

2023 TSRI ARC Summer High School Mentorship Program:

Introduction to neuroscience and brain development

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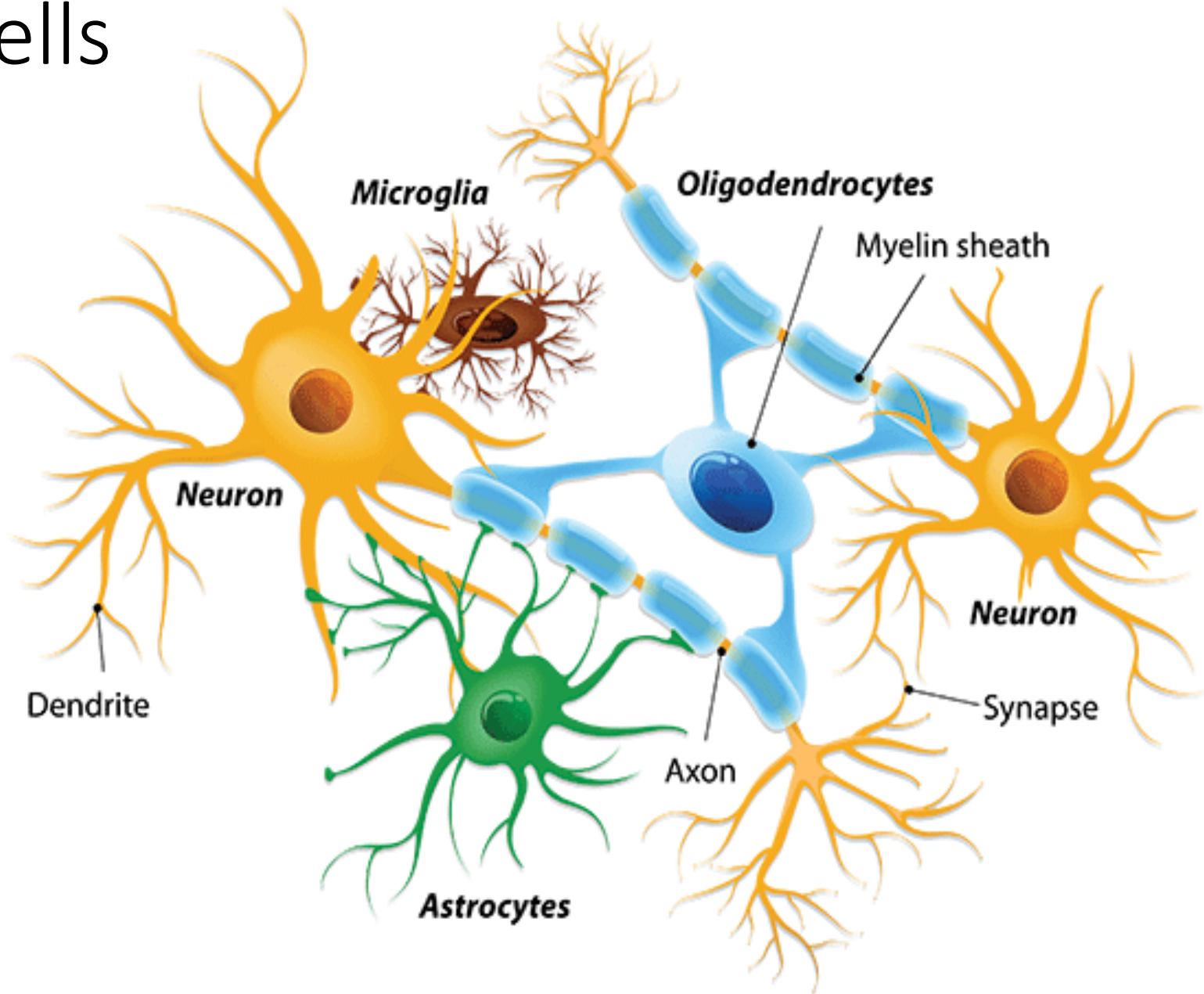
June 27, 2023



Topics to cover

- Cells
- Brain structure/function
- Adolescent brain development
- Promoting healthy brain development

Cells



- Neurons (16.34 billion)
 - sensory
 - motor
 - projection neurons
 - local interneurons
- Glia (60.84 billion)
 - Astrocytes (support & protect)
 - Microglia (immune protection and clean-up)
 - Oligodendrocytes (make myelin)

Cell communication

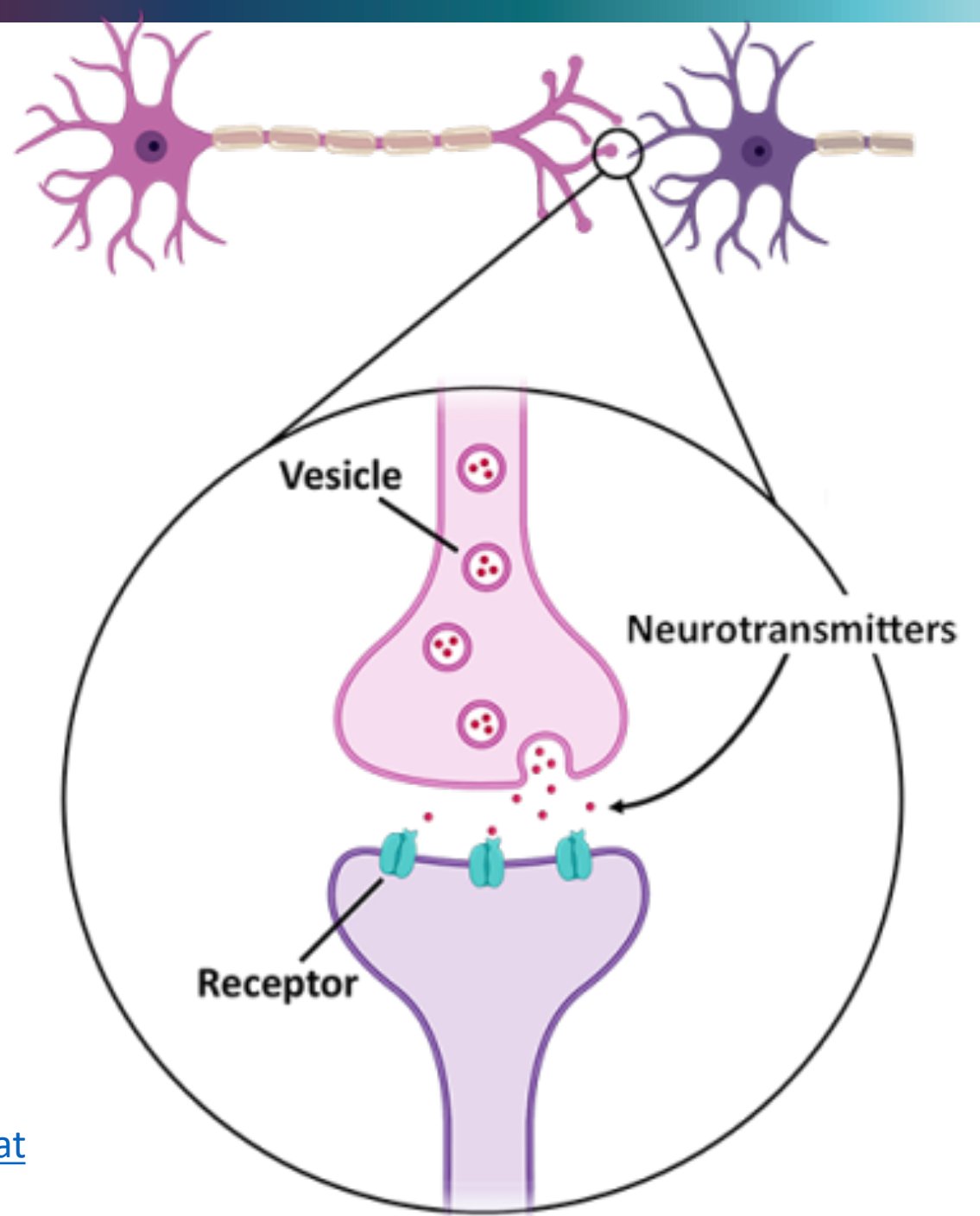
When the signal reaches the end of the axon it stimulates the release of tiny **vesicles**.

These structures release chemicals known as **neurotransmitters** into the **synapse**.

The neurotransmitters cross the synapse and attach to **receptors** on the neighboring cell.

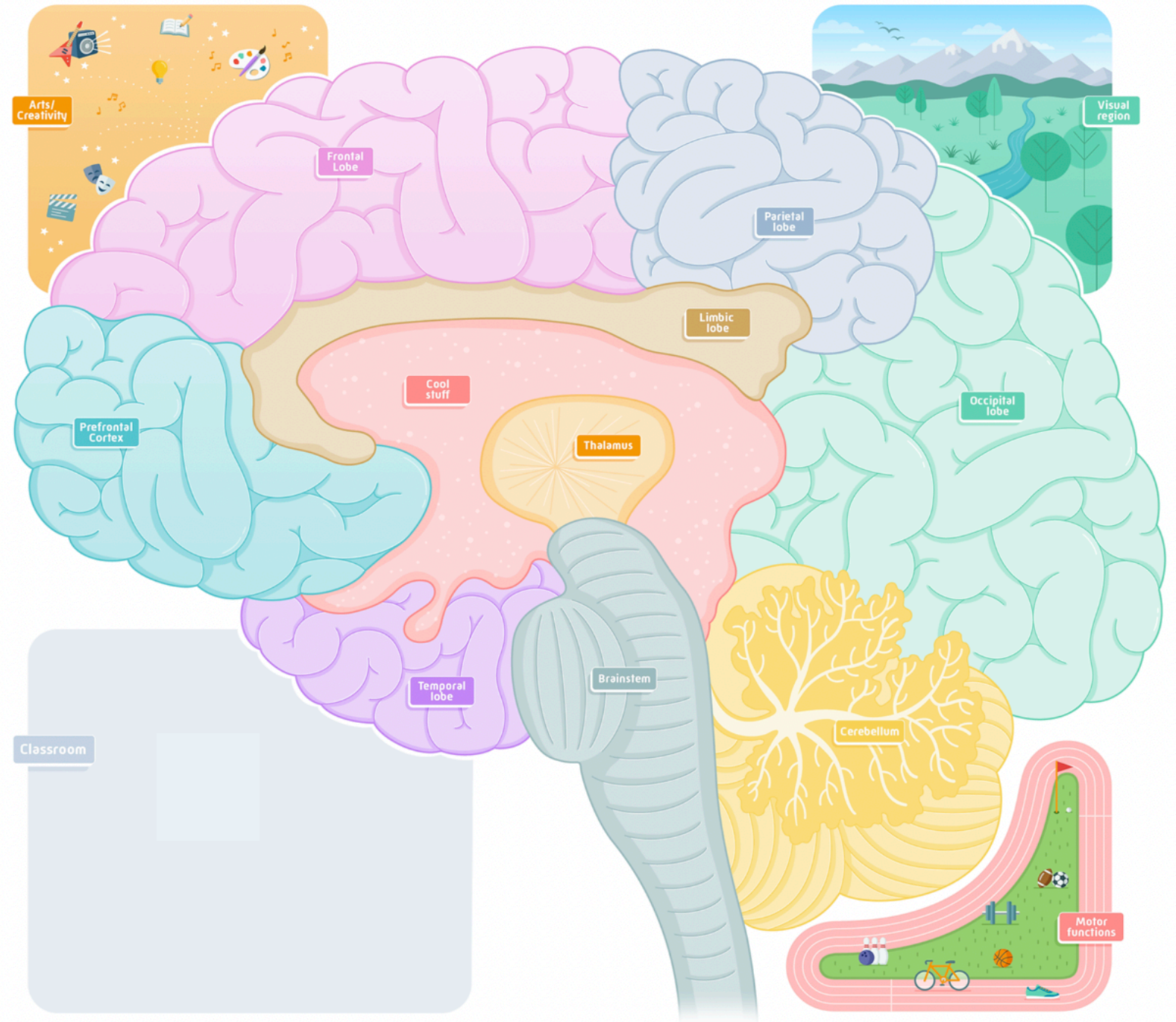
These receptors can change the properties of the receiving cell.

If the receiving cell is also a neuron, the signal can continue the transmission to the next cell.



<https://www.ninds.nih.gov/health-information/public-education/brain-basics/brain-basics-know-your-brain#:~:text=The%20brain%20can%20be%20divided,as%20respiration%20and%20heart%20rate.>

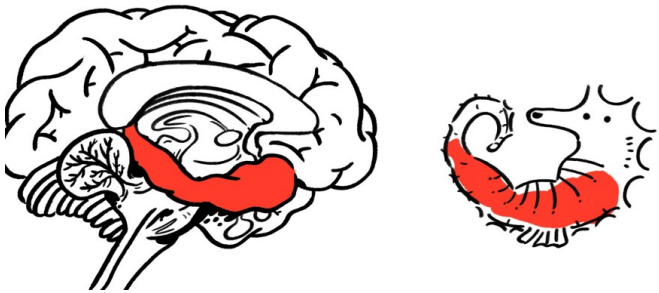
Brain structure/function



<https://epscoderjb.github.io/Scripts/BrainInteractiveDraft.html>

Brain structure/function

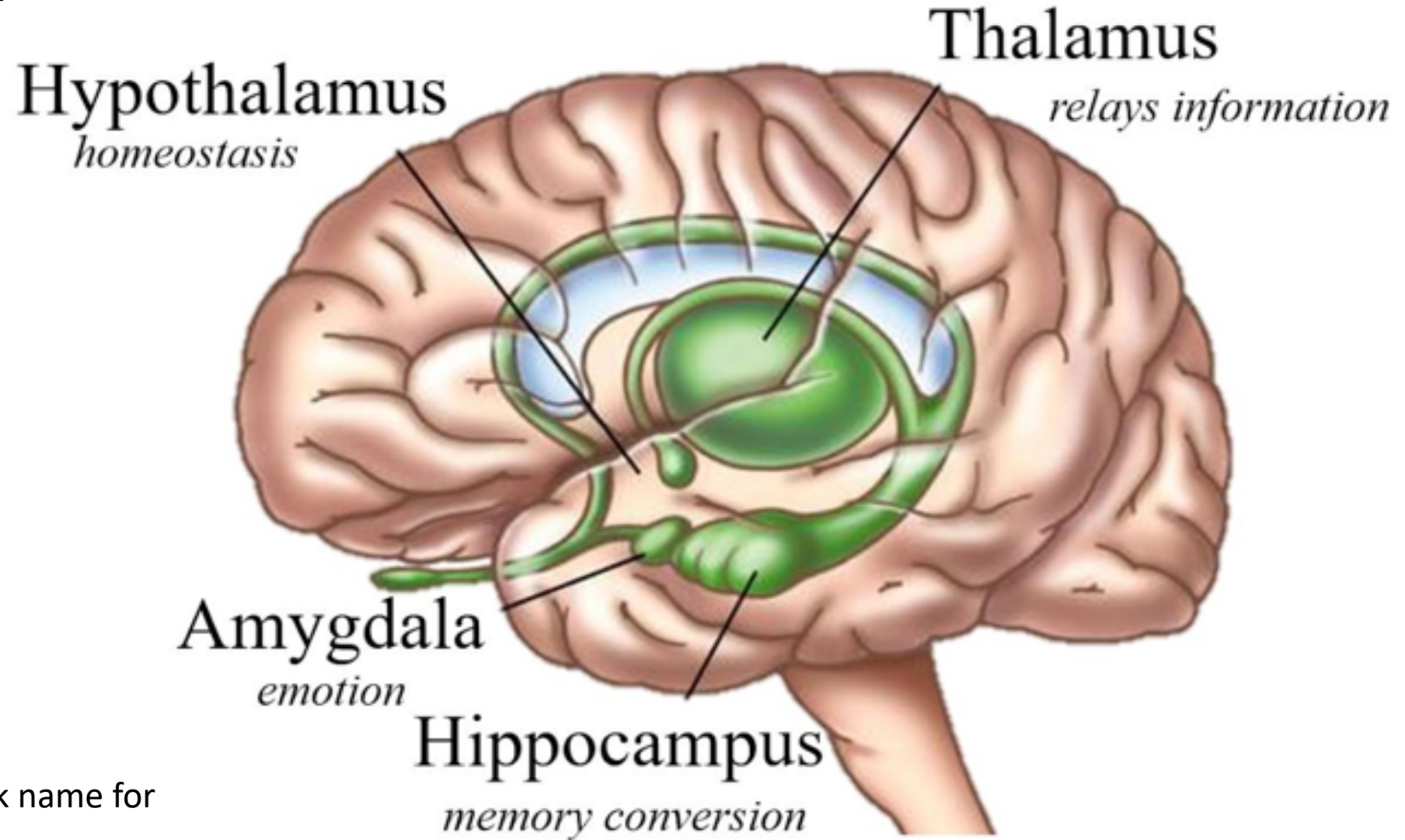
The limbic system



Hippocampus comes from the Greek name for Seahorse!

Thalamus: inner chamber

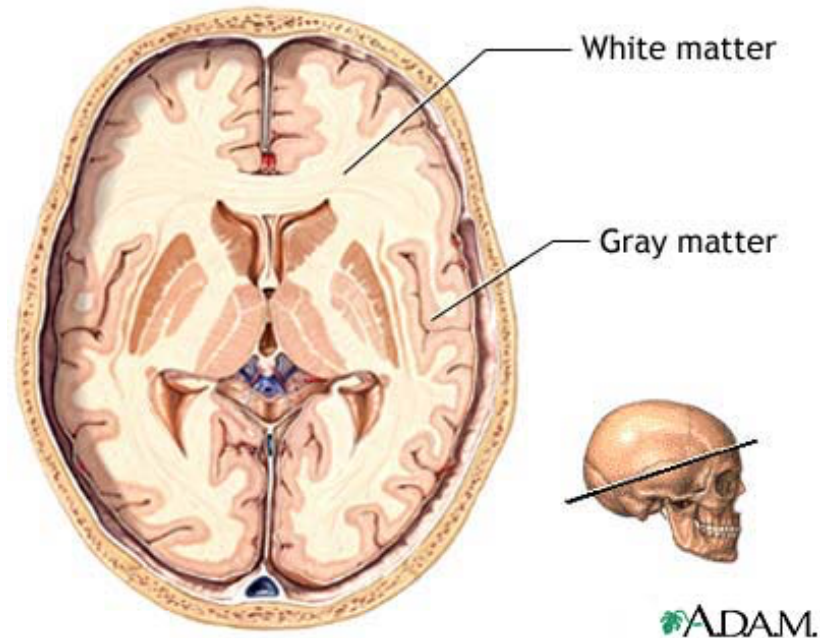
Amygdala: almond



gray & white matter

- gray matter

- mostly nerve cell bodies
- cortical
- coordinates the processing going on in the brain
- Important for controlling movement, memory, and emotions



- white matter

- bundles of nerve fibers - myelin
- subcortical
- provides connections to brain's processing regions
- Important for problem-solving, mood, walking & balance

Brain structure/function

- Lateralization
 - Some left vs right functions
 - The left hemisphere controls the right half of the body, and the right hemisphere controls the left half of the body
 - The brain's two hemispheres are joined together by the corpus callosum, a thick bundle of millions of nerve fibers.
 - No evidence of people being right vs left brained

RIGHT-BRAIN FUNCTIONS

Art awareness
Creativity
Imagination
Intuition
Insight
Holistic thought
Music awareness
3-D forms
Left-hand control



LEFT-BRAIN FUNCTIONS

Analytic thought
Logic
Language
Reasoning
Science and math
Written
Numbers skills
Right-hand control

Studying the brain

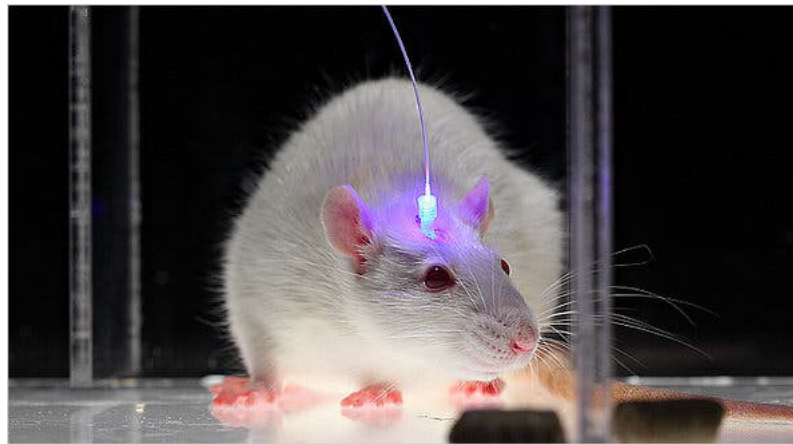
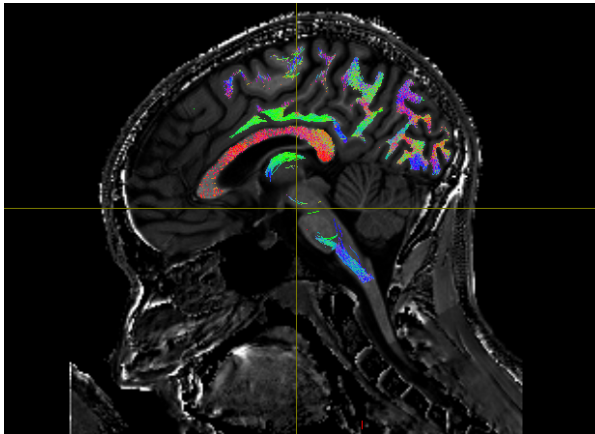


- Humans
 - Imaging
 - Electroencephalography (EEG)
- Laboratory animals
 - In vivo (“in life”)
 - In vitro (“in glass”)
- Computer simulations

<https://vkc.vumc.org/vkc/eeg/>

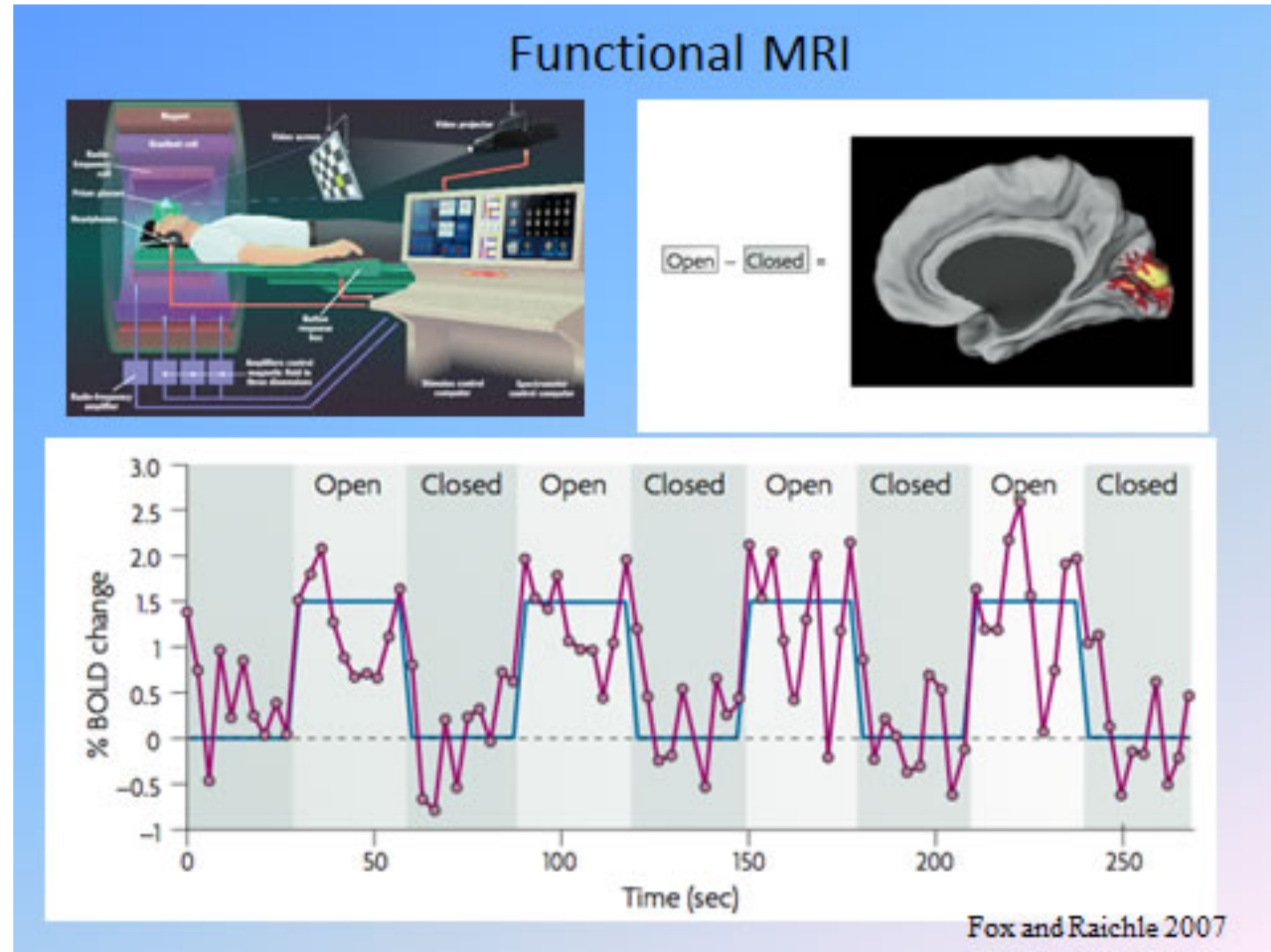
<https://www.nytimes.com/2011/05/17/science/17optics.html>

<https://www.news-medical.net/health/Studying-the-Human-Brain.aspx>



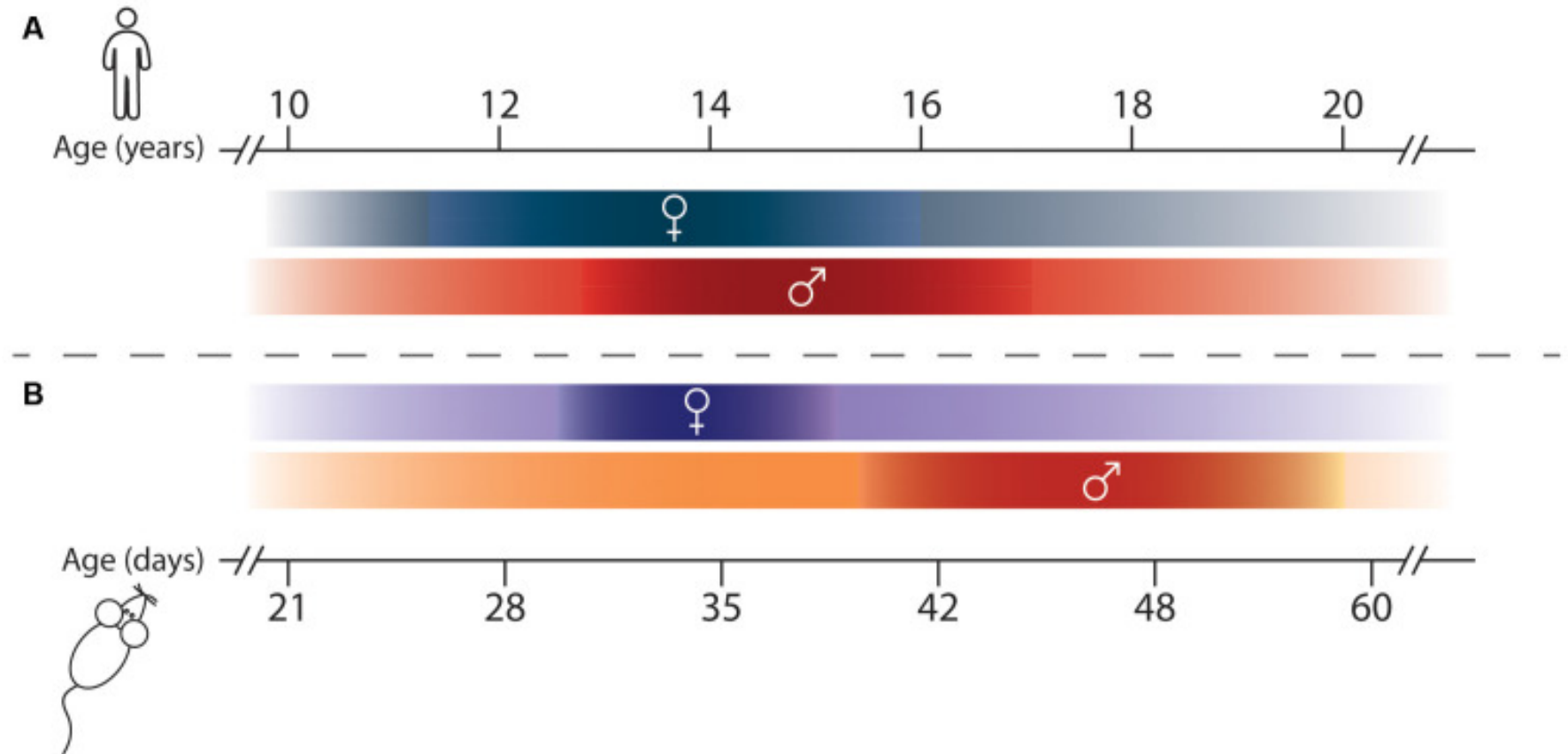
imaging: functional magnetic resonance imaging (fMRI)

- oxygen rich blood and oxygen poor blood have different magnetic properties related to hemoglobin
- blood is more oxygenated when neural activity increases
- can identify brain circuitry activated by certain behaviors or exposure to stimuli



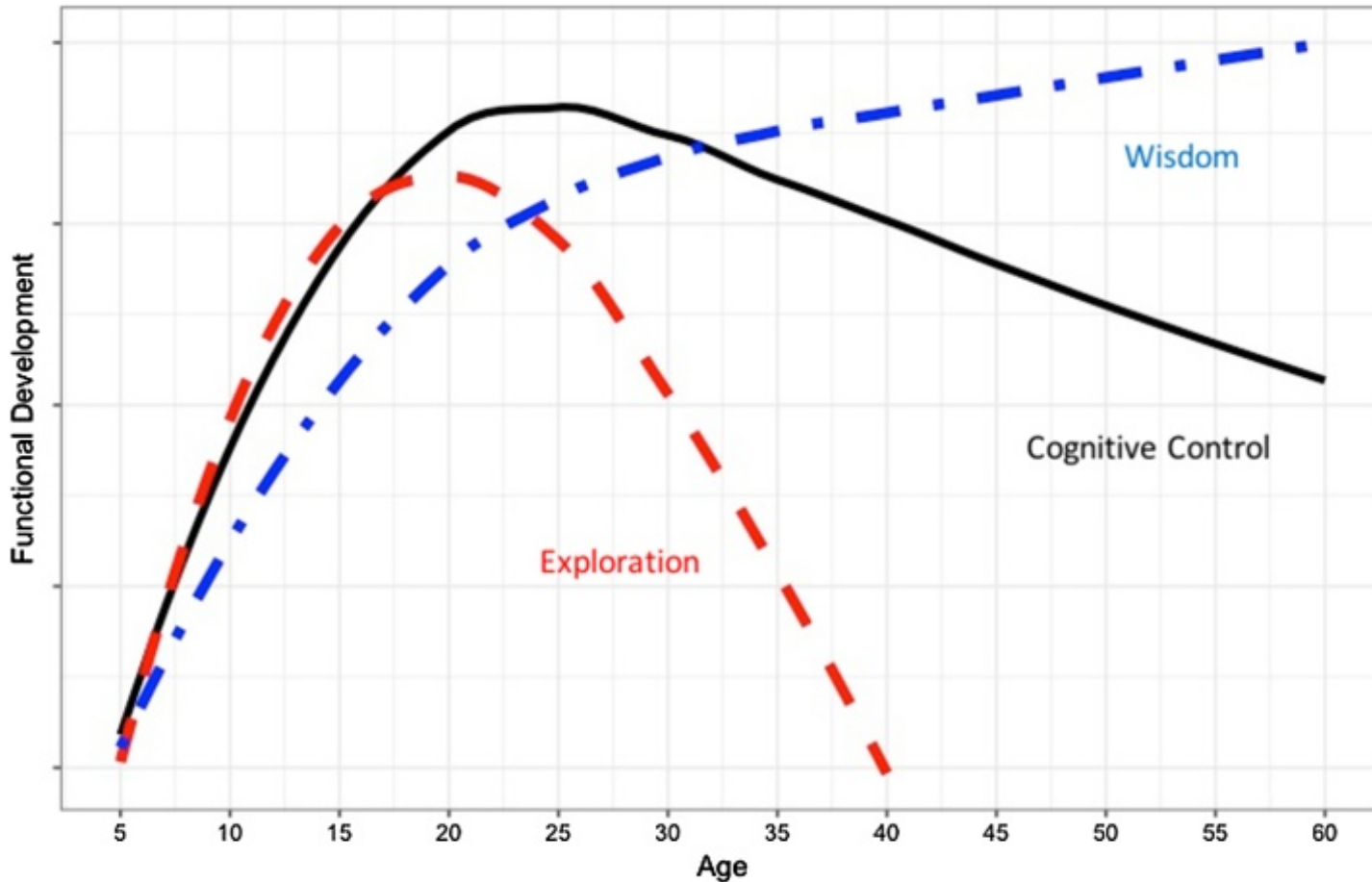
adolescence

- transition between juvenile and adult
- physical, hormonal & behavioral changes
- 10-24 years in humans
- modeled in laboratory rats and mice between 21 & 60 days



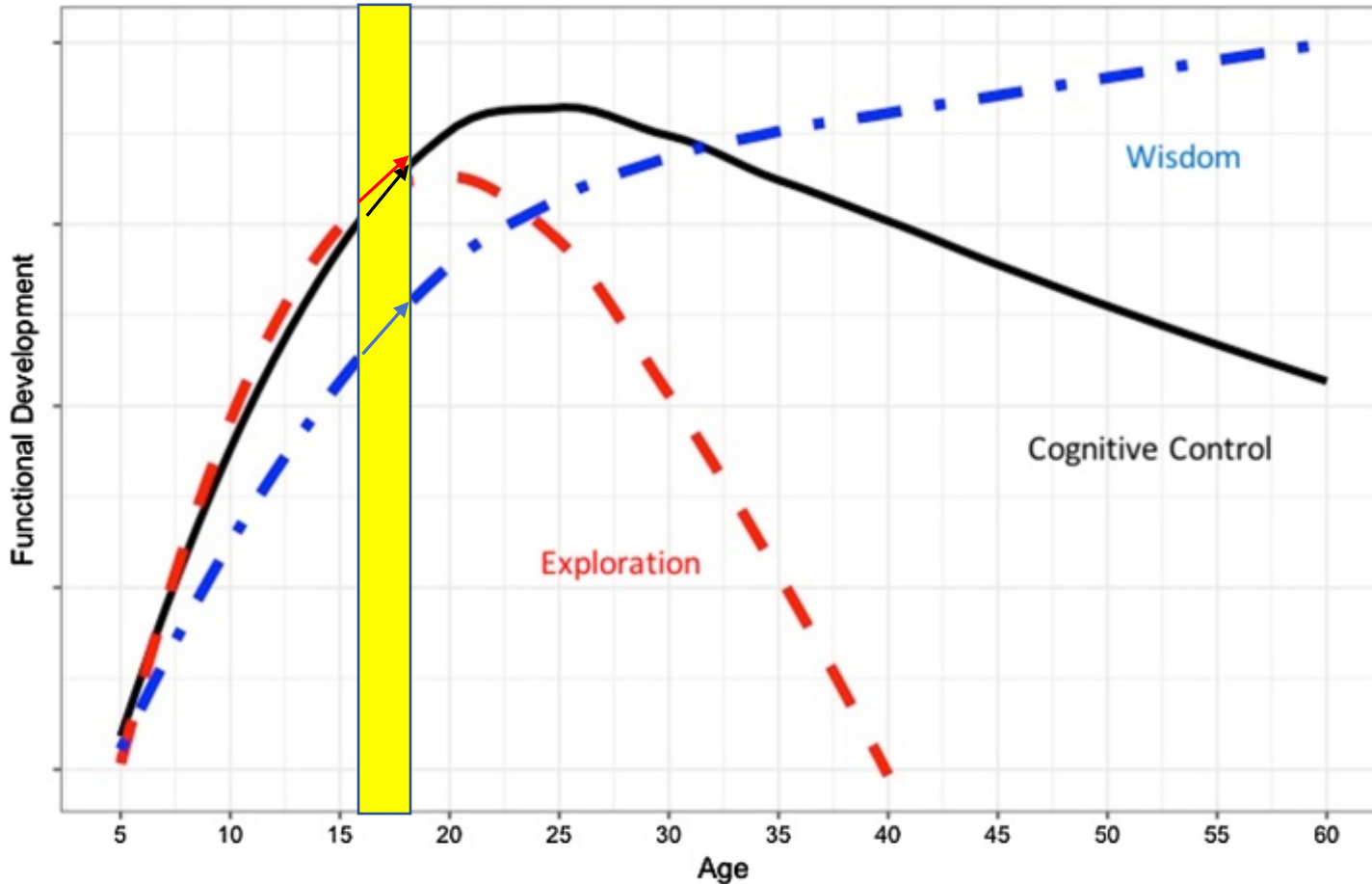
Adolescence and Puberty timing in humans and rodents. **(A)** Timeline of adolescence (shaded lines) and puberty (darker portions of the lines) in girls (♀) and boys (♂), adapted from Hollenstein and Loughheed (2013); Sawyer et al. (2018); and Brix et al. (2019). **(B)** Adolescence (shaded lines) and puberty (darker portions of the lines) timing in female (♀) and male (♂) rodents, adapted from Vetter-O'Hagen and Spear (2012) and Schneider (2013).

life-span wisdom model



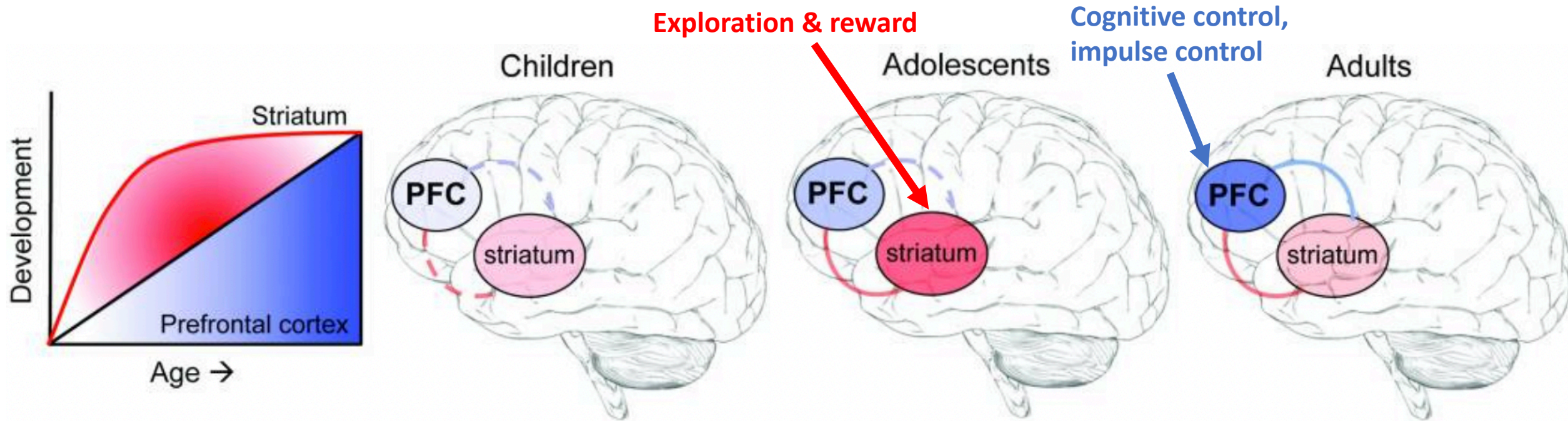
- Cognitive control (executive functioning): peaks in late adolescence/early adulthood
- Exploration (sensation-seeking): peaks earlier, but decreases earlier too
- These two processes set the stage for sound actions and decision making across the lifespan

life-span wisdom model



- Adolescence is a period when exploration is high, and control and wisdom are still developing
- Great for trying new things and learning about the world
- Can make it more difficult to always make the best choices

Brain development through adolescence



Cartoon model of ventral striatal and prefrontal cortex (PFC) interactions across development. Deeper color indicates greater regional signaling. Line represents functional connectivity, with solid line indicating mature connection and dotted line indicating immaturity

Casey BJ, Jones RM. Neurobiology of the adolescent brain and behavior: implications for substance use disorders. *J Am Acad Child Adolesc Psychiatry*. 2010 Dec;49(12):1189-201; quiz 1285. doi: 10.1016/j.jaac.2010.08.017. Epub 2010 Oct 8. PMID: 21093769; PMCID: PMC3099425.

reward & learning

Adolescence: hyperexcitability of the dopamine-rich regions of the brain

This benefits learning: making future decisions based on associating actions with reward

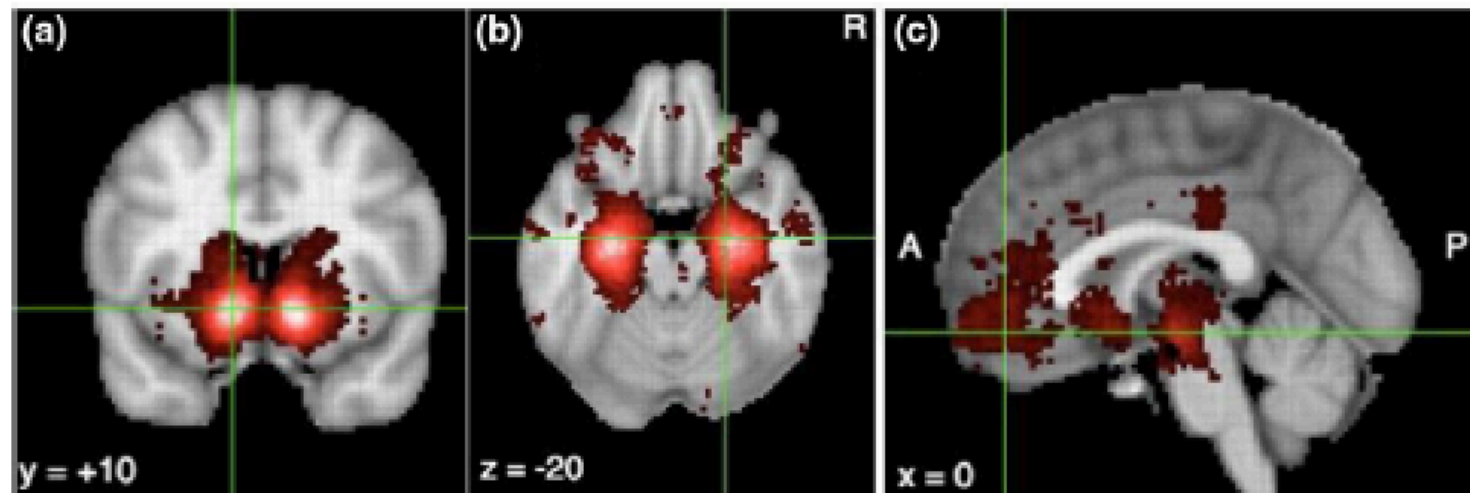


FIGURE 1 Neurosynth, an online tool for large-scale, automated synthesis of functional magnetic resonance imaging (fMRI) data, was used to identify regions central to reward processing and reinforcement ($n = 922$ studies): (a) ventral striatum (crosshairs at $x = -10$, $y = 10$, $z = -6$); (b) hippocampus and amygdala (crosshairs at $x = 24$, $y = -12$, $z = -20$); (c) medial orbitofrontal cortex (crosshairs at $x = 0$, $y = 46$, $z = -12$). [A, anterior; P, posterior].

social behavior

**Adolescence: increasing integration and refinement of all regions in the social circuit.
And greater activation of reward circuitry to prosocial stimuli**

This benefits sociability: development of the understanding of fairness, trust, and reciprocity; ability to read other people's emotions; increased social influence

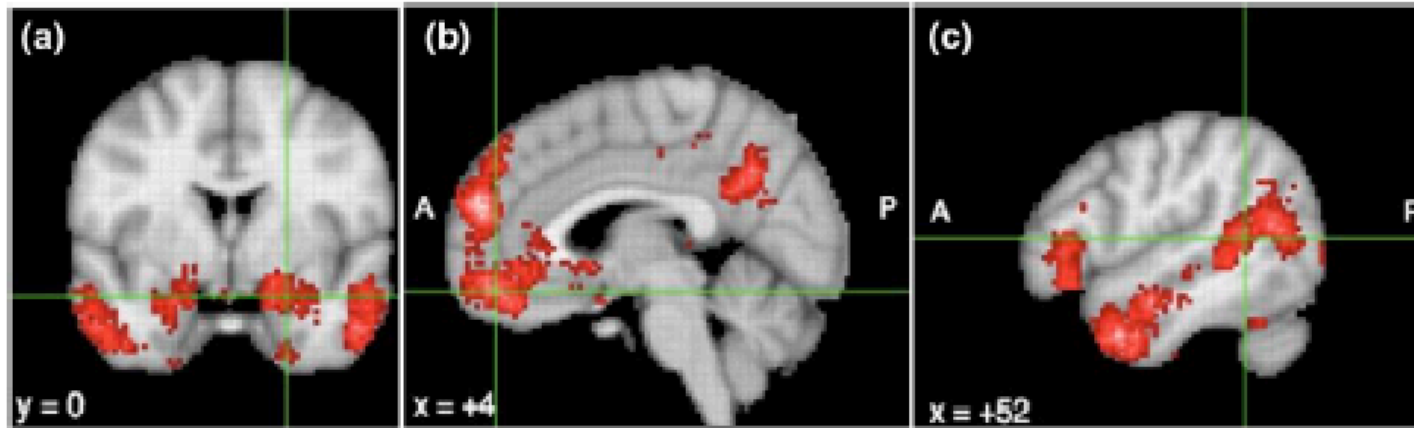
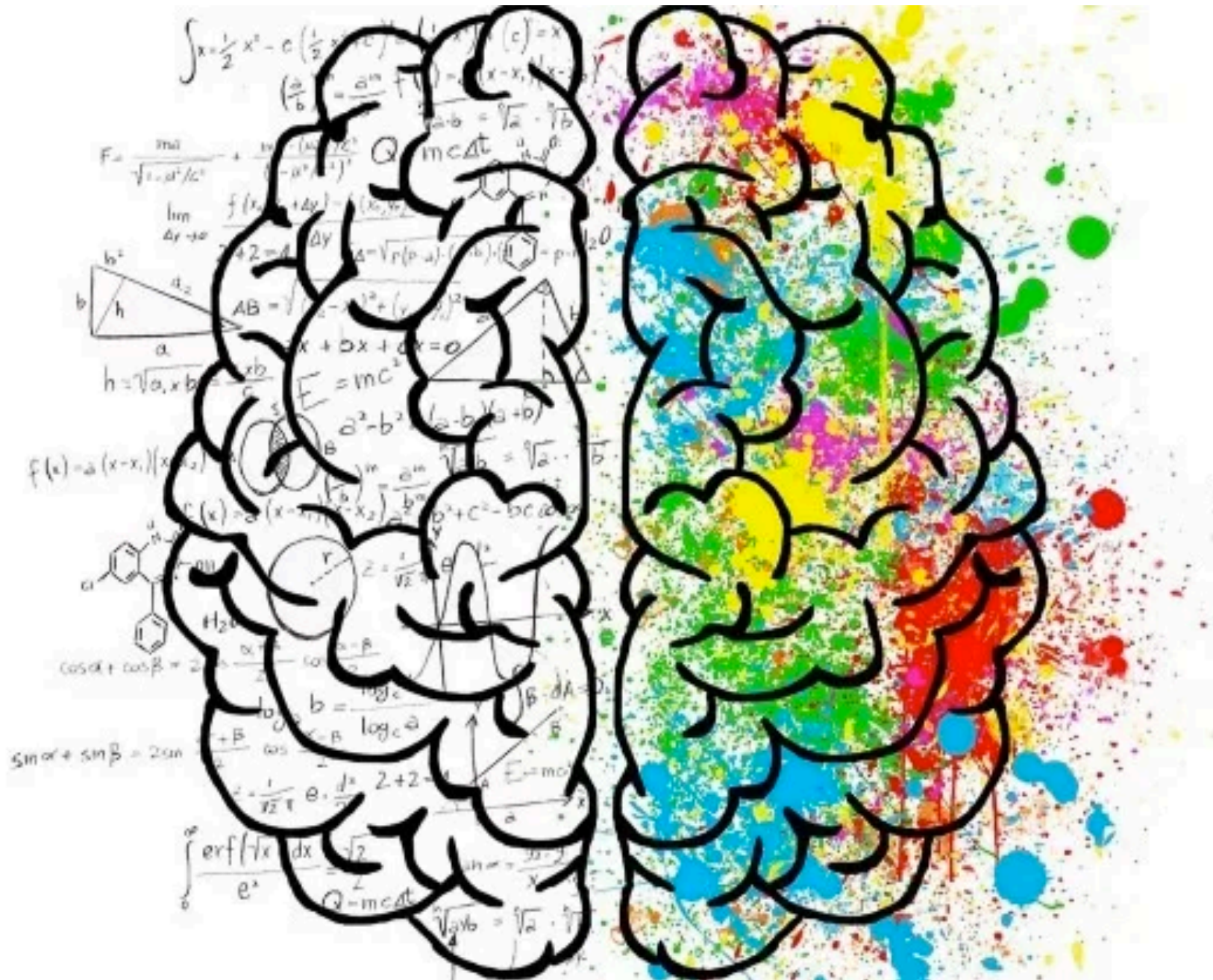


FIGURE 2 Neurosynth was used to identify regions central to processing social behavior ($n = 1302$ studies): (a) temporal gyrus and amygdala (crosshairs at $x = 24$, $y = 0$, $z = -20$); (b) medial frontal cortex (crosshairs at $x = 4$, $y = 50$, $z = -16$); (c) temporoparietal junction (TPJ) (crosshairs at $x = 52$, $y = -46$, $z = 8$). [A, anterior; P, posterior].



neurodivergence

- the concept that certain developmental disorders are normal variations in the brain. And people who have these features also have certain strengths
- Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), Dyslexia, Dyscalculia, Dyspraxia, Tourette Syndrome, Obsessive-Compulsive Disorder (OCD), Auditory processing and/or Learning Disorders, etc.
- continuum & context-dependent?

benefits of neurodiversity

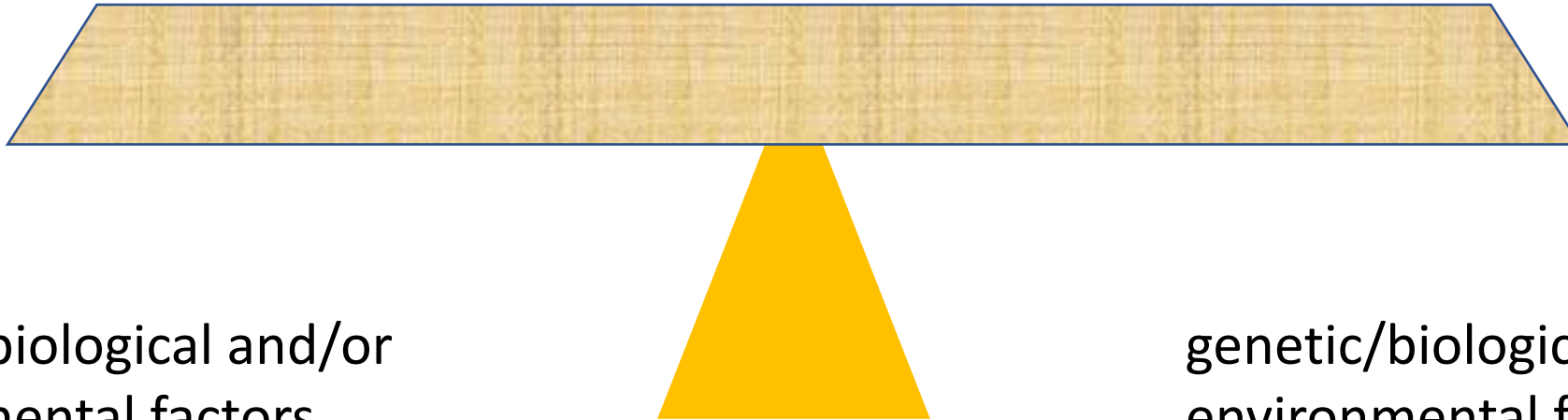
- **Attention deficit hyperactivity disorder (ADHD):** may have a variety of skills and abilities beyond those of their neurotypical counterparts. These may include hyperfocus, resilience, creativity, conversational skills, spontaneity, and abundant energy
- **Autism spectrum disorder (ASD):** the ability to hyperfocus, attention to detail, good memory, and creativity were the most frequently described traits. Participants also described specific qualities relating to social interaction, such as honesty, loyalty, and empathy for animals or for other autistic people
- **Dyslexia:** can perceive certain kinds of visual information better than those without the condition. This skill can be useful in jobs like engineering and computer graphics.
- **Obsessive compulsive disorder (OCD):** there may be close links between some dimensions of OCD and behaviors that evolved to protect our ancestors from infectious disease, and which continue to do so now in a modified form

- <https://www.medicalnewstoday.com/articles/adhd-benefits#seeking-help>
- Russell G, Kapp SK, Elliott D, Elphick C, Gwernan-Jones R, Owens C. Mapping the Autistic Advantage from the Accounts of Adults Diagnosed with Autism: A Qualitative Study. *Autism Adulthood*. 2019;1(2):124-133. doi:10.1089/aut.2018.0035
- <https://www.webmd.com/add-adhd/features/what-is-neurodiversity>
- Rajkumar RP. Contamination and infection: What the coronavirus pandemic could reveal about the evolutionary origins of obsessive-compulsive disorder. *Psychiatry Res*. 2020;289:113062. doi:10.1016/j.psychres.2020.113062

promoting healthy brain development

Risk

Resilience

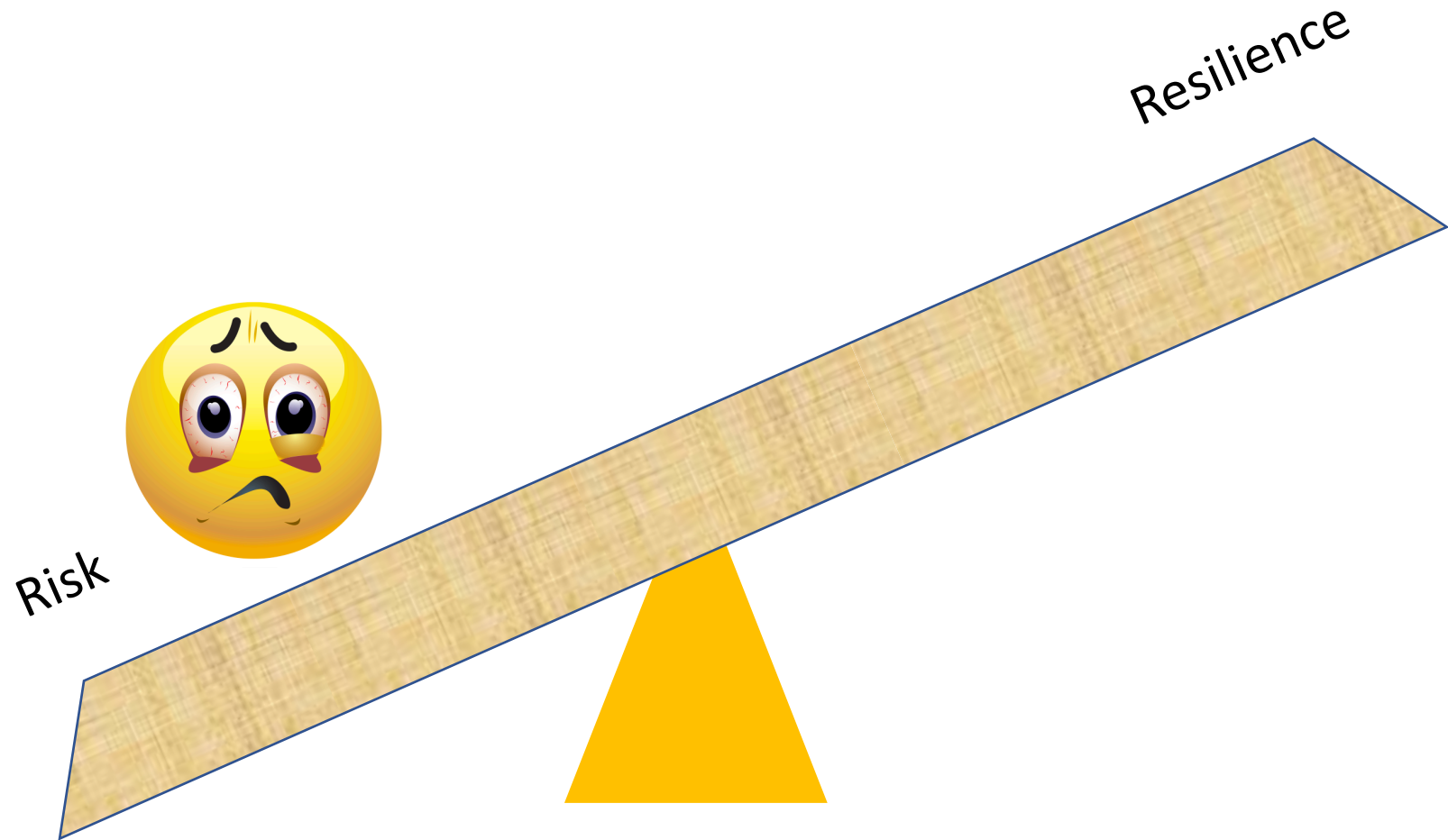


genetic/biological and/or environmental factors that **decrease** the likelihood of a positive outcome

genetic/biological and/or environmental factors that **increase** the likelihood of a positive outcome

Risk

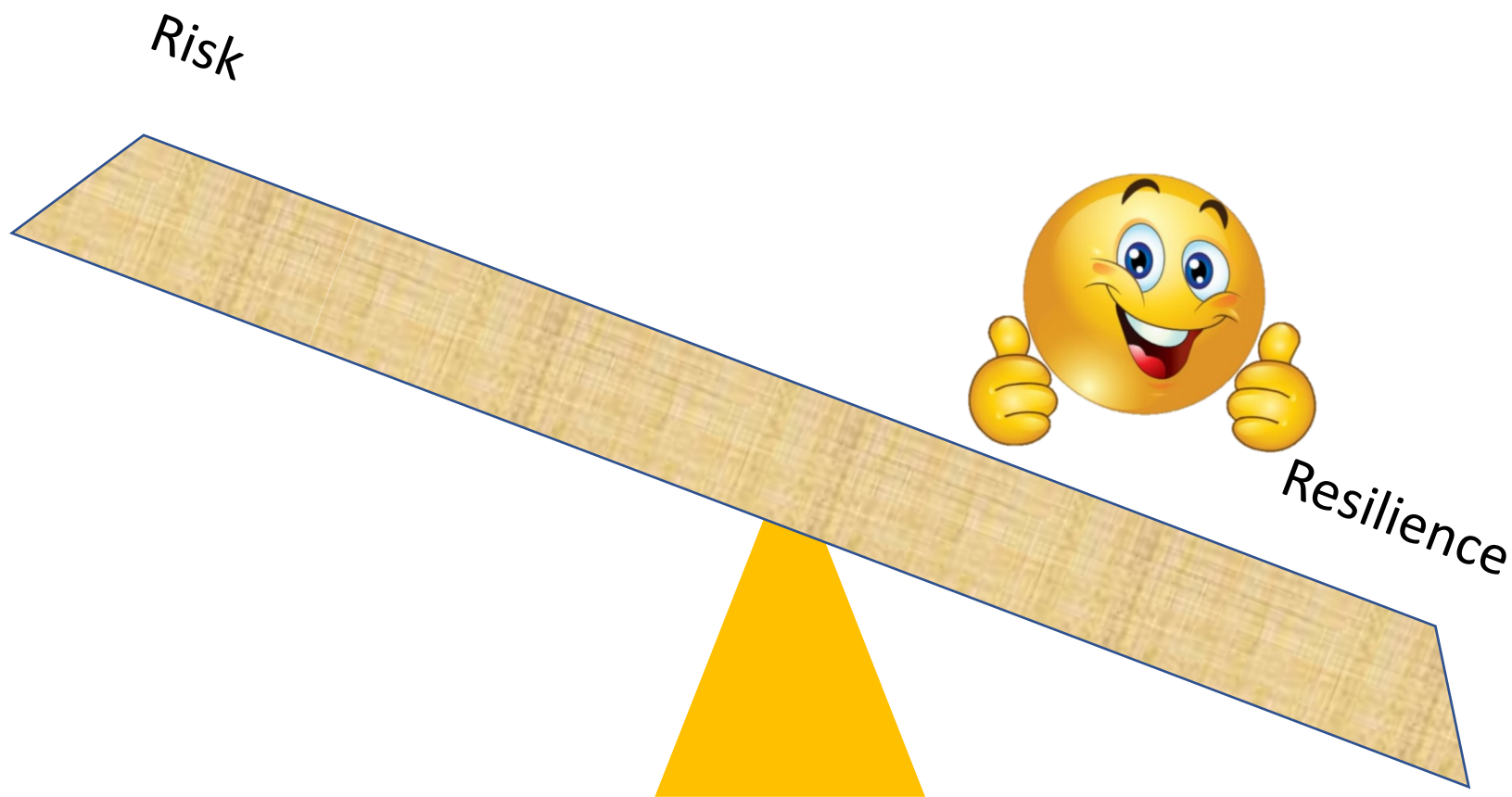
What are some risk factors that high school students (or you personally) have?



<poll>

Resilience

What are some resilience factors that high school students (or you personally) have?



<poll>

pro-social



a

social

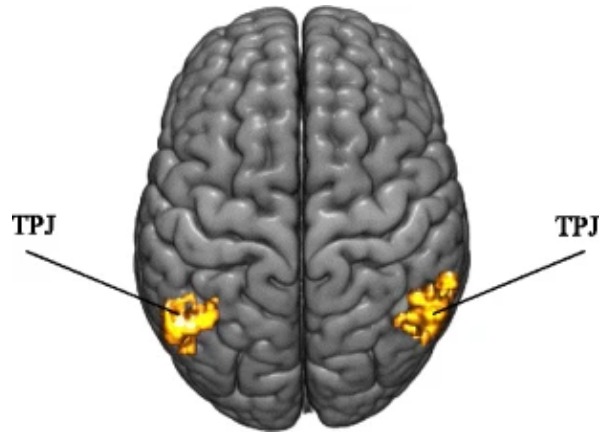


b

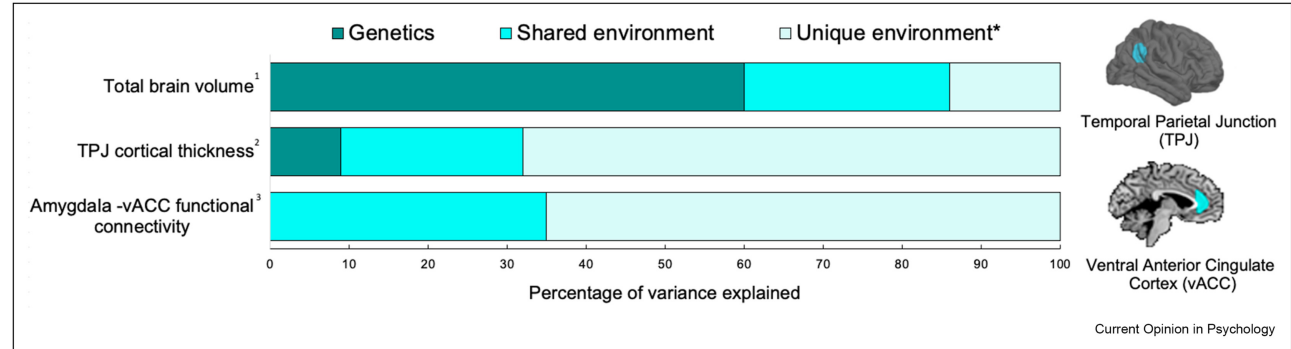
Non-interactive



c



social interaction

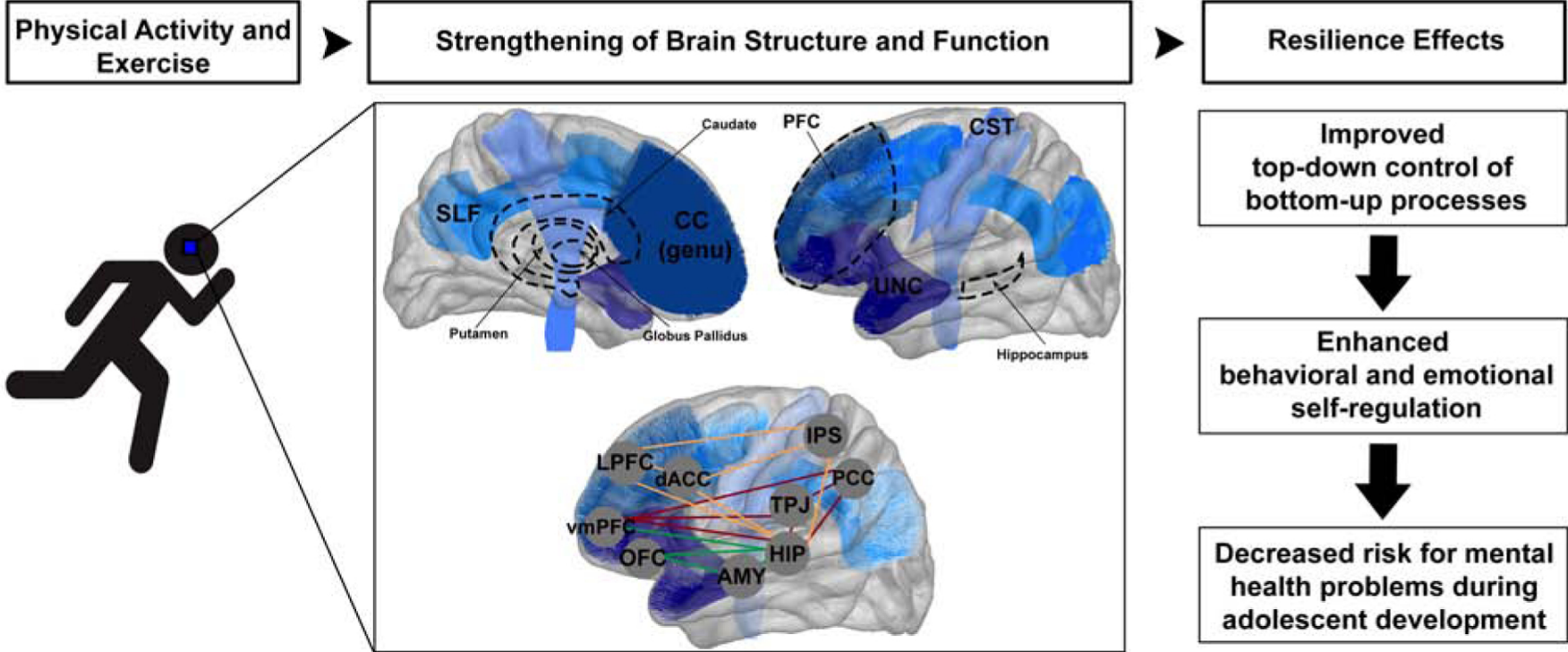


- Activation of the temporoparietal junction (TPJ) specifically when viewing pro-social scenes
- This is directly tied to the amygdala – important for emotion, and the hippocampus – important for learning and memory

physical activity & exercise

structure: strengthens white matter fiber tracts

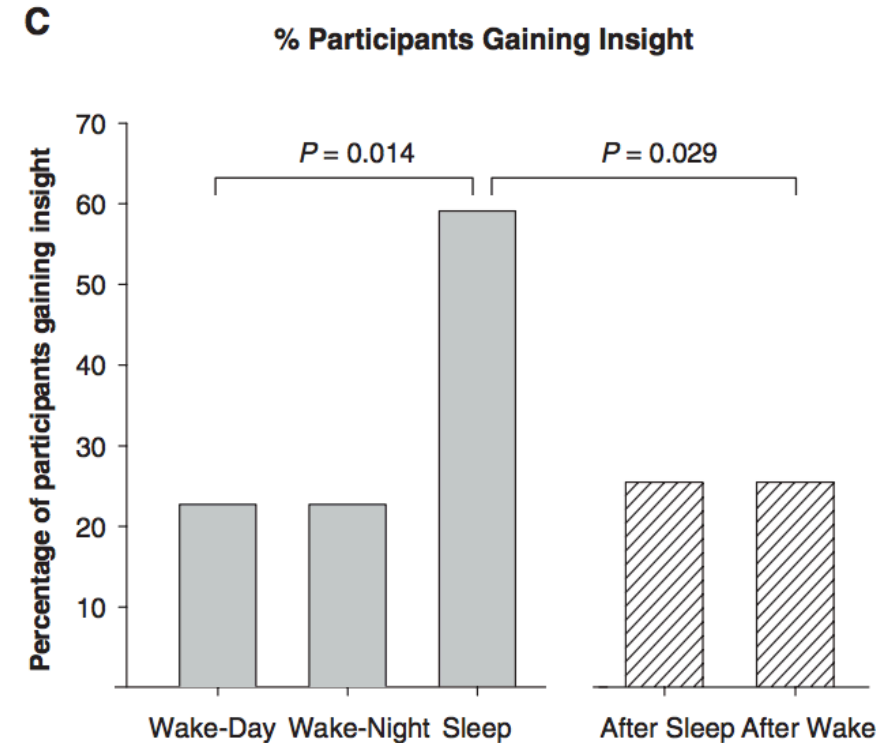
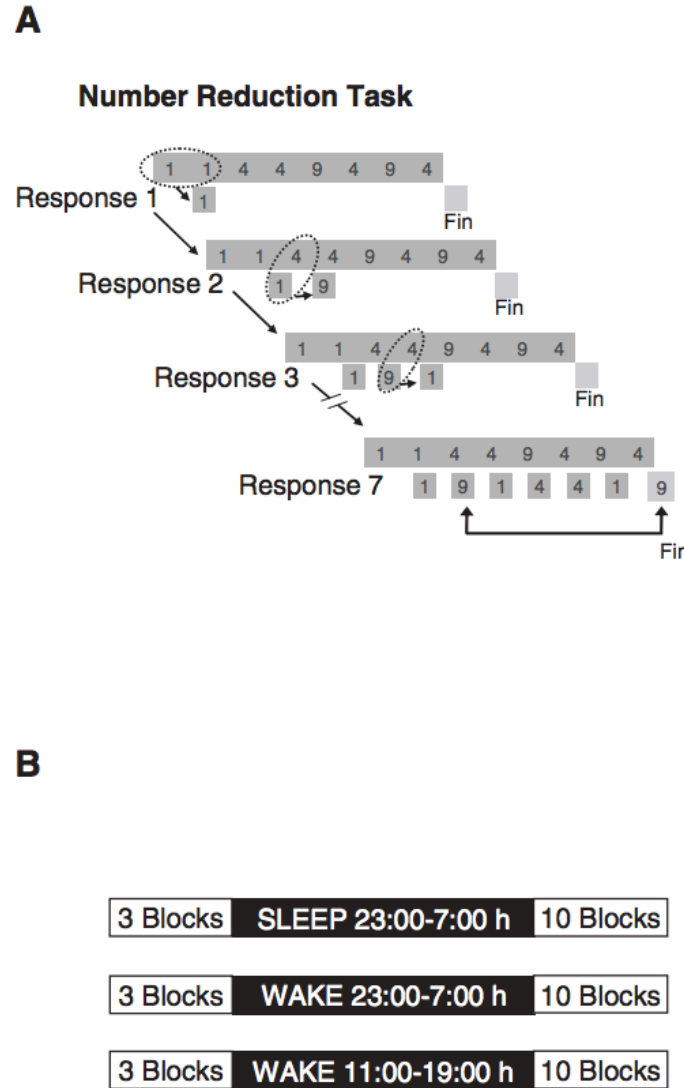
function: increases activity of motor and reward systems



Belcher BR, Zink J, Azad A, Campbell CE, Chakravarti SP, Herting MM. The Roles of Physical Activity, Exercise, and Fitness in Promoting Resilience During Adolescence: Effects on Mental Well-Being and Brain Development. *Biol Psychiatry Cogn Neurosci Neuroimaging*. 2021 Feb;6(2):225-237. doi: 10.1016/j.bpsc.2020.08.005. Epub 2020 Aug 18. PMID: 33067166; PMCID: PMC7878276.

sleep

- optimizes the consolidation of newly acquired information in memory
- slow oscillations in slow wave sleep allow feedback between the hippocampus and cortical networks in their most sensitive state, creating long-lasting changes in these cortical networks



social media



Digital media

Peer/social connection
Novelty/adventure
↑ Choices (best options)
Immediacy/Individualized
Low failure cost
Virtual arena for drives
of sex/aggression

- hunger for human connectedness
 - social connection is a basic human need & is rewarding
 - “likes” increase activity of the reward circuitry (fMRI study)
- appetite for adventure
 - adolescent increase in sensation seeking & risk taking seen in all social animals – to master threats that may be harmful
 - the virtual world offers exploration, expression, experimentation & refinement of our drives & desires
- desire for data
 - an important mission of the brain: assess the environment and initiate survival behaviors
 - increases in connectivity among brain regions (↑ white matter)
 - peers become more important – and now this can be global



Bottom Line

- The brain, especially the prefrontal cortex which is associated with cognitive and impulse control, planning, and executive functioning is not developed until about age 25!!!
- This is very important in development, but can lead to risky choices
- Social interaction, exercise and sleep are important in healthy brain development
- Social media does have positive aspects for adolescents. Of course.... we need to be careful about bullying, FOMO, comparisons, & addiction!