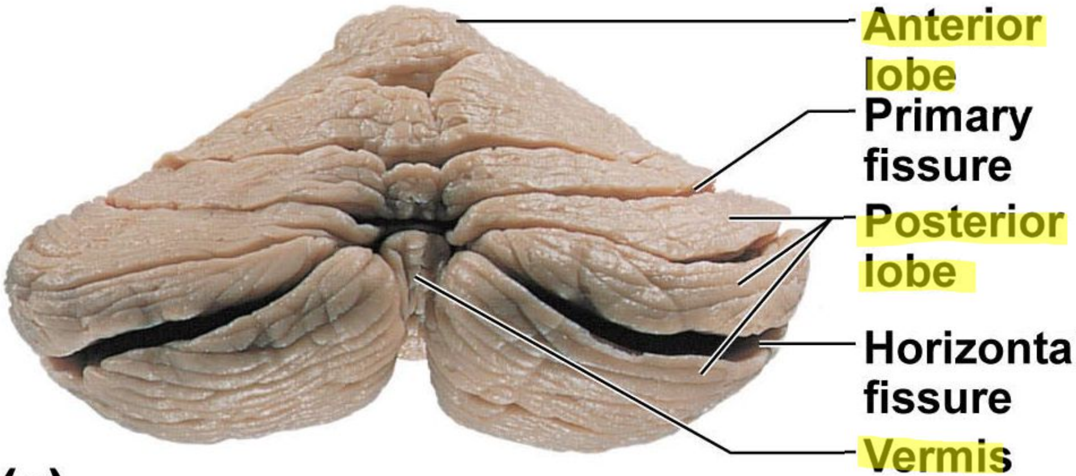
- anterior & posterior lobes have overlapping sensory & motor maps of body

medial: trunk & girdle

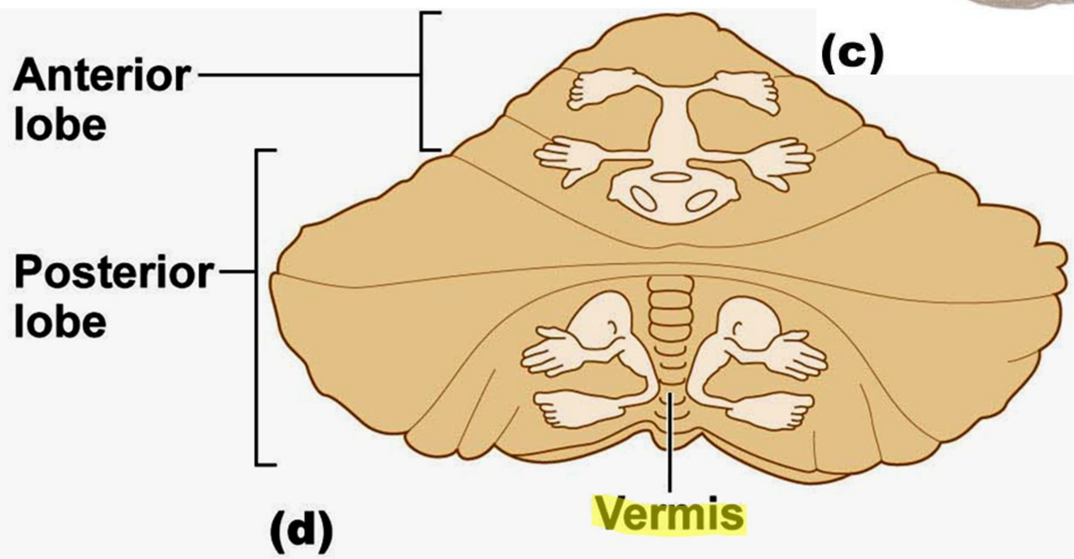
intermediate: distal limbs, skilled movements

lateral: input from association areas of cortex (esp. planning movements)

- flocculonodular lobes – input from equilibrium sensors: balance, some eye movements



(c)

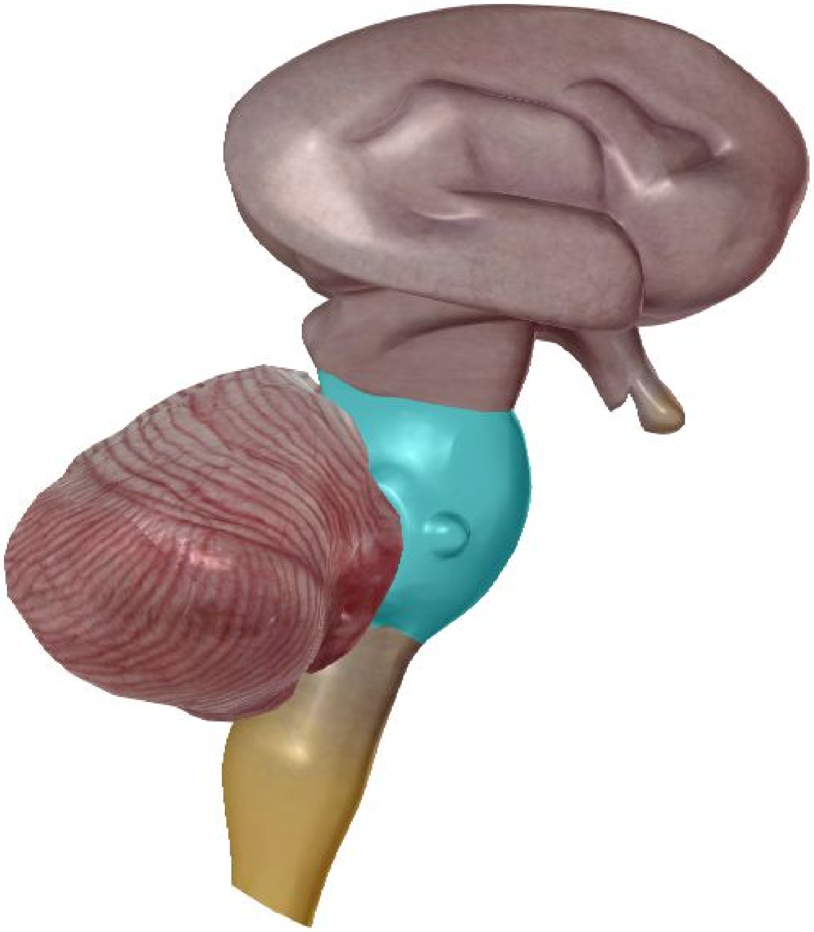


(d)

Fig. 12.16

From Visible Body

Vermis highlighted



Pons highlighted

Cerebellar Peduncles

- connect cerebellum to brain stem
- virtually all fibers entering & leaving cerebellum are **ipsilateral** (unlike cerebral cortex)

Superior: connect cerebellum & midbrain; fibers originate from neurons in deep cerebellar nuclei & project to cerebral motor cortex via thalamus (**gateway to the cortex**)

Middle: connect pons & cerebellum; one-way communication from pons to cerebellar neurons (informs cerebellum of voluntary motor activities initiated by motor cortex)

Inferior: connect cerebellum & medulla; afferent (incoming) tracts - sensory info to cerebellum from muscle proprioceptors & vestibular nuclei of brain stem (equilibrium & balance)

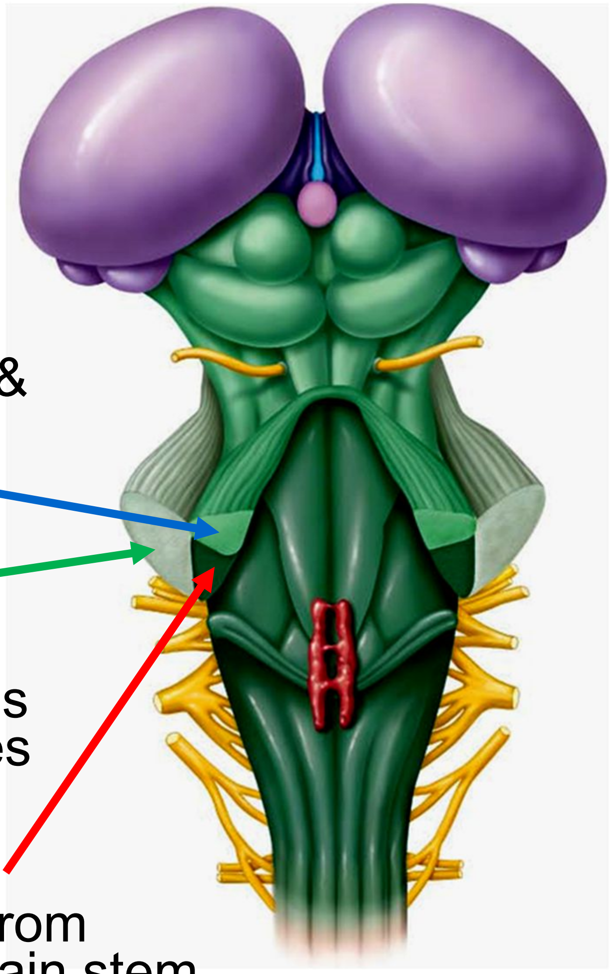


Fig. 12.14c

Cerebellar processing:

Cortex frontal motor association area indicates intent to initiate action & sends collaterals to **cerebellum** to notify

⇓

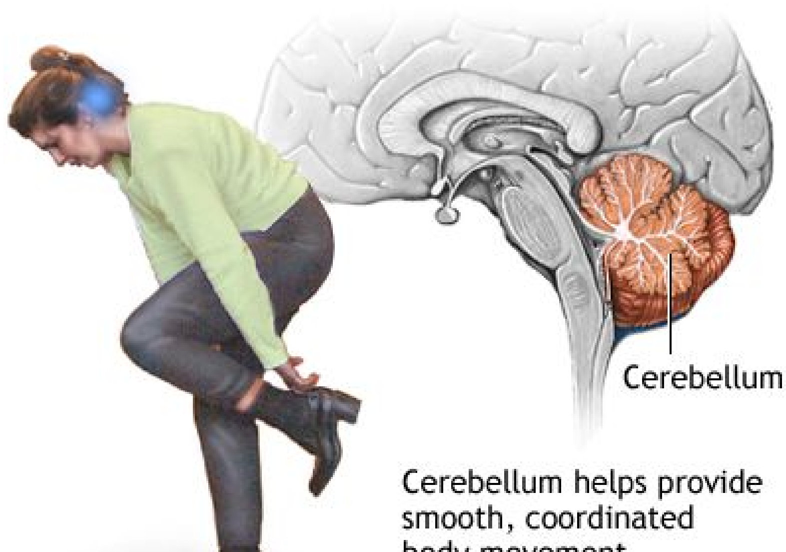
Cerebellum also receives proprioceptive info & info from visual & equilibrium pathways: *Where is body & where going? How well are movements being done (do you lose balance on the first try?)?*

⇓

Cerebellar **cortex** (not cerebral cortex) receives this info & determines best way to coordinate force, direction extent of muscle contraction

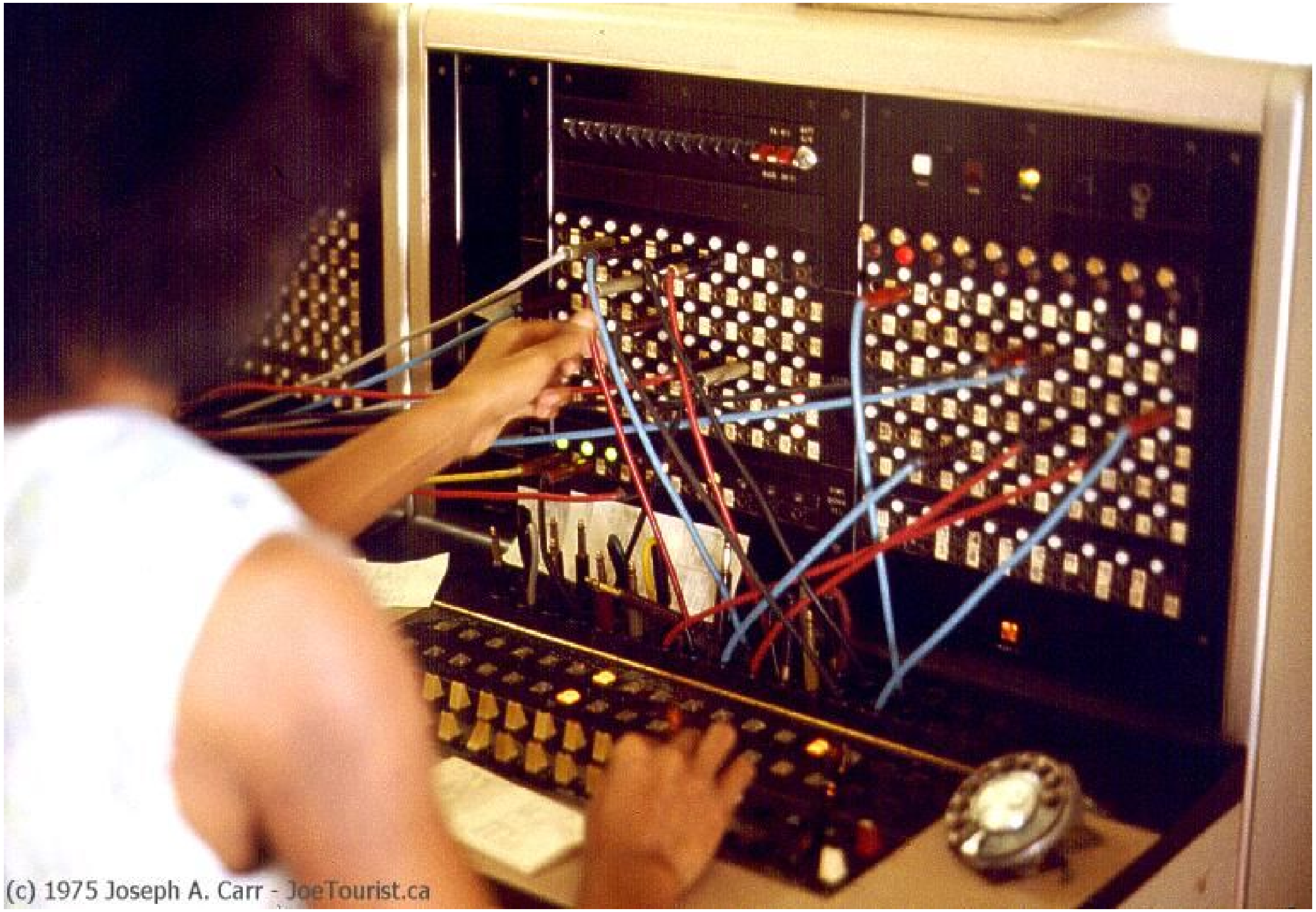
⇓

Via superior peduncles, **cerebellum** dispatches blueprint for coordination to **cortex**; output also to **brain stem nuclei** (eg: red nucleus) which project to **motor neurons** of spinal cord



Functional Brain Systems:

- networks of neurons that work together but span large distances within brain



Limbic system: (limbus = ring)

- medial aspect of each cerebral hemisphere & diencephalon
- emotional-visceral brain – esp: **amygdala** (anger, fear, assess danger), **hippocampus** (emotions & memory), **anterior cingulate gyrus** (gestures, resolve conflicts when frustrated, body language)
- link between odours, memories & emotions
- link for psychosomatic illnesses: stress & effects on bp, GI tract, heart
- links with cortex:(i) aware of emotions, (ii) react emotionally if consciously understand; also: emotions can override logic; reason can stop us from expressing emotions (fight w sibling vs boss)

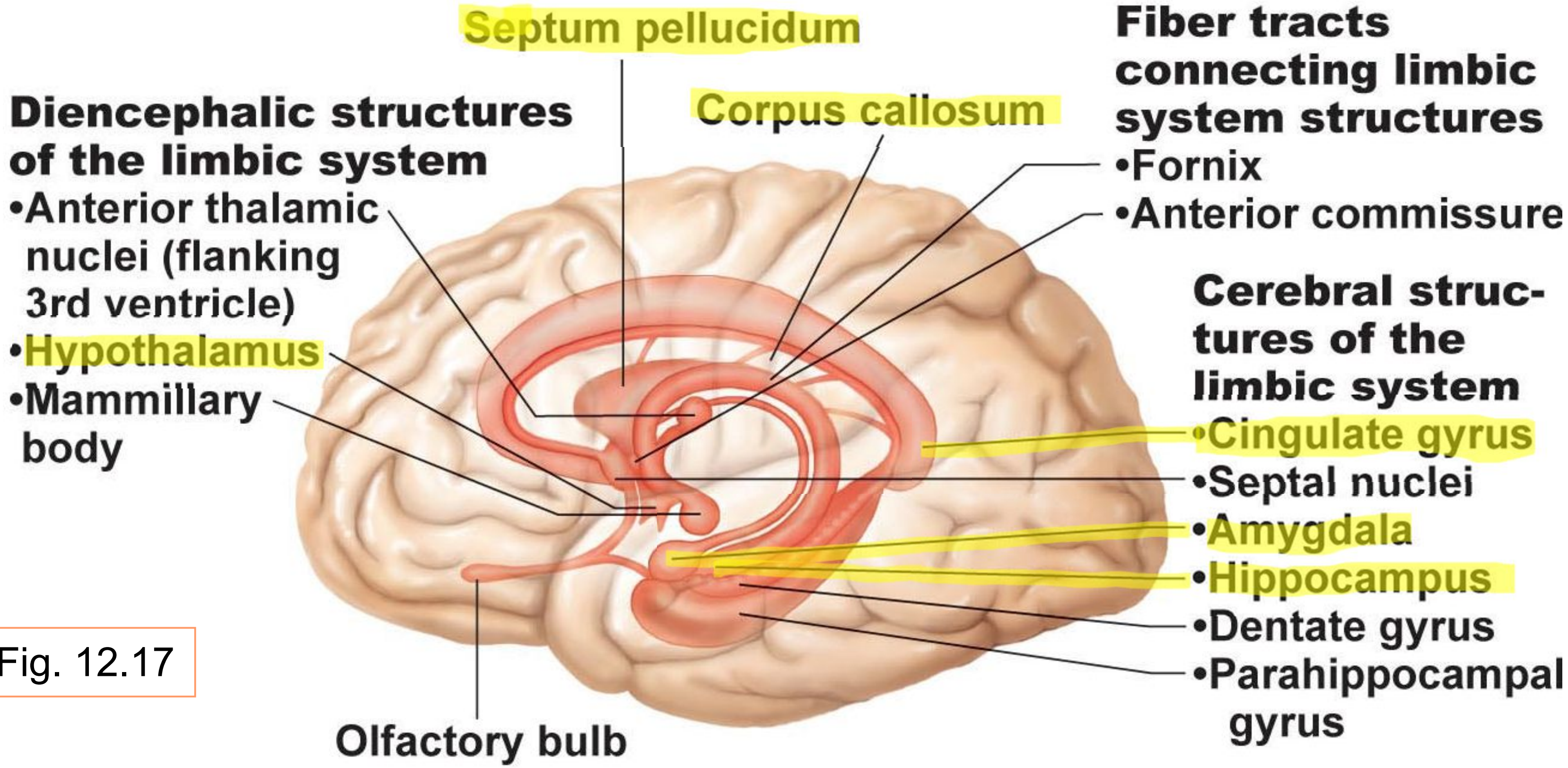


Fig. 12.17

Reticular formation:

- central core of medulla oblongata, pons, midbrain; neurons project to hypothalamus, thalamus, cortex, cerebellum, spinal cord
- reticular activating system (RAS):
  (i) maintains arousal of brain;
  (ii) filter for incoming signals (RAS & cerebral cortex disregard ~99% of all sensory stimuli)

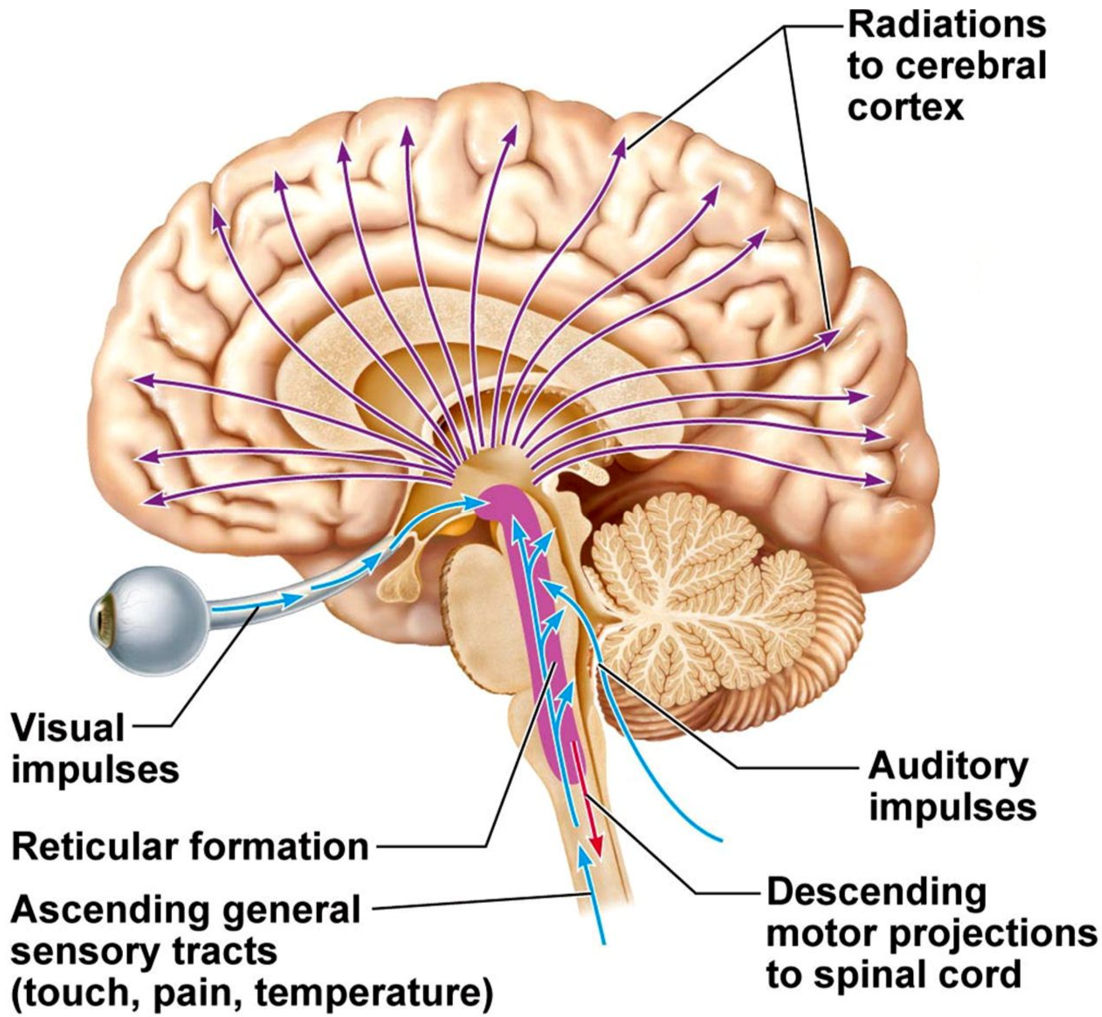


Fig. 12.18