Neuroanatomical Correlates of Brain Function

Malay Dave

Topics

- Default Mode Network
- Salience Network, Reward & Misery Fleeing Pathways
- Central Executive Network
- Emotion Processing
- Memory
- Mirror Neurons, Error Neurons, Place Neurons, Rose Hip Neurons
- Cerebellum & Psychiatry

Default Mode Network

DMN

Neurological basis for the self

- **Autobiographical information:** Memories of collection of events and facts about one's self
- **Self-reference:** Referring to traits and descriptions of one's self
- **Emotion of one's self:** Reflecting about one's own emotional state

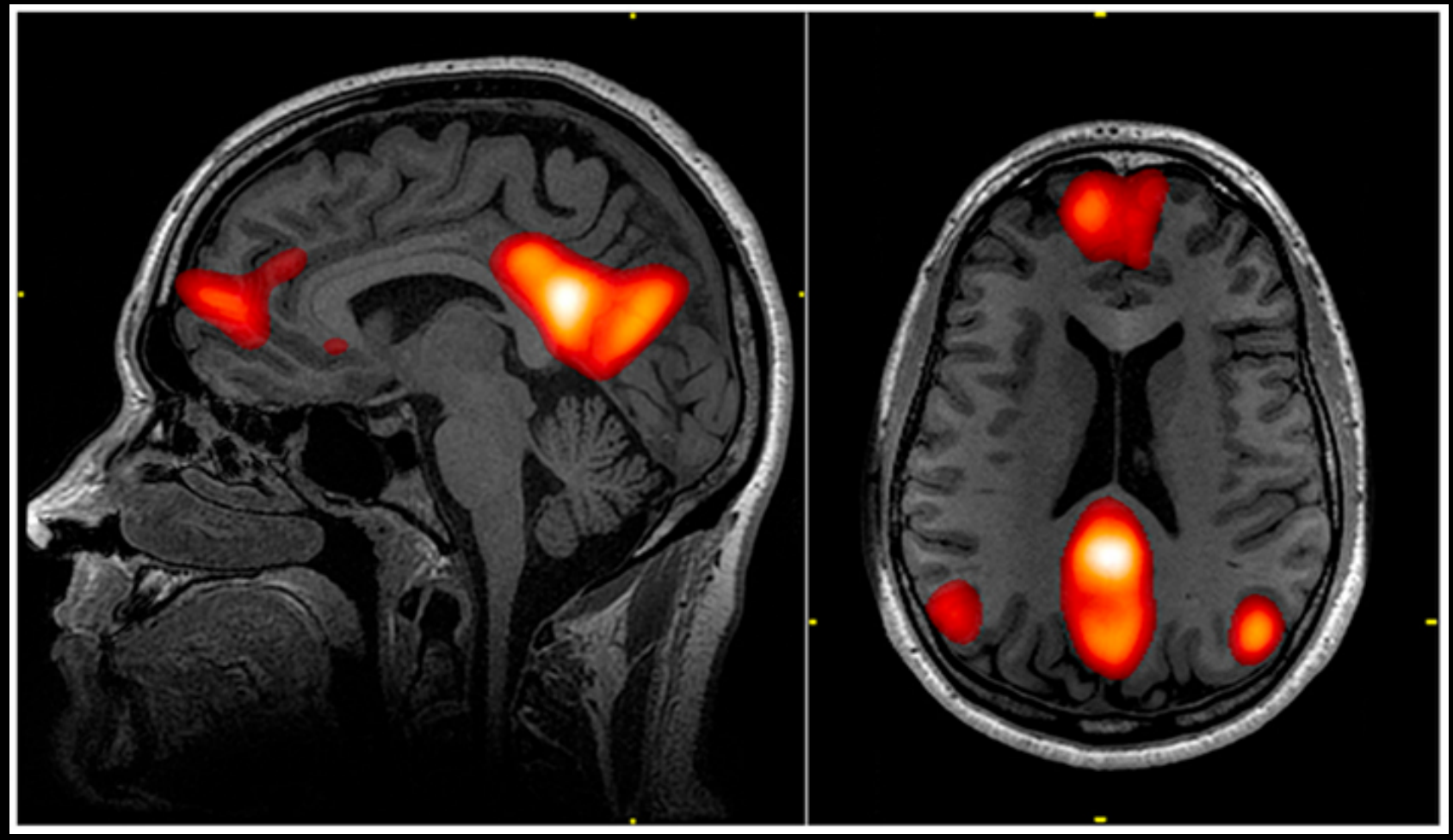
Thinking about others

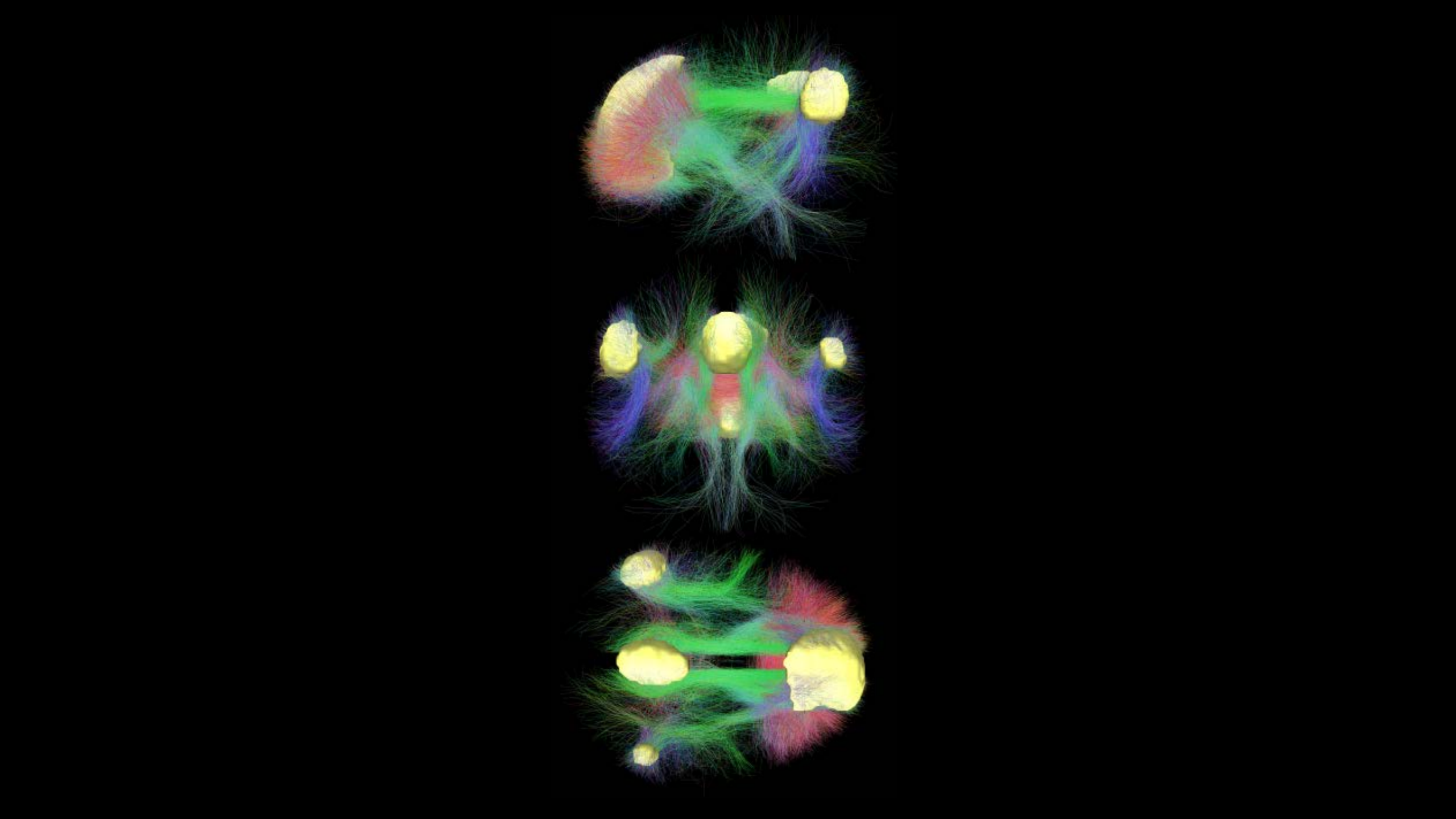
- **Theory of Mind:** Thinking about the thoughts of others and what they might or might not know
- **Emotions of other:** Understanding the emotions of other people and empathizing with their feelings
- **Moral reasoning:** Determining just and unjust result of an action
- **Social evaluations:** Good-bad attitude judgments about social concepts
- **Social categories:** Reflecting on important social characteristics and status of a group

DMN

Remembering the past and thinking about the future

- **Remembering the past:** Recalling events that happened in the past
- **Imagining the future:** Envisioning events that might happen in the future
- **Episodic memory:** Detailed memory related to specific events in time
- **Story comprehension:** Understanding and remembering a narrative



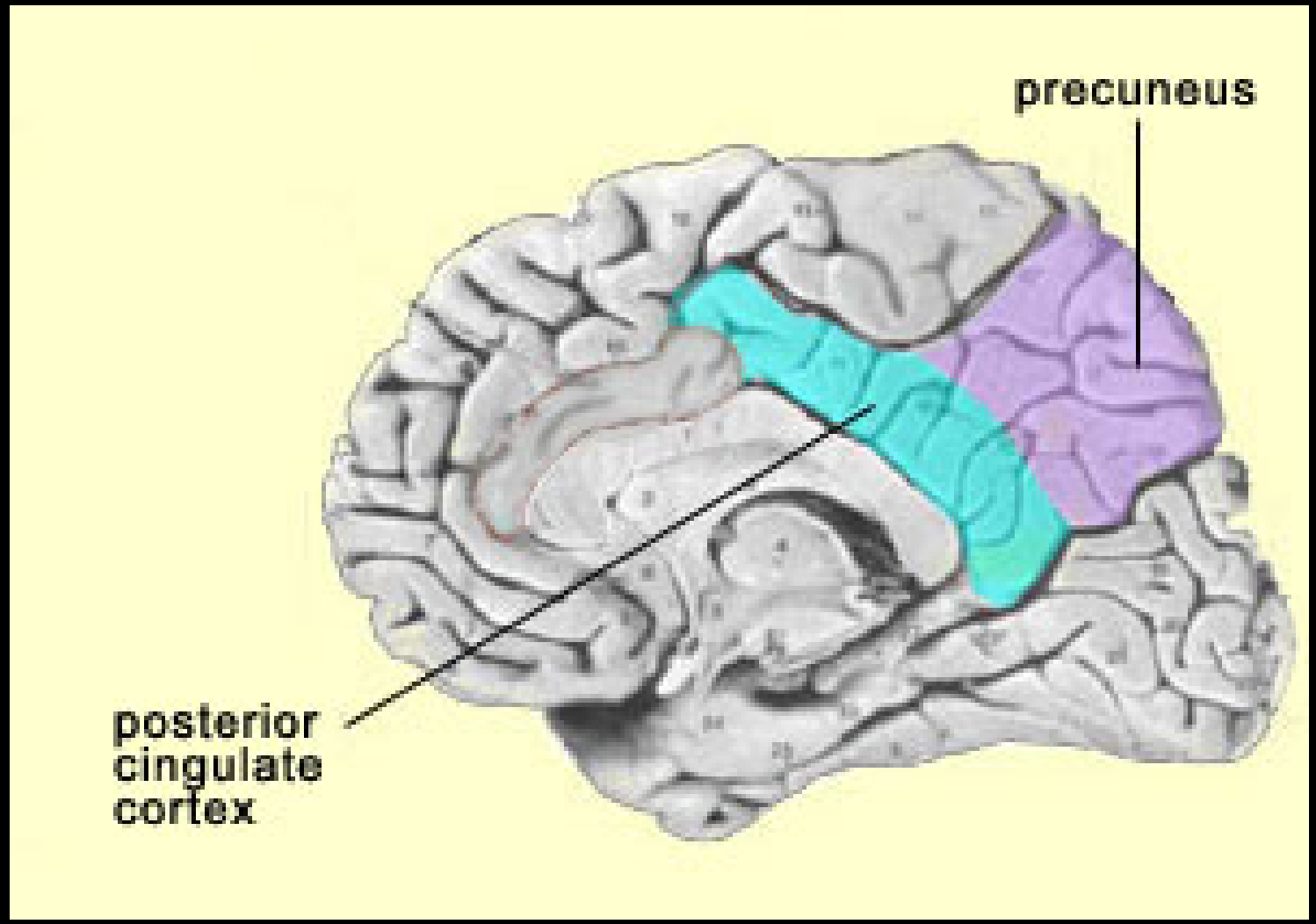


Functional hubs

Information regarding the self

PCC & Precuneus

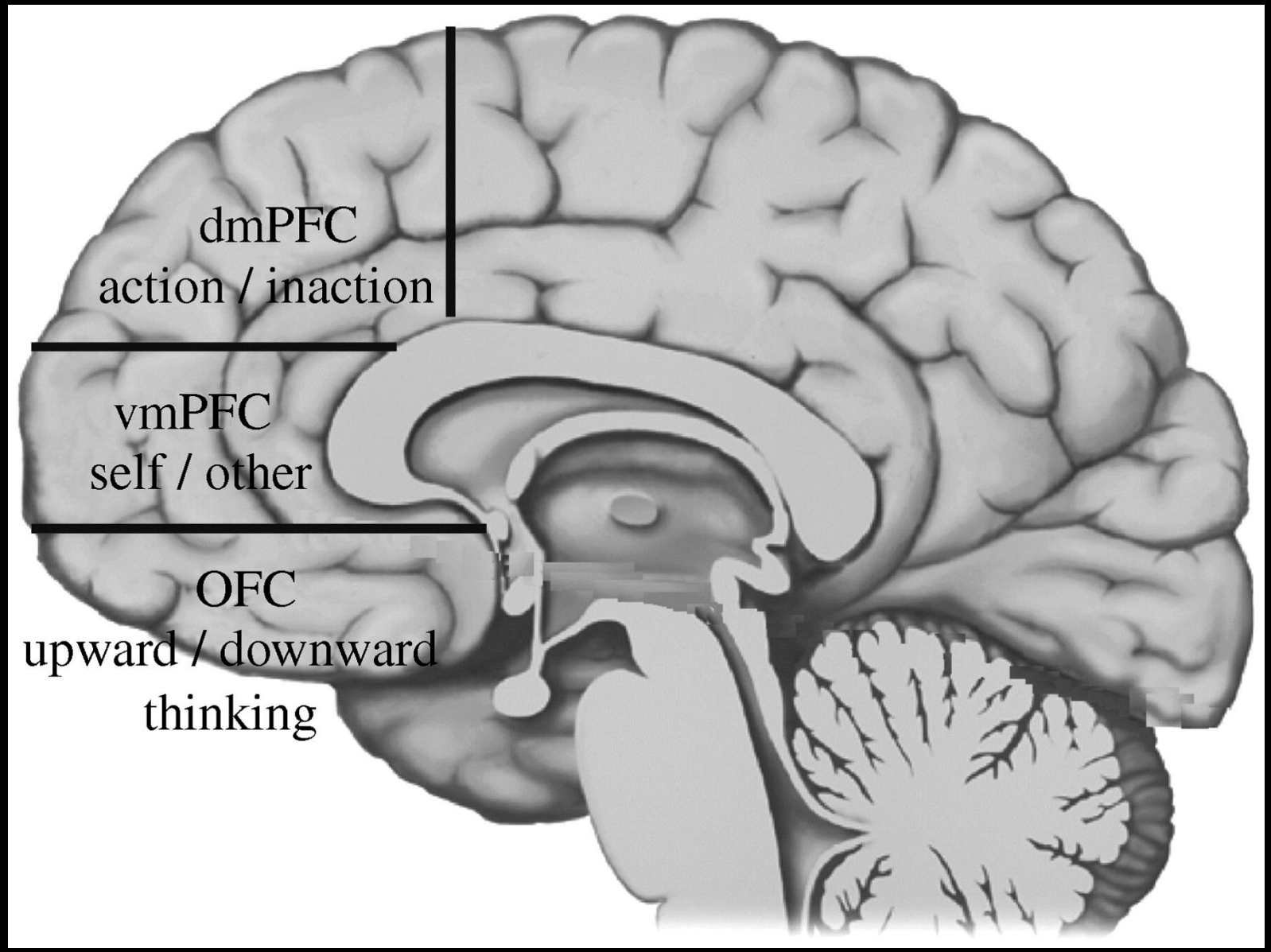
- Combines bottom-up (not controlled) attention with information from memory and perception
- The ventral (lower) part of PCC activates in all tasks which involve the DMN including those related to the self, related to others, remembering the past, thinking about future, and processing concepts plus spatial navigation
- The dorsal (upper) part of PCC involves involuntary awareness and arousal
- The precuneus is involved in visual, sensorimotor, and attentional information


precuneus
posterior
cingulate
cortex

Medial Prefrontal Cortex (mPFC)

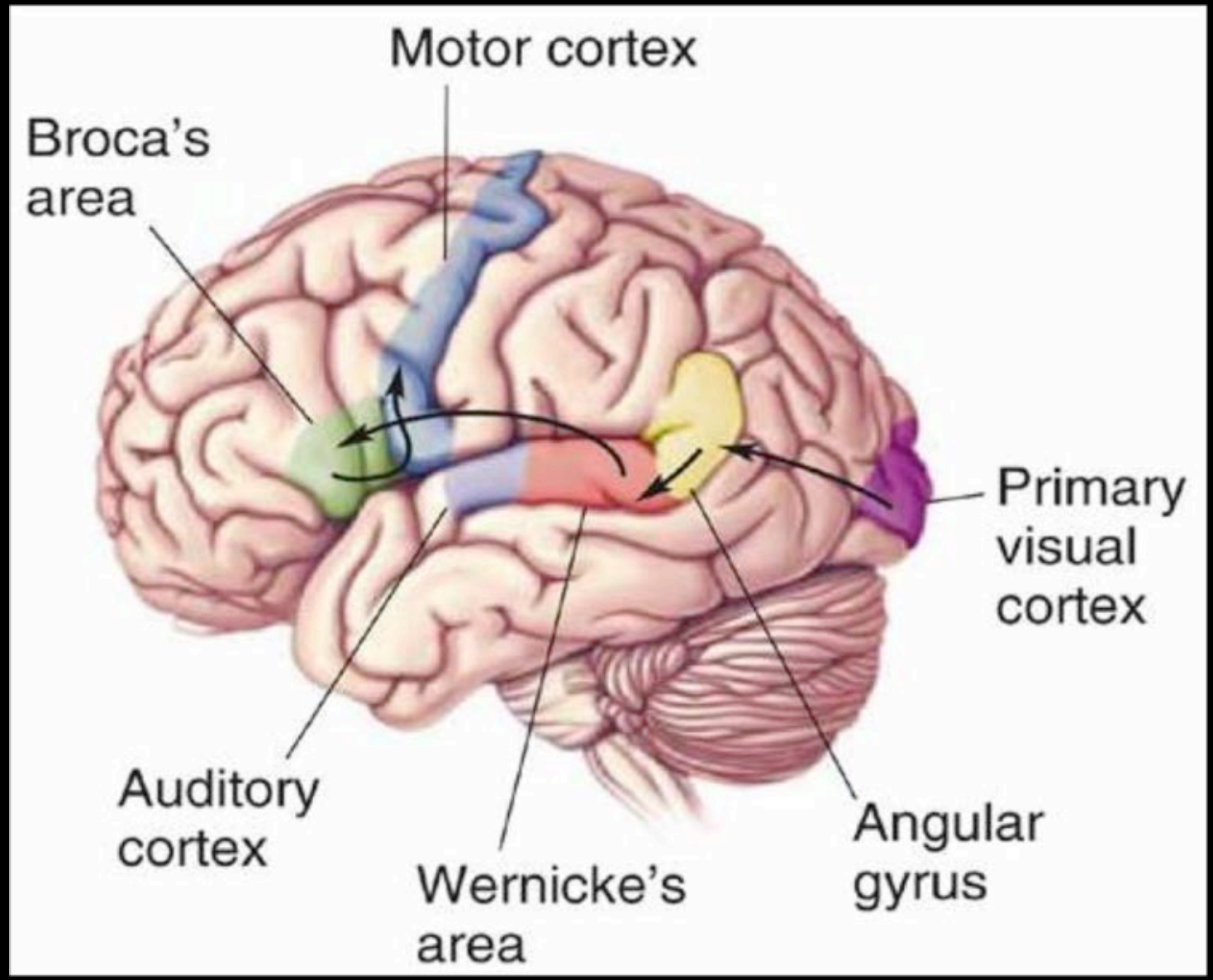
- Decisions about self processing such as personal information, autobiographical memories, future goals and events, and decision making regarding those personally very close such as family

- The ventral (lower) part is involved in positive emotional information and internally valued reward


dmPFC
action / inaction
vmPFC
self / other
OFC
upward / downward
thinking

Angular Gyrus

- Connects perception, attention, spatial cognition, and action and helps with parts of recall of episodic memories


Motor cortex
Broca's area
Primary visual cortex
Auditory cortex
Wernicke's area
Angular gyrus

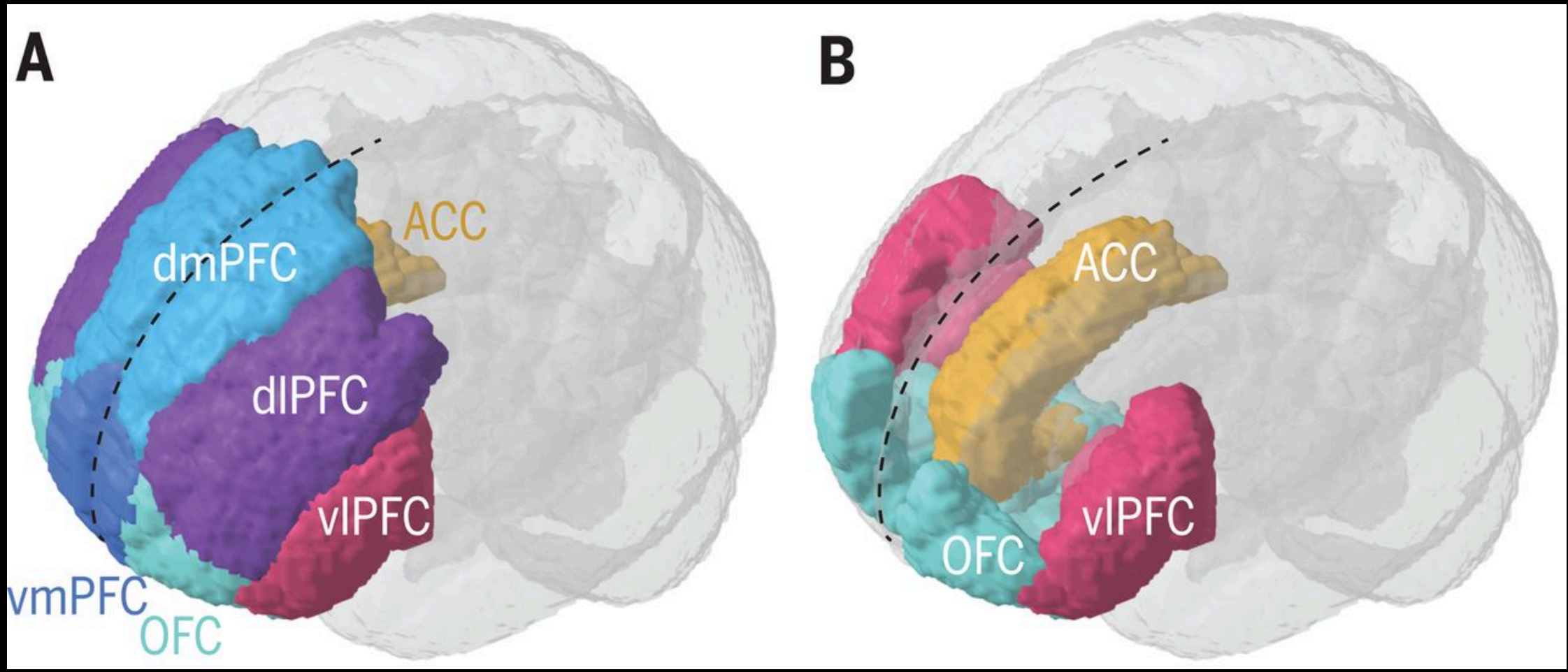
Dorsal medial subsystem

Thinking about others

Functional hubs: PCC, mPFC & AG

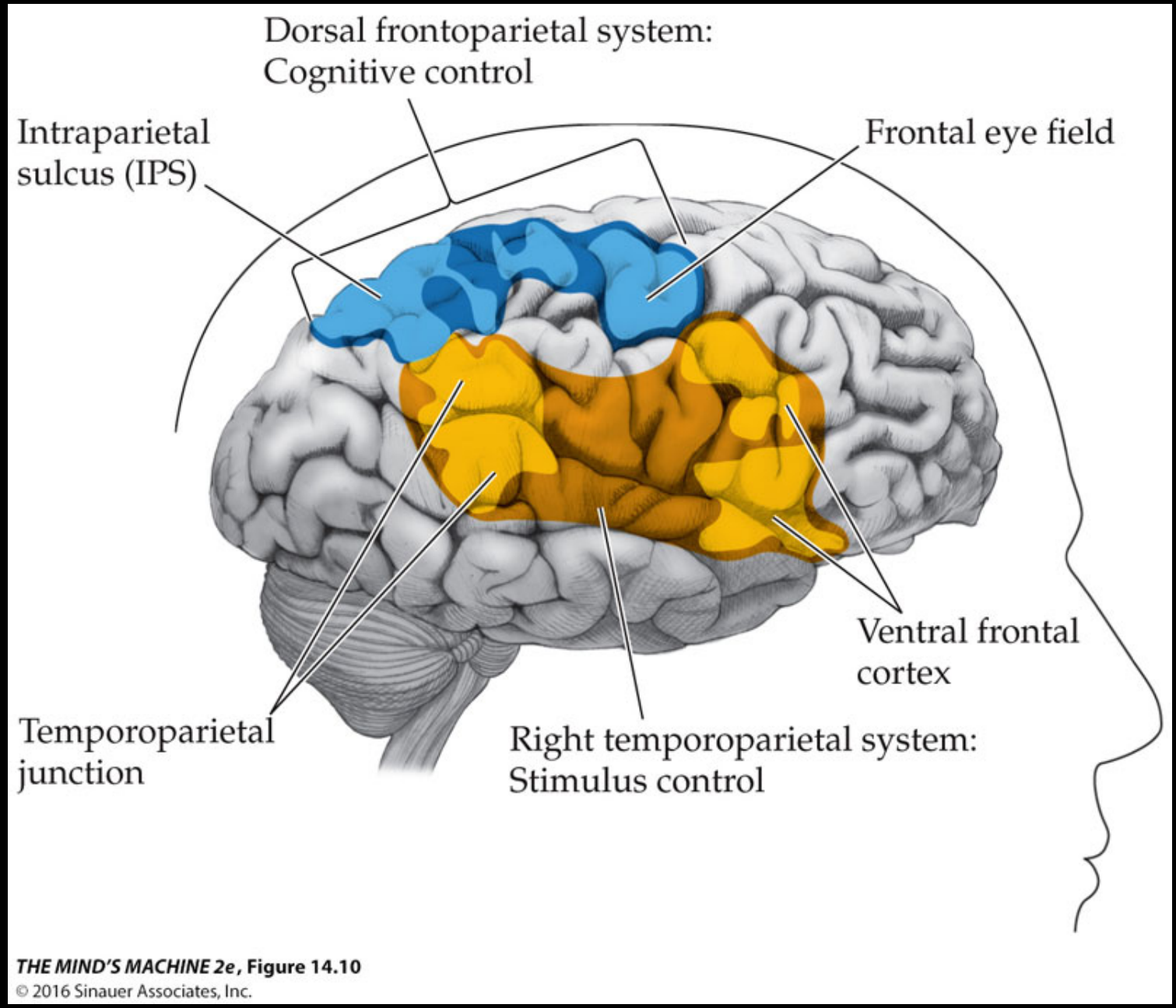
Dorsal medial Prefrontal Cortex (dmPFC)

- Involved in social directed thought such as determining or inferring the purpose of others' actions

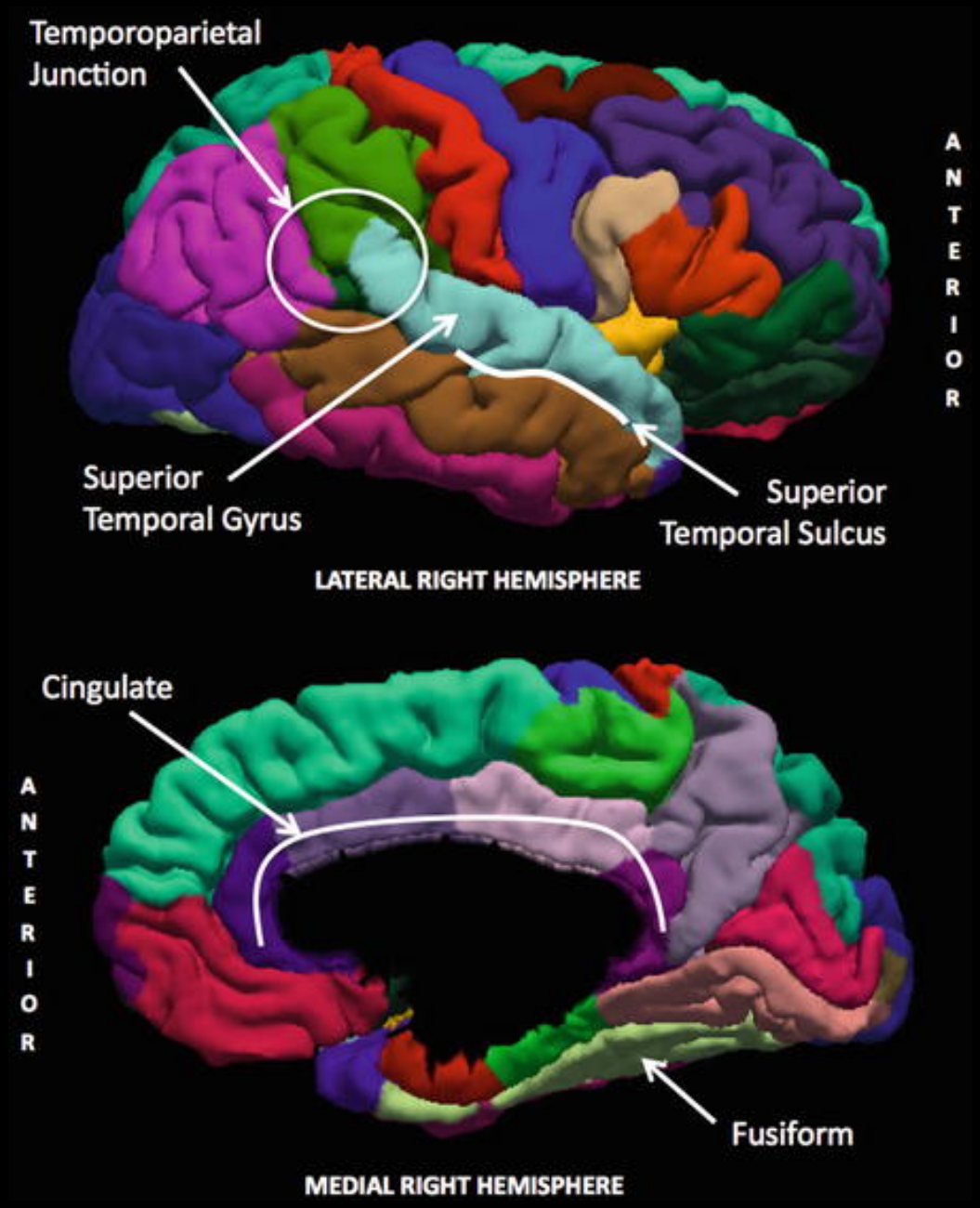

A
dmPFC
ACC
dlPFC
vlPFC
vmPFC
OFC
B
ACC
vlPFC
OFC

Temporoparietal Junction (TPJ)

- Reflects on beliefs about others, also known as TOM



***THE MIND'S MACHINE 2e*, Figure 14.10**

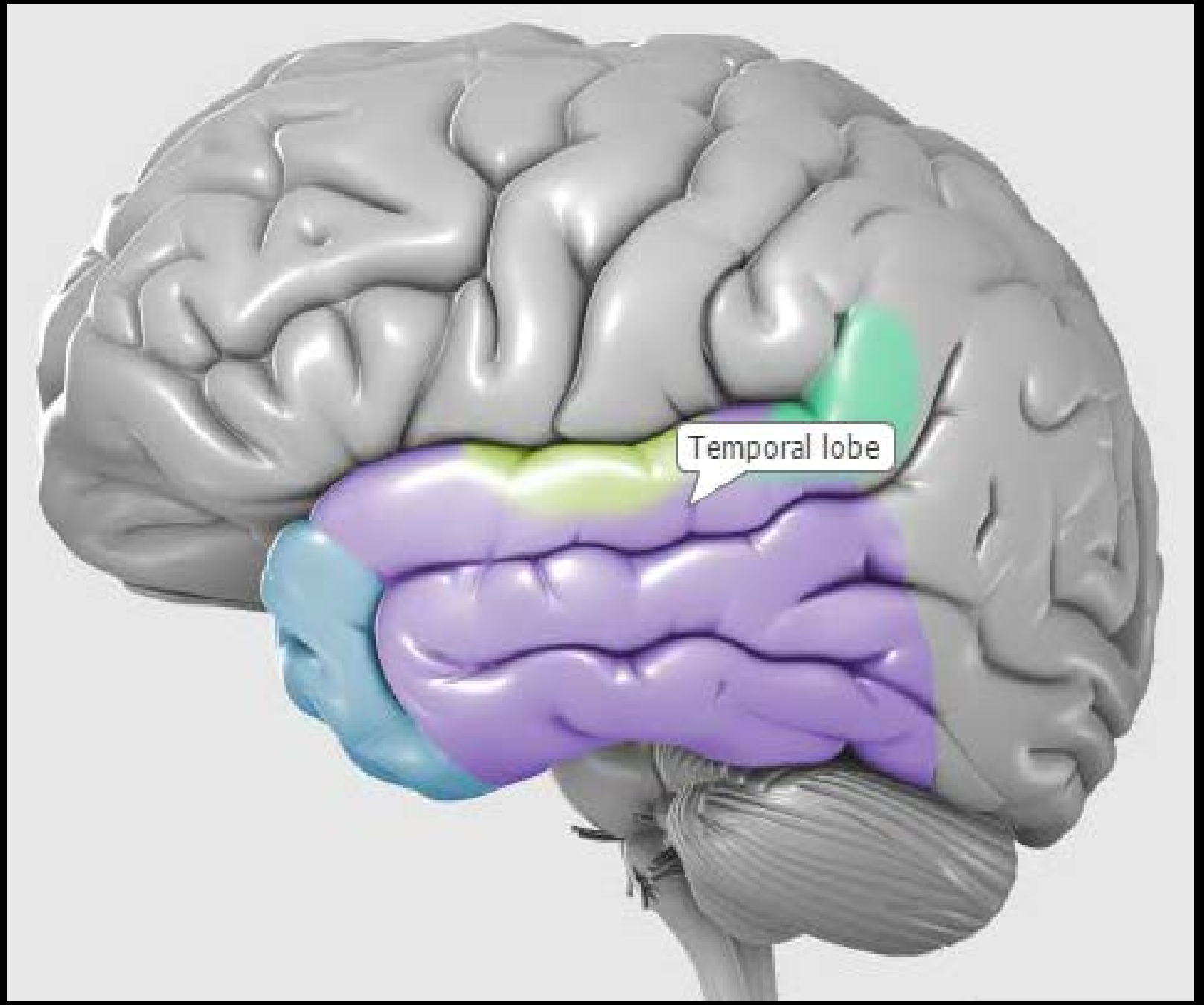

Temporoparietal
Junction
Superior
Temporal Gyrus
Superior
Temporal Sulcus
ANTERIOR
LATERAL RIGHT HEMISPHERE
Cingulate
ANTERIOR
Fusiform
MEDIAL RIGHT HEMISPHERE

Lateral Temporal Cortex

- Retrieval of social semantic and conceptual knowledge

Anterior Temporal Pole

- Abstract conceptual information particularly social in nature


Temporal lobe

Medial temporal subsystem

Autobiographical memory and future simulations

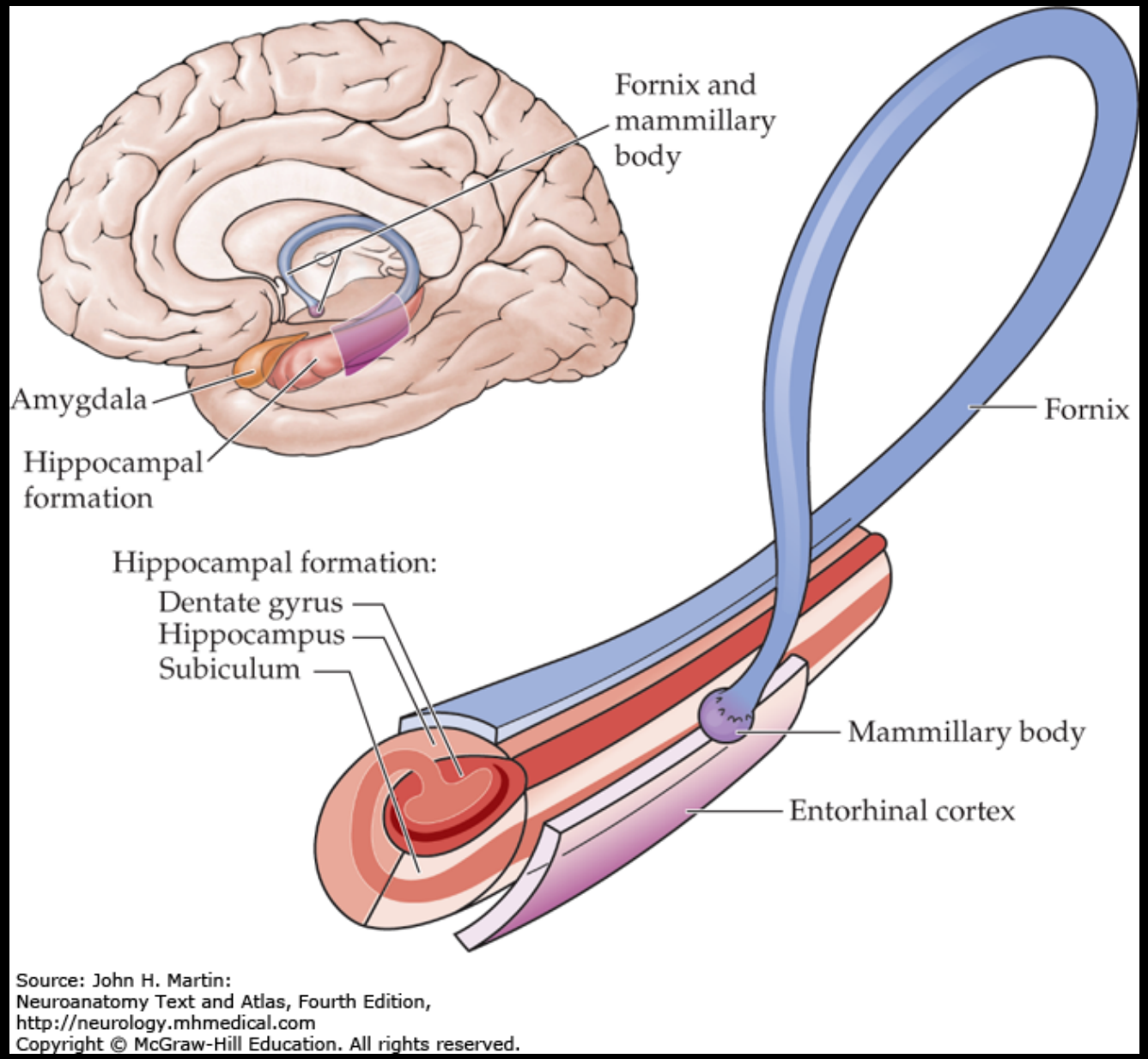
Functional hubs: PCC, mPFC, and AG

Hippocampus (HF+)

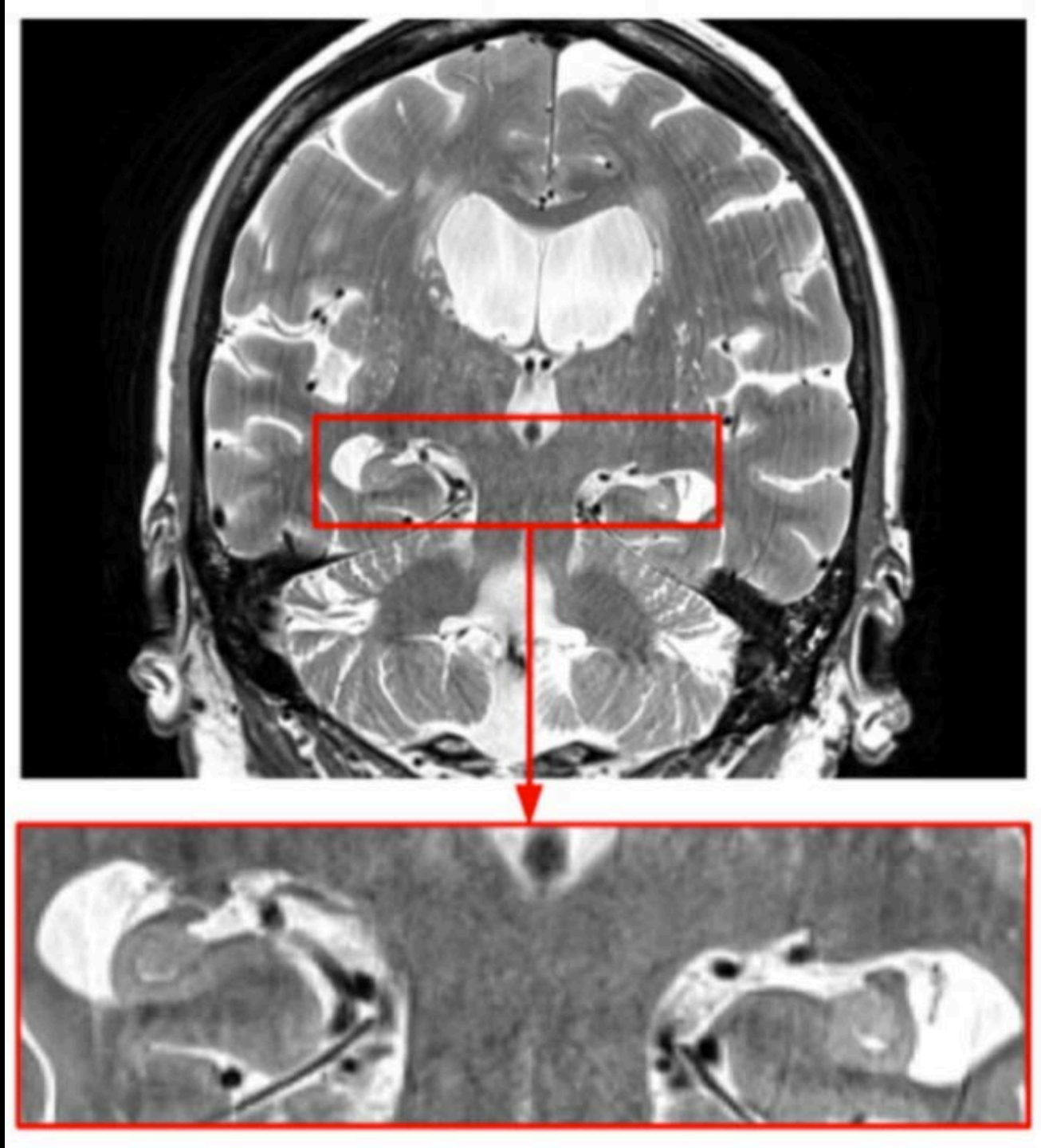
- Formation of new memories as well as remembering the past and imagining the future

Parahippocampus (PHC)

- Spatial and scene recognition and simulation

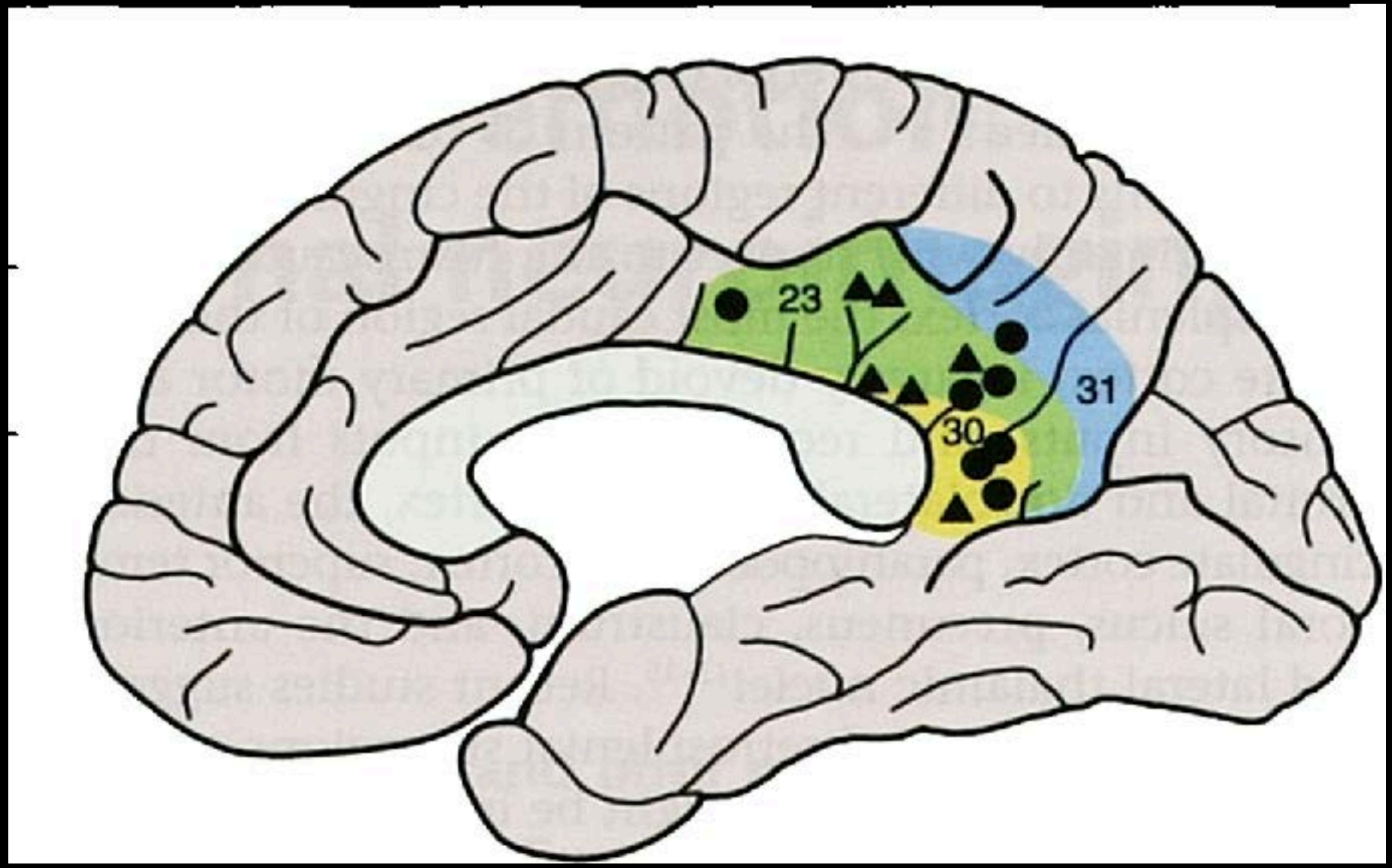


Source: John H. Martin:
Neuroanatomy Text and Atlas, Fourth Edition,
http://neurology.mhmedical.com



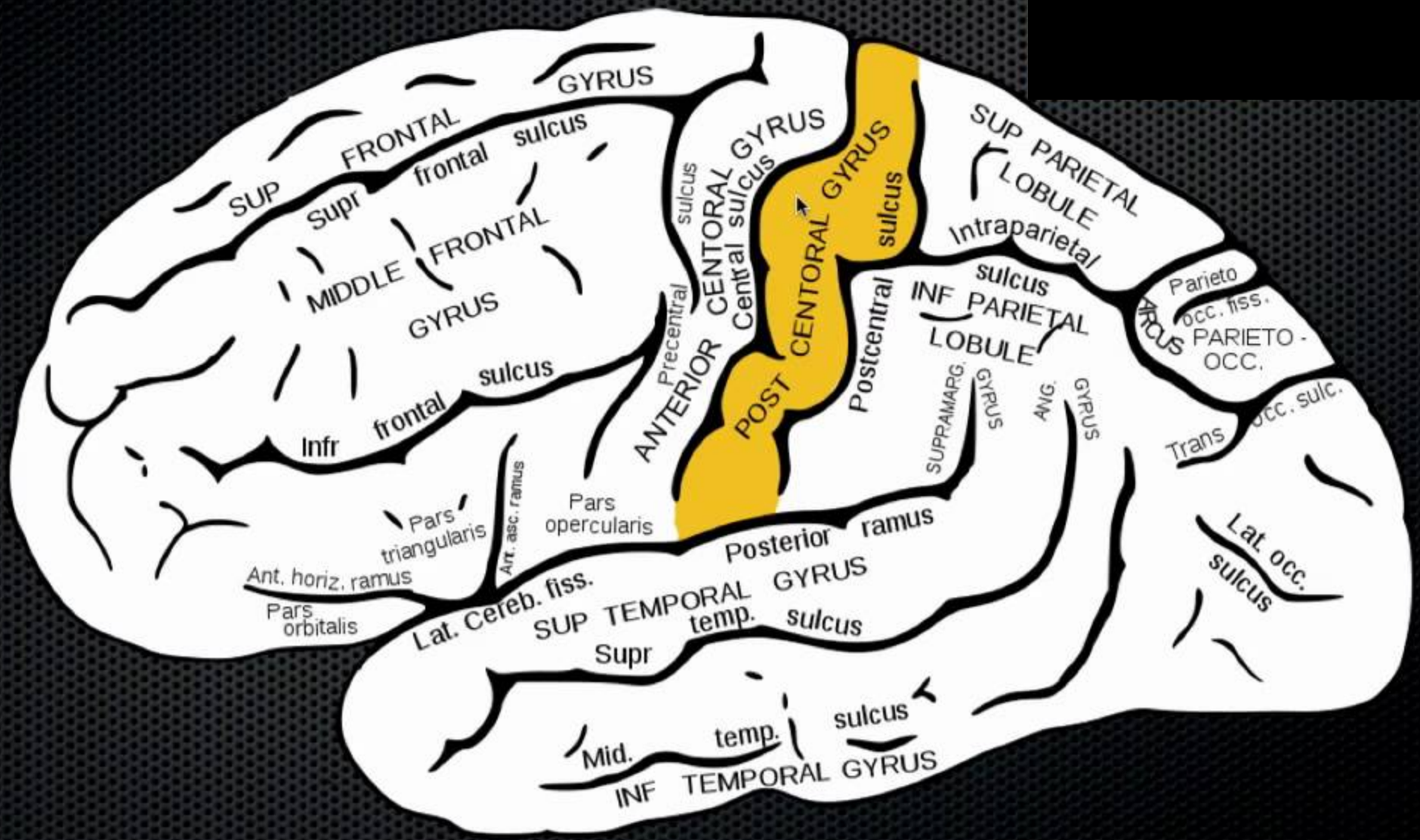
Retrosplenial Cortex (RSC)

- Spatial navigation


23
31
30

Posterior Inferior Parietal Lobe (pIPL)

- Junction of auditory, visual, and somatosensory information and attention


SUP FRONTAL GYRUS
Supr frontal sulcus
MIDDLE FRONTAL GYRUS
Infr frontal sulcus
Precentral sulcus
ANTERIOR CENTORAL GYRUS
POST CENTORAL GYRUS
sulcus
Central sulcus
Postcentral
SUP PARIETAL LOBULE
Intraparietal sulcus
INF PARIETAL LOBULE
ARCUS
Parieto occ. fiss.
PARIETO - OCC.
SUPRAMARG. GYRUS
ANG. GYRUS
Trans occ. sulc.
Lat. occ. sulcus
Pars triangularis
Pars opercularis
Art. asc. ramus
Posterior ramus
Ant. horiz. ramus
Pars orbitalis
Lat. Cereb. fiss.
SUP TEMPORAL GYRUS
Supr temp. sulcus
Mid. temp. sulcus
INF TEMPORAL GYRUS

Salience Network, Reward & Misery Fleeing Pathways

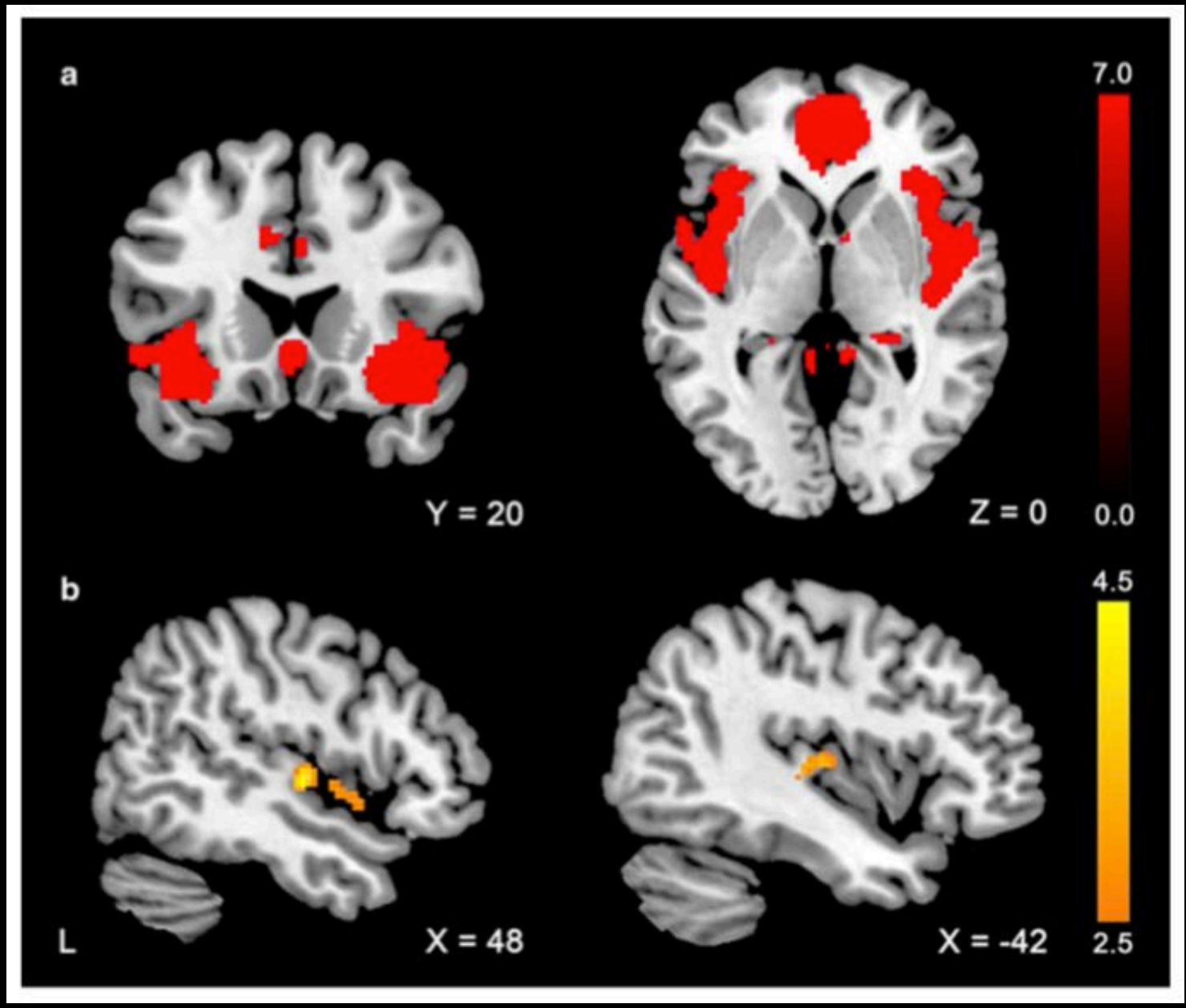
Salience Network

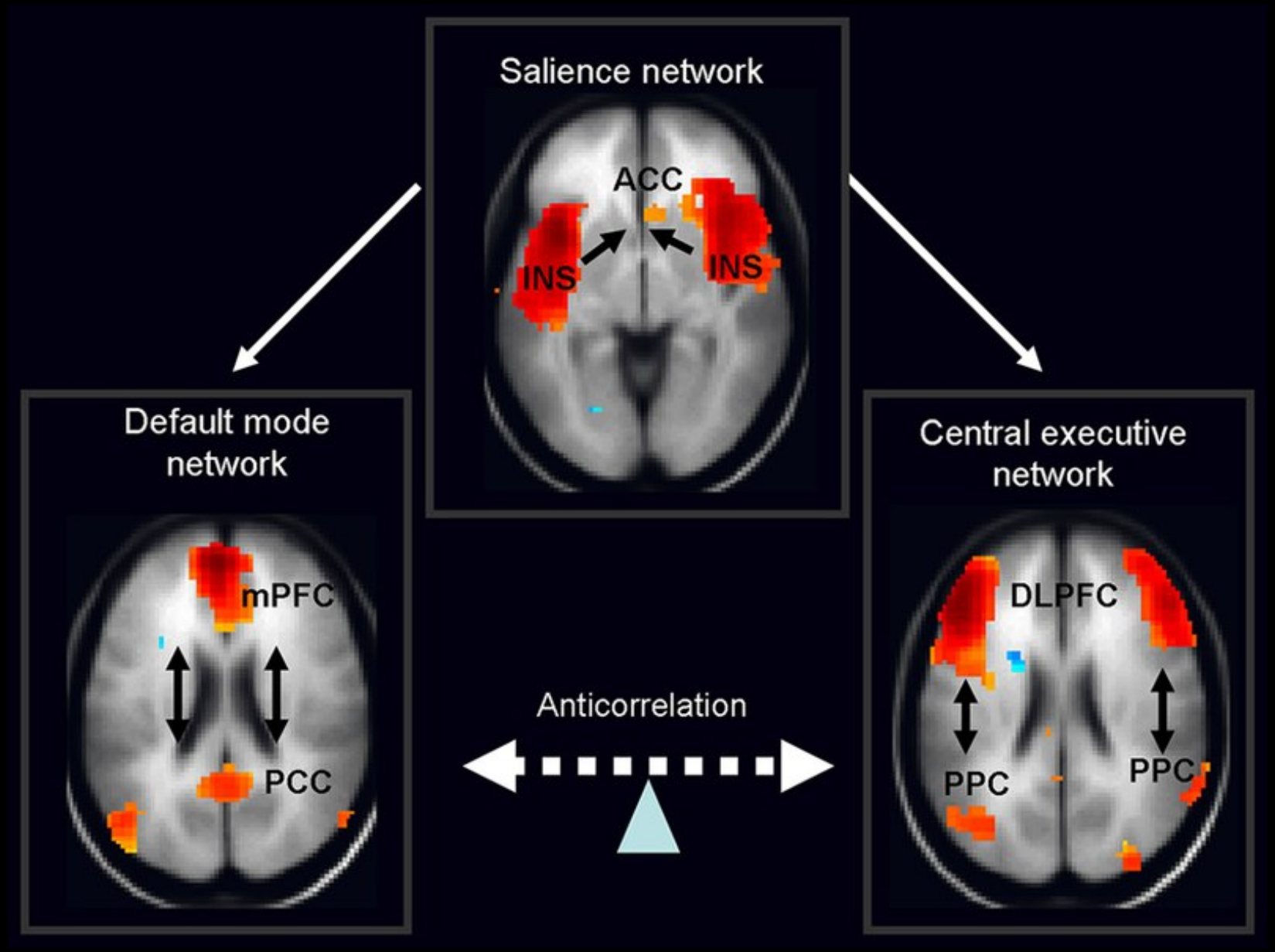
- Anterior Insula (AI) and dorsal Anterior Cingulate Cortex (dACC)
- Also consists of the Substantia Nigra, VTA, Ventral Striatum, Amygdala, Dorsomedial Thalamus, and Hypothalamus
- Involved in detecting and filtering salient stimuli, as well as in recruiting relevant functional networks
- Together with its interconnected brain networks, the SN contributes to a variety of complex functions, including communication, social behavior, and self-awareness through the integration of sensory, emotional, and cognitive information

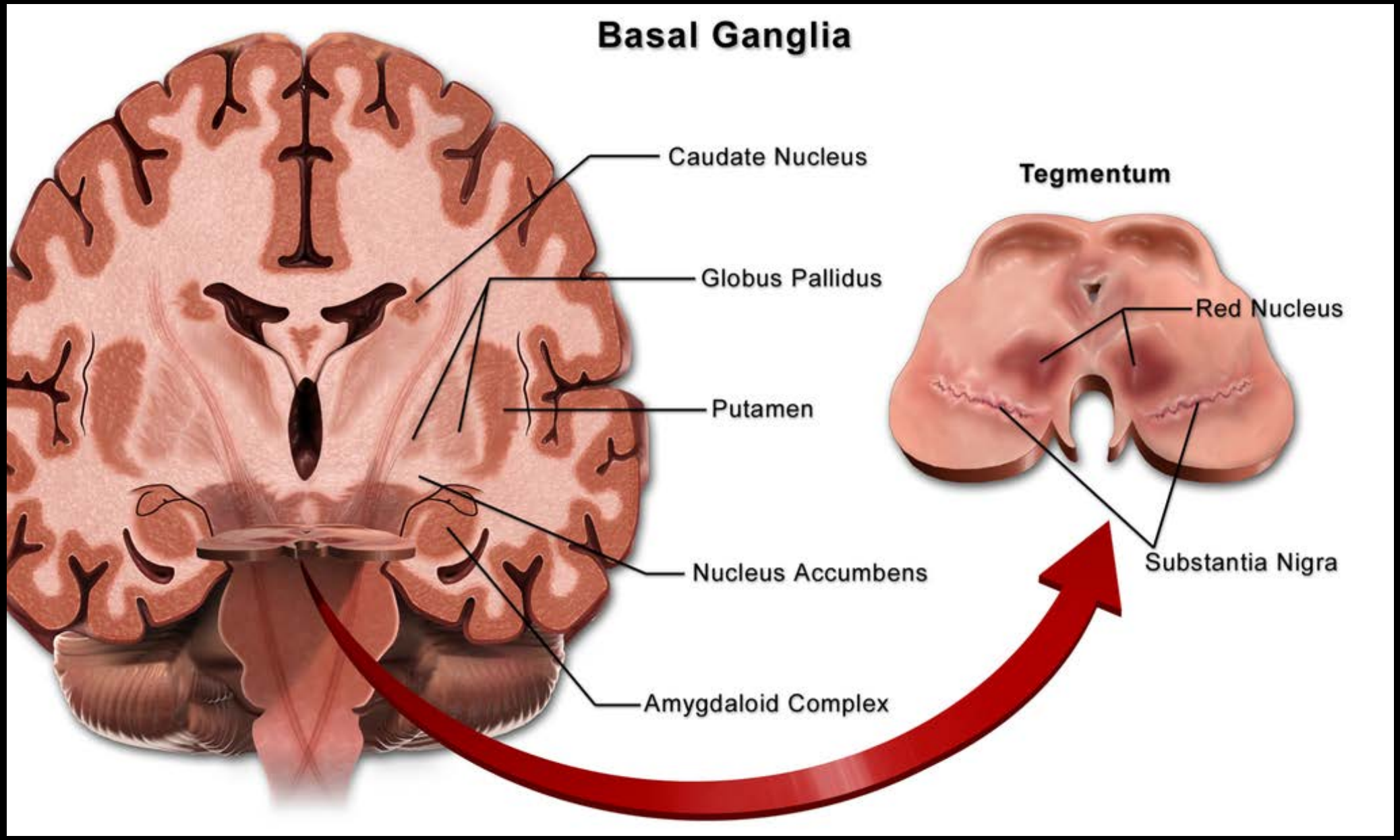
Salience Network

- Insula – stimuli originating from the body itself, eg. Visceral organs

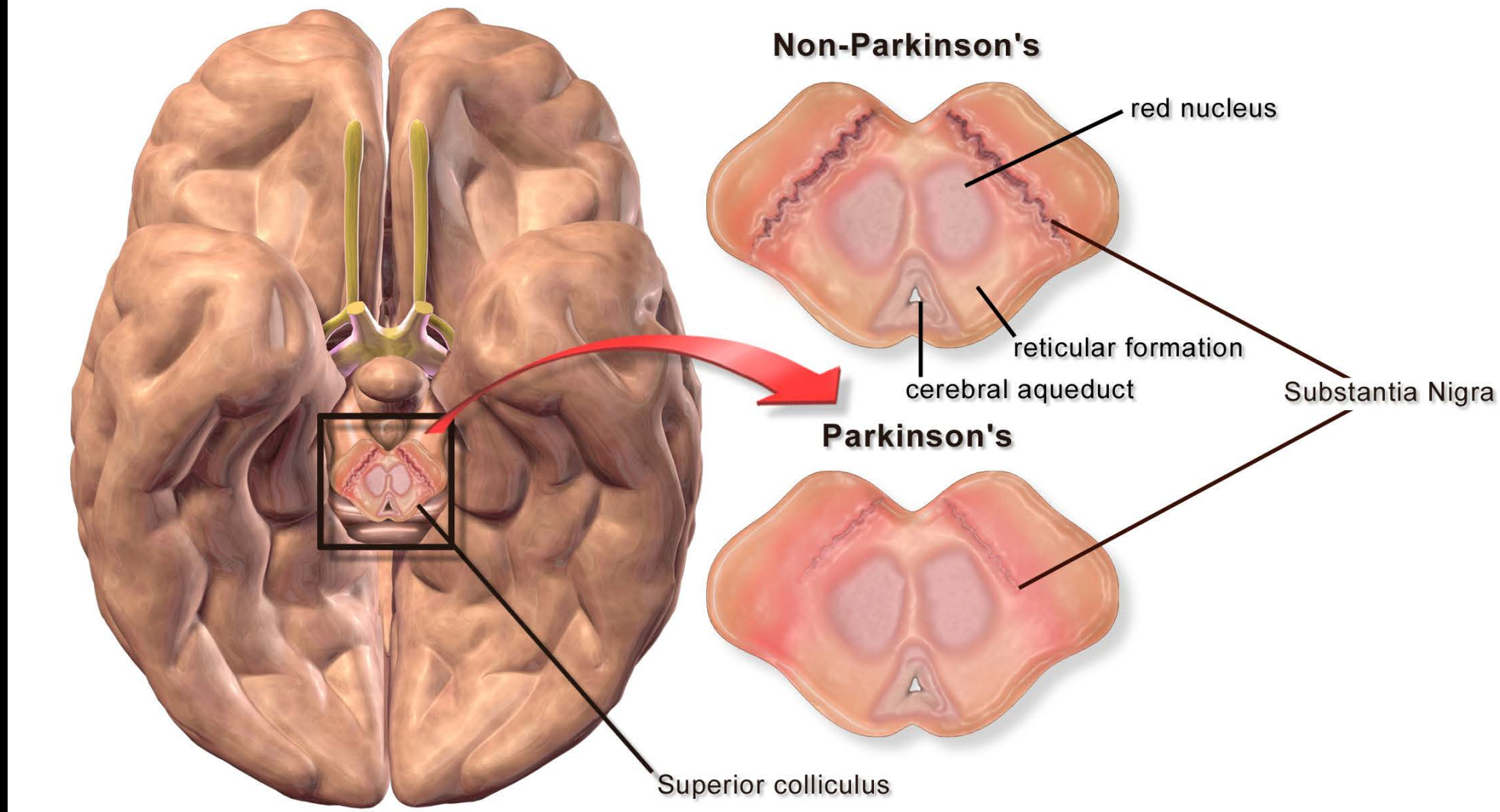
- Shifts mode from DMN to CEN

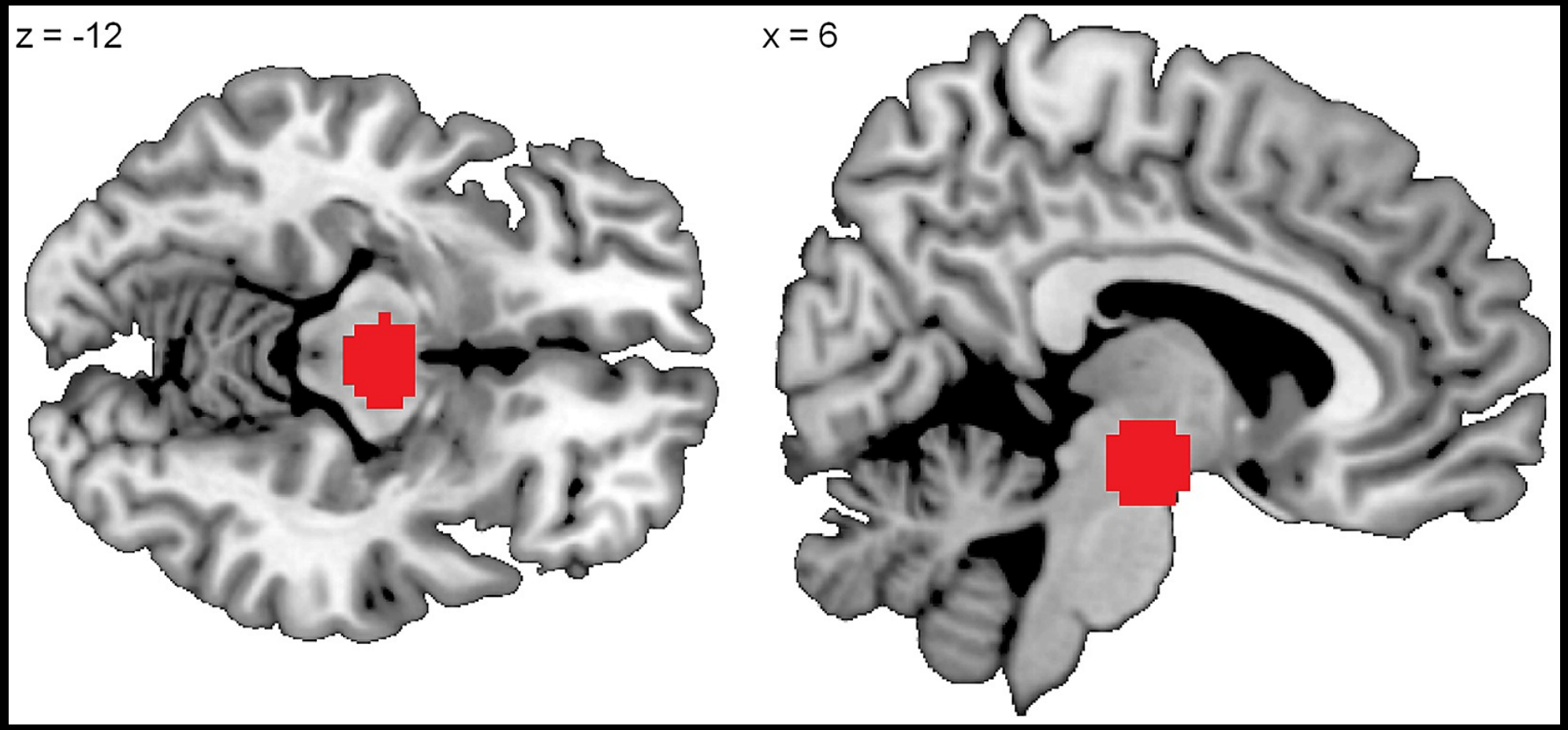

a
7.0
0.0
Y = 20
Z = 0
b
4.5
2.5
L
X = 48
X = -42

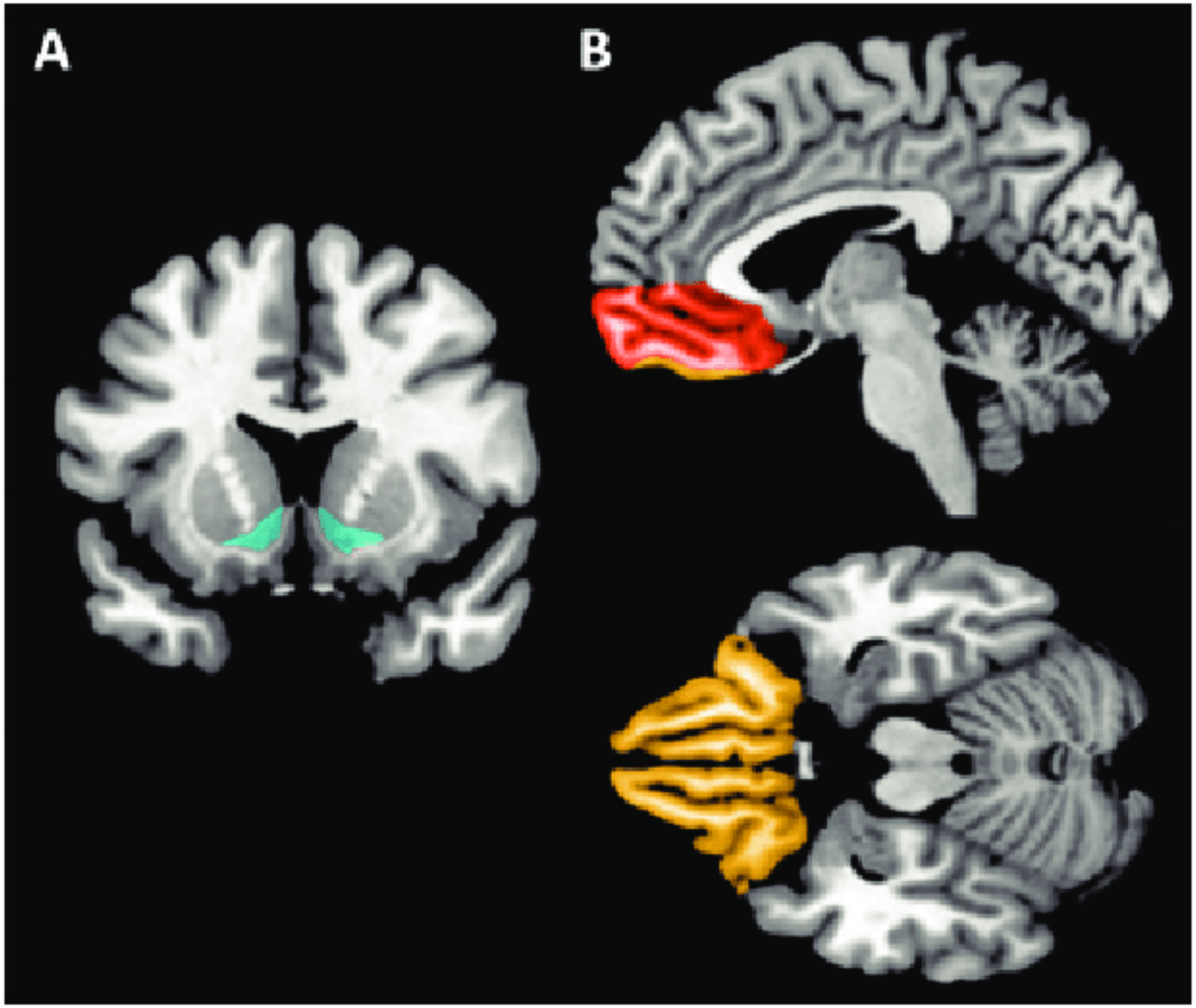

Salience network
ACC
INS
INS
Default mode network
mPFC
PCC
Central executive network
DLPFC
PPC
PPC
Anticorrelation

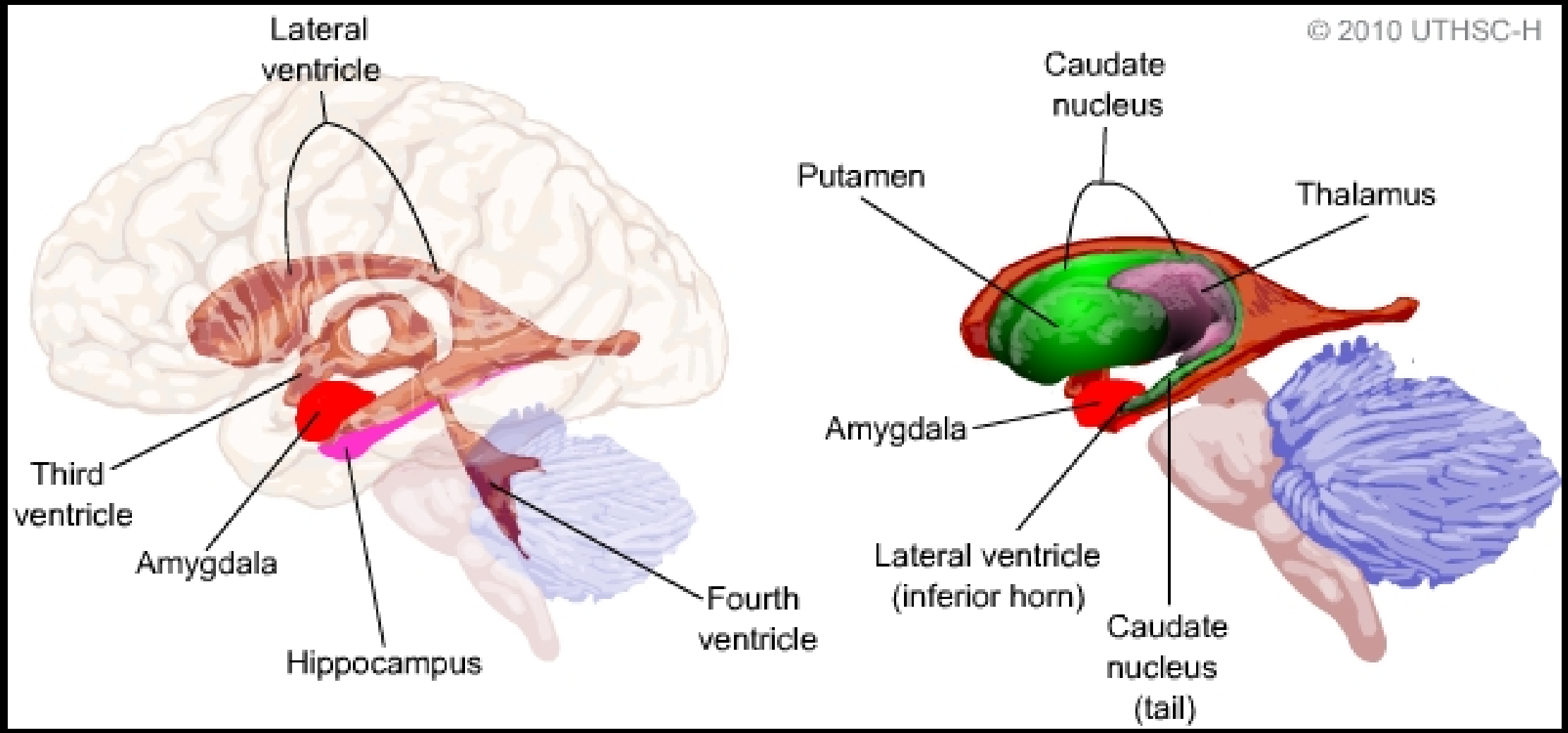

Basal Ganglia
Caudate Nucleus
Globus Pallidus
Putamen
Nucleus Accumbens
Amygdaloid Complex
Tegmentum
Red Nucleus
Substantia Nigra

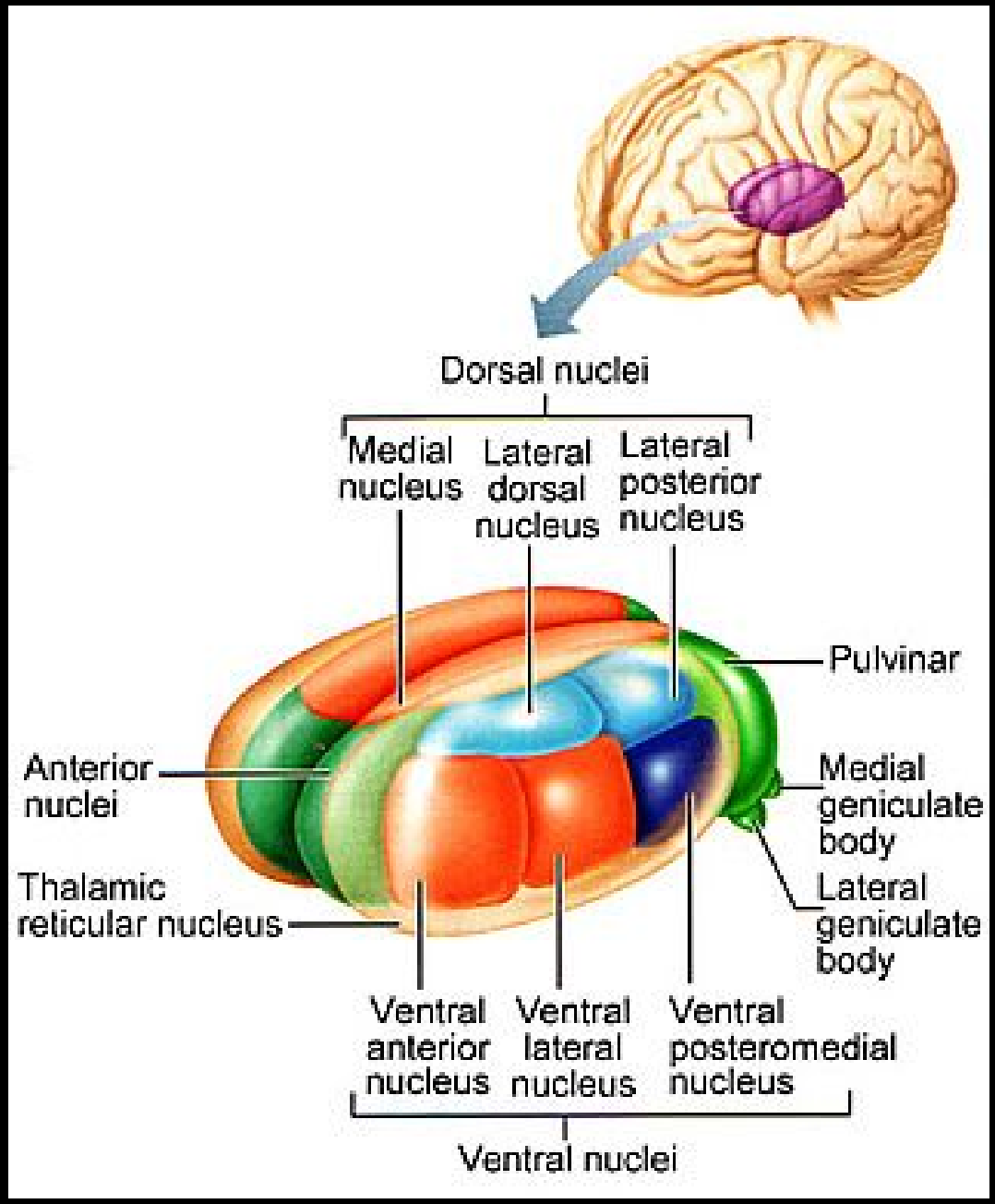
Parkinsons Disease

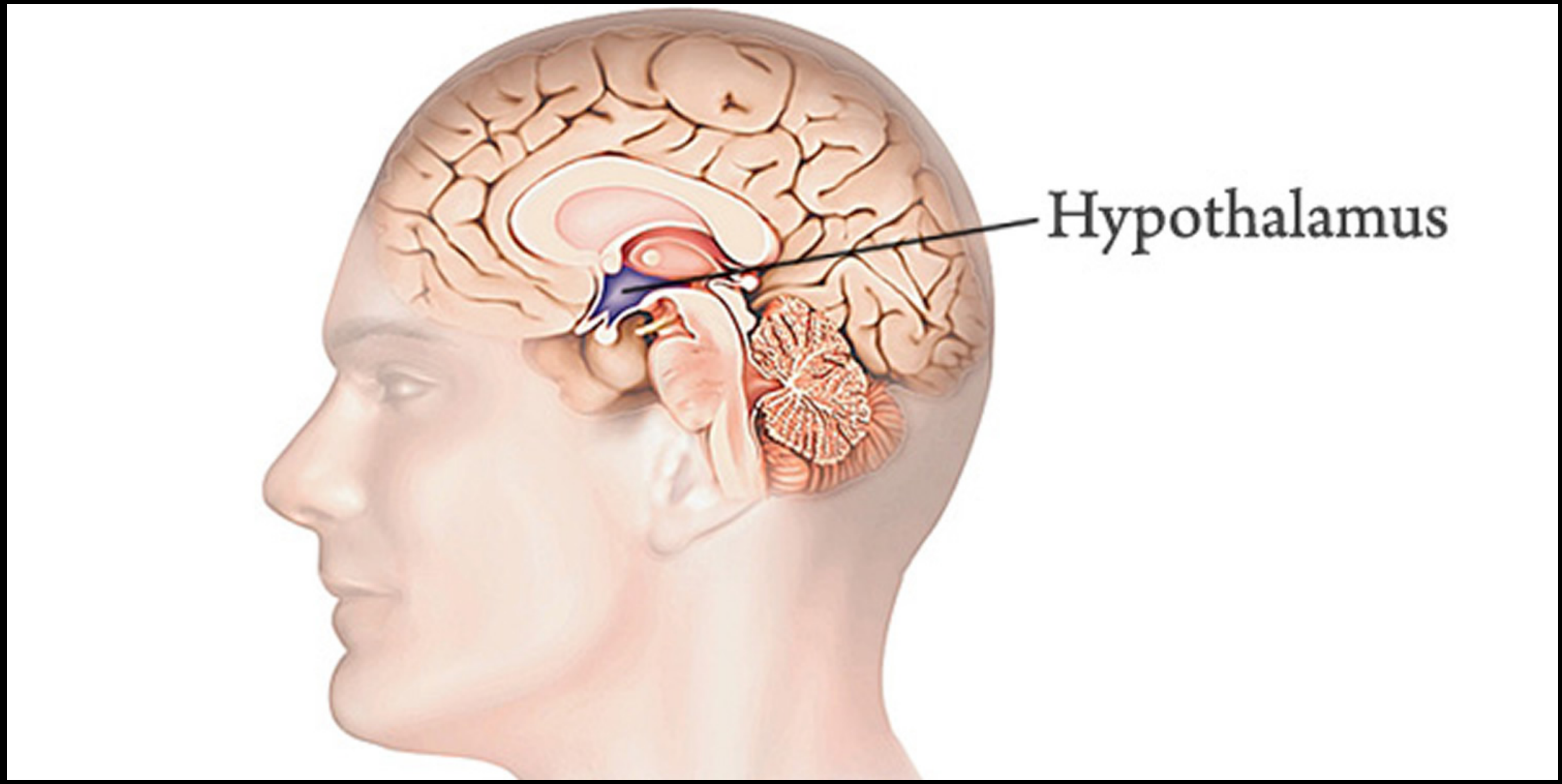



z = -12
x = 6


A
B


Lateral ventricle
Third ventricle
Amygdala
Hippocampus
Fourth ventricle
© 2010 UTHSC-H
Caudate nucleus
Putamen
Thalamus
Amygdala
Lateral ventricle (inferior horn)
Caudate nucleus (tail)


Dorsal nuclei
Medial nucleus
Lateral dorsal nucleus
Lateral posterior nucleus
Pulvinar
Anterior nuclei
Medial geniculate body
Lateral geniculate body
Thalamic reticular nucleus
Ventral anterior nucleus
Ventral lateral nucleus
Ventral posteromedial nucleus
Ventral nuclei


Hypothalamus

Reward Pathways

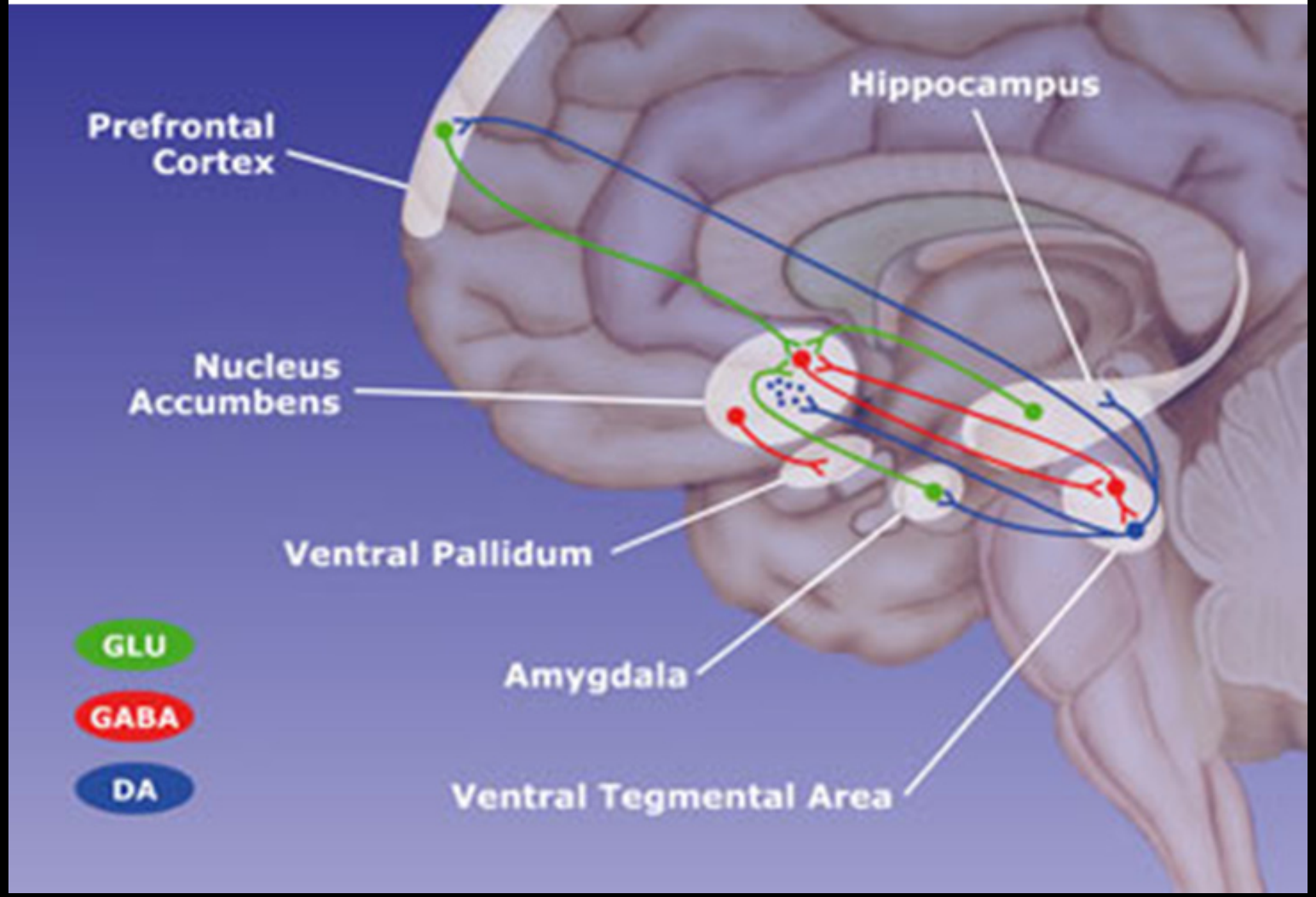
Reward Pathways

- The ventral tegmental area (VTA), the nucleus accumbens, and the prefrontal cortex

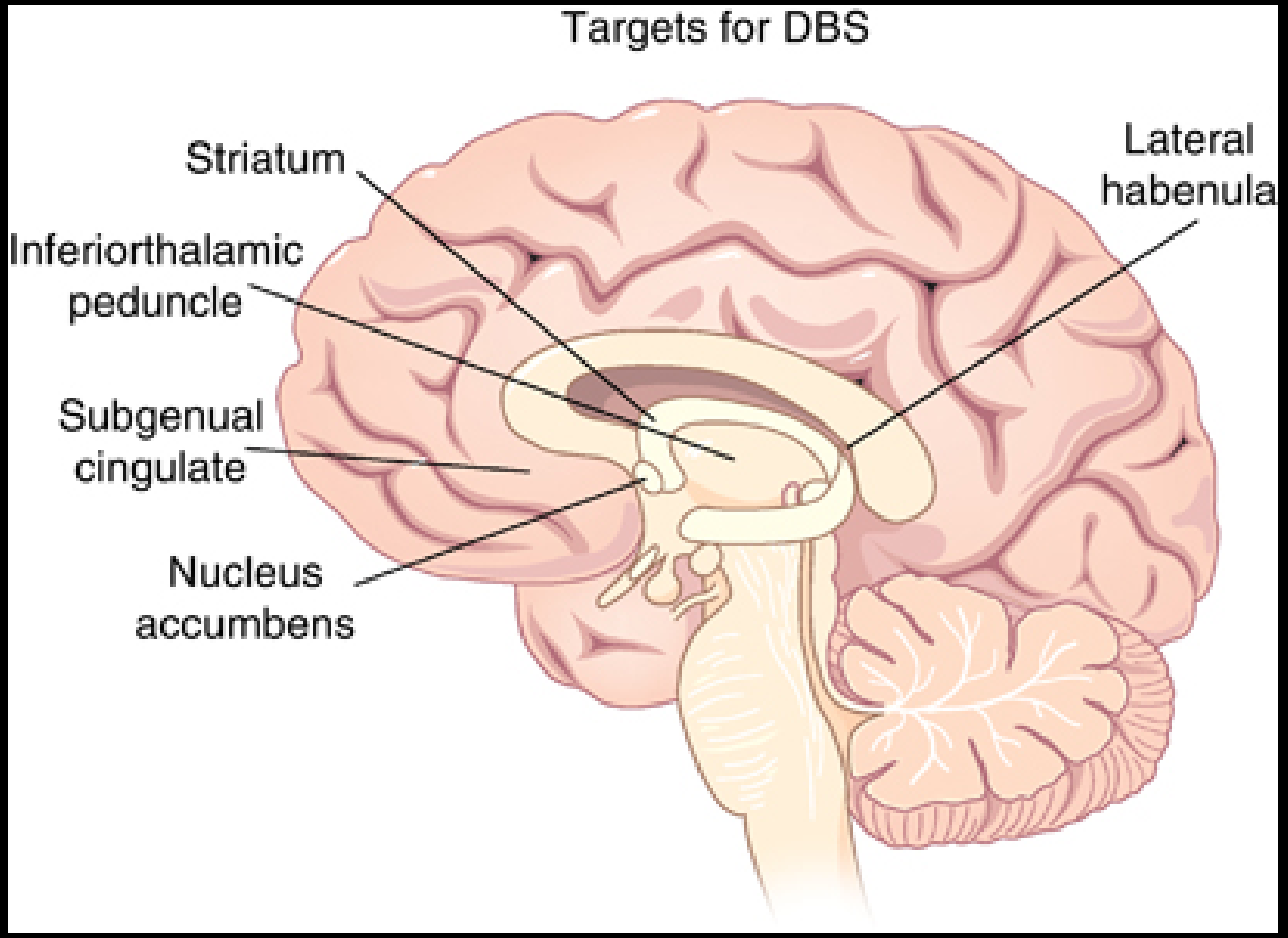
- When activated by a rewarding stimulus (e.g., food, water, sex), information travels from the VTA to the nucleus accumbens and then up to the prefrontal cortex.

- Basis of Addiction behaviors

The Reward Circuit



Misery Fleeing Pathway


Targets for DBS
Striatum
Inferiorthalamic peduncle
Subgenual cingulate
Nucleus accumbens
Lateral habenula

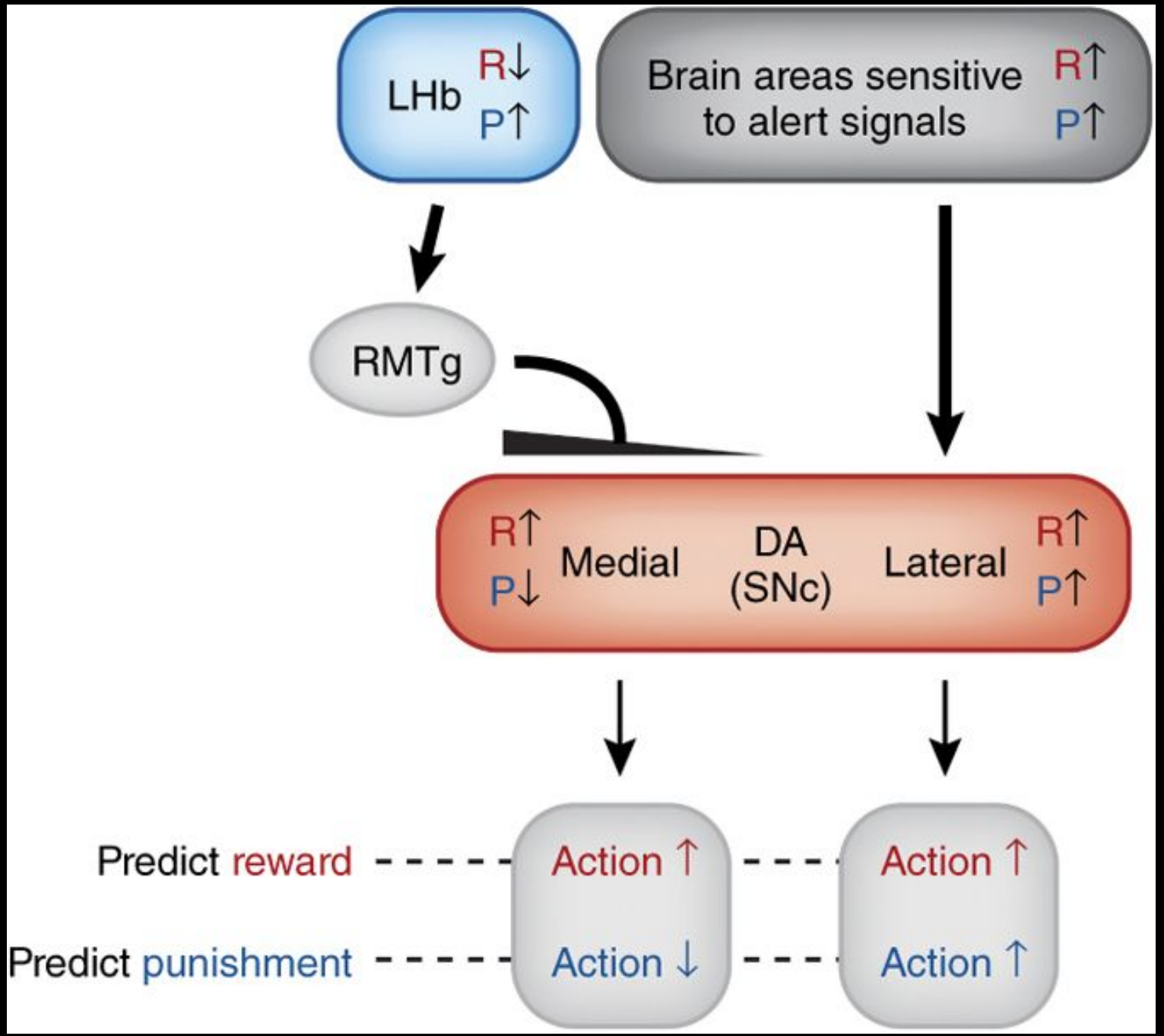
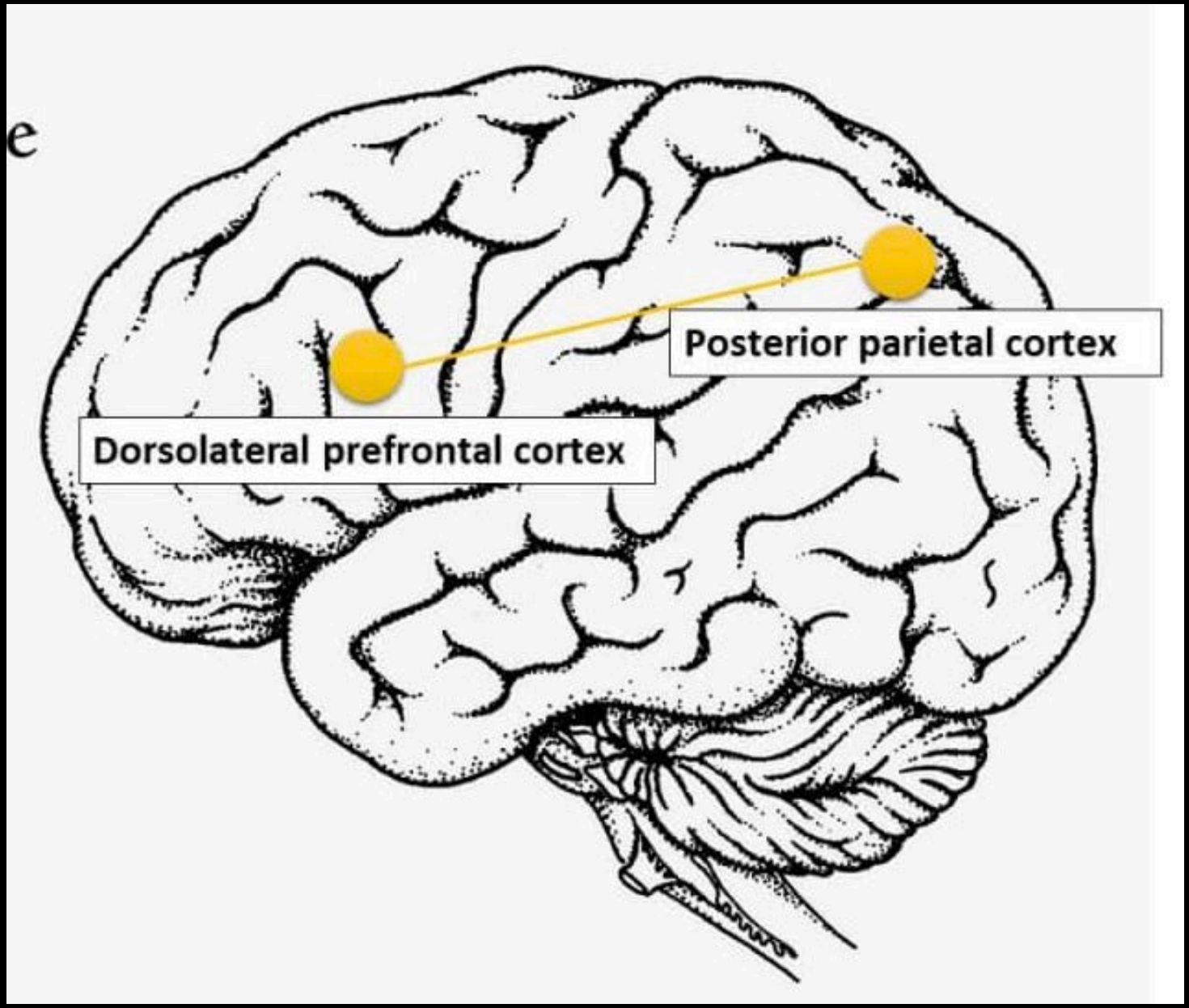

LHb
R↓
P↑
Brain areas sensitive to alert signals
R↑
P↑
RMTg
R↑
P↓
Medial
DA (SNc)
Lateral
R↑
P↑
Predict reward
Action ↑
Action ↑
Predict punishment
Action ↓
Action ↑

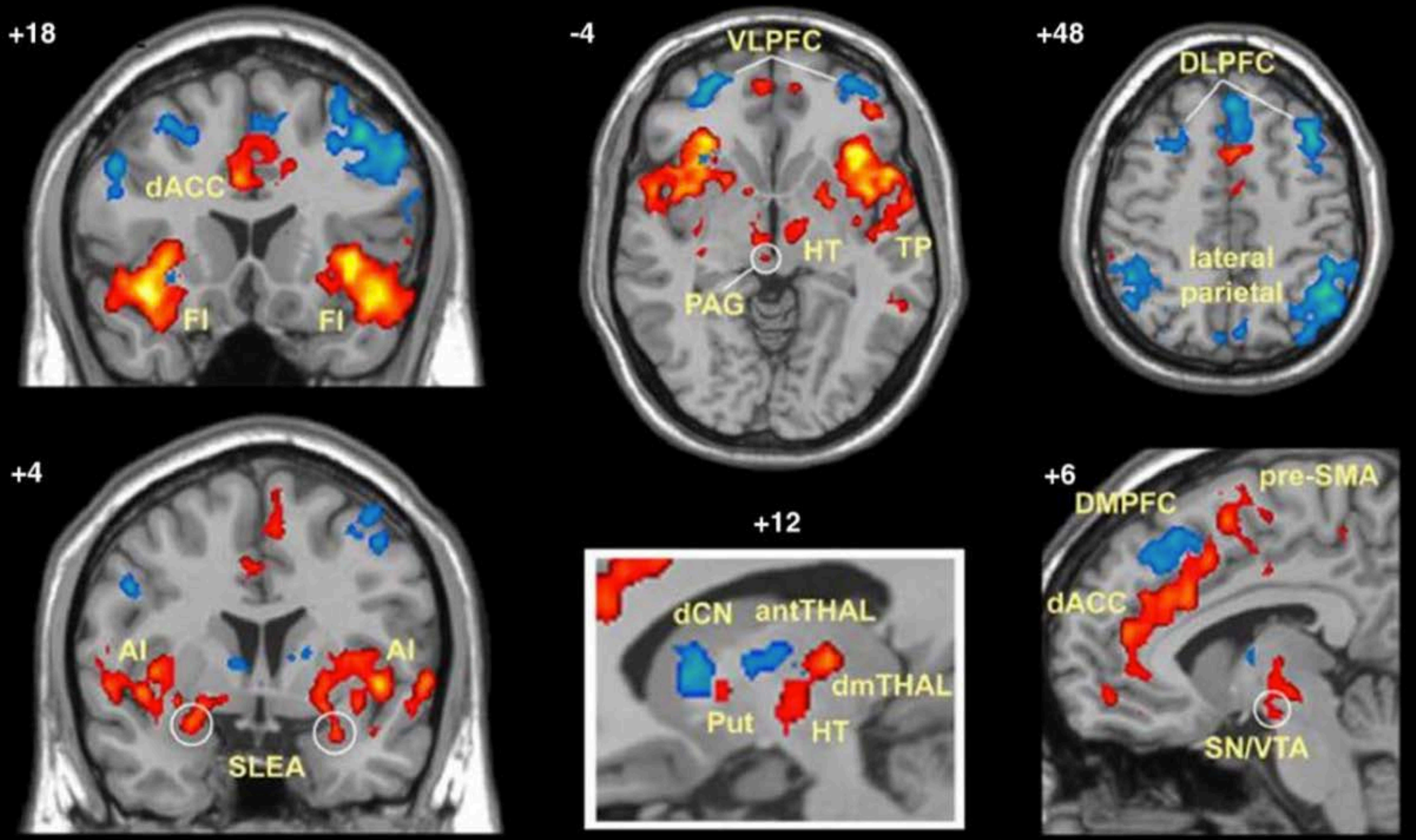
Figure 1 Inhibitory effects originating from the LHb create functional heterogeneity among DA neurons. LHb neurons encode negative motivational values (inhibited by reward and excited by punishment) and inhibit DA neurons in the SNc and VTA through the RMTg. In the monkey, the LHb-induced inhibition is stronger for DA neurons in the medial part of SNc. The medial DA neurons therefore signal positive values, and thereby facilitate reward-approaching actions (shown in red) when reward is predicted and suppress actions (blue) when punishment is predicted. In contrast, the lateral DA neurons are excited when either reward or punishment is predicted, and thereby facilitate both reward-approaching actions when reward is predicted (red) and punishment-avoiding actions when punishment is predicted (blue). R and P indicate reward and punishment. The punishment-related excitation of the lateral DA neurons may be caused by inputs from other brain areas sensitive to alert signals. Note that this scheme may not apply to all DA neurons; for example, some DA neurons in the rodent VTA receive excitatory inputs from the LHb.

Central Executive Network

Central Executive Network

- Focus & working memory
- Tasks that require rational thought and conscious control
- Suppression of impulses


e
Posterior parietal cortex
Dorsolateral prefrontal cortex

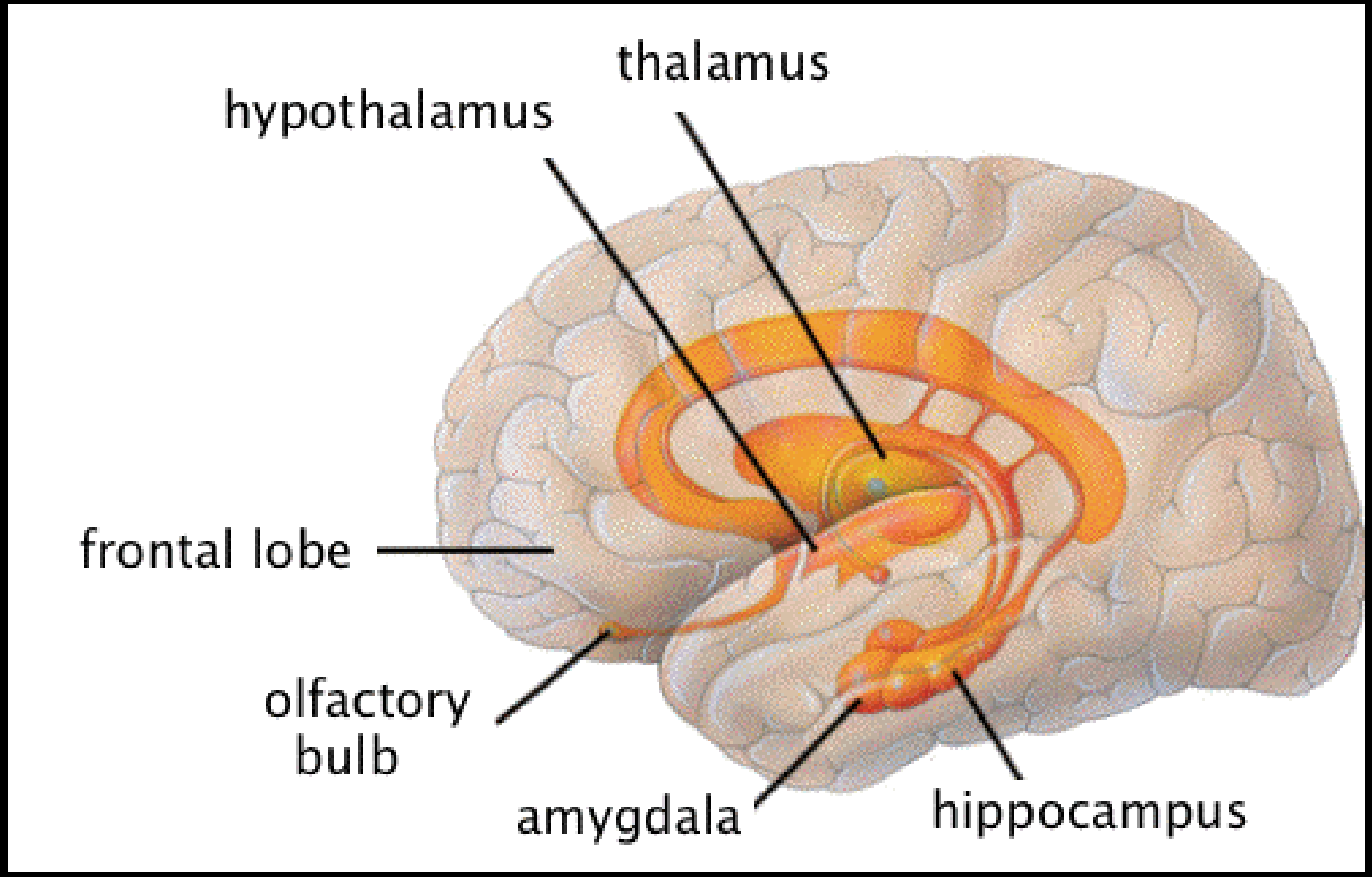

+18
dACC
FI
FI
-4
VLPFC
HT
TP
PAG
+48
DLPFC
lateral
parietal
+4
AI
AI
SLEA
+12
dCN
antTHAL
dmTHAL
Put
HT
+6
DMPFC
pre-SMA
dACC
SN/VTA

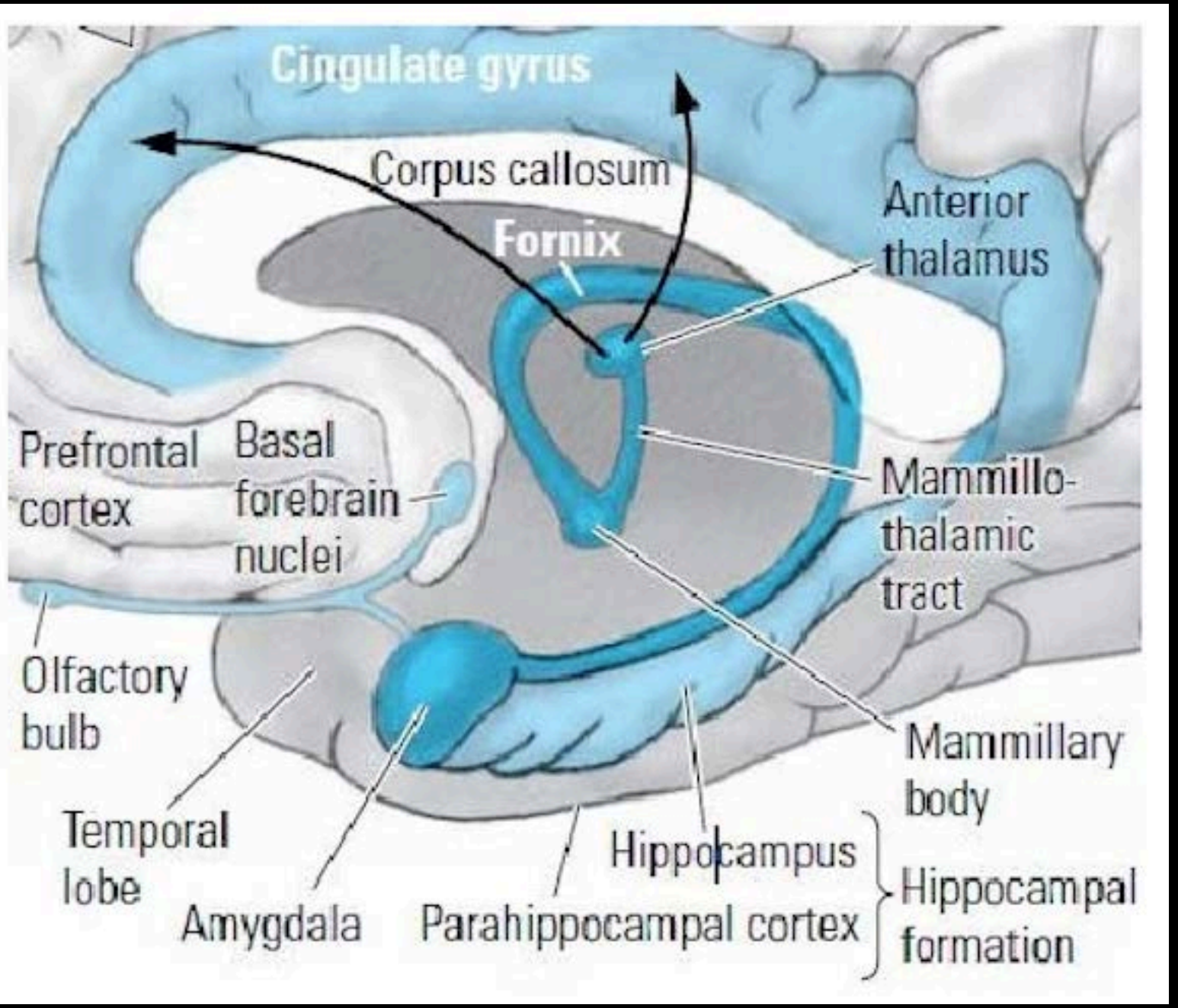
Emotion Processing

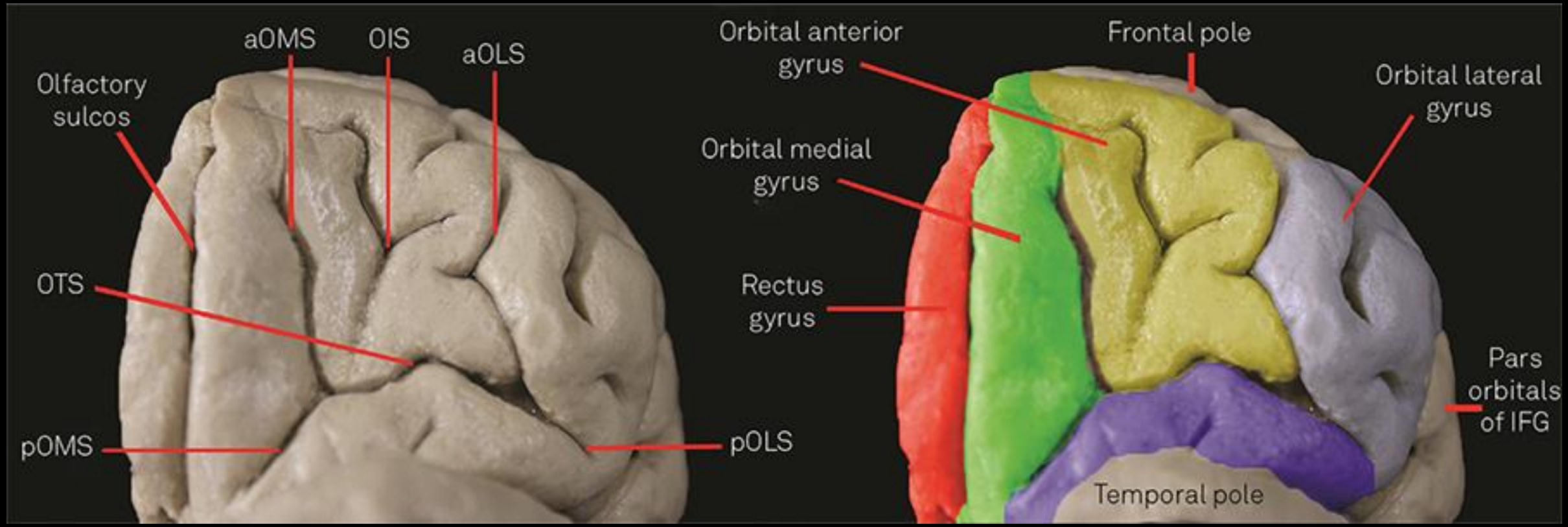
Emotion Processing

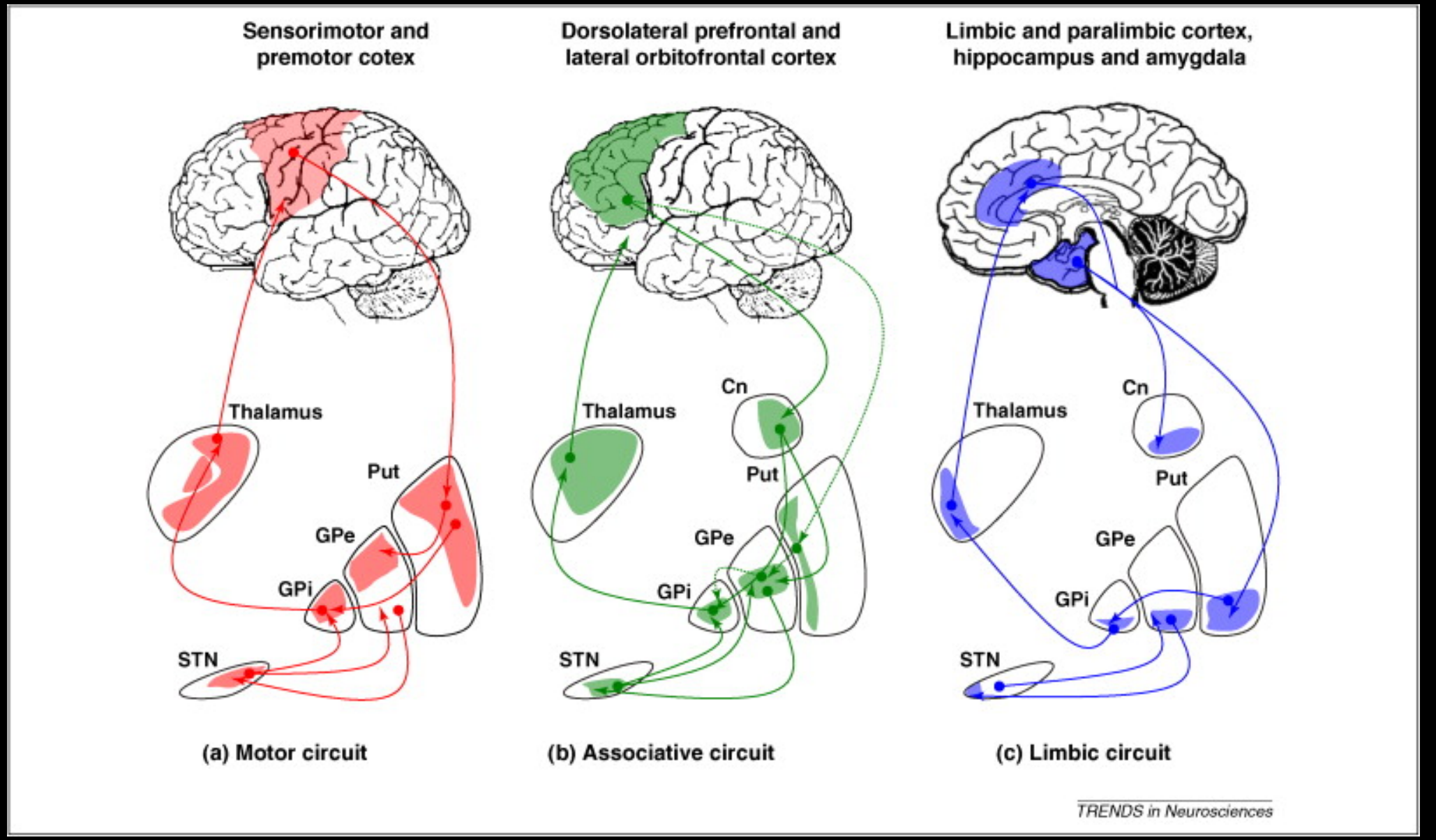
- Emotion generation - ”Limbic System

- Emotion processing – Orbitofrontal Cortex


thalamus
hypothalamus
frontal lobe
olfactory bulb
amygdala
hippocampus


Cingulate gyrus
Corpus callosum
Fornix
Anterior thalamus
Prefrontal cortex
Basal forebrain nuclei
Mammillo-thalamic tract
Olfactory bulb
Mammillary body
Temporal lobe
Hippocampus
Amygdala
Parahippocampal cortex
Hippocampal formation


aOMS
OIS
aOLS
Olfactory sulcos
OTS
pOMS
pOLS
Orbital anterior gyrus
Frontal pole
Orbital lateral gyrus
Orbital medial gyrus
Rectus gyrus
Pars orbitals of IFG
Temporal pole

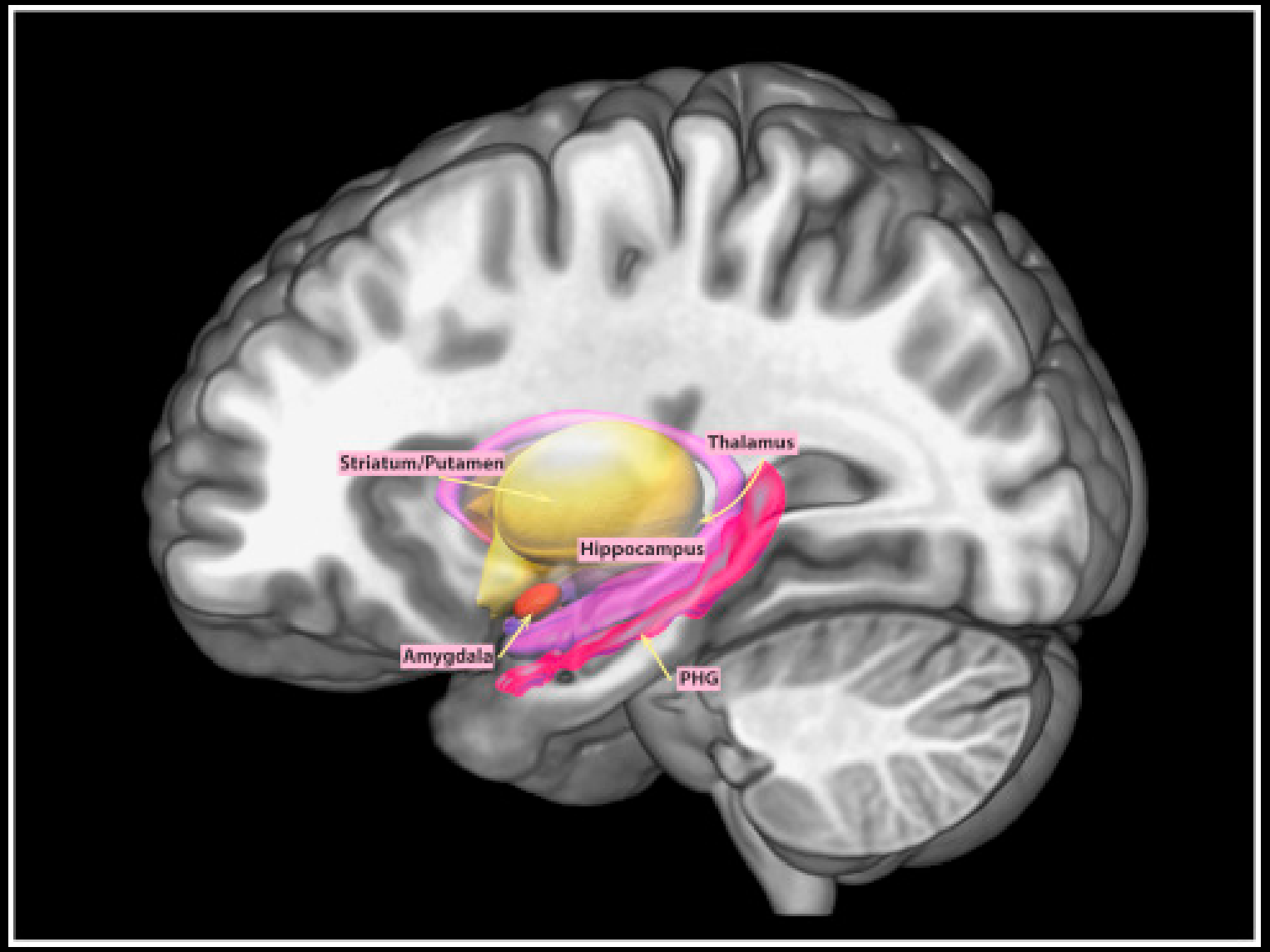

Sensorimotor and premotor cotex
Dorsolateral prefrontal and lateral orbitofrontal cortex
Limbic and paralimbic cortex, hippocampus and amygdala
Thalamus
Put
GPe
GPi
STN
Cn
(a) Motor circuit
(b) Associative circuit
(c) Limbic circuit
TRENDS in Neurosciences

Memory

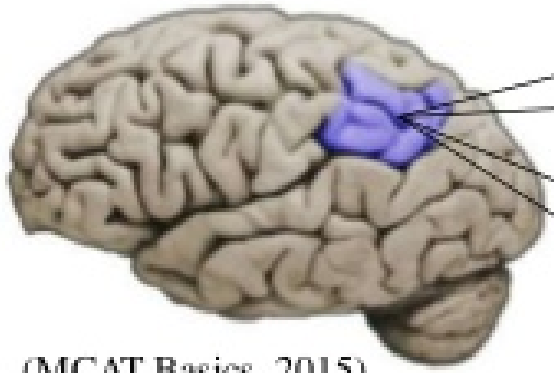
Memory

- Long Term Memory – LTP (Hippocampus)

- Working Memory – Hippocampus + Widespread


Striatum/Putamen
Thalamus
Hippocampus
Amygdala
PHG

Working Memory Tasks
Activate the Supramarginal Gyrus (SMG) Bilaterally



(MCAT Basics, 2015)

SMG Activated during

- **Short-Term Memory**
- **Verbal Working Memory**
  - *activates* → **Phonemic Representations**
  - *stores* → **Sentences**
- **Visual Working Memory**
- **Spatial Working Memory**

(Deschamps, Baum, & Gracco, 2013; Meyer, Obleser, Anwander, & Friederici, 2012; Paulesu, Frith, & Frackowiak, 1993 in Weems & Reggia, 2006; Stoeckel, Gough, Watkins, & Devlin, 2009)

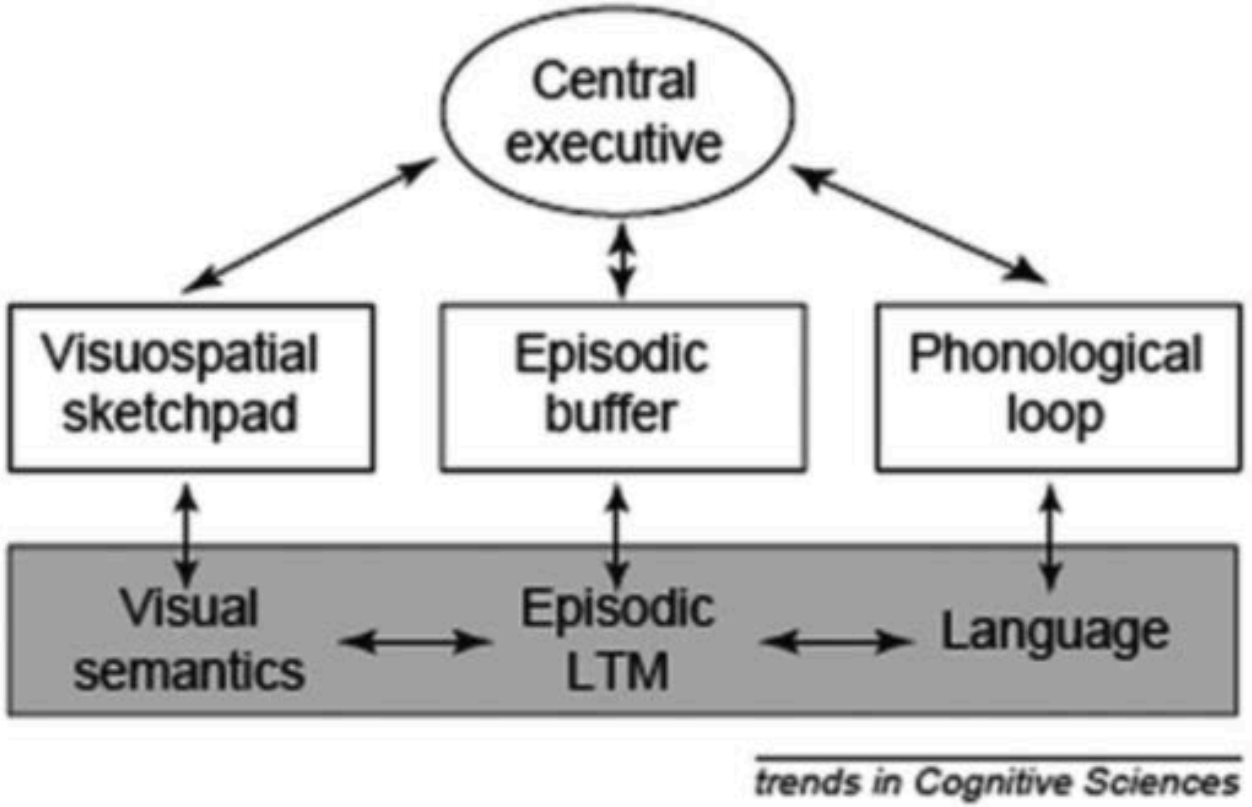
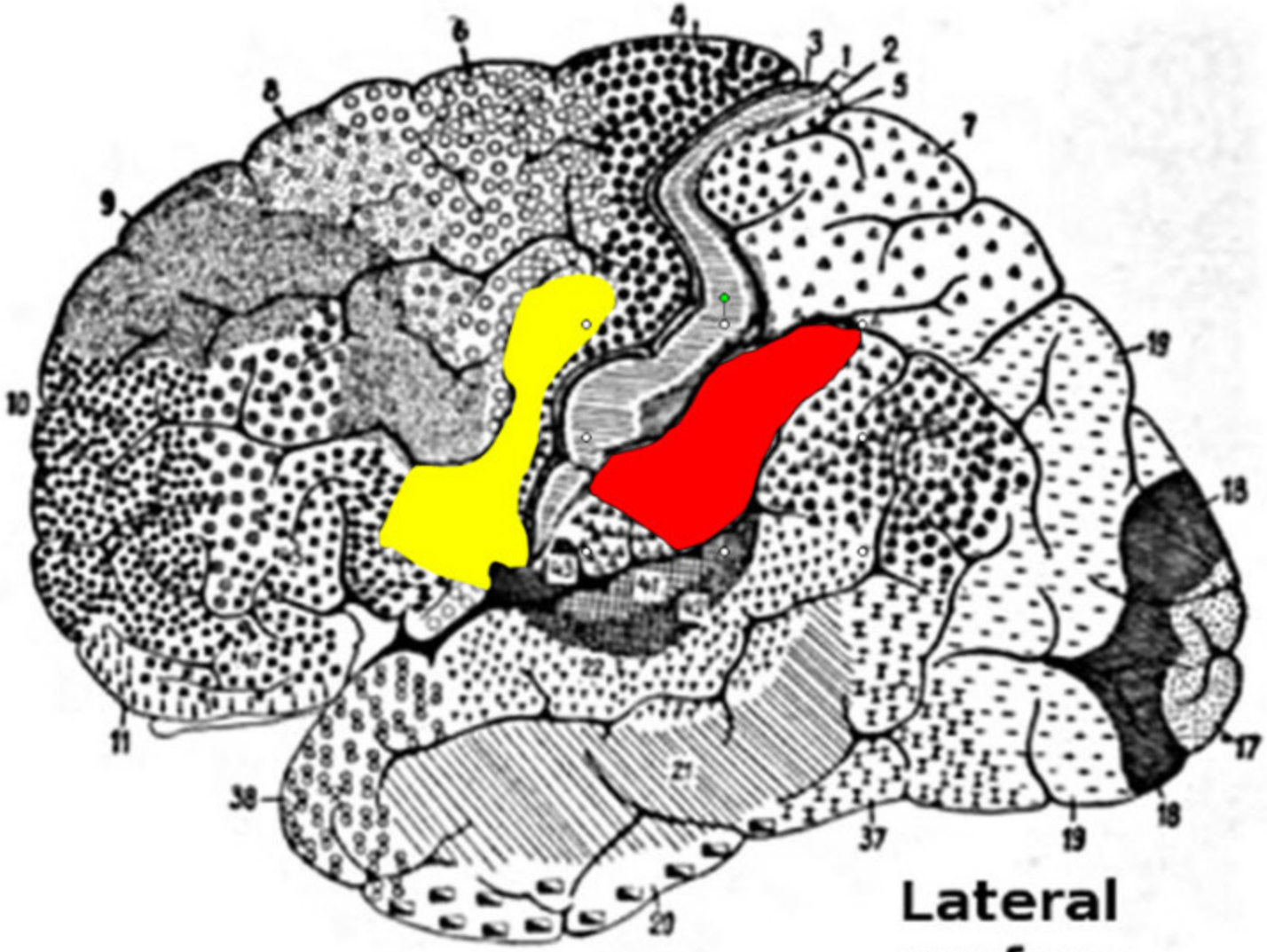


Fig. 1. The multicomponent working memory model. The phonological loop and the visuospatial sketchpad are the slave systems that can independently process different types of information. Information from different sources is integrated by a unitary control mechanism, the central executive. Both are linked to long-term memory (LTM) via an episodic buffer. From Baddeley (2000) with kind permission of Elsevier.

Mirror Neurons

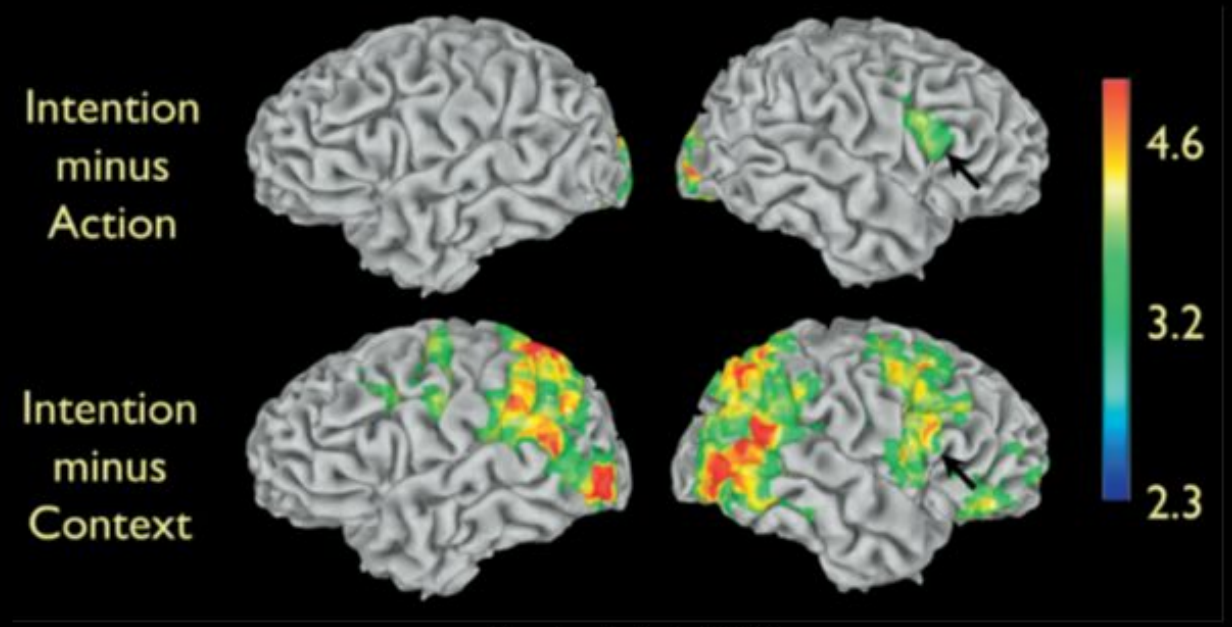
- Evidence for mirror neurons in humans is indirect
- Inferior Frontal Cortex, Superior Parietal Lobe
- Active when the person performs an action and also when the person sees another individual performing an action
- Assessment of intention

The main components of the human mirror system



Neuronicus

- Marco Iacoboni, Istvan Molnar-Szakacs, Vittorio Gallese, Giovanni Buccino, John C. Mazziotta, Giacomo Rizzolatti. Grasping Intentions with Mirror Neurons. PLoS Biol 3(3): e79



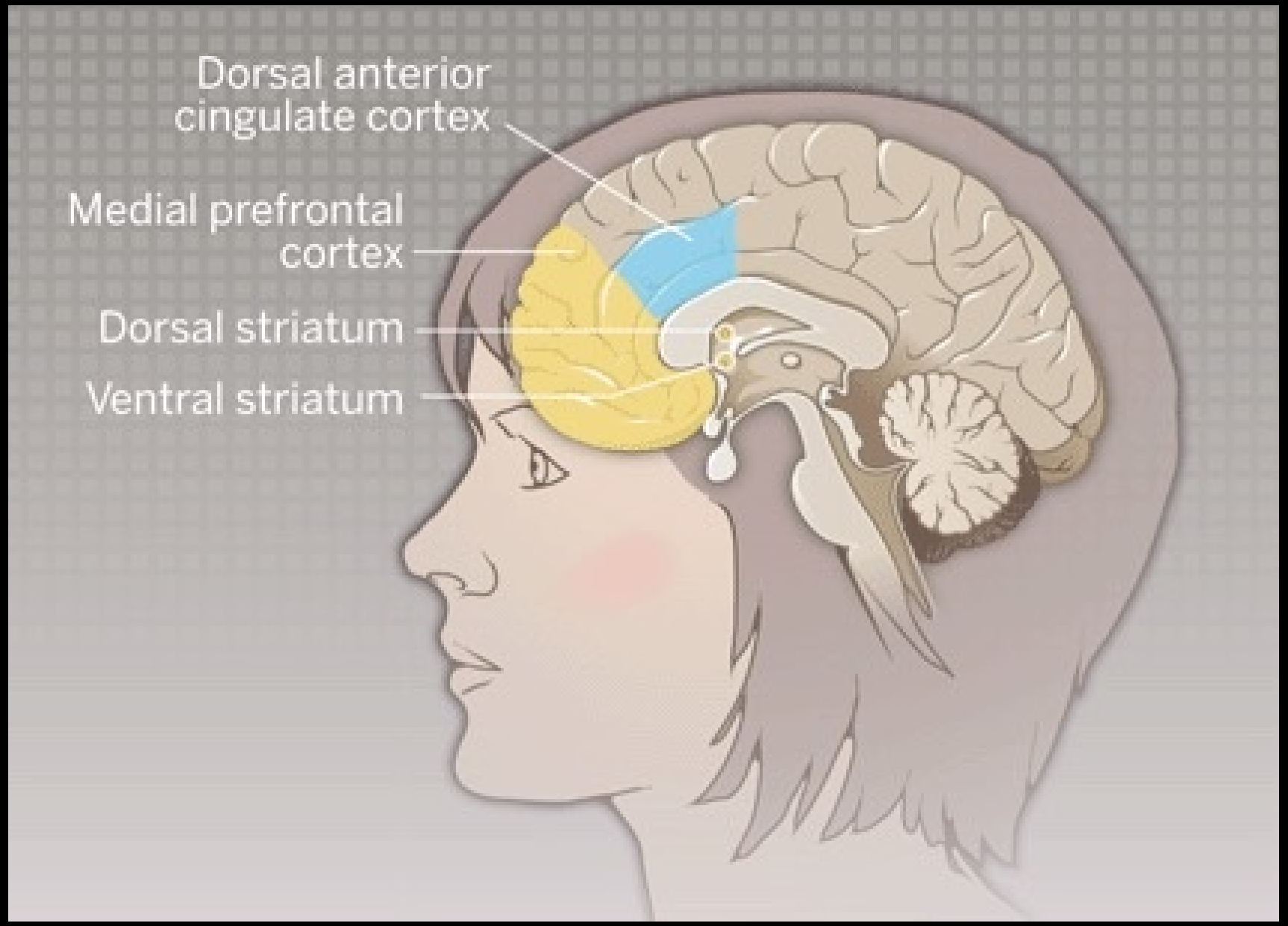
Significant fMRI increase in the posterior part of the **inferior frontal gyrus**

(Iacoboni et al., 2005)

Mirror Neurons, Error Neurons, Place Neurons, Rose Hip Neurons

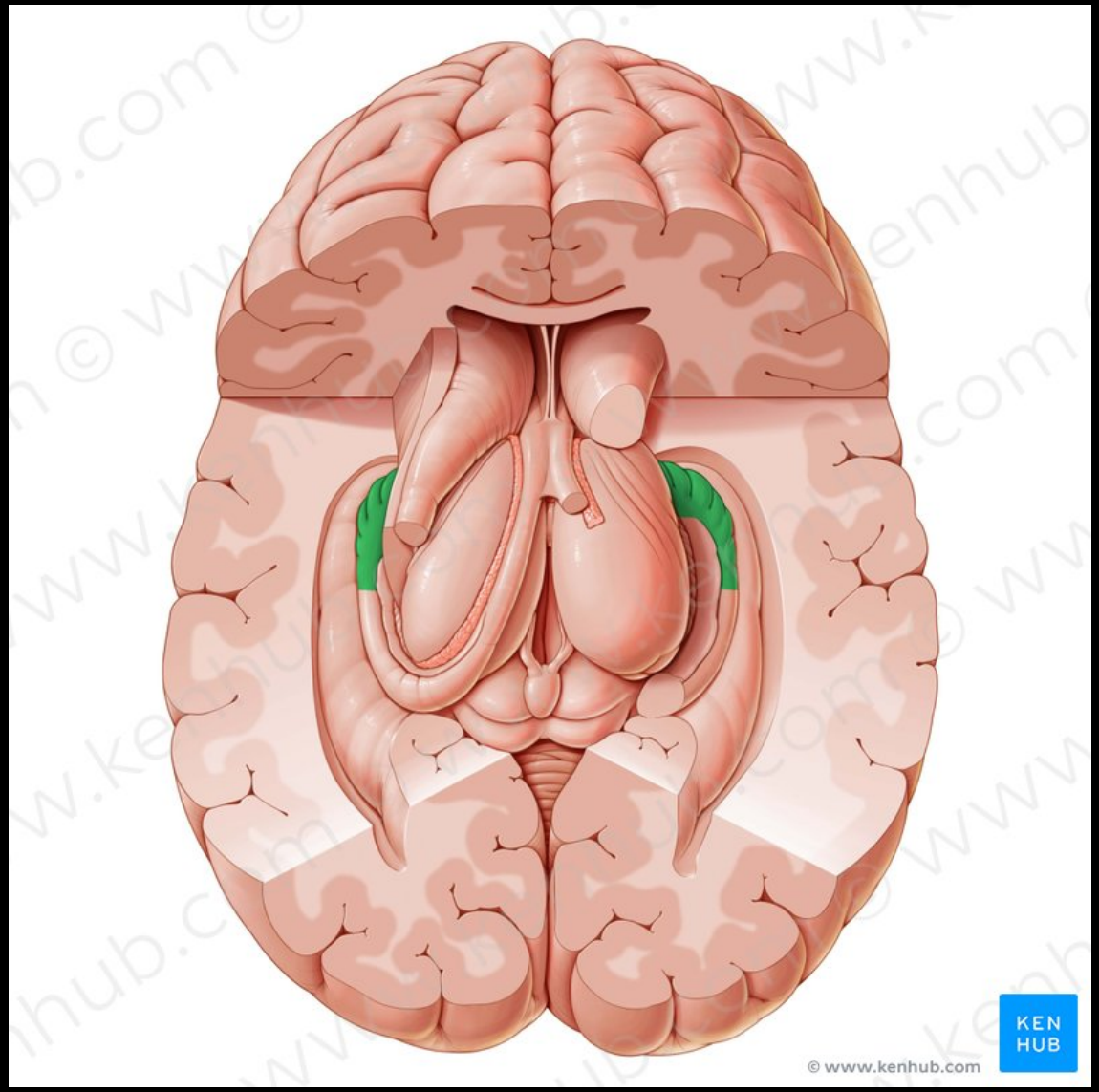
Error Neurons

- Error detection
- “Oh shit” neurons
- mPFC & ACC
- OCD & Schizophrenia


Dorsal anterior cingulate cortex
Medial prefrontal cortex
Dorsal striatum
Ventral striatum

Place Neurons

- Pyramidal neuron
- Hippocampus
- Activated when an animal enters a particular place in its environment; this place is known as the *place field*.
- No apparent topography to the pattern of place fields, unlike other brain areas such as visual cortex—neighboring place cells are as likely to have nearby fields as distant ones
- In a different environment, typically about half the place cells will still have place fields, but these will be in new places unrelated to their former locations
- Place cells are thought, collectively, to act as a cognitive representation of a specific location in space, known as a cognitive map
- Place cells work with other types of neurons in the hippocampus and surrounding regions to perform this kind of spatial processing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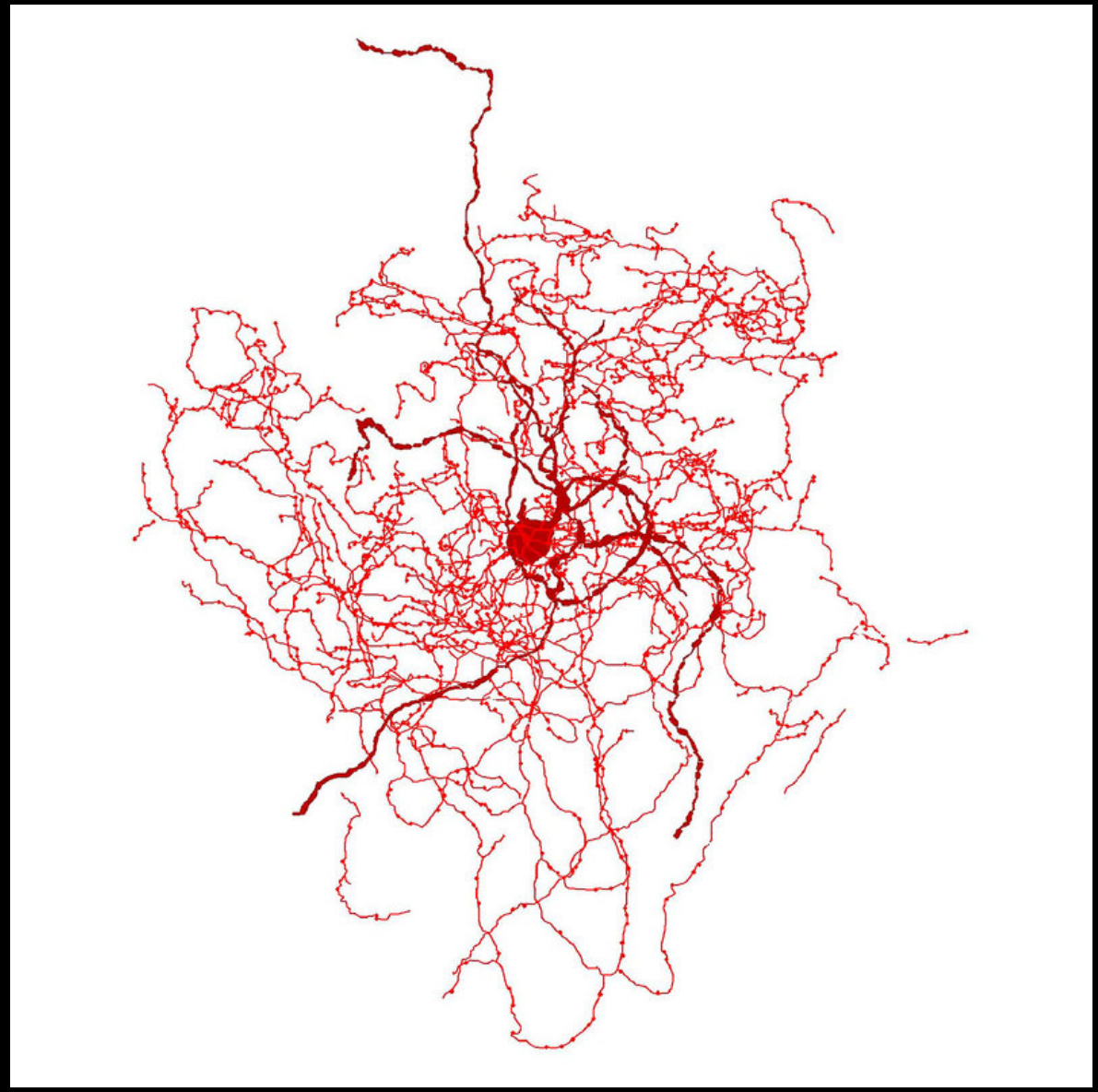
Rose Hip Neurons

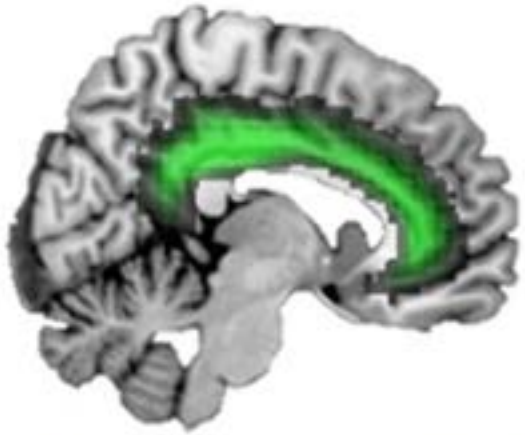
- Uniquely human
- GABAergic
- Cerebral cortex



Cerebellum & Psychiatry

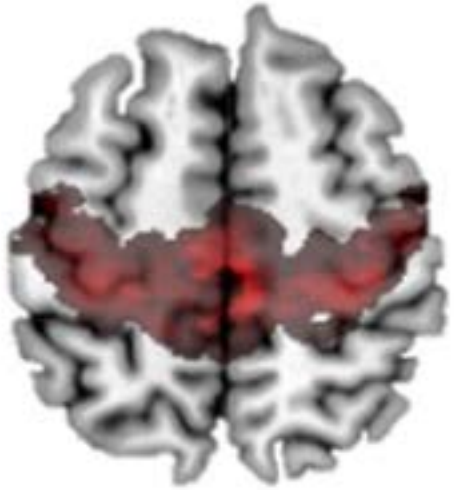
Cerebellum & Psychiatry

- As for motor function, so for cognition - emotion



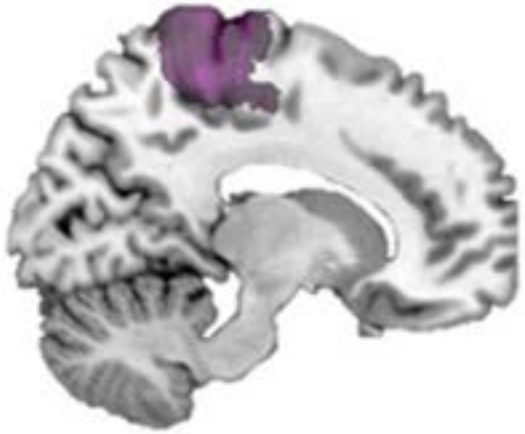
Posterior Vermis

- Affective dysregulation
- Social processing deficits
- Irritability



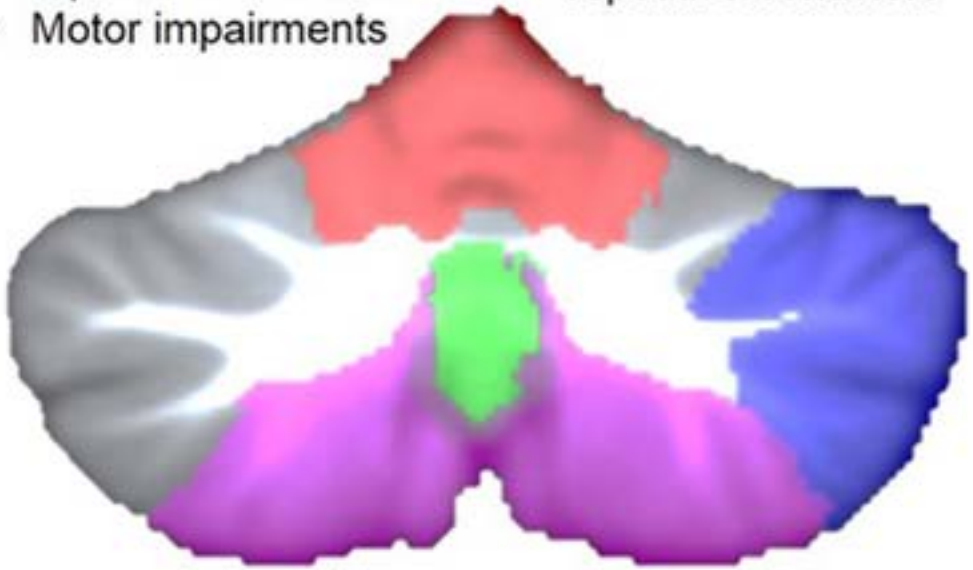
Anterior lobe

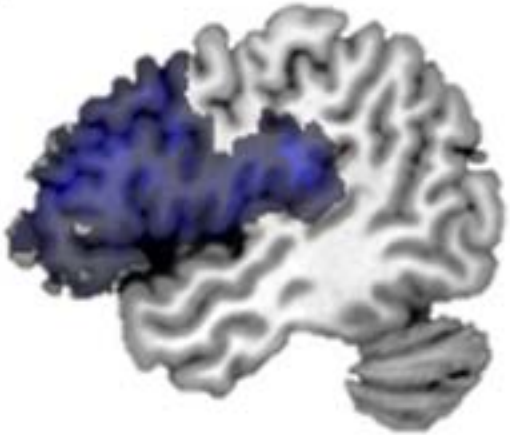
- Stereotyped and repetitive behaviors
- Motor impairments



VIIIA & VIIIB

- Stereotyped and repetitive behaviors





Right Crus I & II

- Language deficits
- Social cognition deficits
- Theory of mind deficits
- Face processing impairments
- Imitation impairments
- Stereotyped and repetitive behaviors

Global brain functioning
Olivo-cerebellar system (cells & circuits)
Awarness
Neuron computation & synaptic plasticity
Spatiotemporal transformation & coordinate transformation
Adjustable forward model computing inverse dynamics
Detection of discrepancies in multiparametric space
Learning and memory
Circuit computations
Error/novelty detection
Working memory
Mental manipulation
Timing
Prediction
Learning
Cerebro-cerebellar loops (large-scale connectivity)
Energing functions
Motor control
Attention switching
Language processing
Imagery and visuo-spatial processing
Decision making and reasoning
Motricity
Cognition, emotion, attention
Ataxia
Cognitive-affective cerebellar syndrome (CCAS)
Schizophrenia
Autism
Depression
Dyslexia
Disfunctions

Thanks for the attention