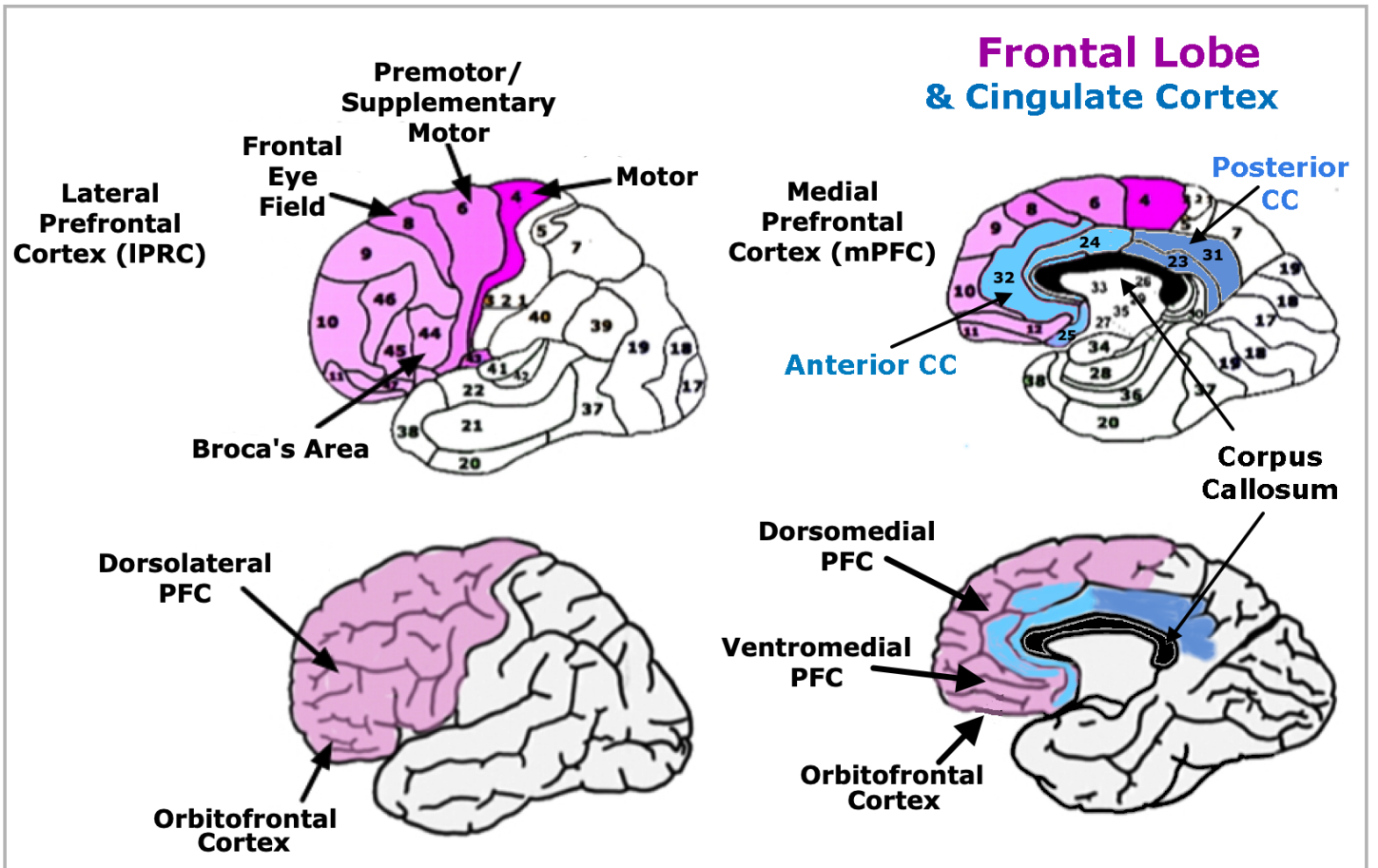
Frontal Lobe Anatomy & Function

(Based on Kolb & Whishaw, 2009, pp. 429 ff et al.)



PFC = Prefrontal Cortex

Comprised of

- Motor cortex (Area 4)
- Premotor cortex (Areas 6 & 8): lateral area 6, medial area 6 (supplementary motor cortex), area 8 (frontal eye field), and area 8A (supplemental eye field)
- Prefrontal cortex (dorsolateral [9 & 46], inferior [11, 12, 13, & 14], and medial [25 & 2]. Inferior frontal is often called orbital frontal

Note: The functions of the frontal lobe are closely connected with the Anterior Cingulate Cortex (ACC; Brodmann Areas 24, 32, & 25). For this reason, the figure above includes the Cingulate Cortex.

Connections

Motor & Premotor Areas

- Motor cortex projects to spinal motor neurons & subcortical structures, e.g., basal ganglia. Hence, it sends out instructions to move muscles.
- Premotor cortex projects to motor cortex or to spinal neurons; receives from parietal areas PE (5 & 7) & PF (40 & 43; limb movement in space)
- Frontal eye fields (8 & 8A) receive from regions controlling eye movement and sent back to those areas (posterior parietal PG [39] & superior colliculus)
- Dorsolateral prefrontal projects to premotor areas

Prefrontal Cortex

- Endpoints of the dorsal (object recognition) and ventral (spatial behavior) visual streams
- Dorsolateral prefrontal cortex: input from/output to posterior parietal & superior temporal sulcus. Also with cingulate cortex, basal ganglia, superior colliculus
- Orbitofrontal cortex: input from temporal lobe (including auditory), visual regions of temporal cortex; from amygdala; somatosensory cortex, gustatory cortex, olfactory regions, that is. From all sensory modalities. Output to amygdala & hypothalamus (some control of ANS).
- Input from dopaminergic cells of tegmentum: regulation of response to emotional stimuli including stress. Perhaps involved in schizophrenia.

Theory of Frontal-Lobe Functioning

Challenged in life to

1. Plan and select from options
2. Ignore extraneous stimuli & persist in task at hand
3. Keep track of what has been done and what remains to be done

Premotor Cortex: Select movement to be executed

- Response selection
- Direction of motor sequences
- Responsive to external cues

Prefrontal Cortex: Control cognitive processes so that appropriate movement is selected at the right time and place using either internal or external information

A. *Internal cues*: temporal or working or short-term memory: dorsolateral

B. *External cues*

- use world to decide upon what to do; world can disorganize behavior by providing distracting stimuli
- learn from world (feedback) on connection of stimuli and reward: orbital cortex

C. *Context cues*

- Context-dependent behaviors: social groups, social rules, social standing

D. *Autonoetic Awareness* (Endel Tulving; "autonoetic" = "self-knowing")

- Behavior determined by our lifetime of experience. Autobiographical knowledge. Continuity of personality across time.

Frontal Cortical Subdivisions: Functions (de la Vega et al., 2016; Stucky, Kirkwood, & Donders, 2020)

Dorsolateral PFC

- Cognitive-executive functions in general, working memory, attentional control of behavior

Orbitofrontal & Ventromedial PFC

- Emotional regulation, reward monitoring ("valuation"), personality & social processing
- vmPFC: valuation, subcortical cues (e.g., fear)

Dorsomedial PFC: Intentional & behavioral activation; processing social interaction

Anterior Cingulate Cortex (ACC; Chaibi et al. 2023, Oane et al. 2020, Schneider et al., 2020)

- Integration of negative affect, pain, and cognitive control.
- Control of aggressiveness and impulsivity where damage to the ACC is associated with higher levels of these behaviors.
- Affective responsiveness from the ACC tends to be more negative and involves discomfort (e.g., fear, anxiety, panic) although some more positive feelings (happiness) may result as well.
- Perception of the emotions of others via signals of self-pain and the observed pain of others.
- Observational fear learning, empathy, harm aversion, and pro-social behavior

References

Chaibi, I., Bouchatta, O., Bennis, M., & Ba-M'hamed, S. (2023) The role of the anterior cingulate cortex in aggression and impulsivity. *Behavioral Neuroscience, 137*(3), 155-169. https://doi.org/10.1037/bne0000552

de la Vega, A., Chang, L. J., Banich, M. T., Wager, T. D., & Yarkoni, T. (2016) Large-scale meta-analysis of human medial frontal cortex reveals tripartite functional organization. *Journal of Neuroscience, 36*(24), 6553-6562. https://dx.doi.org/10.1523/JNEUROSCI.4402-15.2016

Kolb, B. and Whishaw, I.Q. (2009) *Fundamentals of human neuropsychology* (6th ed.). New York, NY: Worth.

Oane, I., Borborica, A., Chetan, F., Donos, C.,… Mindruta, I. (2020). Cingulate cortex function and multi-modal connectivity mapped using intracranial stimulation. *NeuroImage, 220*. https://doi.org/10.1016/j.neuroimage.2020.117059

Schneider, K. N., Sciarillo, X. A., Nudelman, J. L., Cheer, J. F., & Roesch, M. R. (2020). Anterior cingulate cortex signals attention in a social paradigm that manipulates reward and shock. *Current Biology, 30*, 3724–3735. https://dx.doi.org/10.1016/j.cub.2020.07.039

Stucky, K. J., Kirkwood, M. W., & Donders, J. (Eds.). (2020). *Clinical neuropsychology study guide and board review* (2nd ed.). New York, NY: Oxford University Press.