

# ADOLESCENT BRAIN DEVELOPMENT

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Duke-UNC Brain Imaging and Analysis Center



# ADOLESCENCE: A PERIOD OF RISK AND OPPORTUNITY

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<https://www.google.com/search?client=safari&rls=en&q=adolescent+brain+development&ie=UTF-8&oe=UTF-8#fpstate=ive&vld=cid:4e0def8d,vid:-1FRco3Bjyk,st:0>

Did you know that **big and important changes** happen in the brain during adolescence? Here are **seven things to know about the teen brain**

1



2

3



4

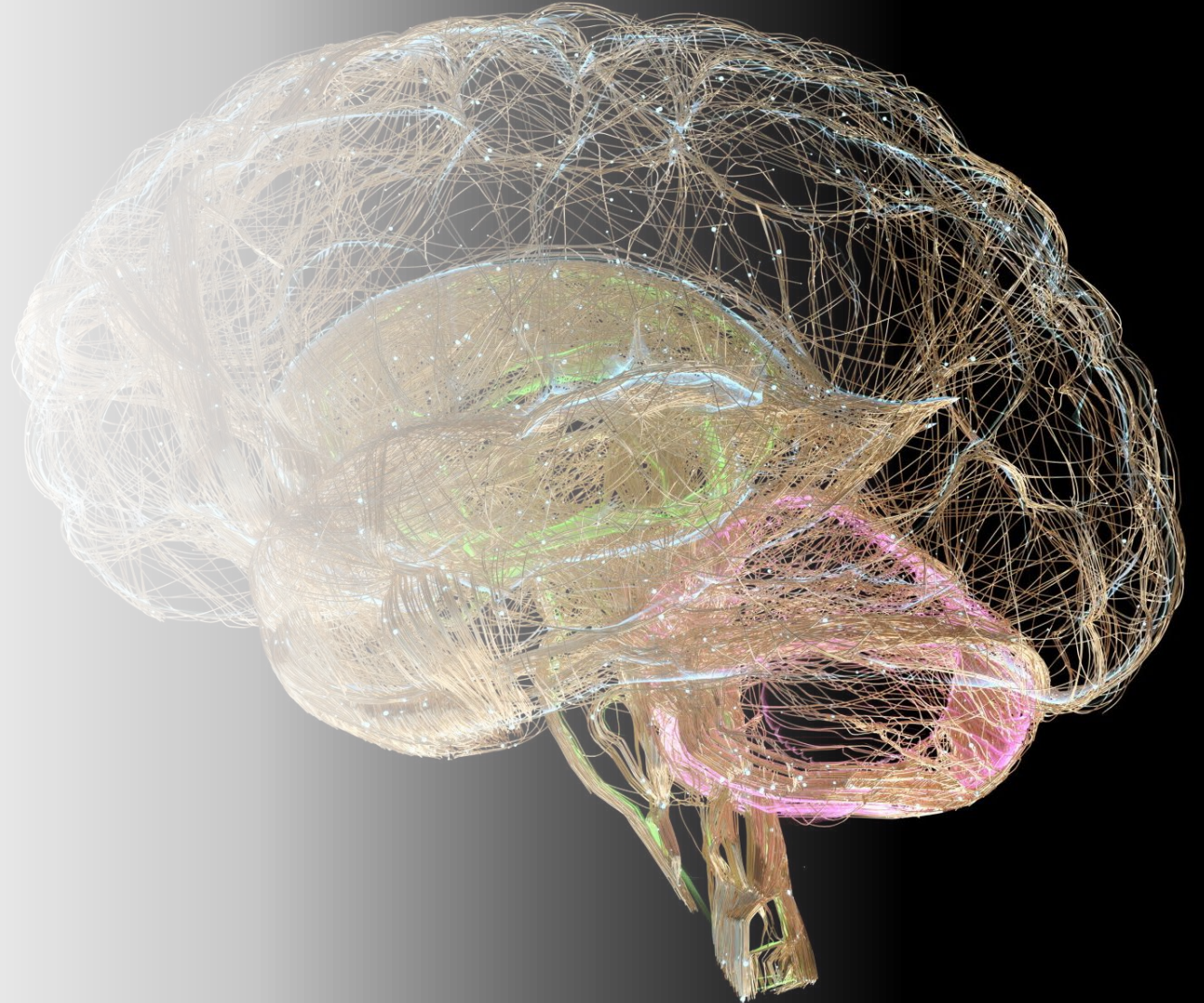


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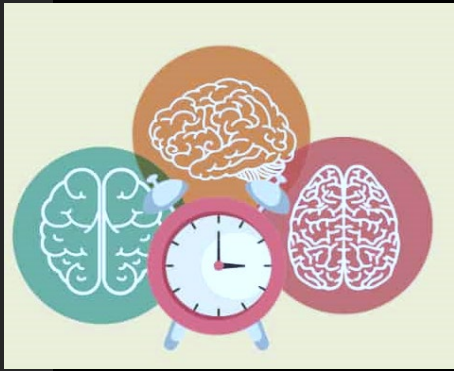
# OUTLINE

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- I. Adolescent Brain Development:  
critical periods**
- II. Neural circuits of self-regulation  
and Cognition**
- III. Trauma effects on Brain  
Development**
- IV. Trauma and Adolescent  
Psychopathology**
- V. Prevention**







# I. Critical periods of neurodevelopment

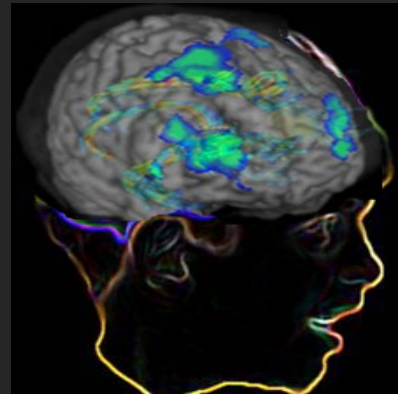
Prenatal



Infancy



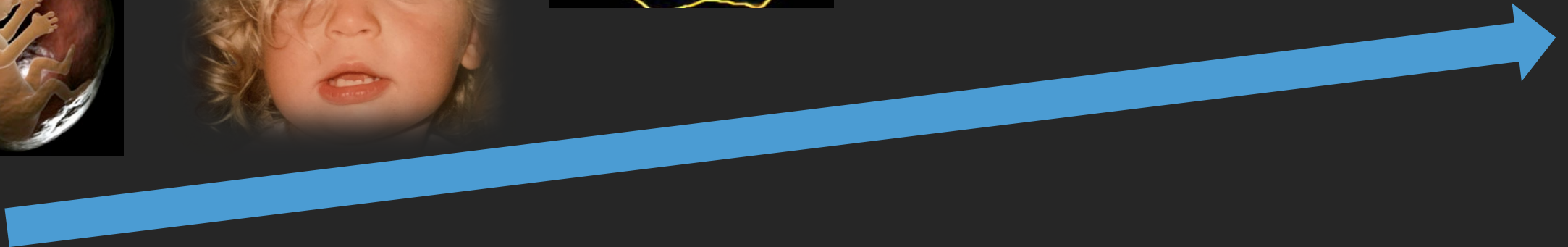
Early Childhood



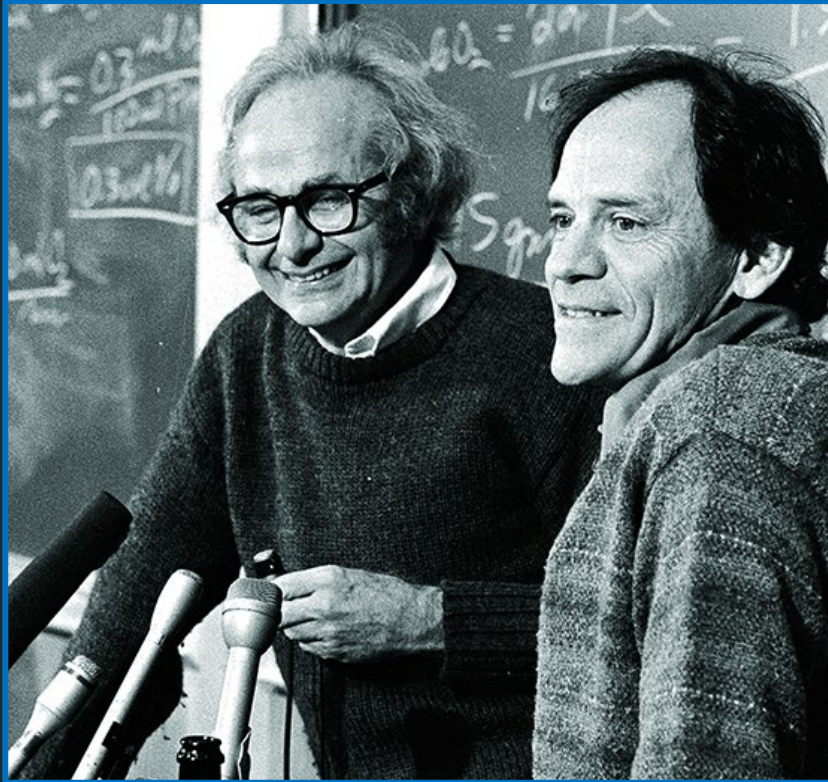
Adolescence



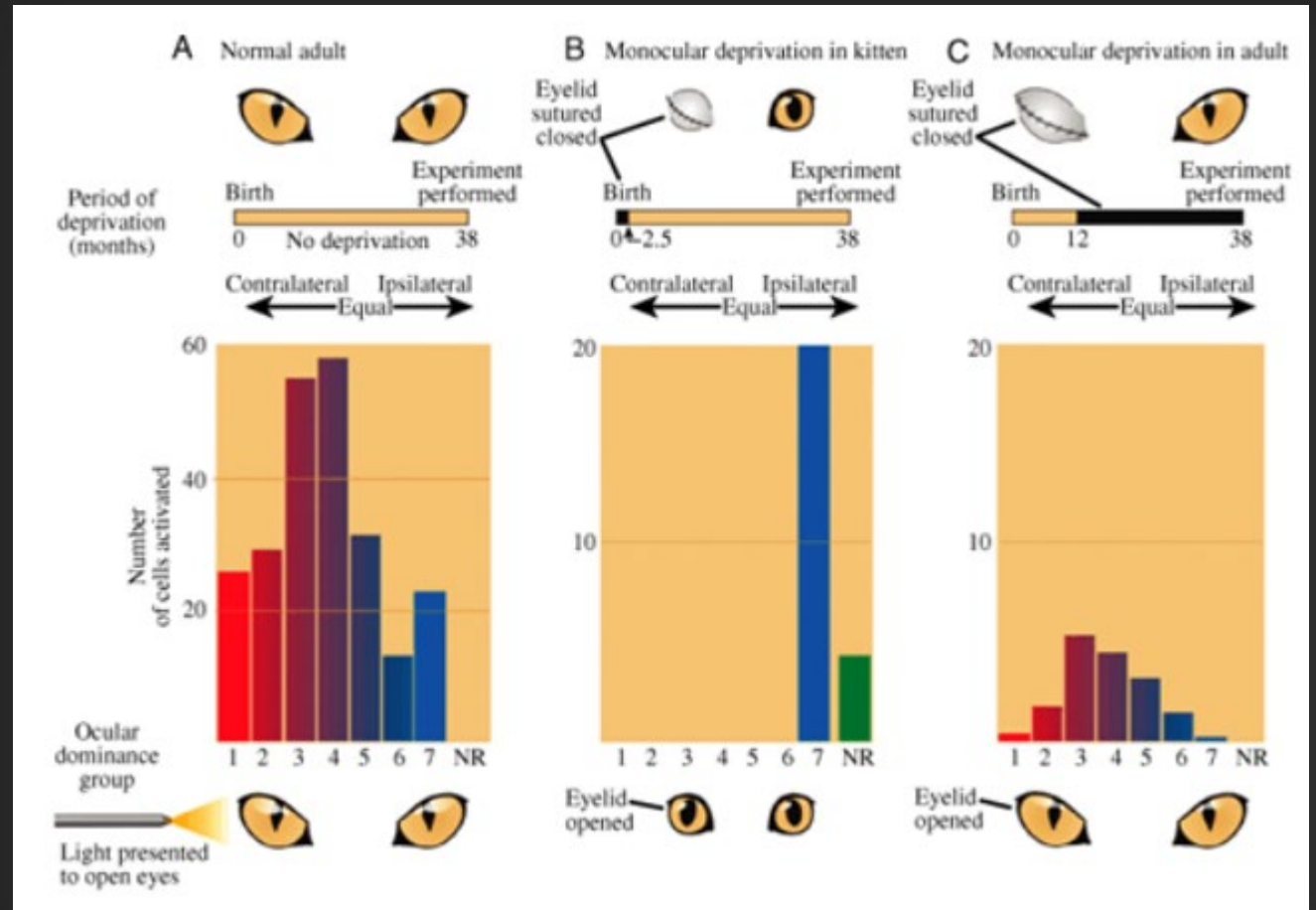
Aging



# What is a "critical period"?

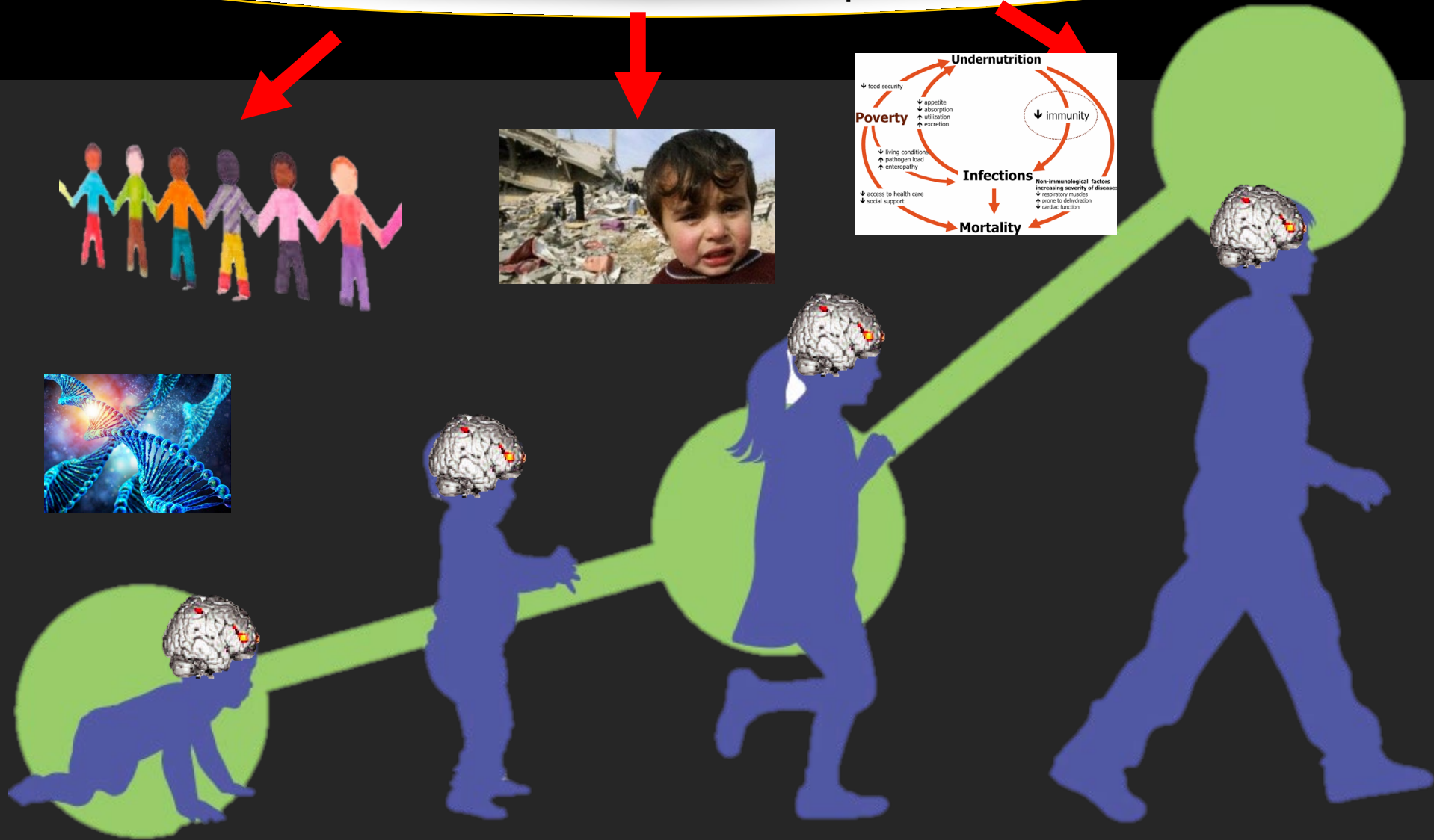


Hubel and Wiesel, 1963



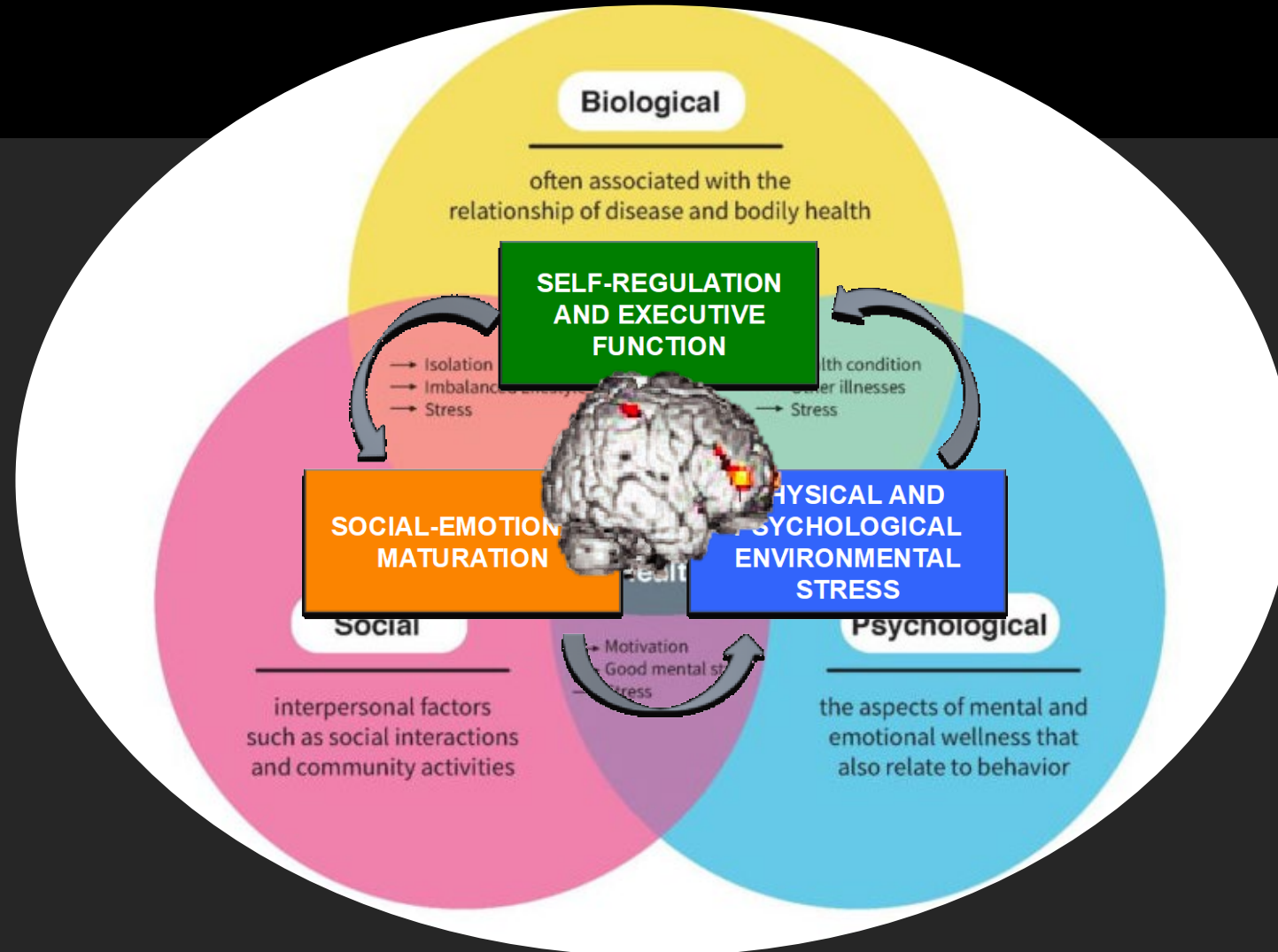
# Developmental Trajectories: Nature x Nurture

Social/Environment/Experiences

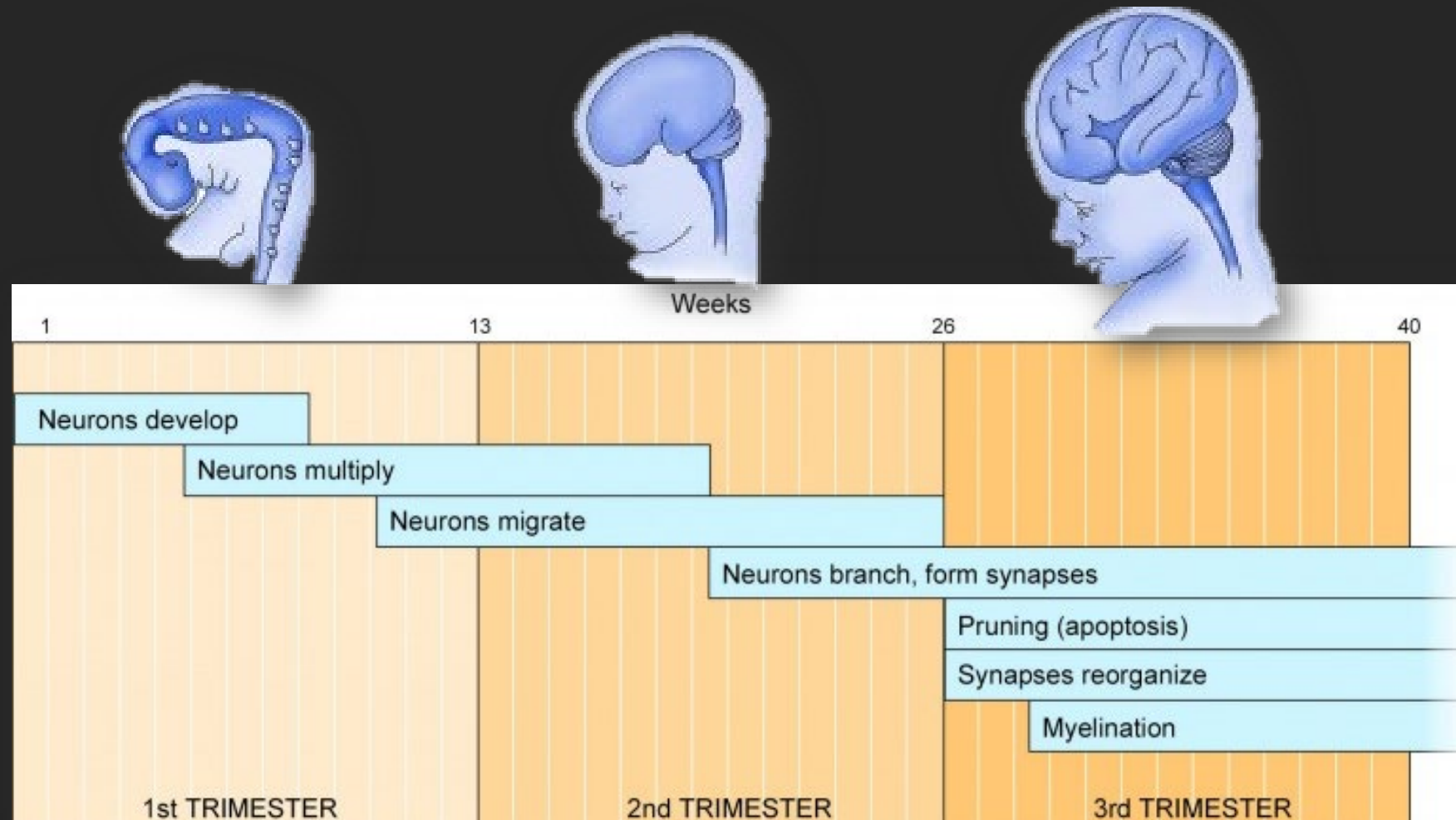




# BIOSPSYCHOSOCIAL MODEL OF BRAIN DEVELOPMENT AND PSYCHOPATHOLOGY



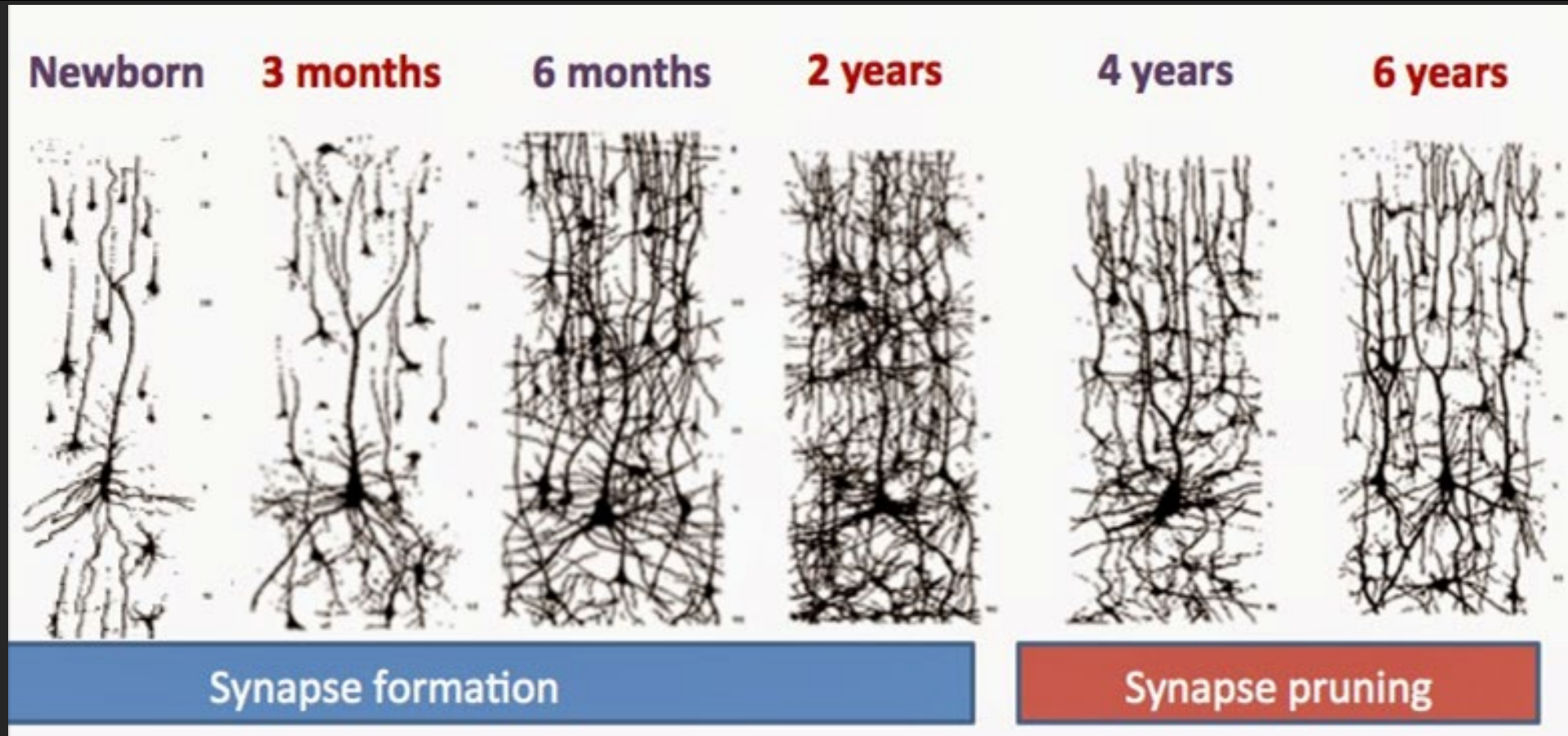
# Prenatal Brain Development: Complex Sequence Of Programs



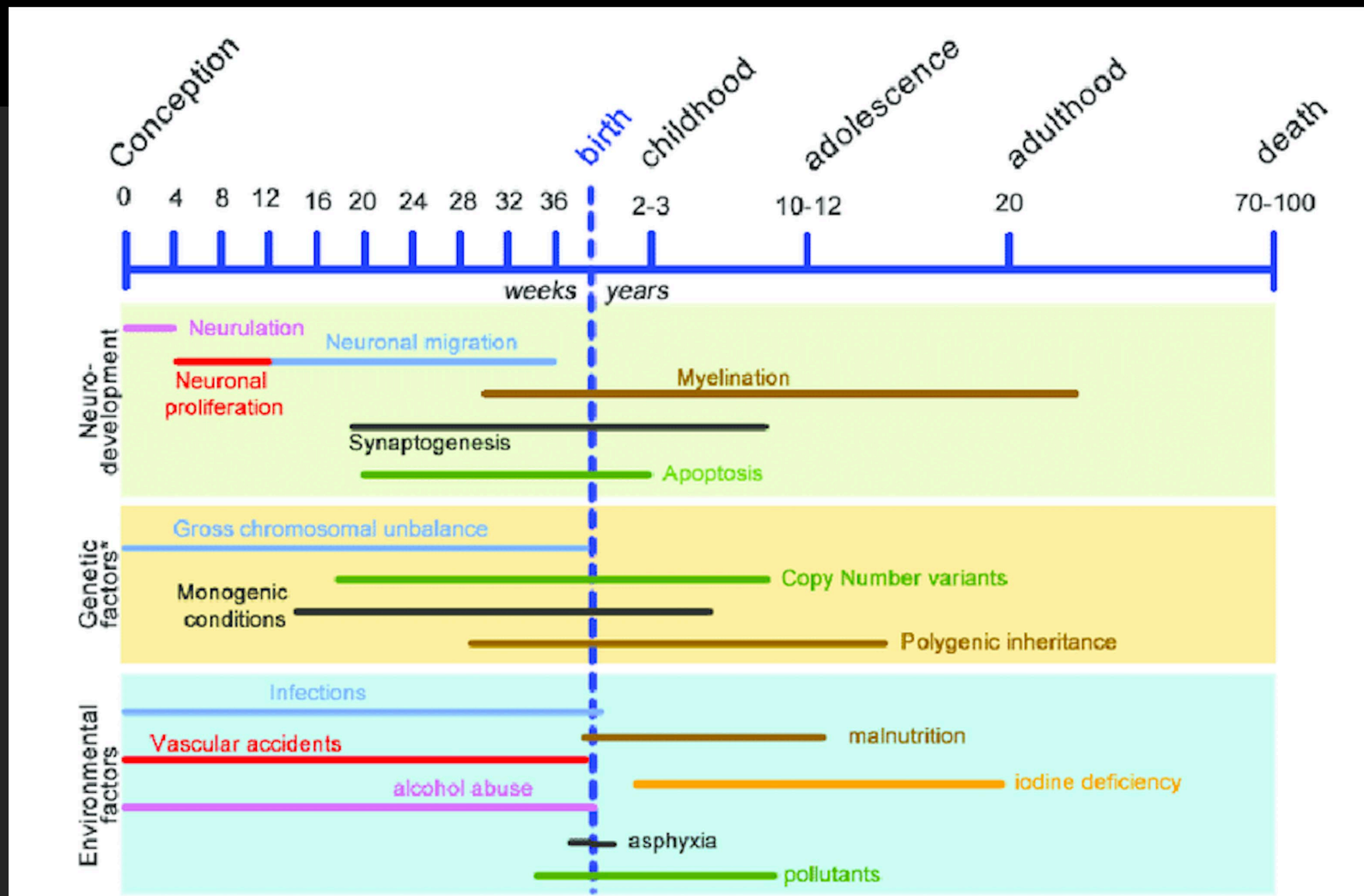




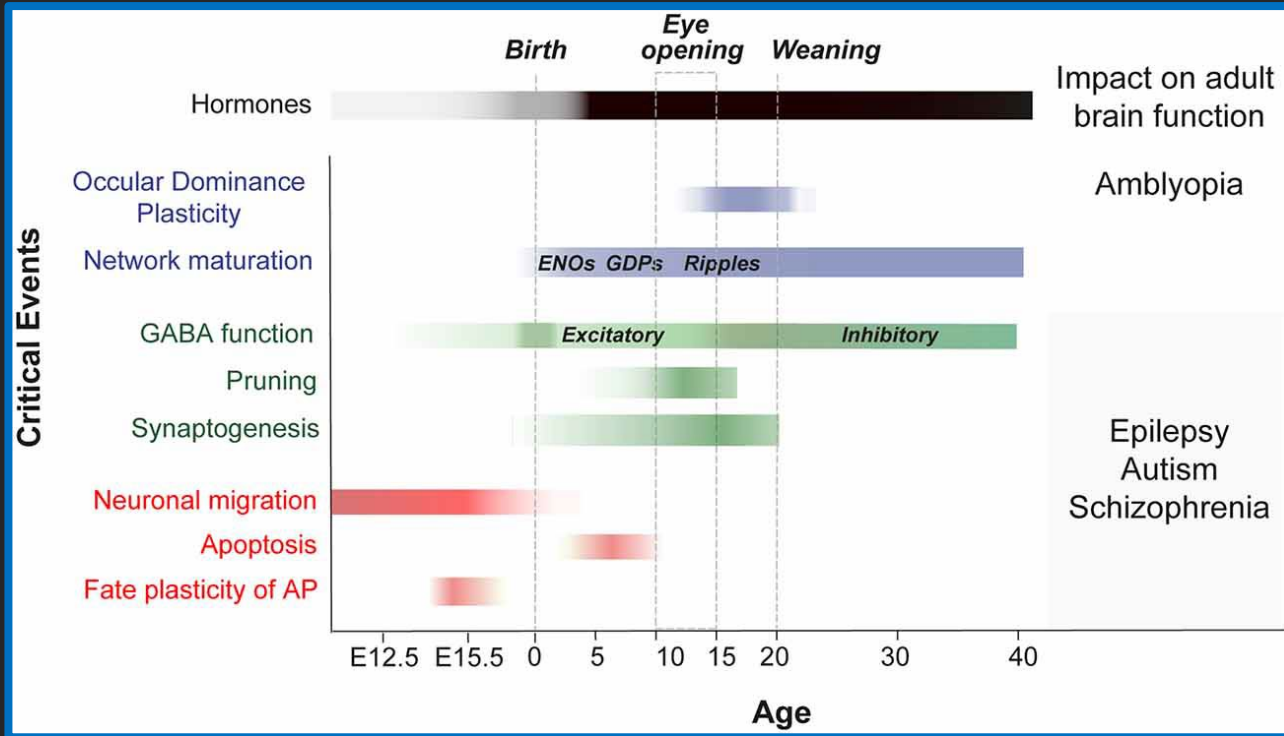
# Early Brain Development: setting the stage for lifetime



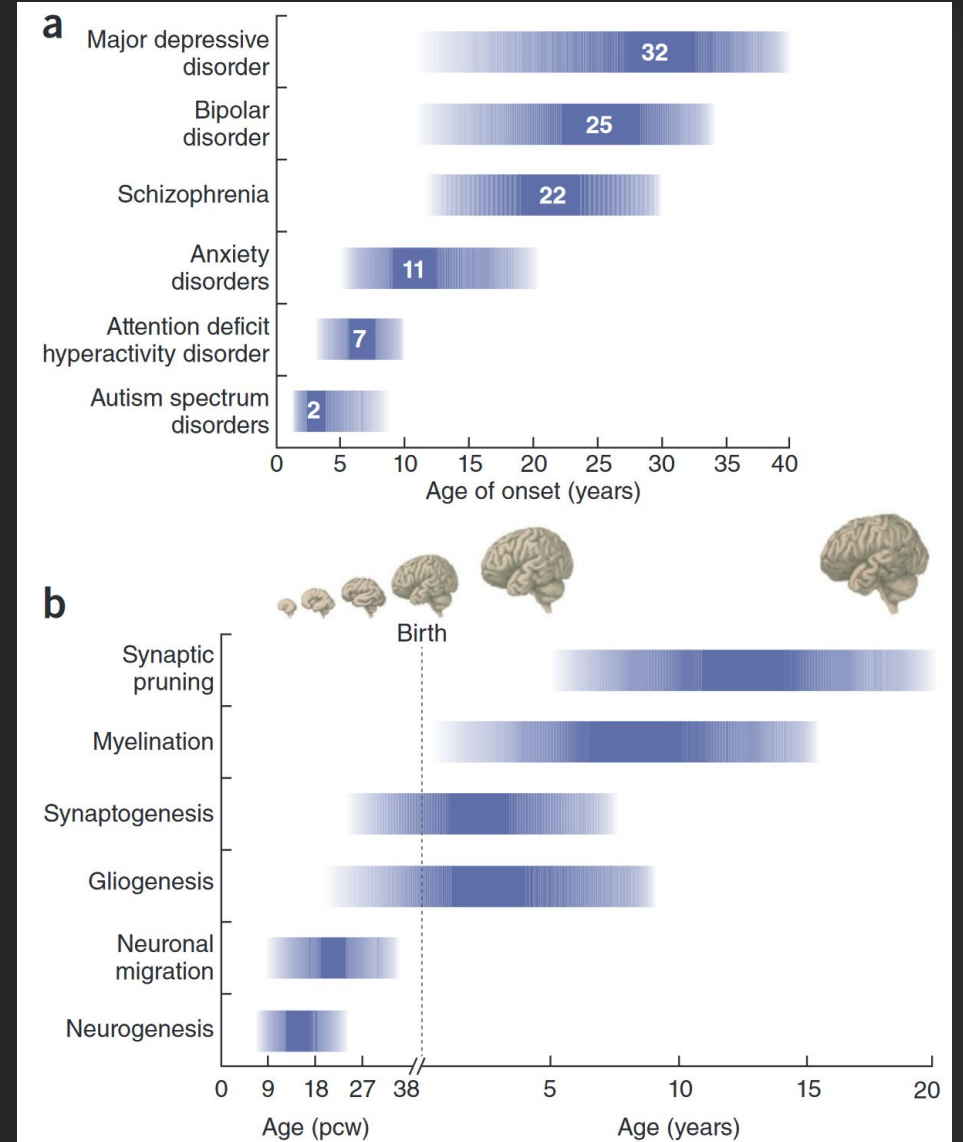
# Gene-environment interactions across development - plasticity



# Critical events and neurodevelopment



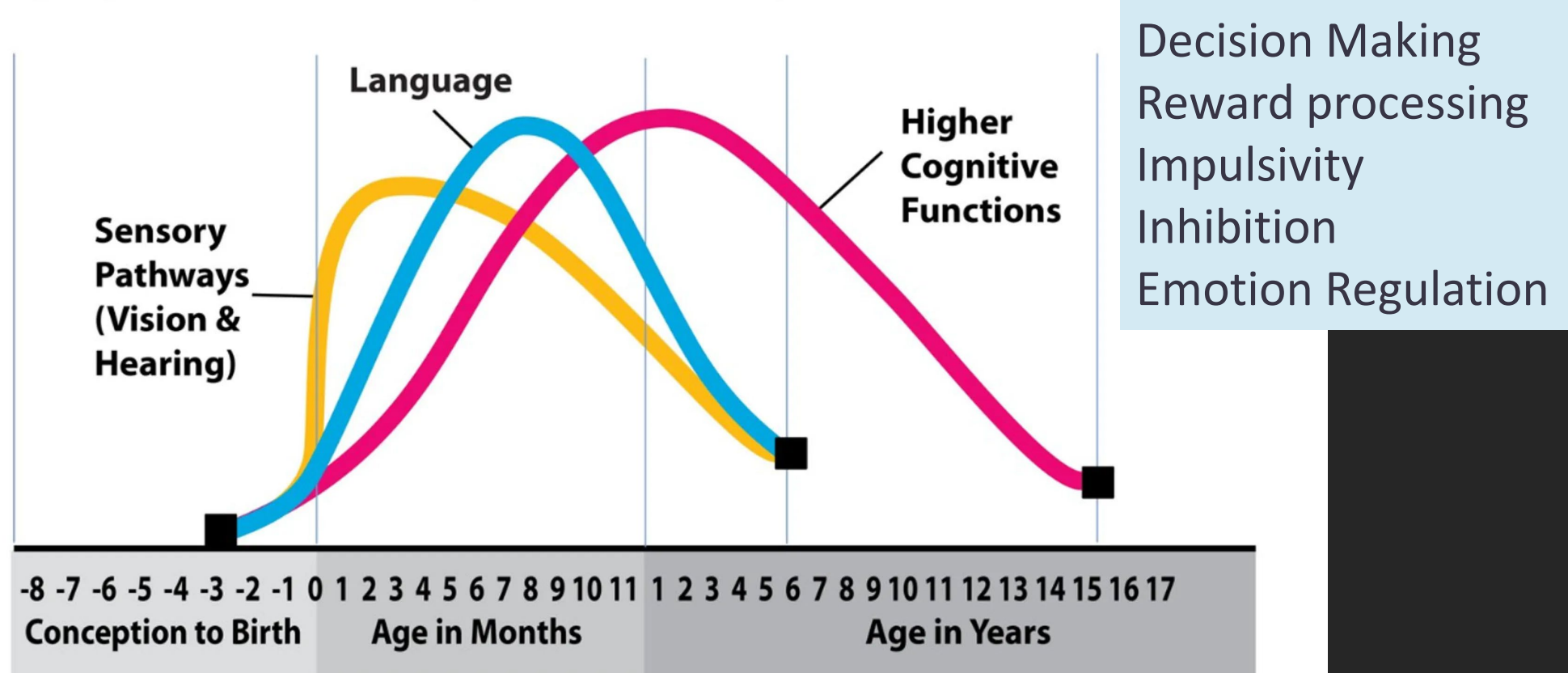
Dehorter & Del Pino, 2020



Marin, 2016

# Human Brain Development

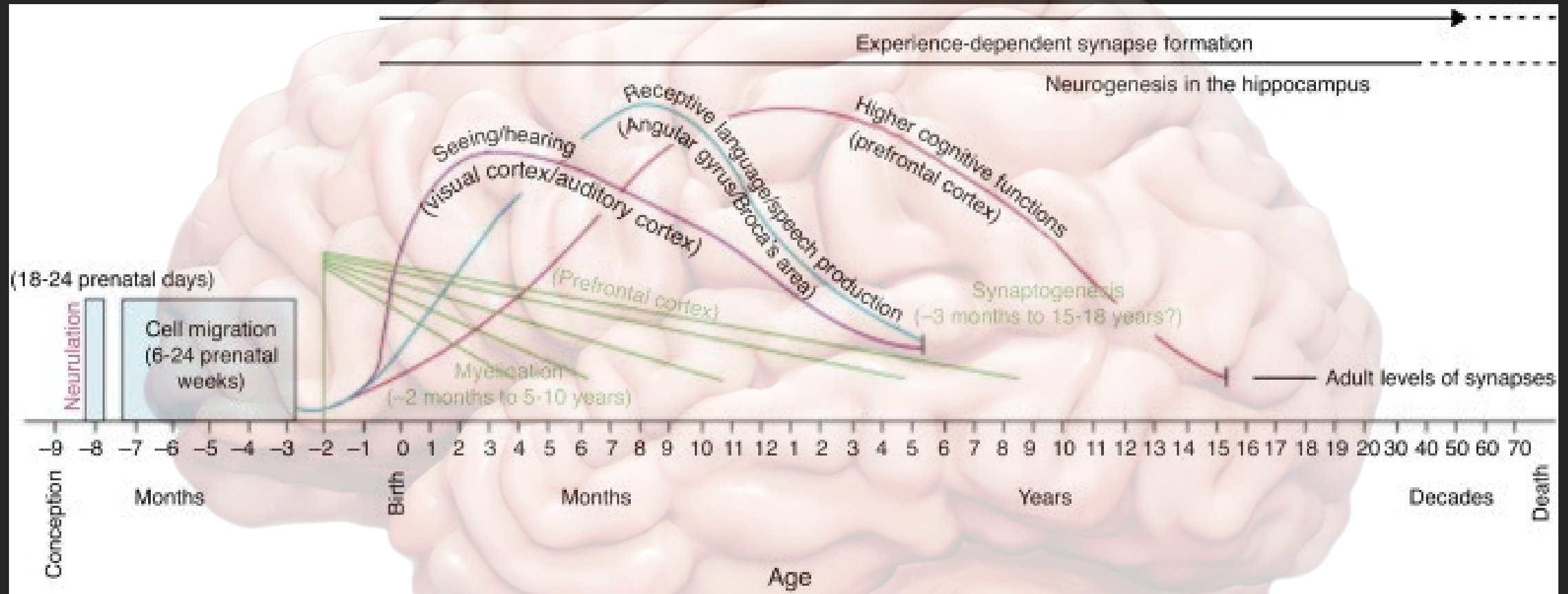
Synapse formation is dependent on early experiences



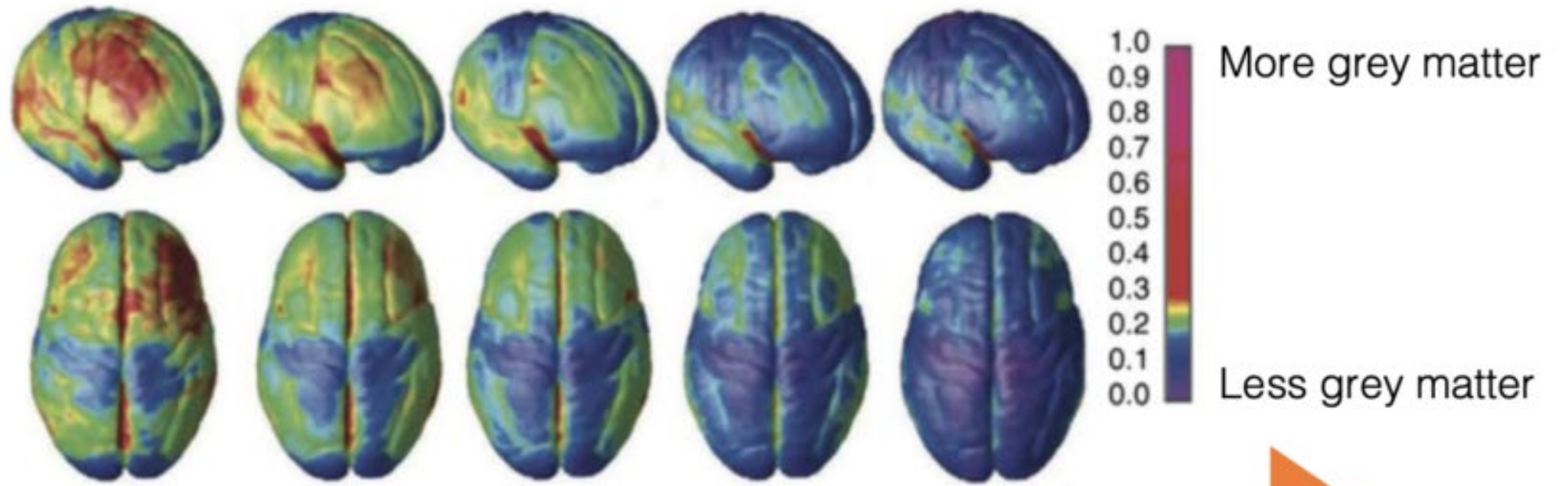
Source: Nelson, C. A. in *Neurons to Neighborhoods* (2000), Shonkoff, J. and Phillips, D. (Eds.)



# BUILDING THE BRAIN







1.0  
0.9  
0.8  
0.7  
0.6  
0.5  
0.4  
0.3  
0.2  
0.1  
0.0

More grey matter

Less grey matter

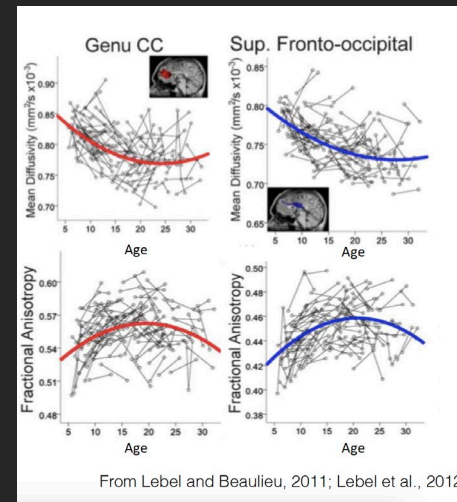
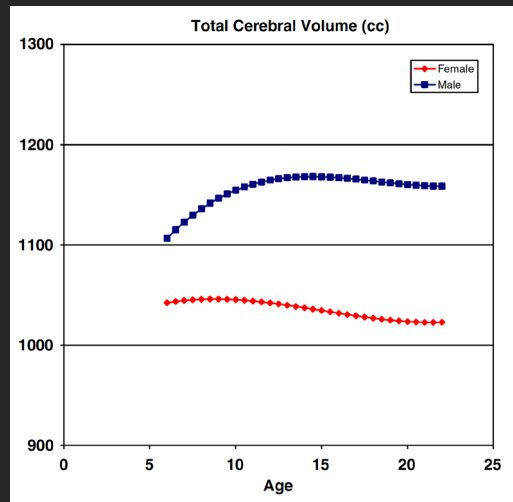
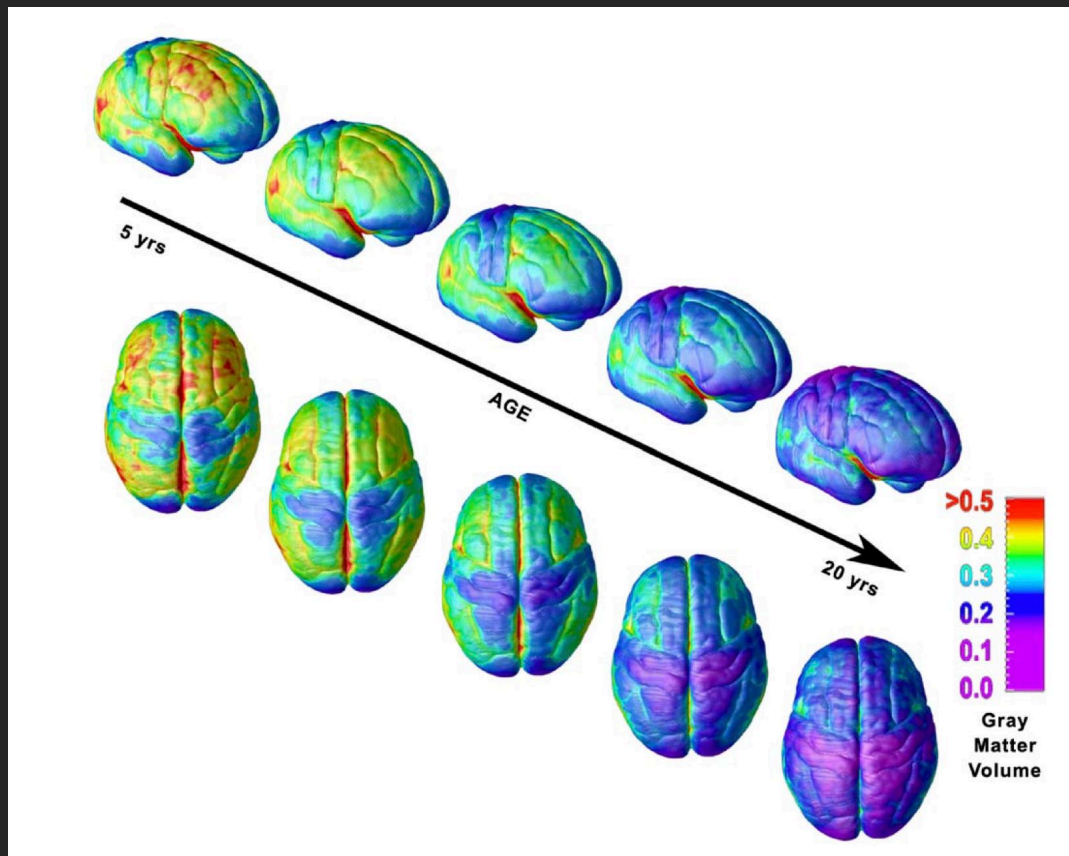


Birth



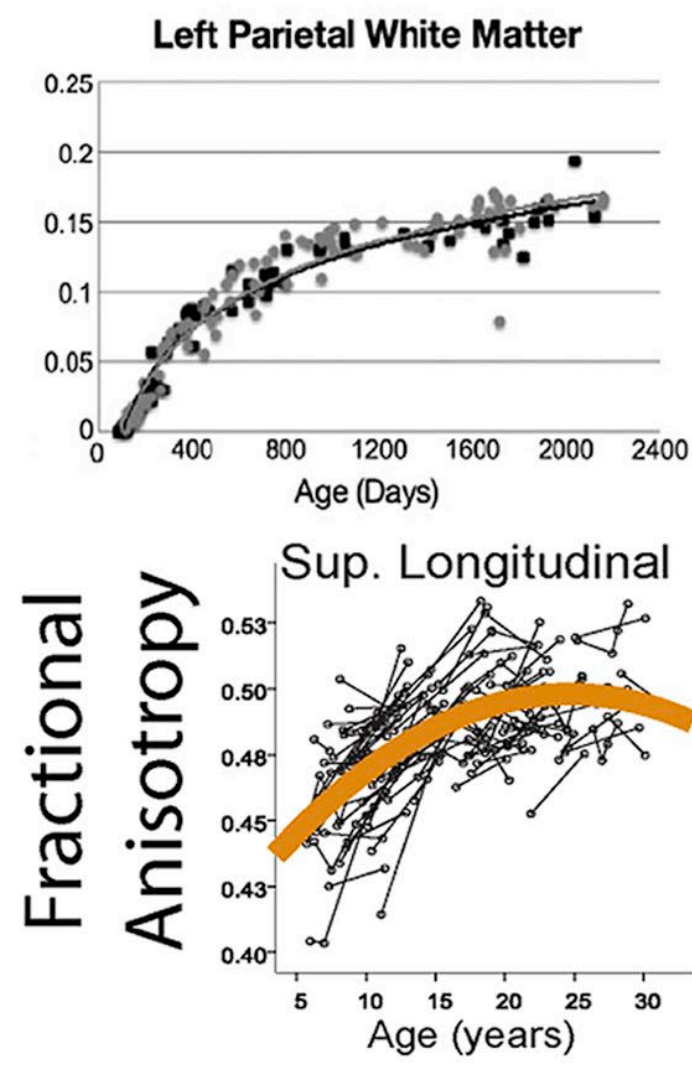
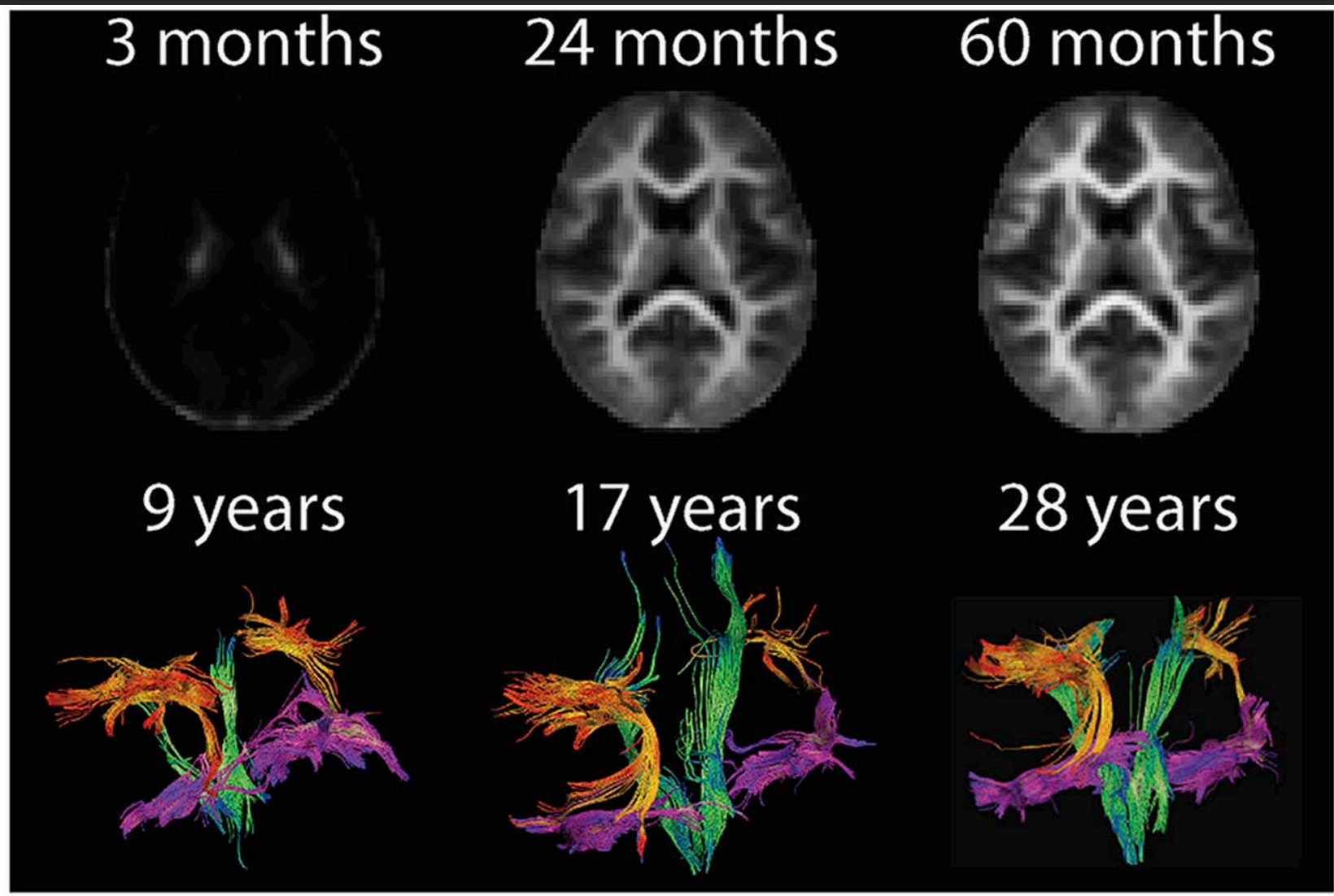
Adulthood



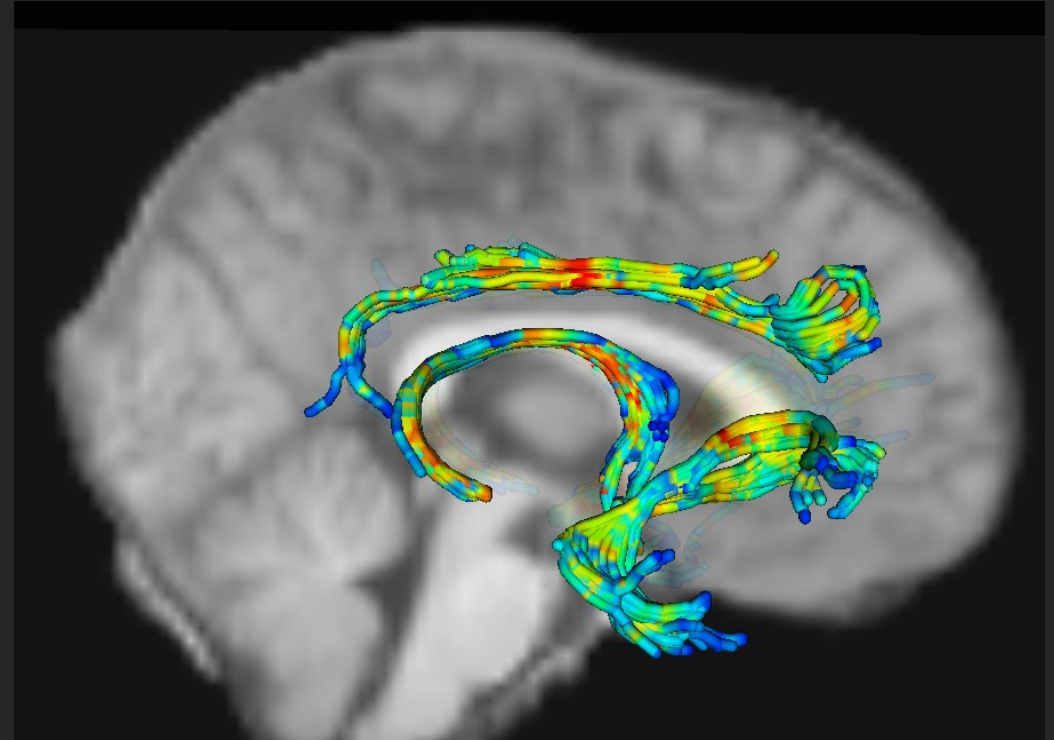
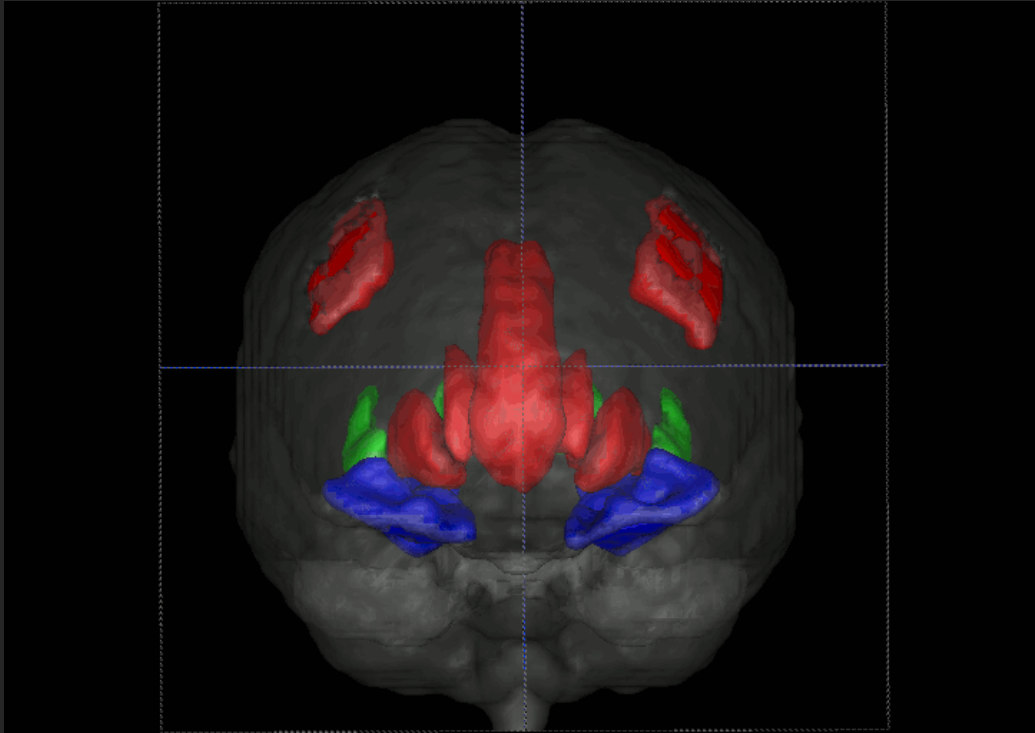


From Lebel and Beaulieu, 2011; Lebel et al., 2012

Diffusion Tensor Imaging Myelin Water Fraction

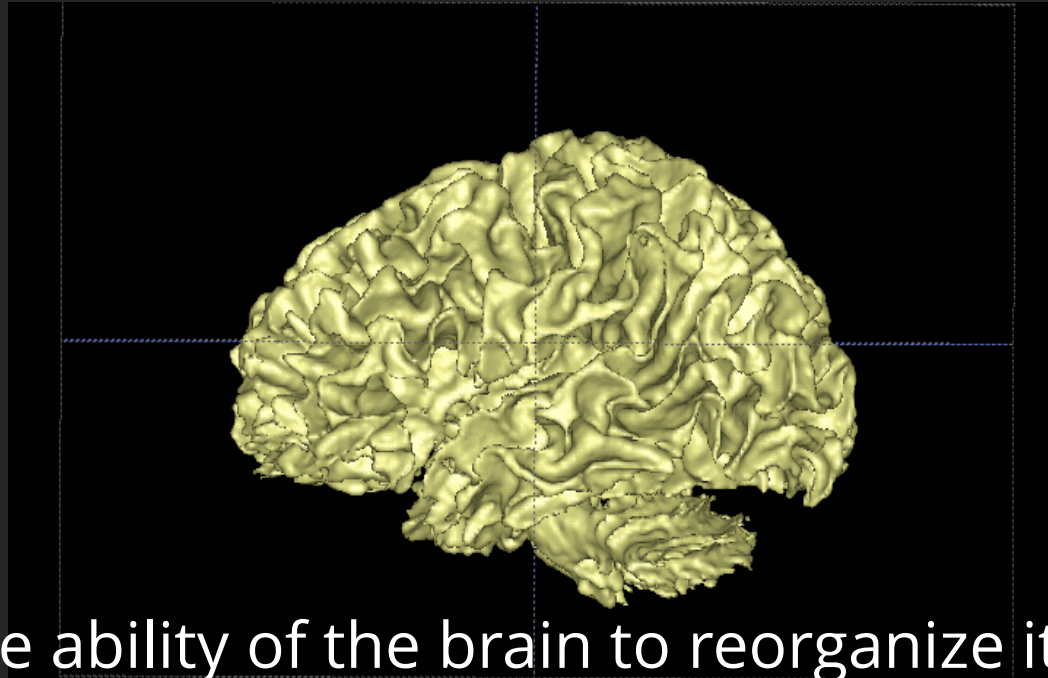


# Integrated Neural Networks





# Plasticity: Opportunity For Rewiring Brain and Behavior



- **Neuroplasticity**: The ability of the brain to reorganize itself, both functionally and structurally. Changes in neural pathways and synapses due to behavior change, environment and neural processes, as well as bodily injury.
- **Synaptic plasticity** (epigenesis): varies throughout the whole life of the cerebral cortex. The adult synapse contains “molecular switches” leading to many distinct functional states. ( Bourgeois, 2005)

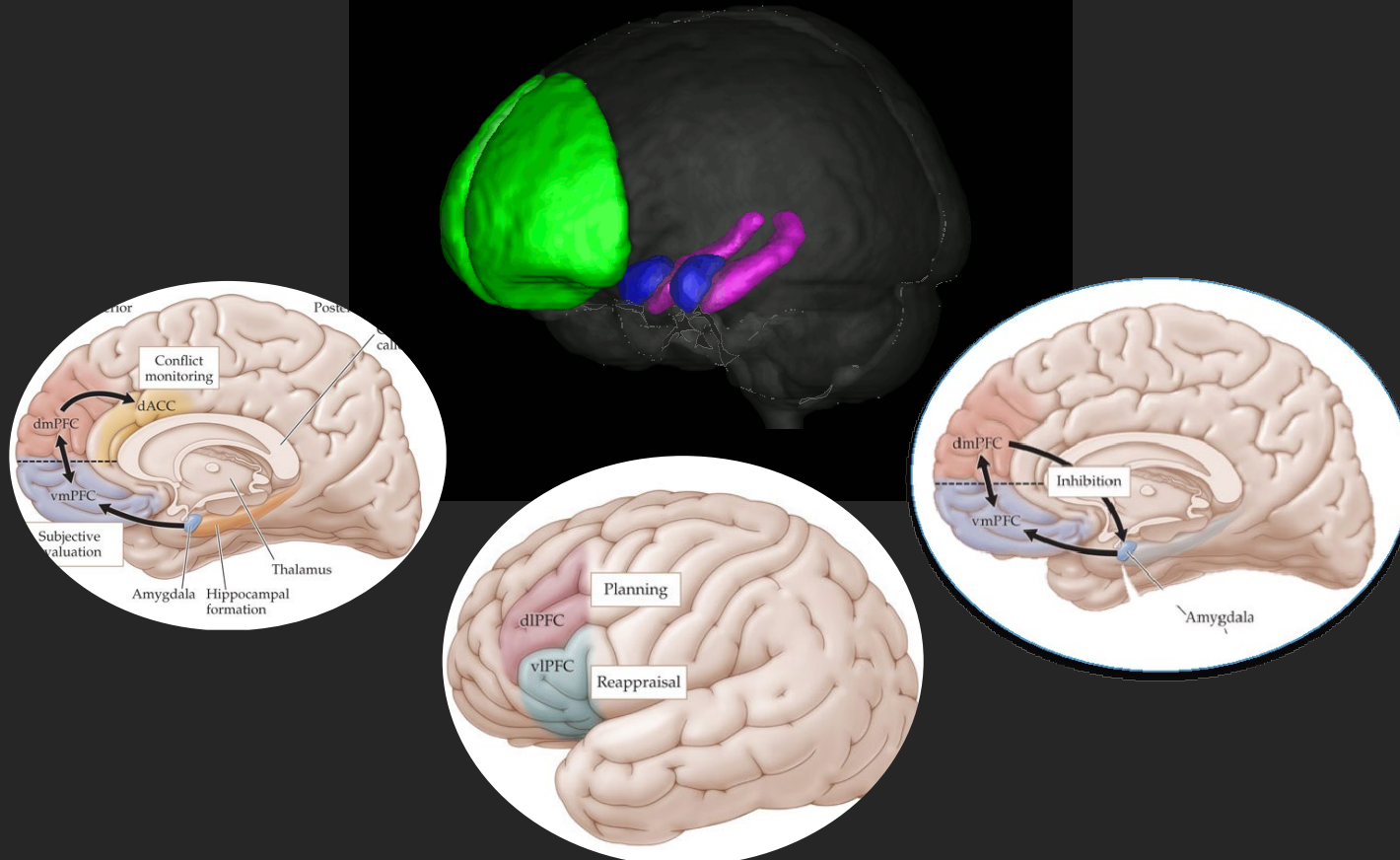


## **II. Neural circuits of self-regulation and cognition**

# II. Neural Circuits Underlying Complex Cognition And Self-regulation

## **Executive Deficits** →

*decreased inhibition, poor anticipation of consequences of action, or an inability to recognize contextually inappropriate behavior*



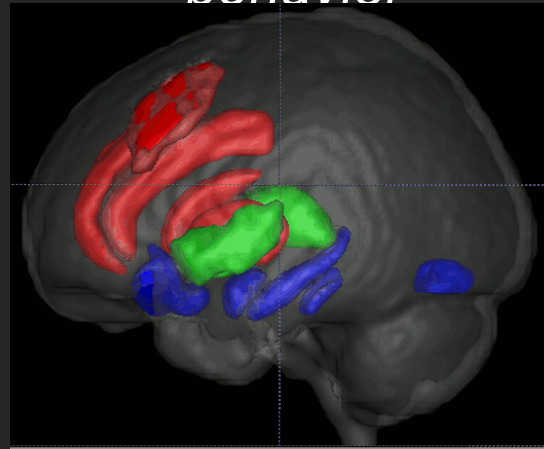
# II. Neural Circuits Underlying Complex Cognition And Self-regulation

## **Executive Deficits** →

*decreased inhibition, poor anticipation of consequences of action, or an inability to recognize contextually inappropriate behavior*

## **Emotion Regulation** →

*Emotional functioning deficits can lead to increased sensitivity to threat and reactive aggression, or an inability to empathize with the feelings of potential victims*



## **Reward** →

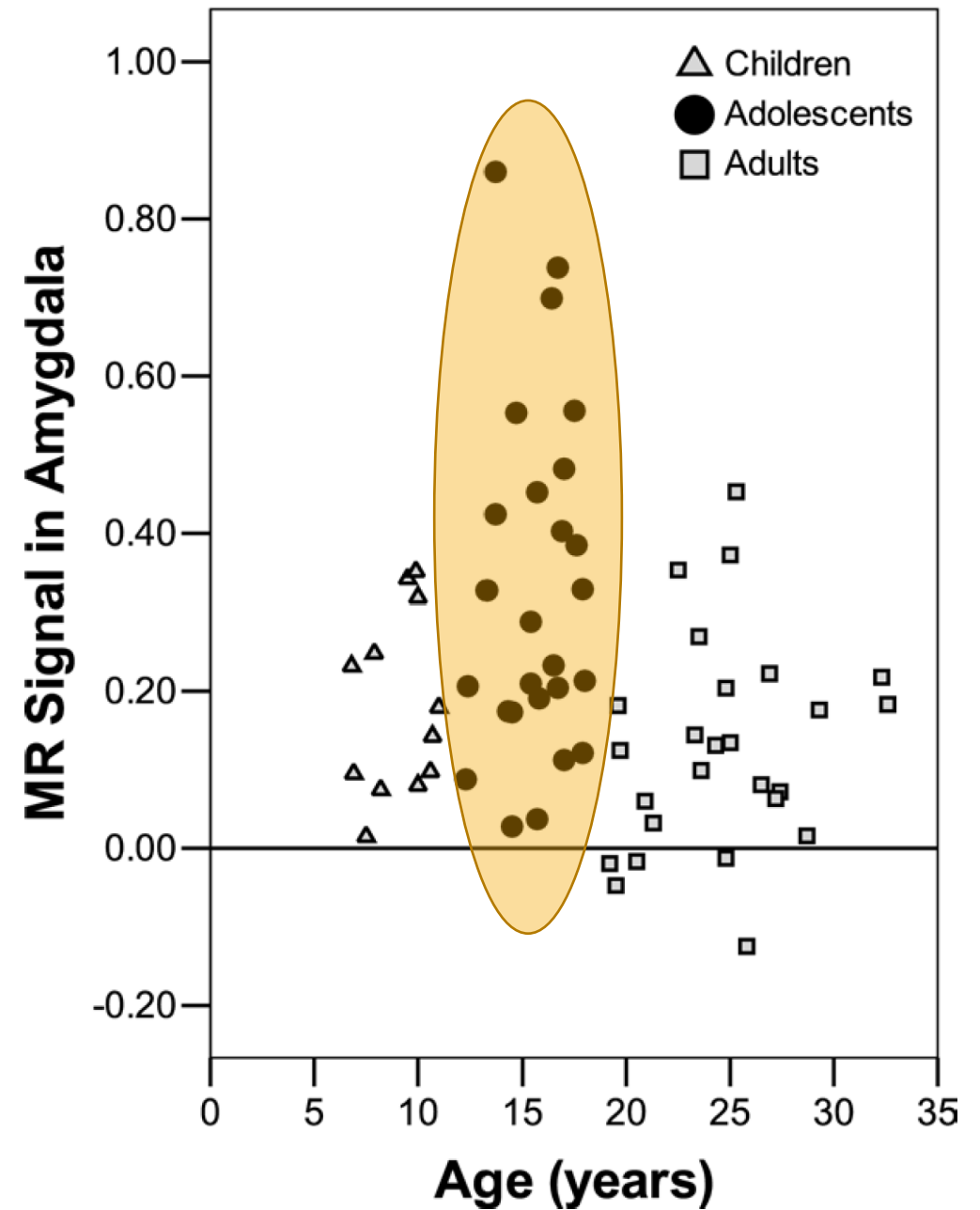
*Reward sensitivity and lack of delayed gratification*

## **Impulsivity** →

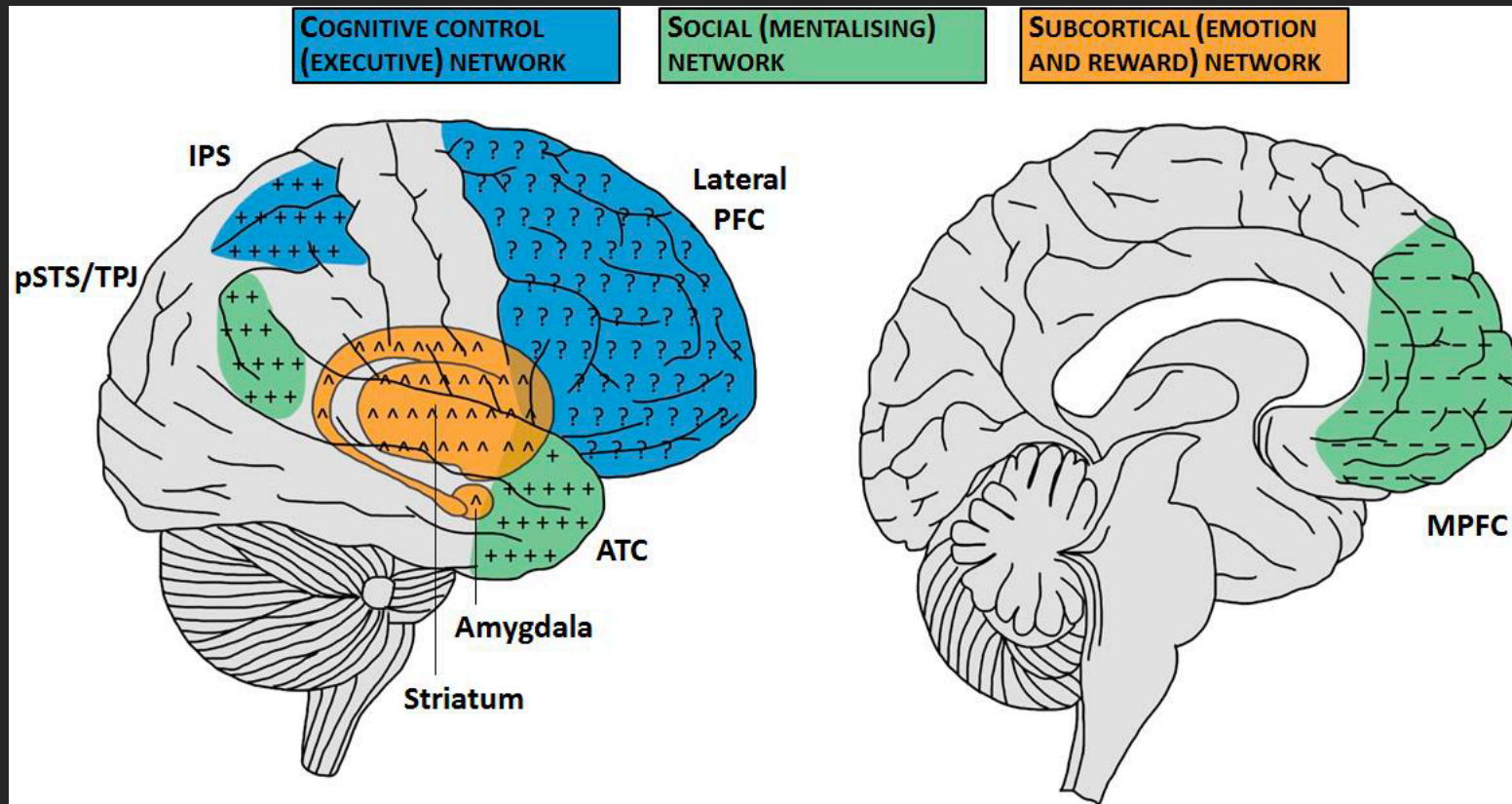
*Risk Taking Behavior leads to acting without forethought, reflection, or consideration of the consequences of behavior, and is the hallmark of much of the typical offending of adolescents*

# The Adolescent Brain

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# Summary of key aspects of brain development during adolescence



- Increase with age (+)
- Decreases with age (-)
- Peaks in activation during adolescence (^)

All cortical regions highlighted here show decreased grey matter volume and cortical thickness during adolescence, while amygdala volume increases during adolescence, and striatum volume decreases during adolescence.



### III. Trauma changes brain and cognition development



What is trauma?

# Forms of Trauma

- Trauma comes in a few forms:
  - Individual trauma
  - Societal/Collective trauma
  - Historical/intergenerational trauma
- Individuals can and often experience more than one form of trauma

# SAMHSA's Definition of Individual Trauma

- An event or circumstance resulting in:
  - Physical harm
  - Emotional harm
  - Life-threatening harm
- The event or circumstance has lasting adverse effects on the individuals:
  - Mental health
  - Physical health
  - Emotional health
  - Social well-being
  - Spiritual well-being

# EVAWI's Definition

- An event that combines fear, horror, or terror with actual or perceived lack of control.
- Trauma is often a life-changing event with negative, sometimes lifelong consequences.



# Collective Trauma

- Collective trauma refers to a traumatic event that is shared by a group of people. It may involve a small group, like a family, or it may involve an entire society.
- Natural disasters, war, genocide, slavery, famine, pandemics, recession, acts of terrorism and community violence are examples

# Historical trauma

- Historical trauma is multigenerational trauma experienced by a specific cultural, racial or ethnic group. It is related to major events that oppressed a particular group of people because of their status as oppressed, such as slavery, the Holocaust, forced migration, and the violent colonization of Native Americans.
- Sometimes referred to as generational trauma, intergenerational trauma.

# How does trauma affect individuals?

- Fundamentally, trauma effects the brain, affecting our ability to think, react, and engage with the world.
- Affects our ability to trust new people.
- Affects our ability to recall and speak about events.
- Affects our ability to respond when confronted.

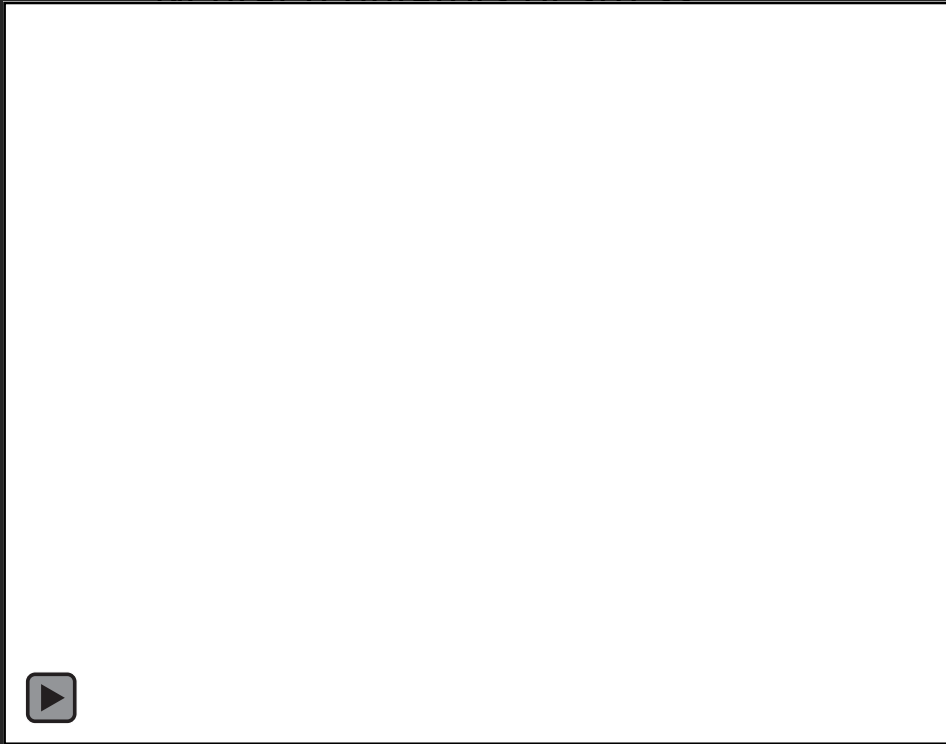
# Trauma changes brain AND COGNITIVE development



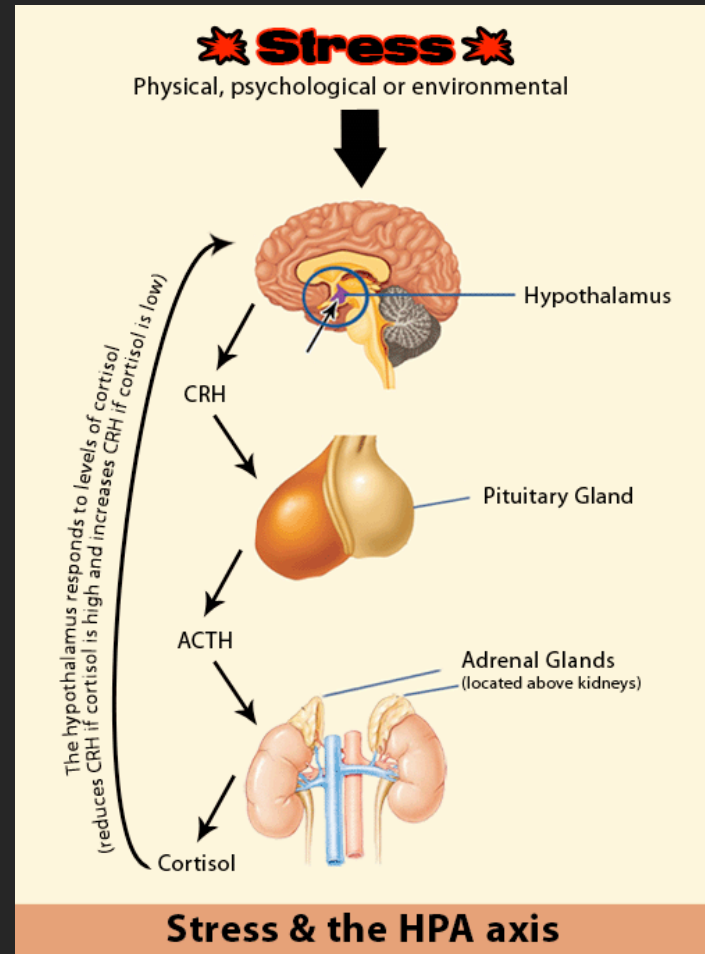


# III. Neurobiology of Stress

Neural regulators of stress



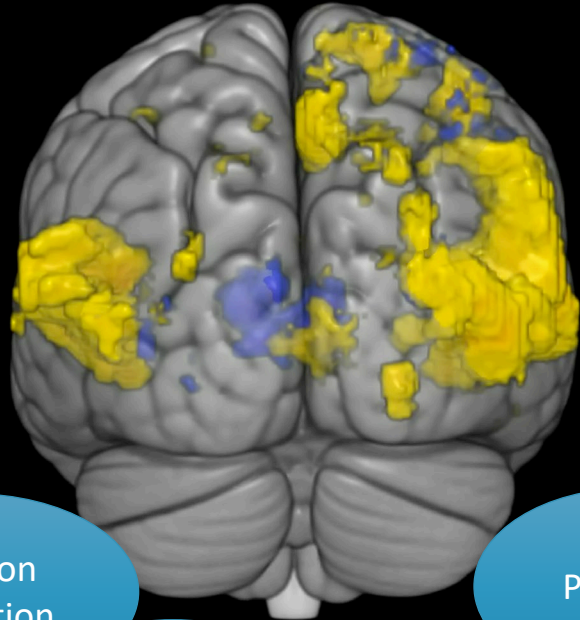
Neural endocrine response



# III. ACUTE STRESS TRIGGERS A COMPLEX MULTISYSTEM BIOLOGICAL RESPONSE

**ACUTE STRESS**

## Neural Regulators of Stress



Emotion Regulation

Pleasure

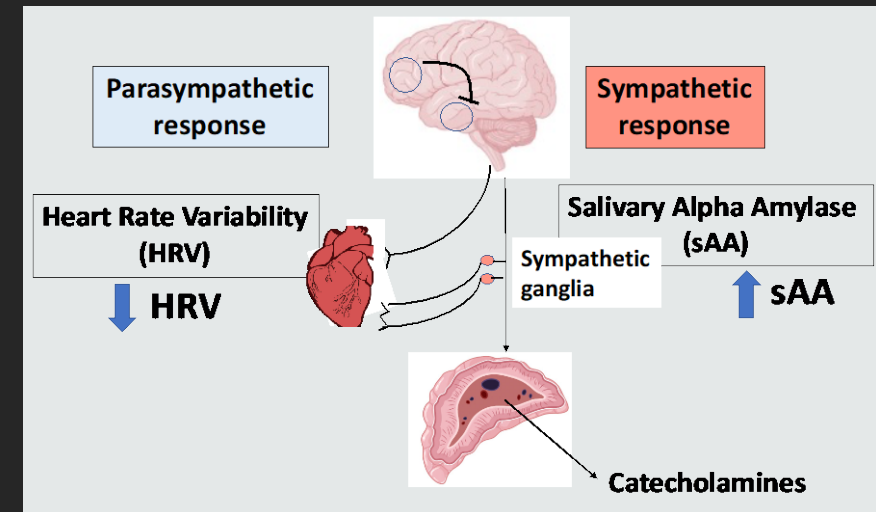
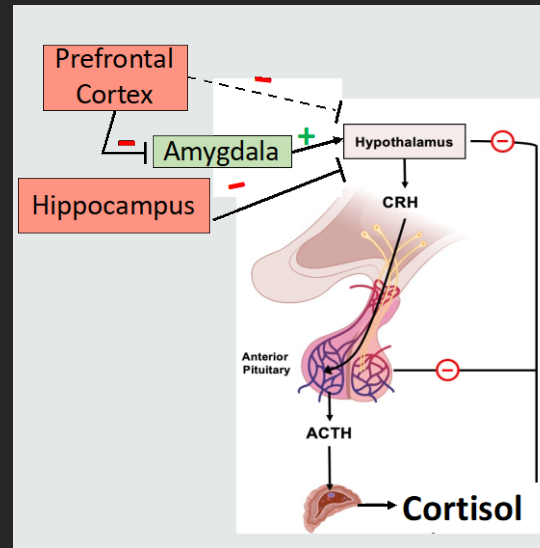
Decision Making

Impulsivity risk taking

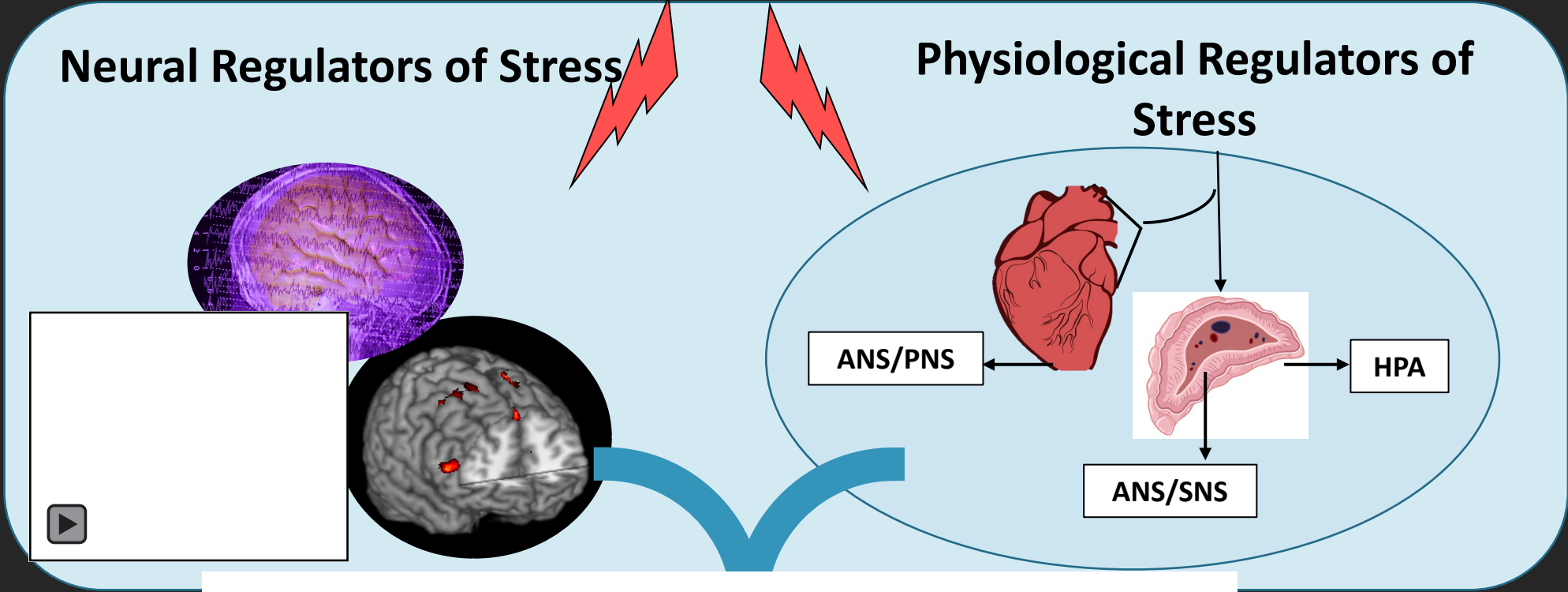
## Physiological Regulators of Stress

HPA

Autonomic



# ACUTE STRESS



## MULTISYSTEM STRESS RESPONSE PROFILES



# PSYCHOPATHOLOGY

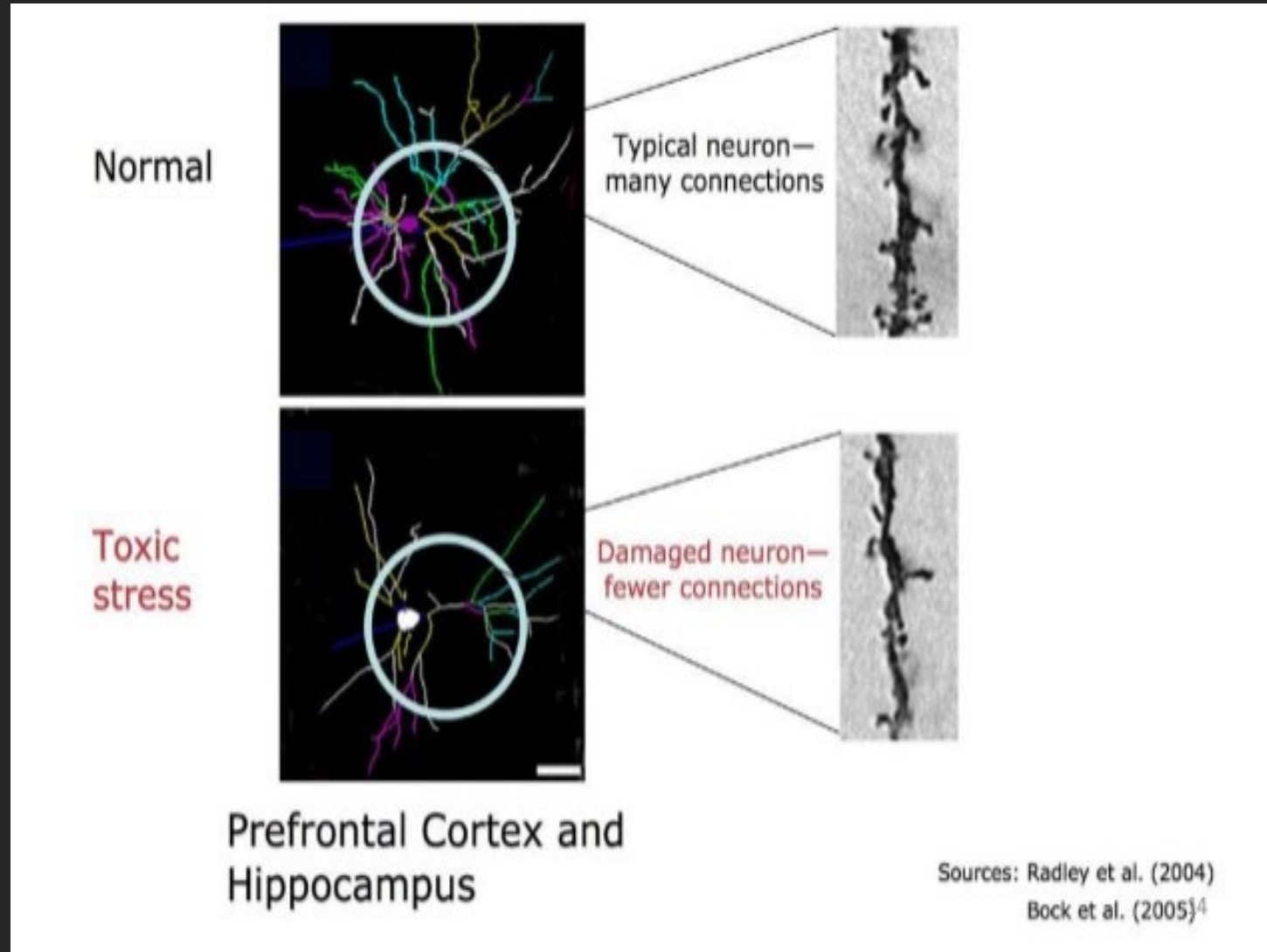
Corr et al., 2022a;  
Corr et al., 2022b;  
Glier et al., 2022a,  
Glier et al., 2022b.

# Adolescence: Critical Period For The Recalibration Of The Stress Response And Maturation Of Biological Systems Involved In Stress Response

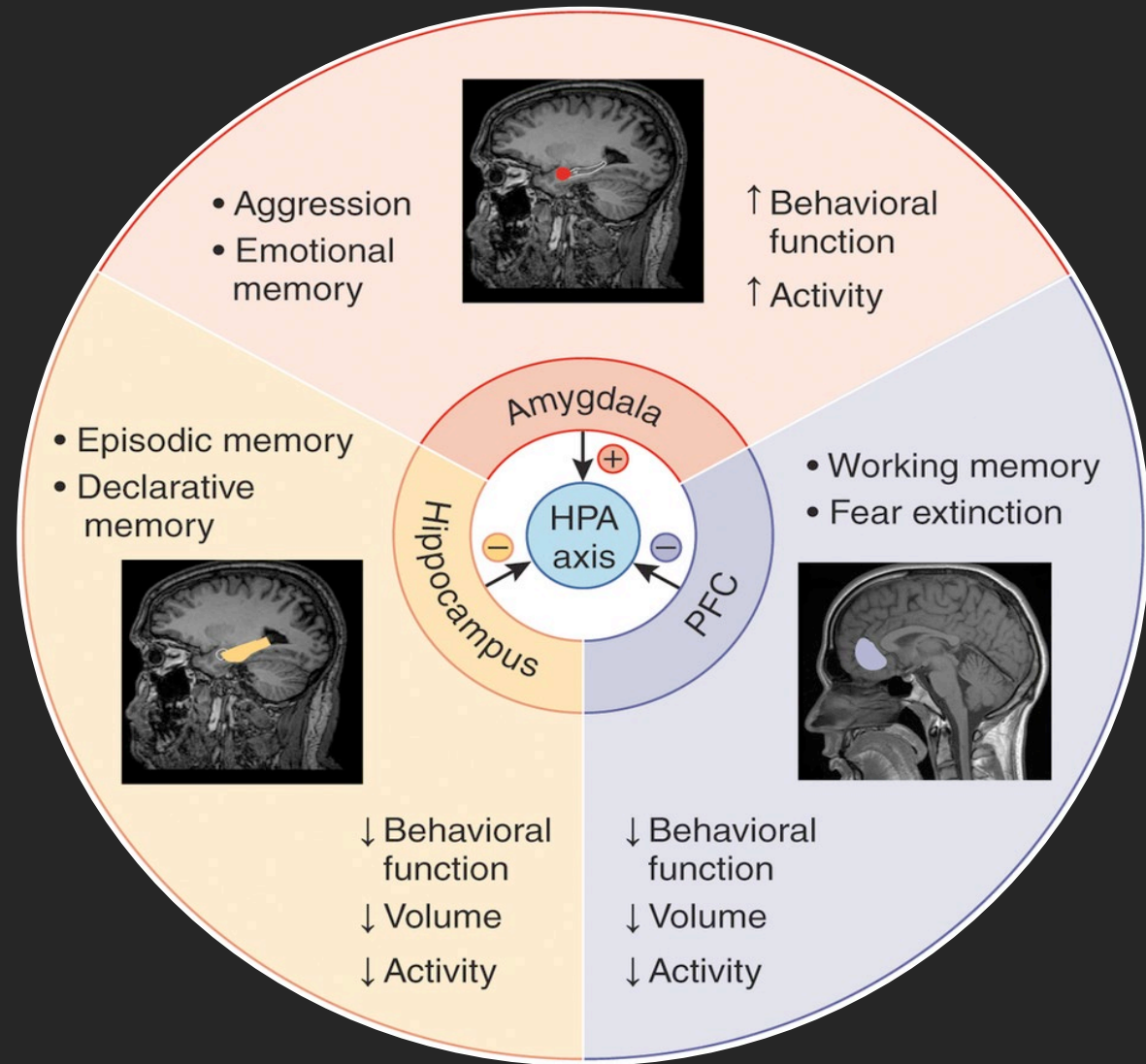
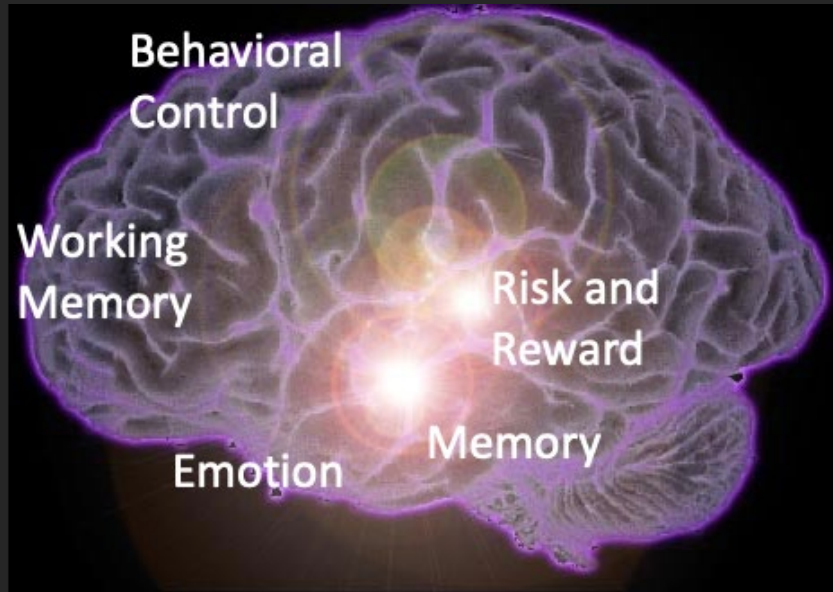
- **Neurodevelopmental Changes:** The prefrontal cortex (PFC) continues to mature leading to improved executive functions, decision making and emotional regulation abilities.
- **Hormonal Changes:** Hormonal fluctuations influence brain development and contribute to the reorganization and refinement of neural circuits involved in stress and emotion regulation and can interact with the developing PFC to shape emotional responses and adaptive coping strategies.
- **Stress Sensitivity:** Increased sensitivity to stress. The brain's stress response system, including the hypothalamic-pituitary-adrenal (HPA) axis, is highly responsive during this period, which can lead to dysregulation of the stress response.
- **Social and Environmental Influences:** Time of increased exploration, novelty-seeking, and social interactions that shape the development and refinement of neural circuits related to stress adaptation and emotion regulation.



# Persistent Stress Changes Brain Architecture



# Stress Impacts ALL areas of Cognition And Emotion





Sensitive window for  
developing the stress  
response

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## Ceausescu's legacy to Romania: Communist Policy: 1966 Decree

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- ❖ Raise production by increasing population
- ❖ Belief that greater population = greater power
- ❖ Establishment of the MENSTRUAL POLICE - State gynecologists who conducted monthly checks of women of childbearing age who had not borne at least 5 children
- ❖ Establishment of CELIBACY TAX - families received a stipend for having more than 2 children; were levied tax for having fewer than 5 children
- ❖ OUTLAWED all contraception and abortion





## Children reared in institutions...

...are at dramatically increased risk for a variety of cognitive, social, and behavioral problems such as:

- ❖ disturbances of social relatedness and attachment
- ❖ externalizing behavior problems
- ❖ inattention/hyperactivity
- ❖ deficits in IQ and executive functions
- ❖ syndrome that mimics autism
- ❖ growth stunting (next slide)

## Effects of institutionalization on growth

17 year old girl



14 year old girl



Institutionalized children lose ~1 month of linear growth for every ~1 month in an institution (pictures courtesy of Dana Johnson, MD, Ph.D)

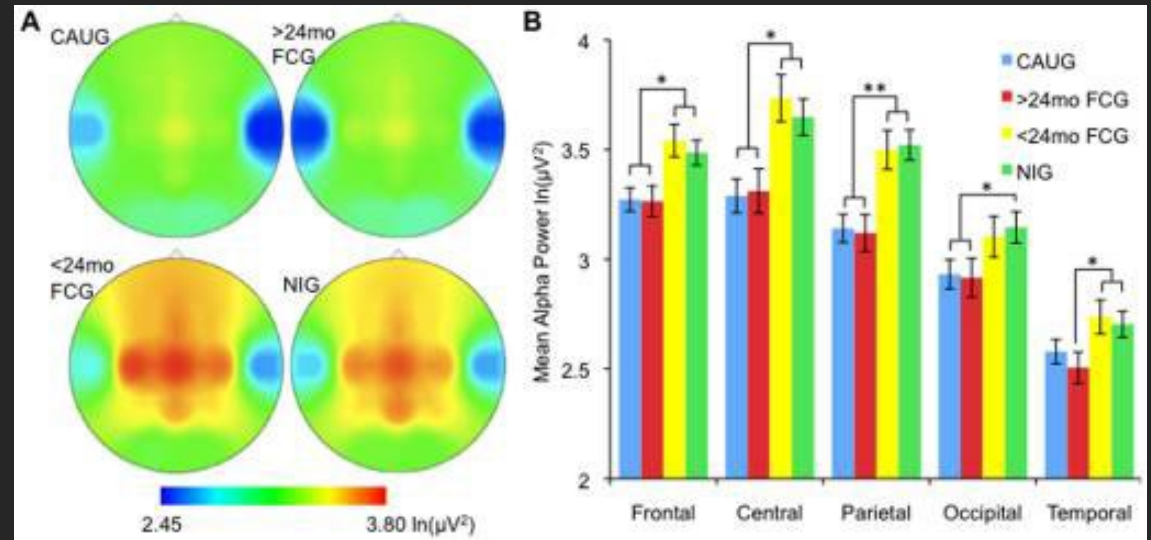
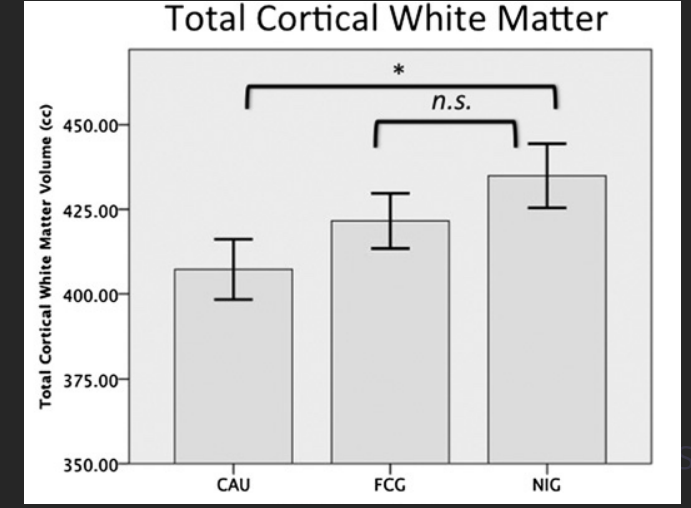
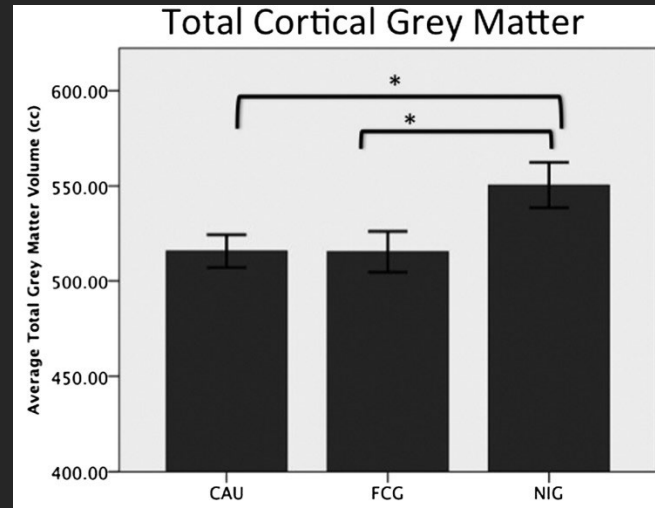
# Neglect In Early Infancy Changes Brain Maturation



# MRI Data Collection

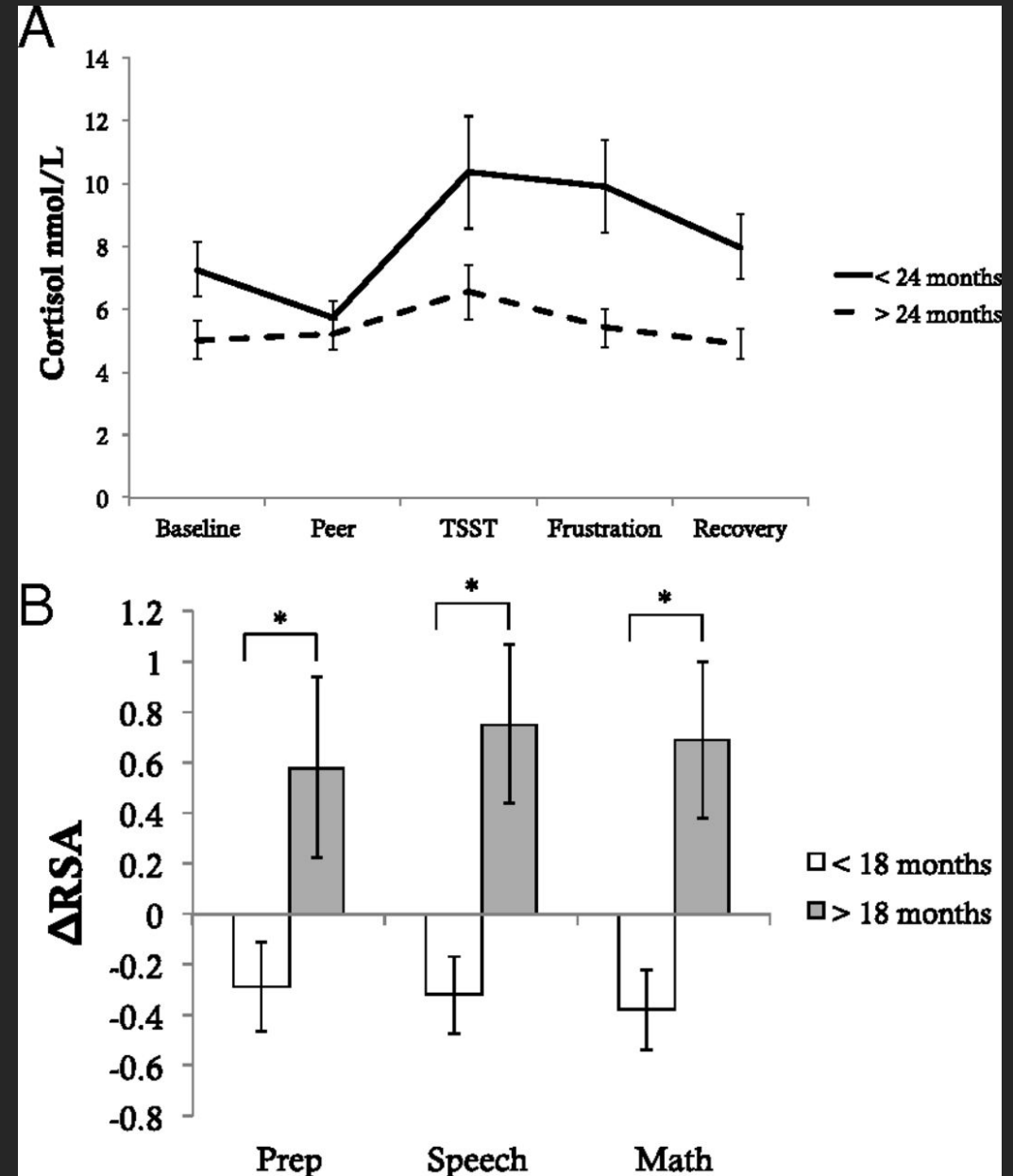
- N = 115 T1 weighted structural scans at age 16 year follow-up.
- Data acquired on a 3T Siemens Scanner with a 16-channel head coil.
- Average age 16.67 years
  - CAUG N = 41 (54 % male)
  - FCG N = 41 (49 % male)
  - NIG N = 33 (42 % male)
- **Of these:** N = 64 children with T1 weighted scans at age 9 and 16 years
  - Average ages 9.84, 16.69
    - CAUG N = 27 (52 % male)
    - FCG N = 23 (56 % male)
    - NIG N = 14 (43 % male)

# Neglect in Early Infancy changes brain maturation



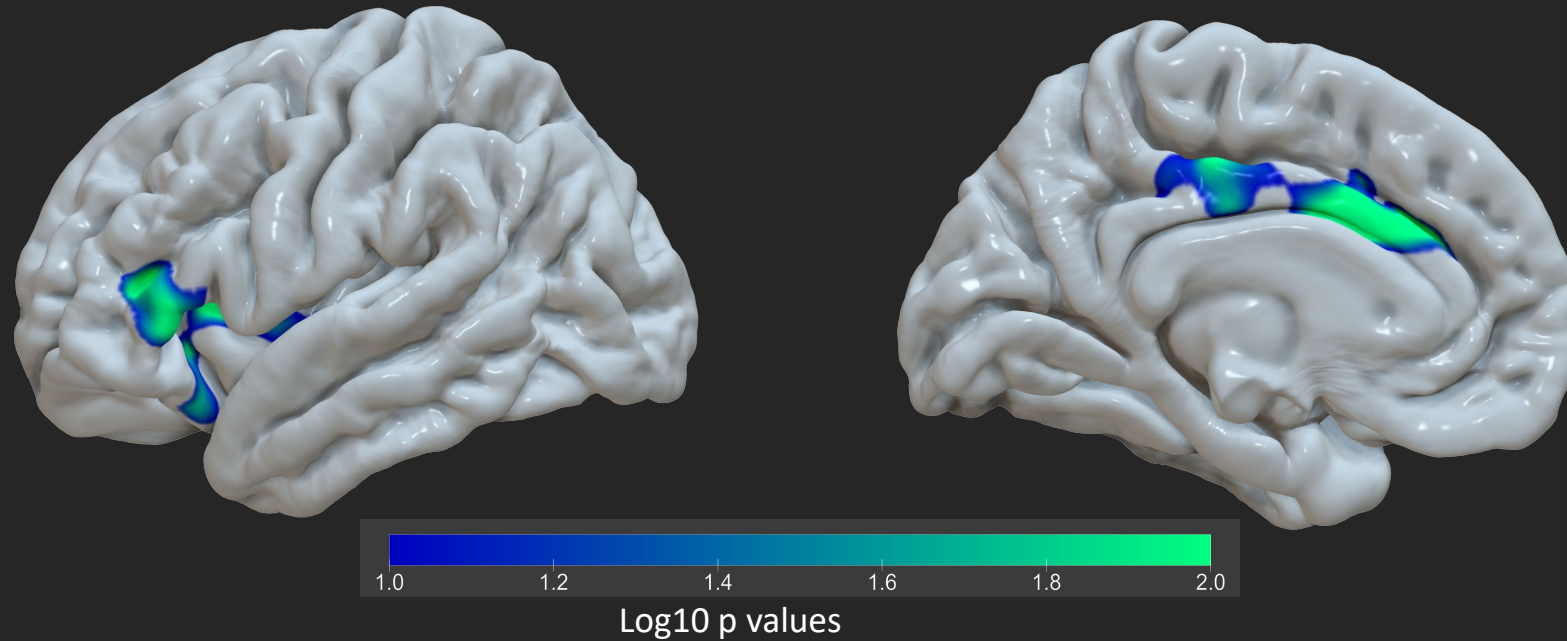
# Early caregiving environment on development of stress response in children

McLaughlin et al., 2015; Bucharest Early Intervention Project

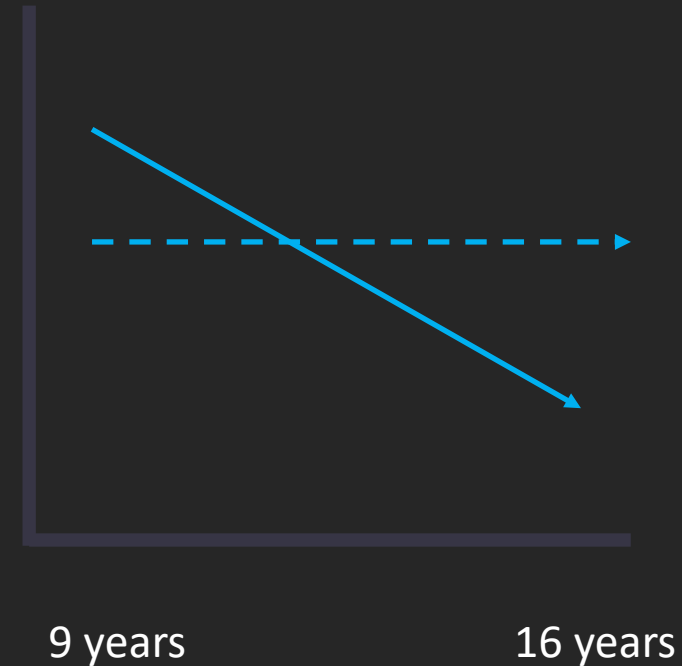
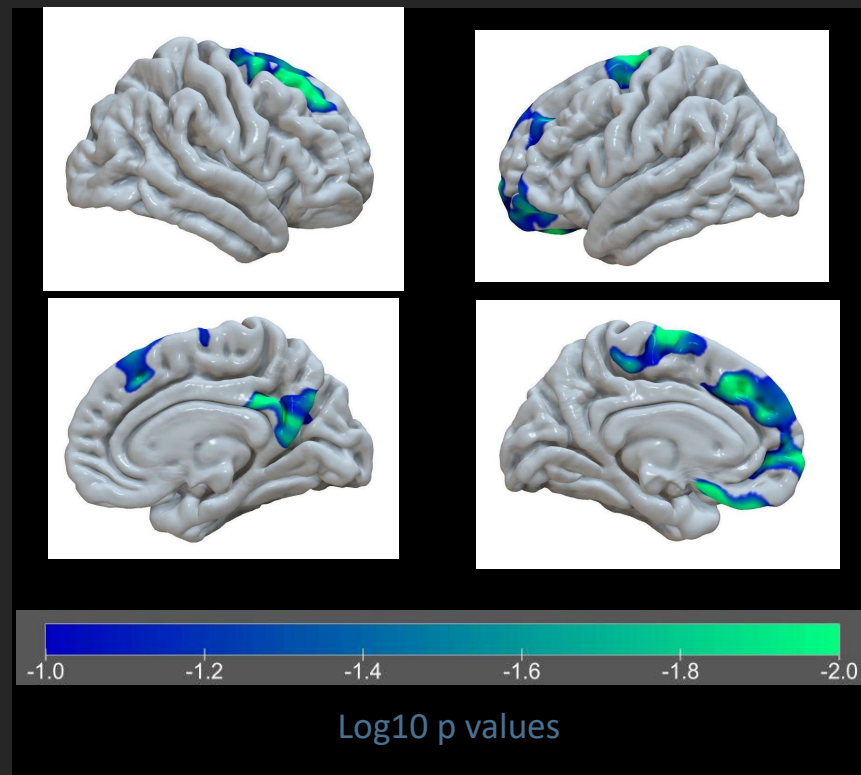




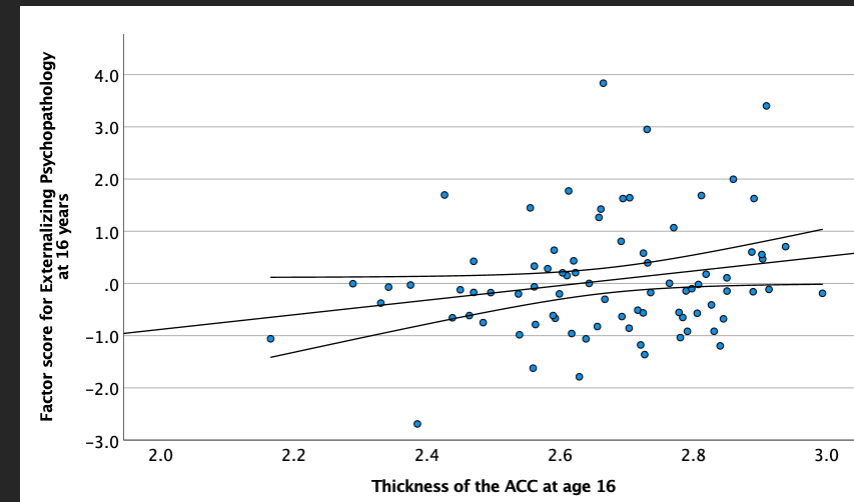
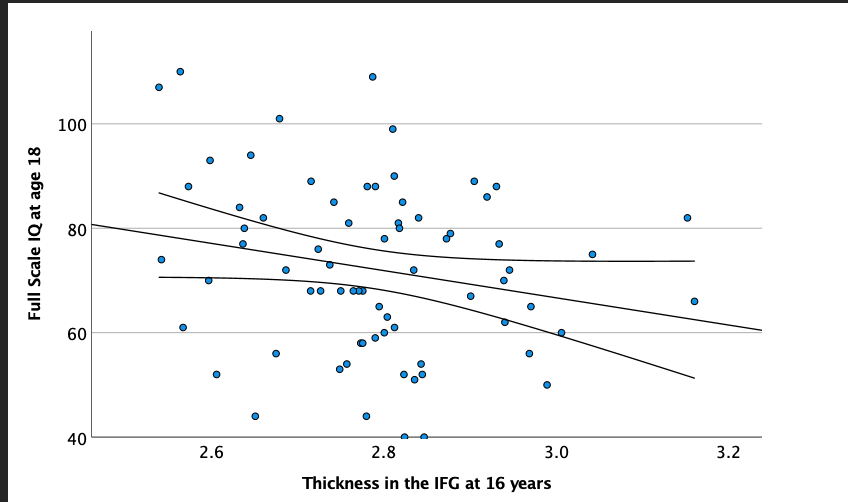
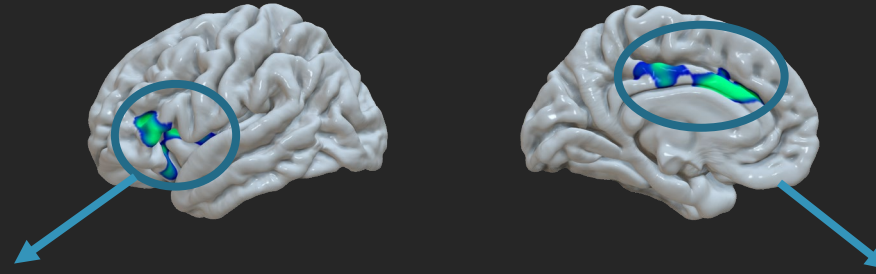
# Thicker prefrontal cortex for Care As Usual vs. Foster Care



# Deprivation shifts developmental trajectories from 9 to 16 years

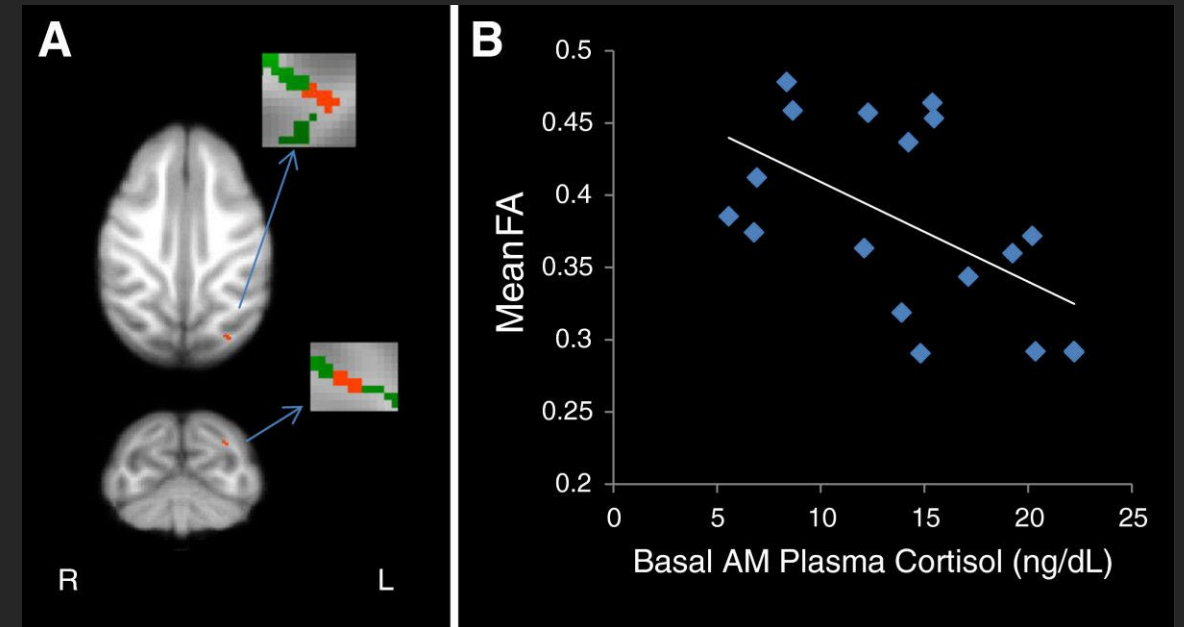
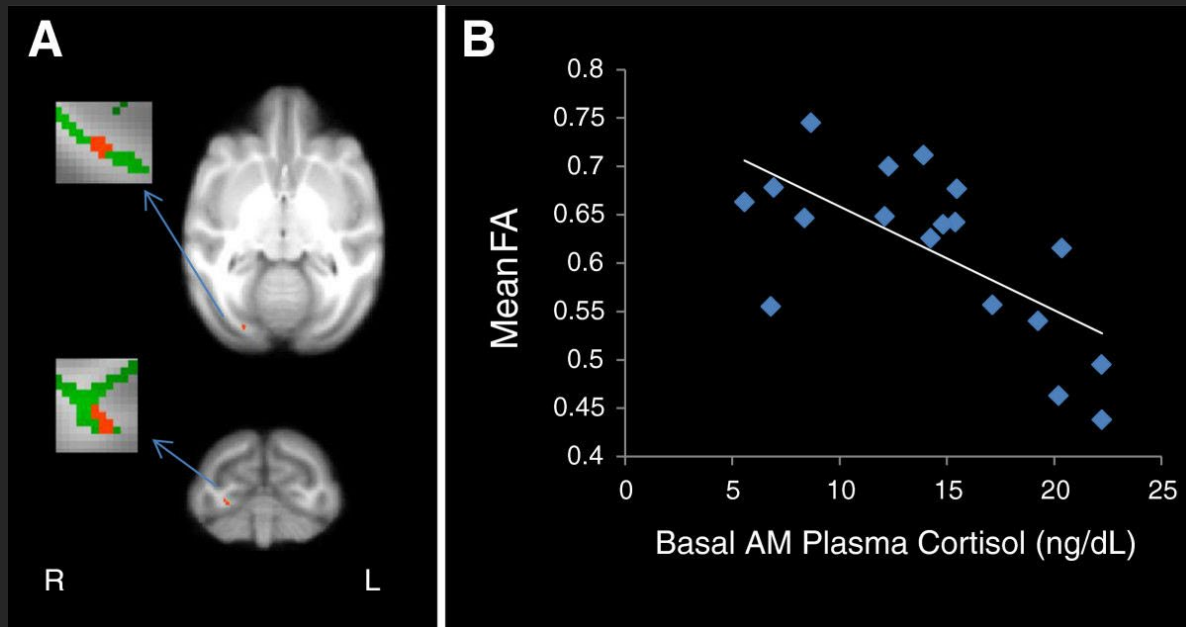


# Differences in brain structure are related to behavioral outcomes



Thickness in the inferior frontal gyrus is associated with IQ and thickness in the dorsal anterior cingulate cortex is associated with **psychopathology**.

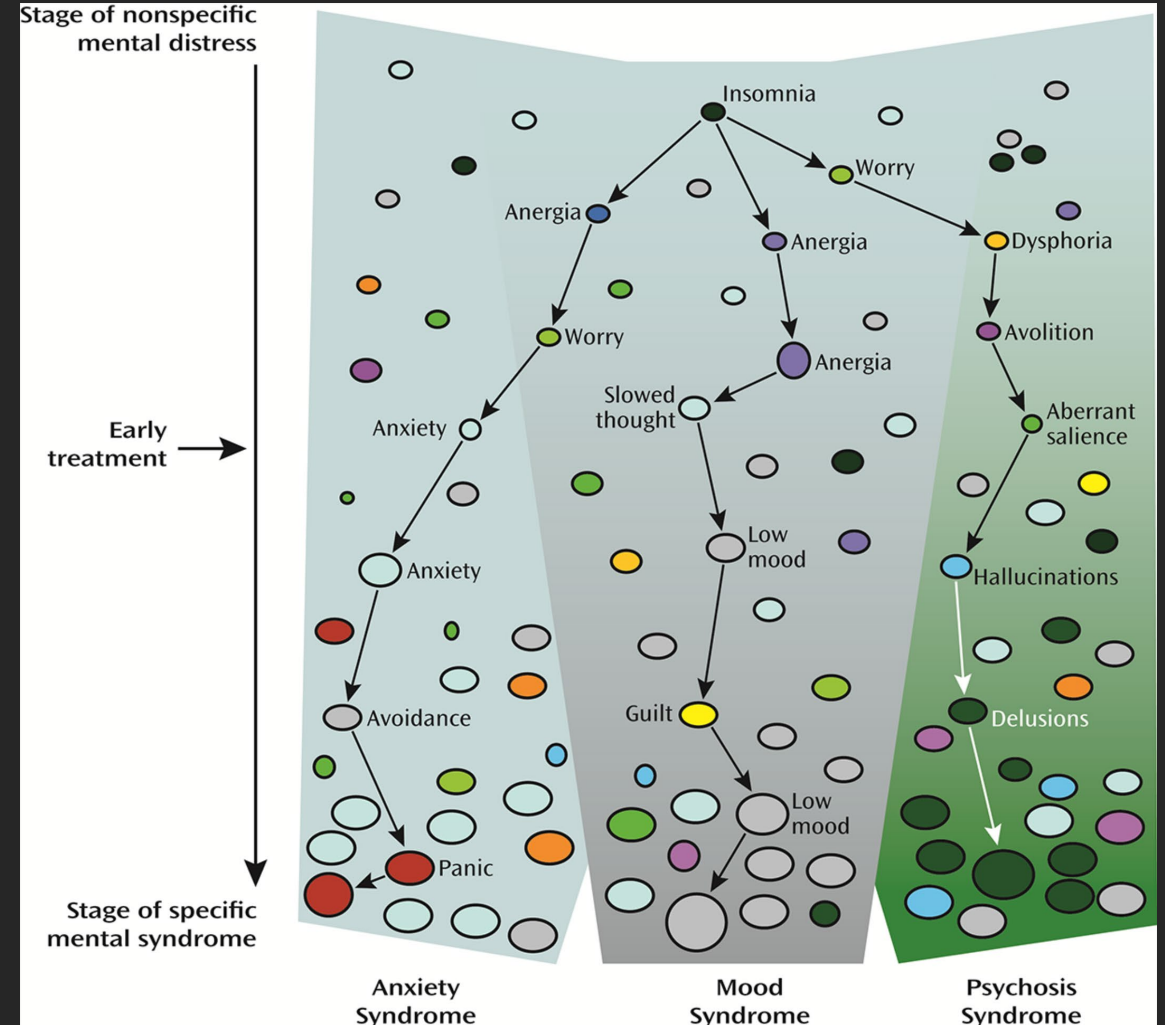
# Early Life Stress and White Matter: Physical Abuse in Early Infancy



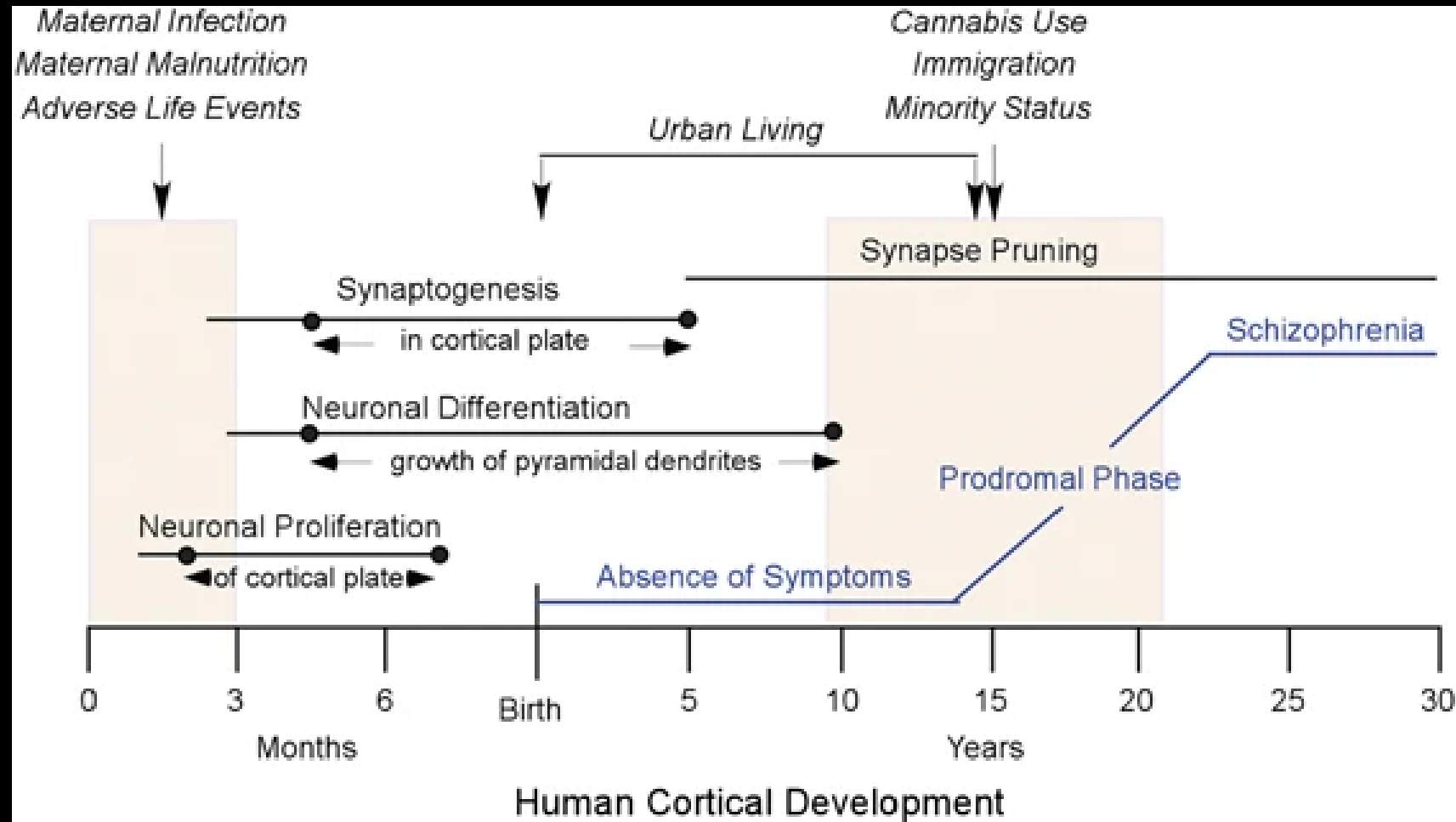
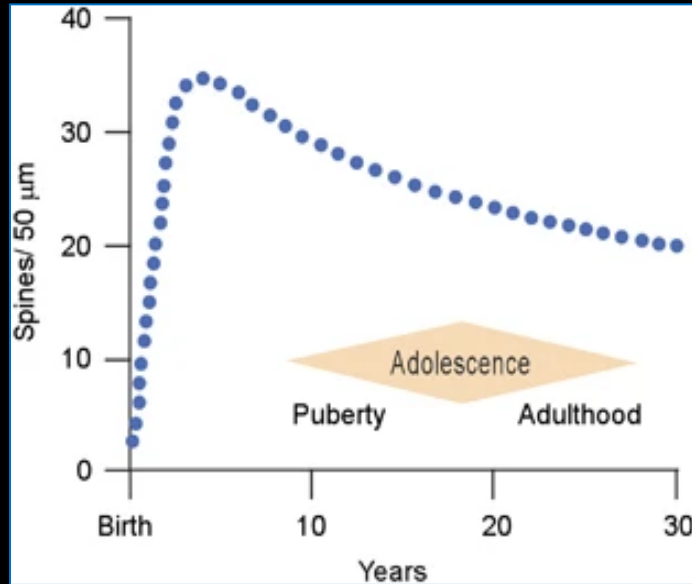
# IV. Trauma and Adolescent Psychopathology



# Adolescence critical period: Early Trauma leads to psychopathology

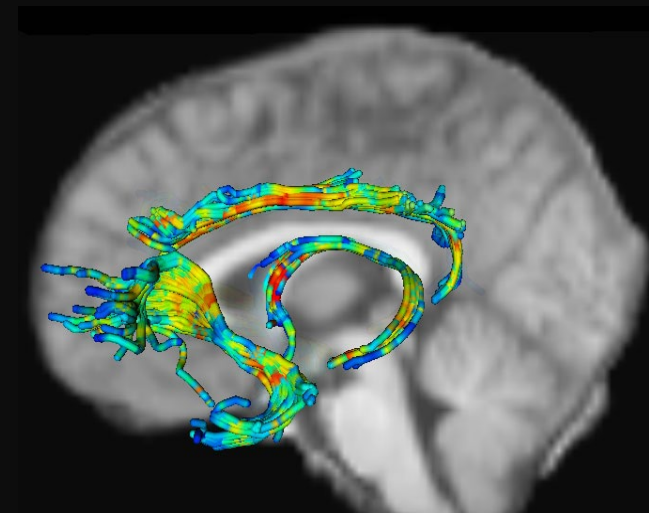
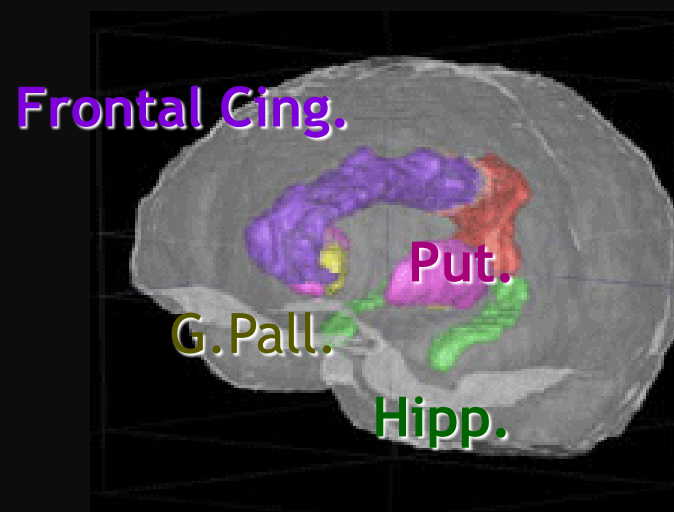


# Critical periods applied to Schizophrenia



Pattern of neurocircuit disruption across major psychiatric disorders in regions and networks key to adaptive emotional reactivity and regulation.

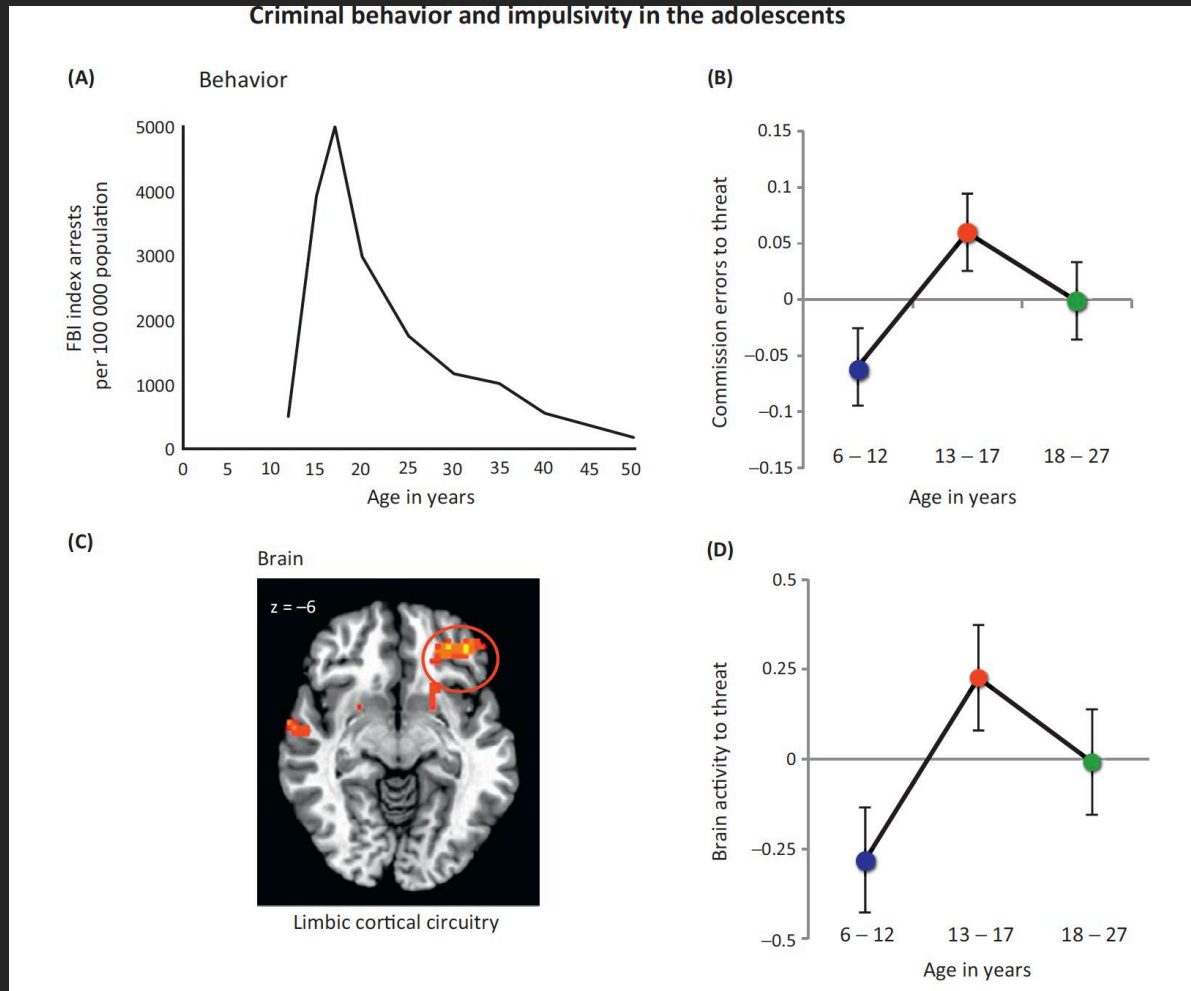
Psychiatric disorders may be productively formulated as dysfunction in transdiagnostic neurobehavioral phenotypes such as neurocircuit activation.



# Adolescents in JJ

- Deficits in areas of executive functioning, including impulse control, planning, and decision making, compared with adults
- **45.5** percent of youth in residential justice settings met criteria for a mental health disorder (Shufelt & Coccozza, 2006).
- **~ 79** percent of youth with one mental health disorder also meeting diagnostic criteria for at least one other disorder, and more than 60 percent meeting criteria for a substance use disorder (Shufelt & Coccozza, 2006).
- Youth with co-occurring behavioral problems (e.g., substance use, conduct disorder) and emotional problems (e.g., anxiety, depression) are at elevated risk for recidivism (Cottle, Lee, & Heibrun, 2001; Hoeve, McReynolds, & Wasserman, 2013) and committing violent offenses during young adulthood (Copeland, Miller-Johnson, Keeler, Angold, & Costello, 2007).

# Adolescents in JJ



Developmental differences in criminal and impulsive behavior and the brain. (A) Arrest rates sharply increase at the beginning of adolescence, peaking at around 17 years of age. (B) Criminal behavior is paralleled by an adolescent-specific increase in impulsive responses to threat cues and (C) increased brain activity in limbic (emotion-related) cortical regions when (D) successfully suppressing the impulse to respond. Data from Dreyfuss, M. et al. (2013)



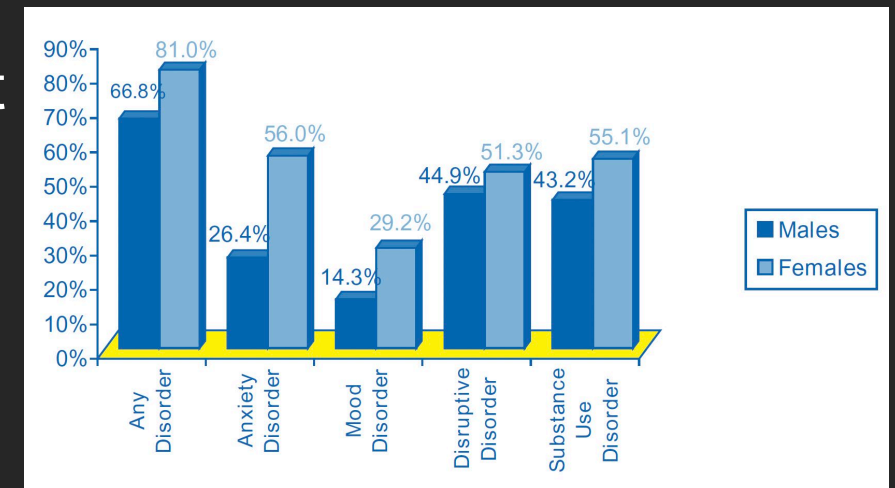
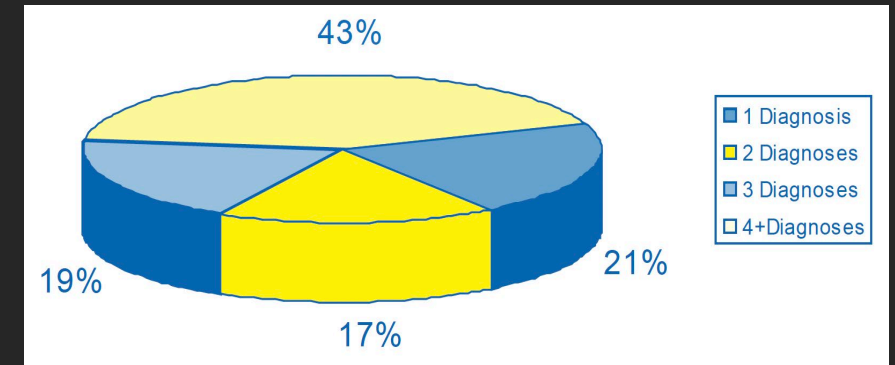
# A Glance at The Problem

- ~65% of justice-involved youth have a substance use and/or mental health disorder (Bowser et al., 2019):
  - Affective disorders (major depression, persistent depression, manic episodes)
  - Psychotic disorders
  - Anxiety disorders (panic, separation anxiety, generalized anxiety, obsessive-compulsive disorder, post-traumatic disorder)
  - Disruptive behavior disorder (conduct, oppositional defiant disorder, and ADHD)
  - Substance use disorder

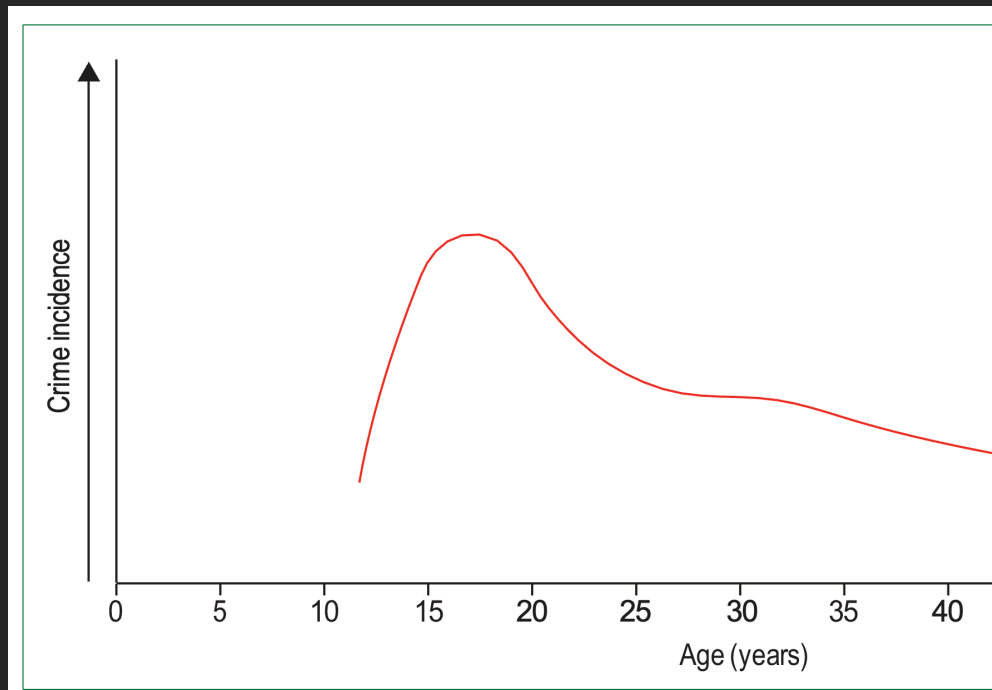
Authors (Year)	% with a Positive Diagnosis
NCMHJJ Prevalence Study (2006)	70.4%
Teplin et al. (2002)	69.0%
Wasserman et al. (2002)	68.5%
Wasserman et al. (2004)	67.2%

# A Glance at The Problem

- 15% to 30% have diagnoses of depression or dysthymia (pervasive depressive disorder),
- 13% to 30% have diagnoses of attention-deficit/hyperactivity disorder,
- 3%–7% have diagnoses of bipolar disorder,
- 11% to 32% have diagnoses of posttraumatic stress disorder.
- 20% has substance use disorders (Washburn et al., 2015)
- Both conduct disorder and substance use disorders are quite prevalent in youth in juvenile courts.

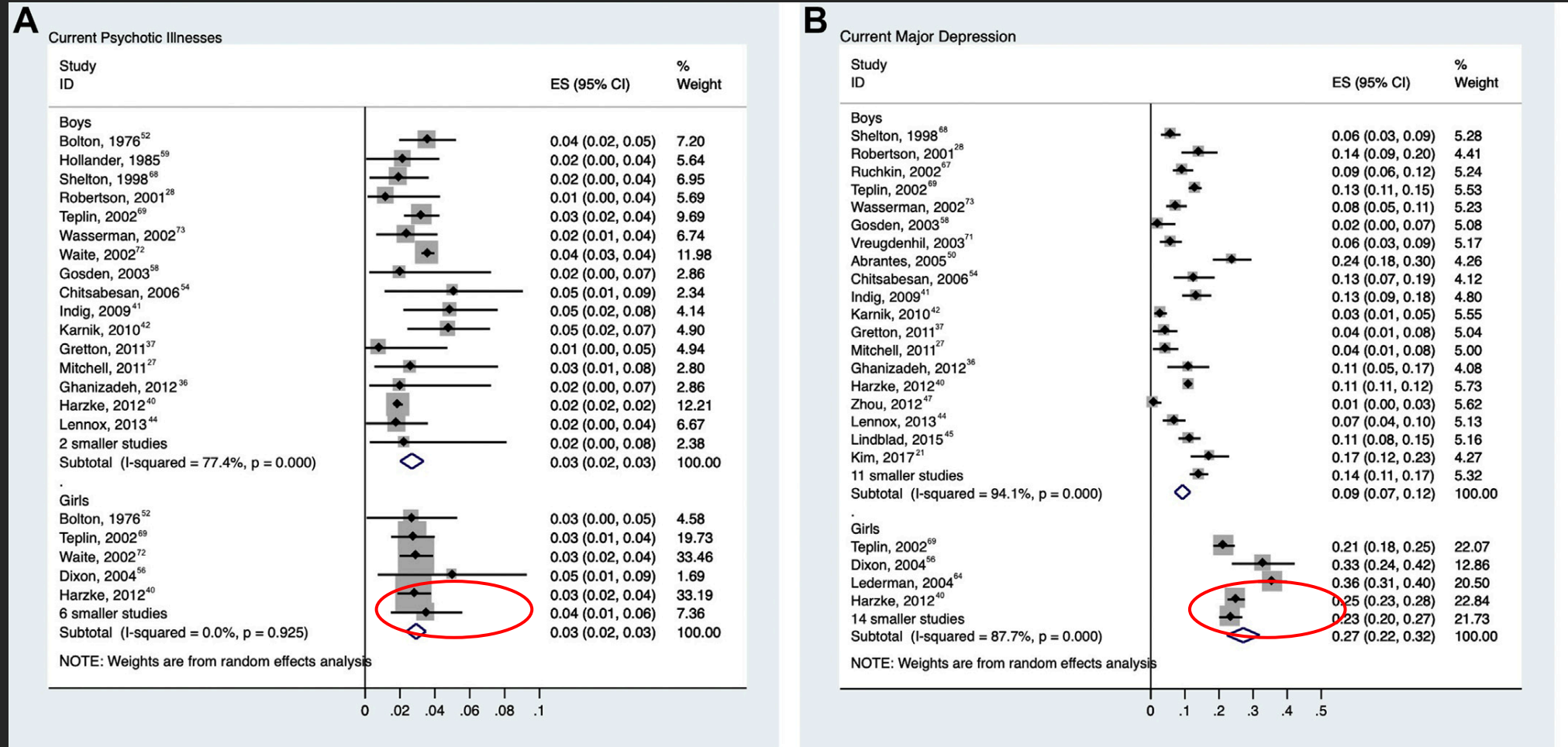


# Psychiatric and Neurologic Disorders in Incarcerated Youth



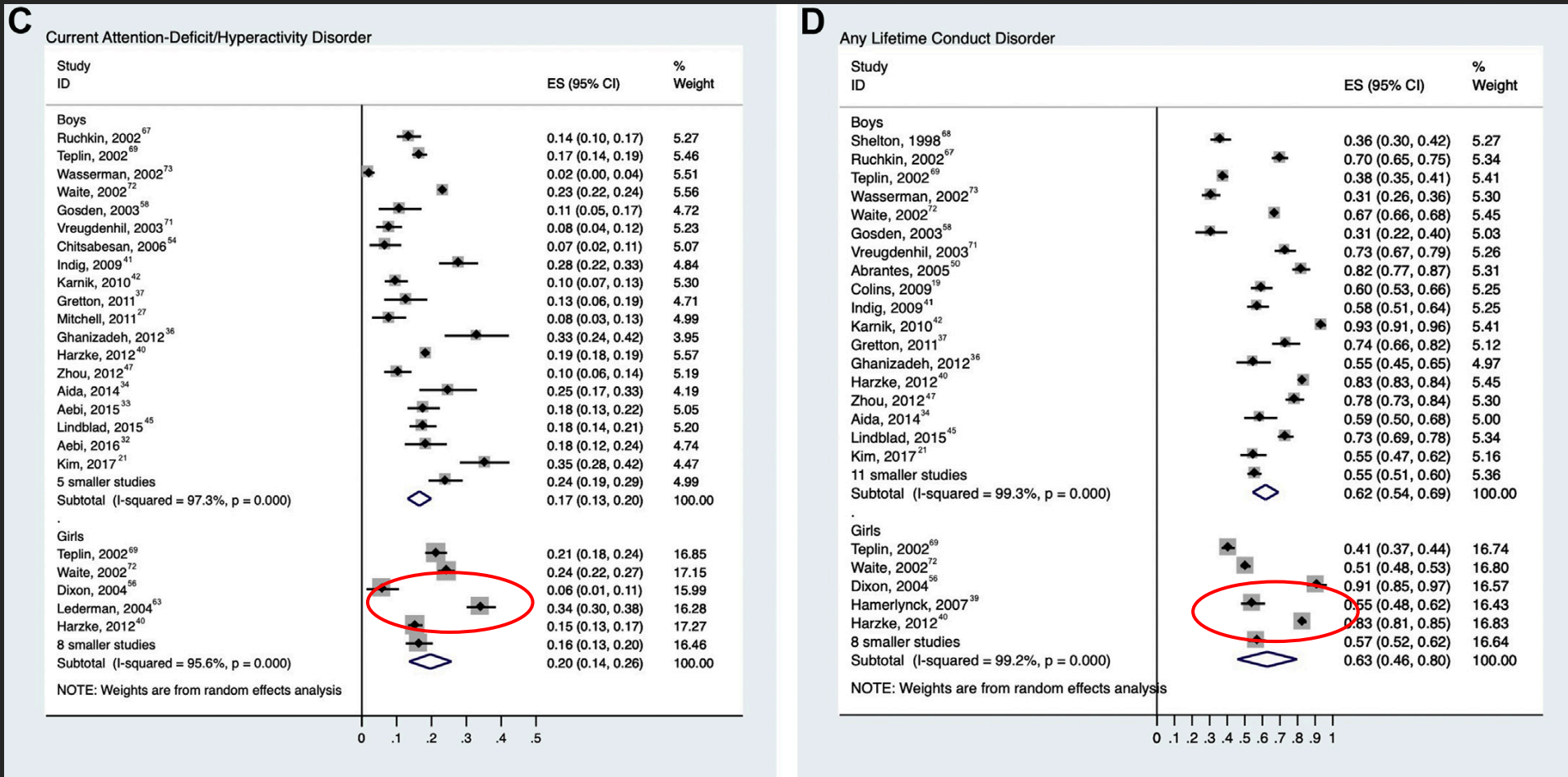
	Young people in the general population	Incarcerated young people
Learning disability	2–4% <sup>9,10</sup>	10–32% <sup>11–17</sup>
Attention-deficit hyperactivity disorder	3–9% <sup>18</sup>	12–30% <sup>19</sup>
Fetal alcohol spectrum disorder	2–5% <sup>20</sup>	11–36% <sup>21,22</sup>
Traumatic brain injury	5–24% <sup>23</sup>	32–50% <sup>23</sup>
Psychiatric disorder	7–12% <sup>24</sup>	..
Male	..	60–70% <sup>25–27</sup>
Female	..	60–80% <sup>25–27</sup>
Major depressive disorder	0·2–3% <sup>28</sup>	..
Male	..	11% <sup>19</sup>
Female	..	29% <sup>19</sup>
Anxiety	4·4% <sup>29</sup>	9–21% <sup>16,26,30–32</sup>
Psychosis	0·4% <sup>33</sup>	..
Male	..	3·3% <sup>19</sup>
Female	..	2·7% <sup>19</sup>
At least one type of adverse childhood experience	38–39% <sup>34</sup>	96% <sup>35</sup>
Experience of a potentially traumatic event	25–50% <sup>36,37</sup>	88–90% <sup>36,38,39</sup>
Post-traumatic stress disorder	0·4% <sup>40</sup>	..
Male	..	10–37% <sup>38,41–46</sup>
Female	..	40–50% <sup>45–47</sup>

# Mental Disorders Among Adolescents in Juvenile Detention and Correctional Facilities



In male adolescents, 2.7% psychotic illness; 10.1% major depression.  
 In female adolescents, 2.9% psychotic illness; 25.8% major depression

# Mental Disorders Among Adolescents in Juvenile Detention and Correctional Facilities

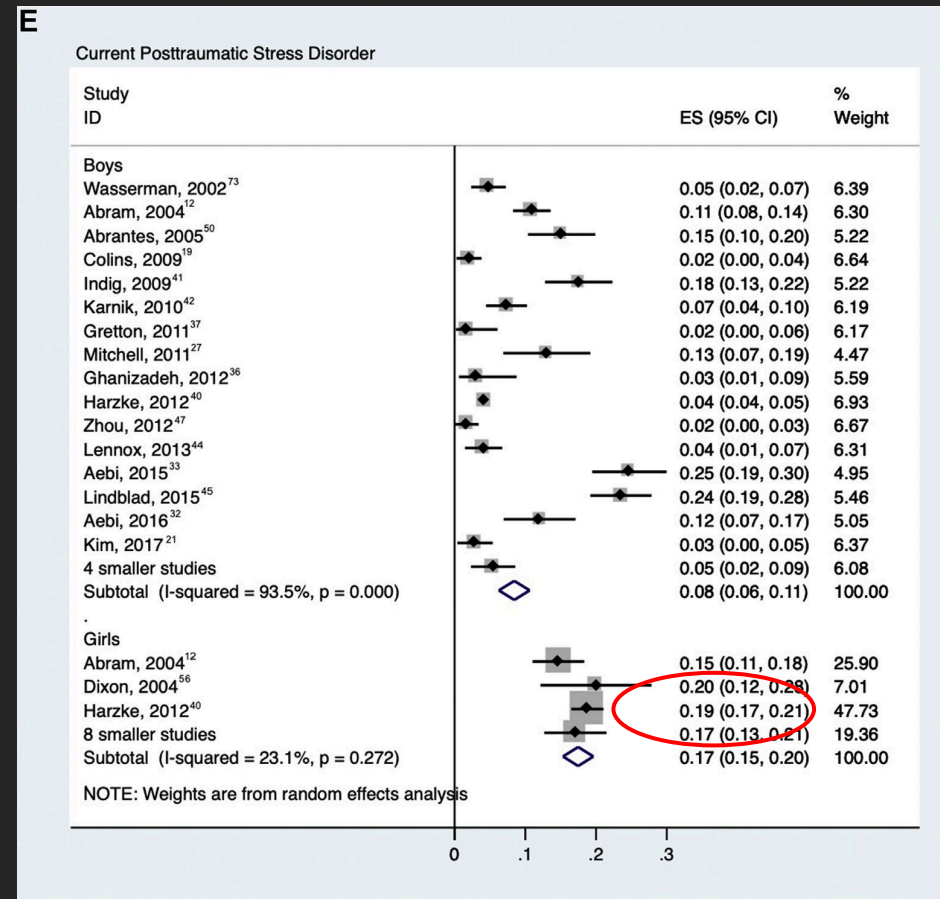


In male youth, 17.3% ADHD; 61.7% conduct disorder.

In female youth (17.5%) ADHD; 59.0% conduct disorder



# Mental Disorders Among Adolescents in Juvenile Detention and Correctional Facilities

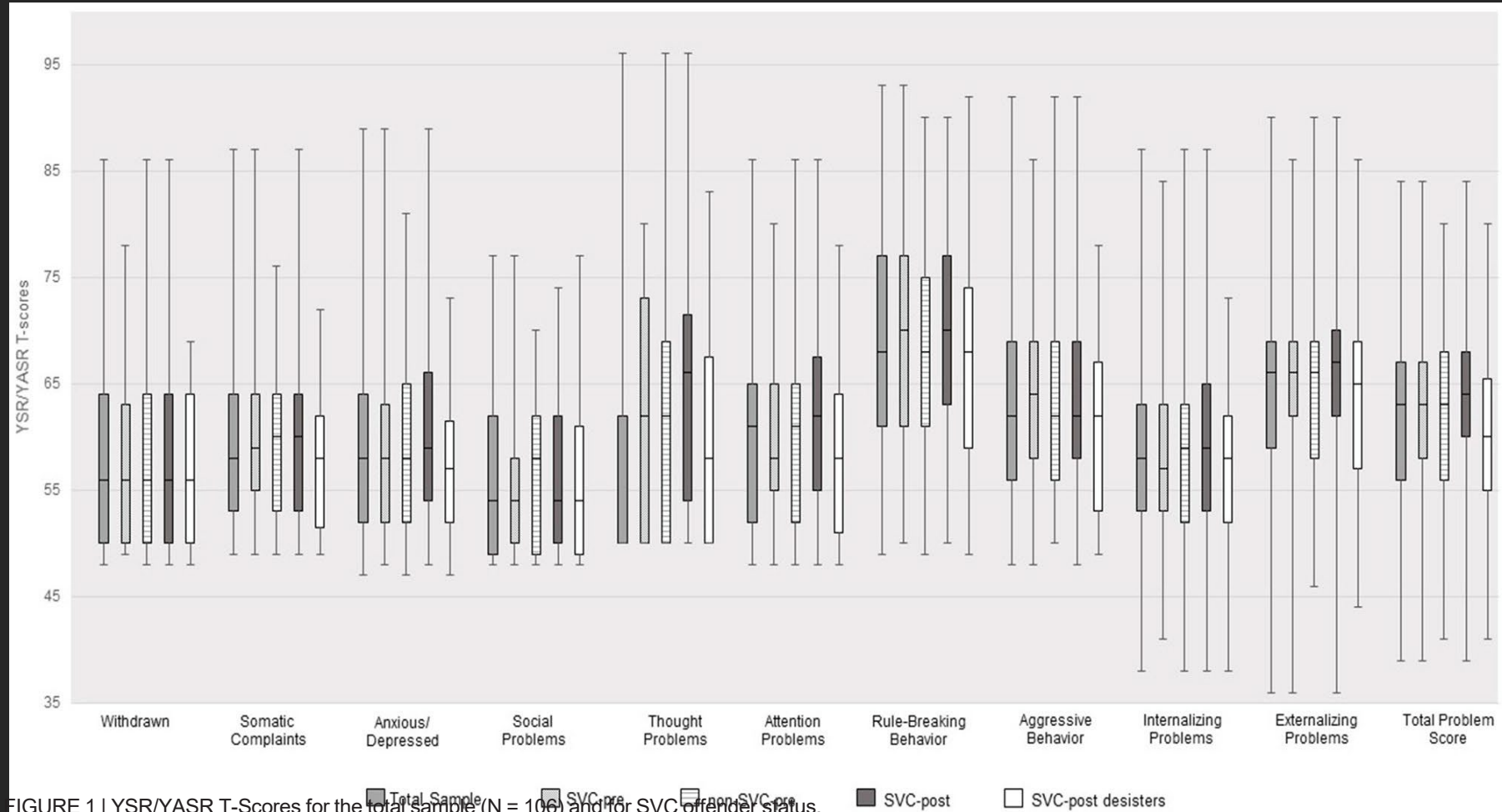


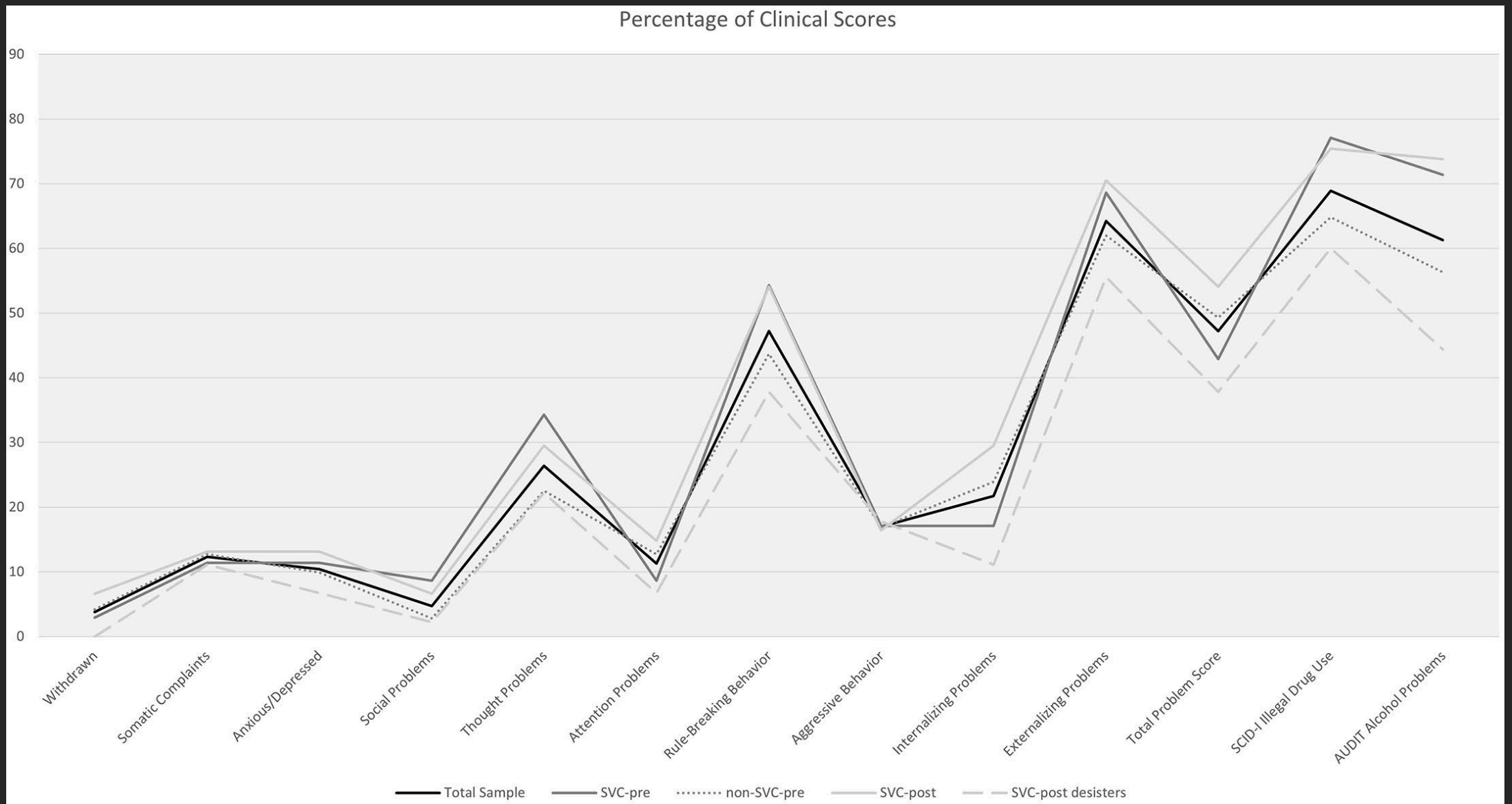
In male adolescents, 8.6% PTSD. In female adolescents 18.2% PTSD. Female adolescents had higher prevalences of major depression and PTSD than male adolescents.

# Mental Disorders Among Adolescents in Juvenile Detention and Correctional Facilities

- The two most common treatable disorders in male adolescents were **depression** (present in about 1 in 10) and **ADHD** (prevalent in 1 in 5). In female adolescents, approximately one in four had **depression**, and one in five had **PTSD**. Higher prevalences of depression and PTSD found in girls in custody compared with boys.
- Mental disorders are substantially more common among detained adolescents compared with general population counterparts. Approximately 3% of detained adolescents were diagnosed with a current psychotic illness, a 10-fold increase compared with age-equivalent individuals in the general population. Higher prevalence of current major depression were found in both male (10%) and female (26%) adolescents compared with the general adolescent population (5% and 11%, respectively).
- About 1 out of 5 detained adolescents had ADHD compared to 1 out of 10 adolescents in the general population. Nearly two-thirds of detained adolescents were diagnosed with any lifetime conduct disorder, whereas the estimated lifetime rate of conduct disorder in US adolescents is approximately 10%. In addition, adolescents in detention also had higher rates of PTSD than those in the general population, 9% versus 2% in male adolescents and 18% versus 8% in female adolescents. These differences underscore the large burden of psychiatric morbidity in detained adolescents.

# Role Of Mental Health In Young Offenders In Predicting Criminal Recidivism: Mental Health In Young Detainees Predicts Perpetration Of And Desistance From Serious, Violent And Chronic Offending (ages 18-21).





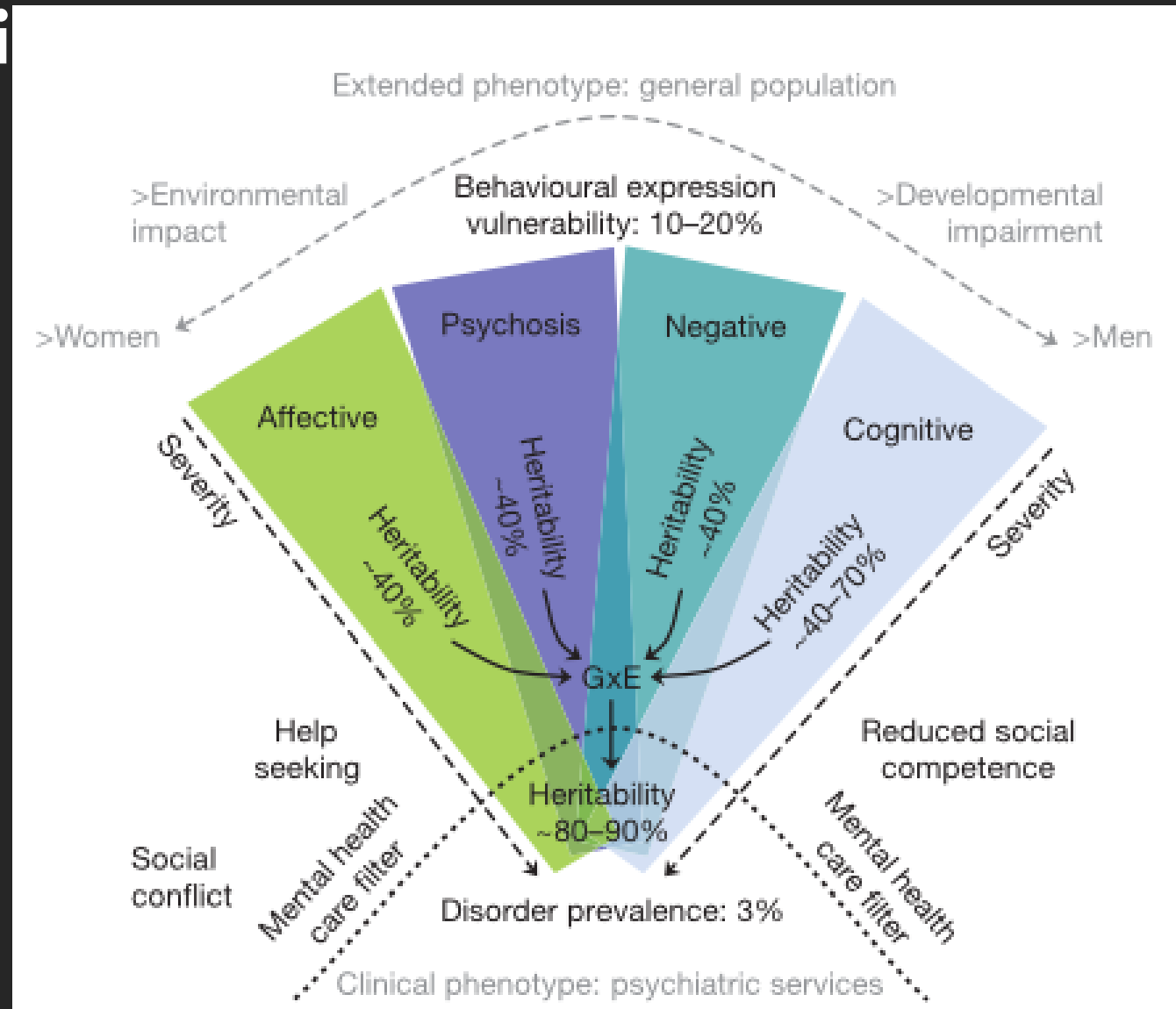
*Percentages of YSR/YASR, SCID-I and AUDIT clinical scores for the total sample (N = 106) and for SVC offender status.*

# Mental Health and wellbeing in NC

- **Mental Health Access:** North Carolina ranks 38<sup>th</sup> in access to mental health care
- **Workforce:** 22 counties have no psychiatrists; 28 have no psychologists
- **Substance Abuse:** Combined drug, alcohol, and suicide deaths totaled 7,114 in 2021
- **Pandemic Effects:** Prevalence of mental health conditions worsened during COVID
- **Community Impacts:** 135 people are exposed to each suicide



# Gene-Envi



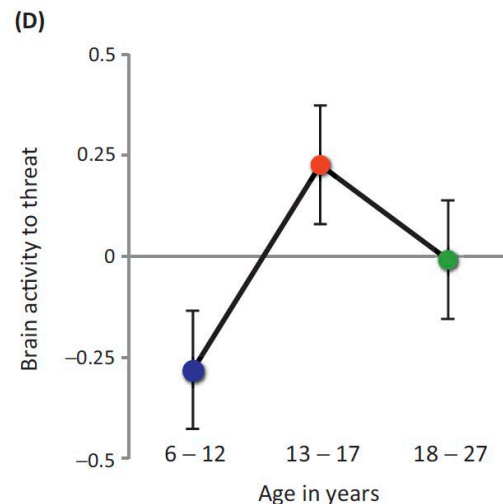
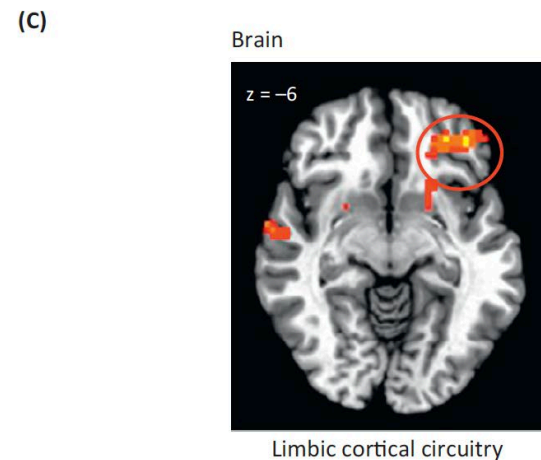
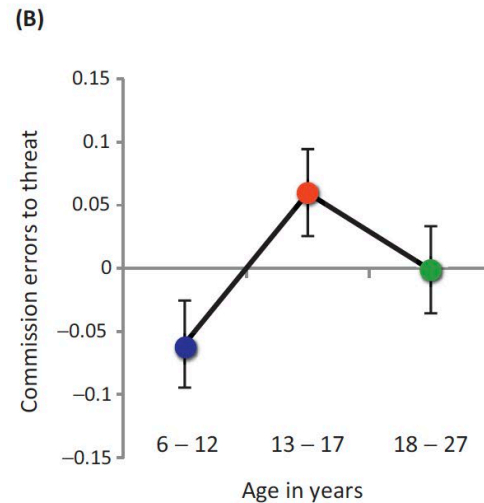
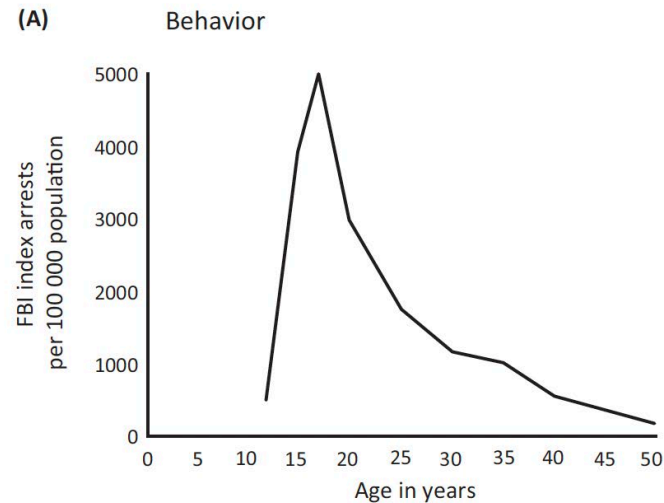
# Adolescents In Transition

- Adolescents and transition age youth show deficits in areas of executive functioning, including impulse control, planning, and decision making, compared with adults (Eshelet et al., 2007; Somerville & Casey, 2010). Indeed, tasks that require behavioral control over responses have a developmental brain maturation trajectory that continues until the early 30s (Hare et al., 2008; Liston et al., 2006). This continued brain development partially explains the challenges that many transition age youth face in making effective decisions, controlling impulsive behavior, and engaging in the long-term planning needed for success across all life domains.
- 45.5 percent of youth in residential justice settings met criteria for a mental health disorder (Shufelt & Coccozza, 2006).
- ~ 79 percent of youth with one mental health disorder also meeting diagnostic criteria for at least one other disorder, and more than 60 percent meeting criteria for a substance use disorder (Shufelt & Coccozza, 2006).
- youth with co-occurring behavioral problems (e.g., substance use, conduct disorder) and emotional problems (e.g., anxiety, depression) are at elevated risk for recidivism (Cottle, Lee, & Heibrun, 2001; Hoeve, McReynolds, & Wasserman, 2013) and committing violent offenses during young adulthood (Copeland, Miller-Johnson, Keeler, Angold, & Costello, 2007).

# What Does Developmental Neurobiology tell us about Brain/Behavior Development in

Criminal behavior and impulsivity in the adolescents

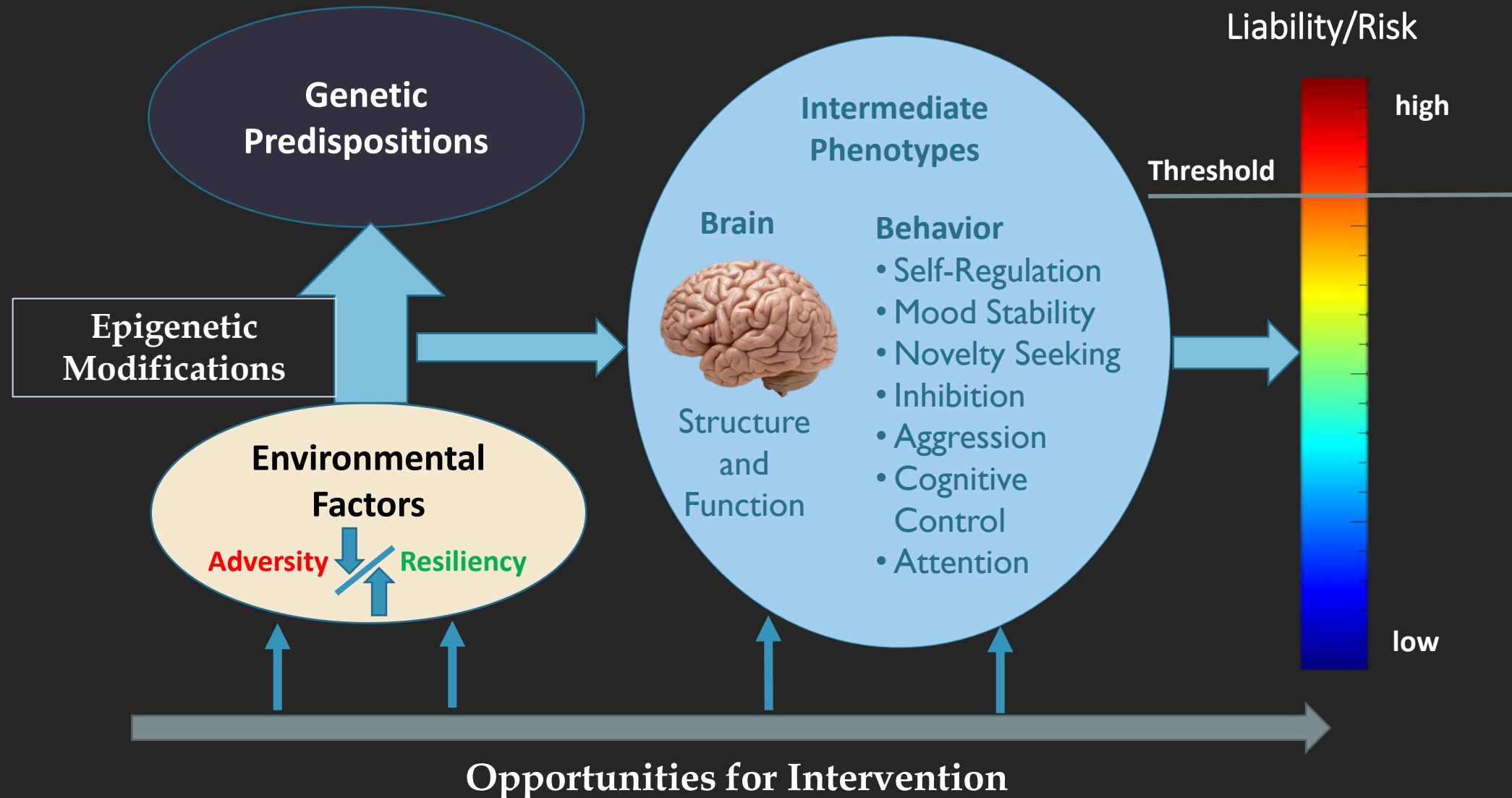
A



Developmental differences in criminal and impulsive behavior and the brain. (A) Arrest rates sharply increase at the beginning of adolescence, peaking at around 17 years of age. (B) Criminal behavior is paralleled by an adolescent-specific increase in impulsive responses to threat cues and (C) increased brain activity in limbic (emotion-related) cortical regions when (D) successfully suppressing the impulse to respond. Data from [Dreyfuss, M. et al. \(2013\)](#)

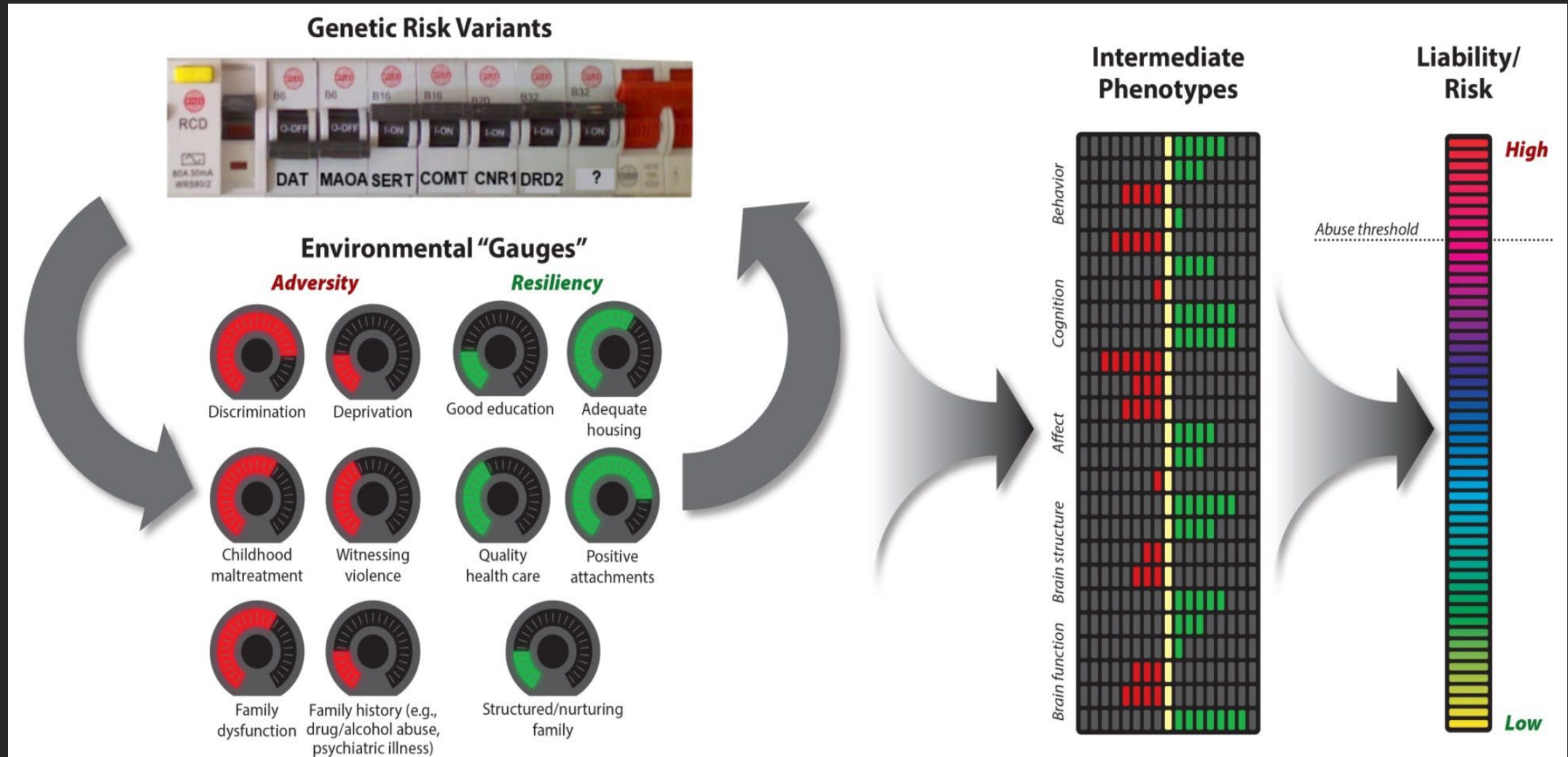
V. ROADMAP FOR ADDRESSING  
WELLBEING OF YOUTH IN JJS Prevention:  
Building resilience at all levels

# Pathways to Psychopathology

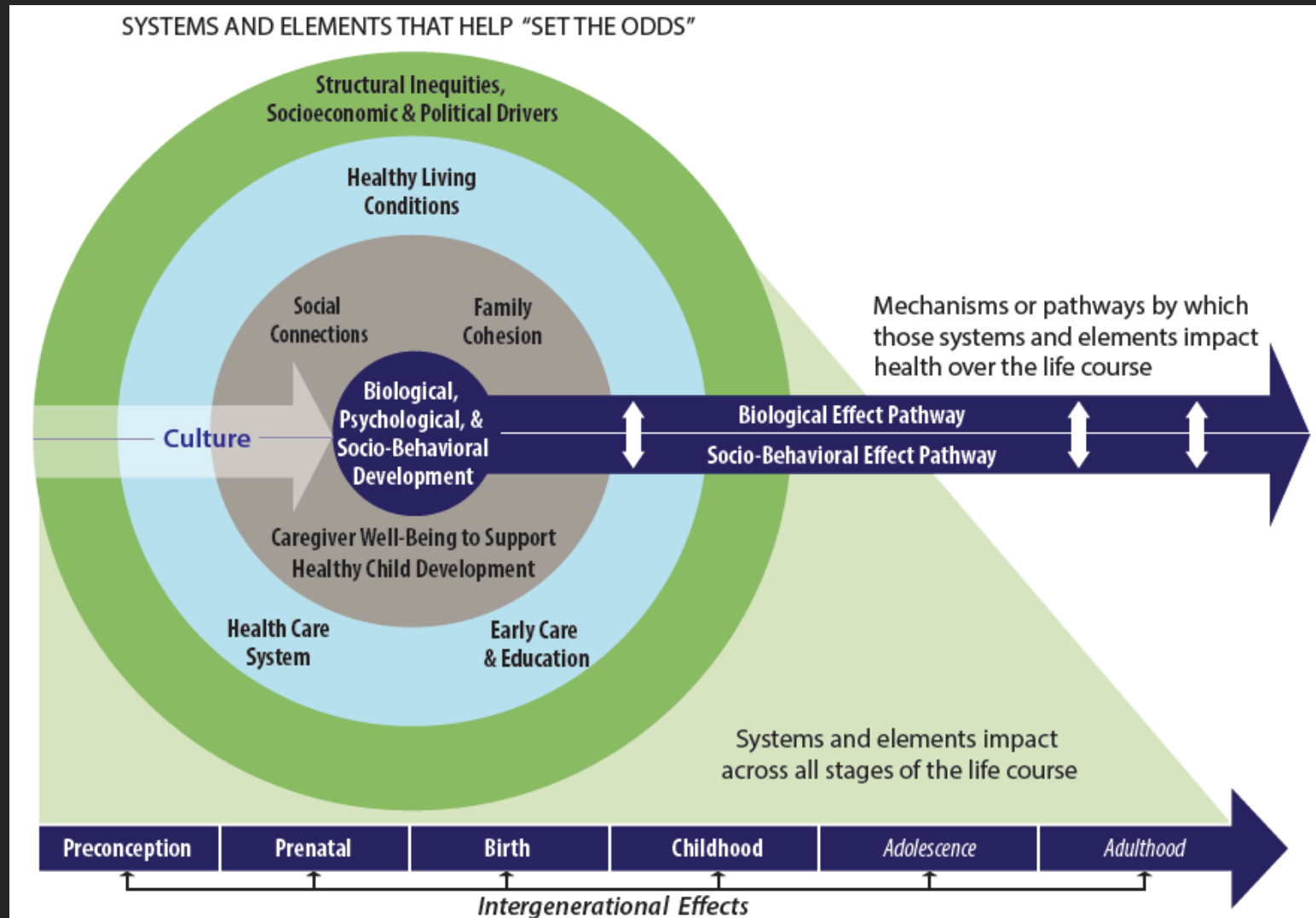




# Accumulative Model of Risk for Psychopathology

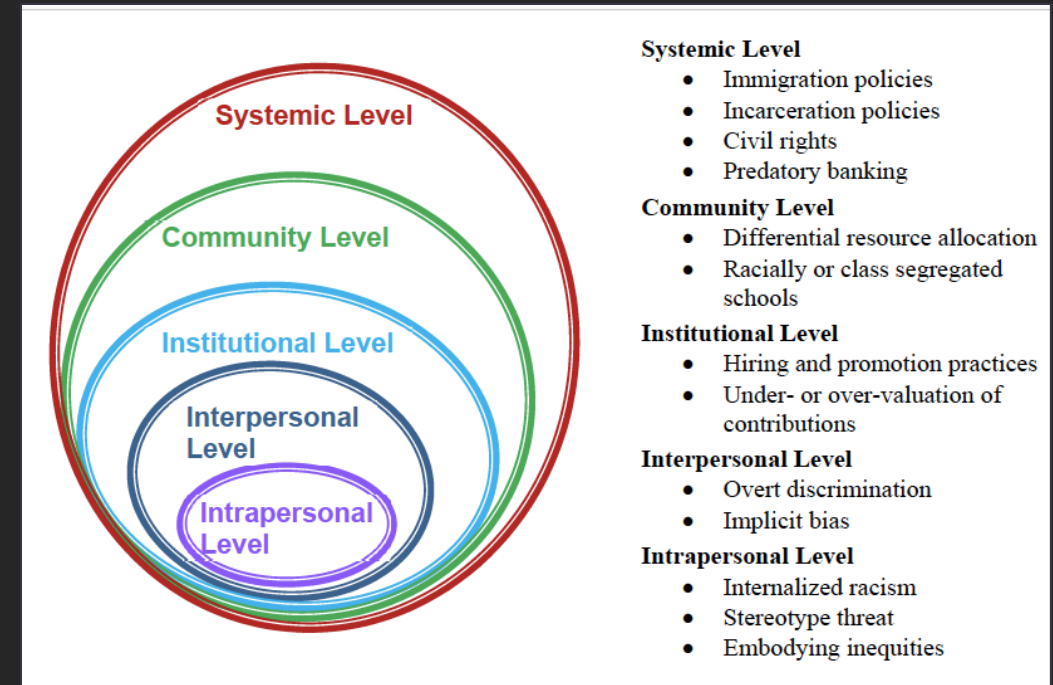
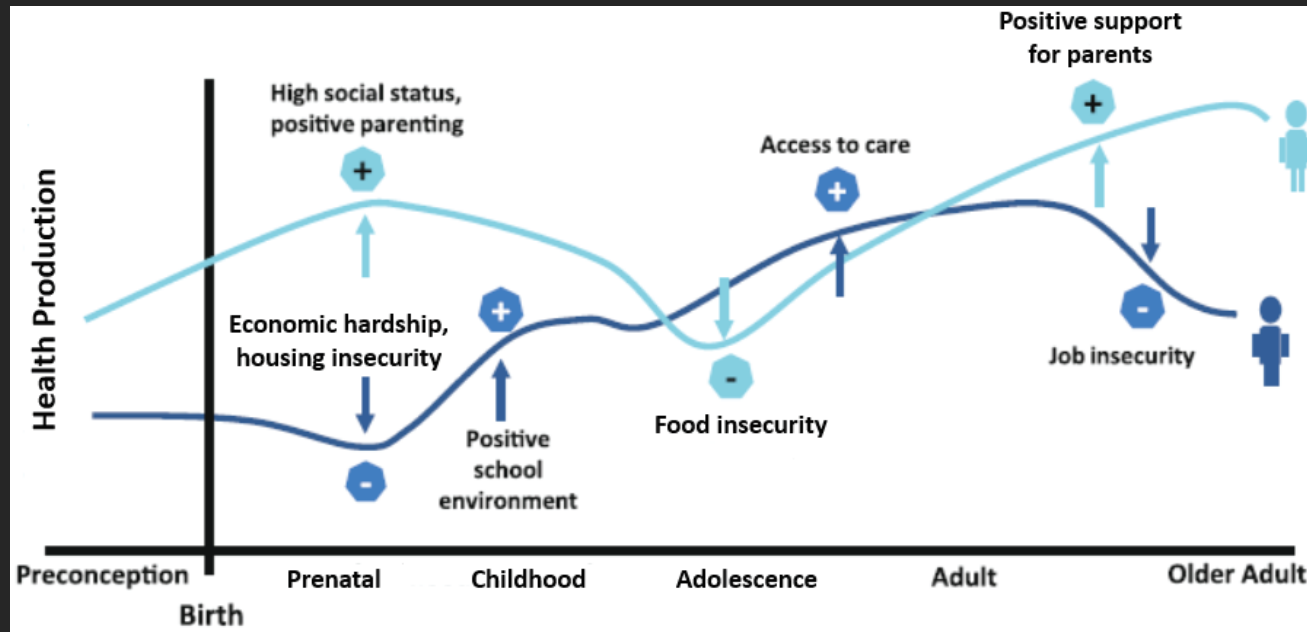


# Roadmap For Improving Outcomes For Youth In The JJS: Setting The Odds For Children

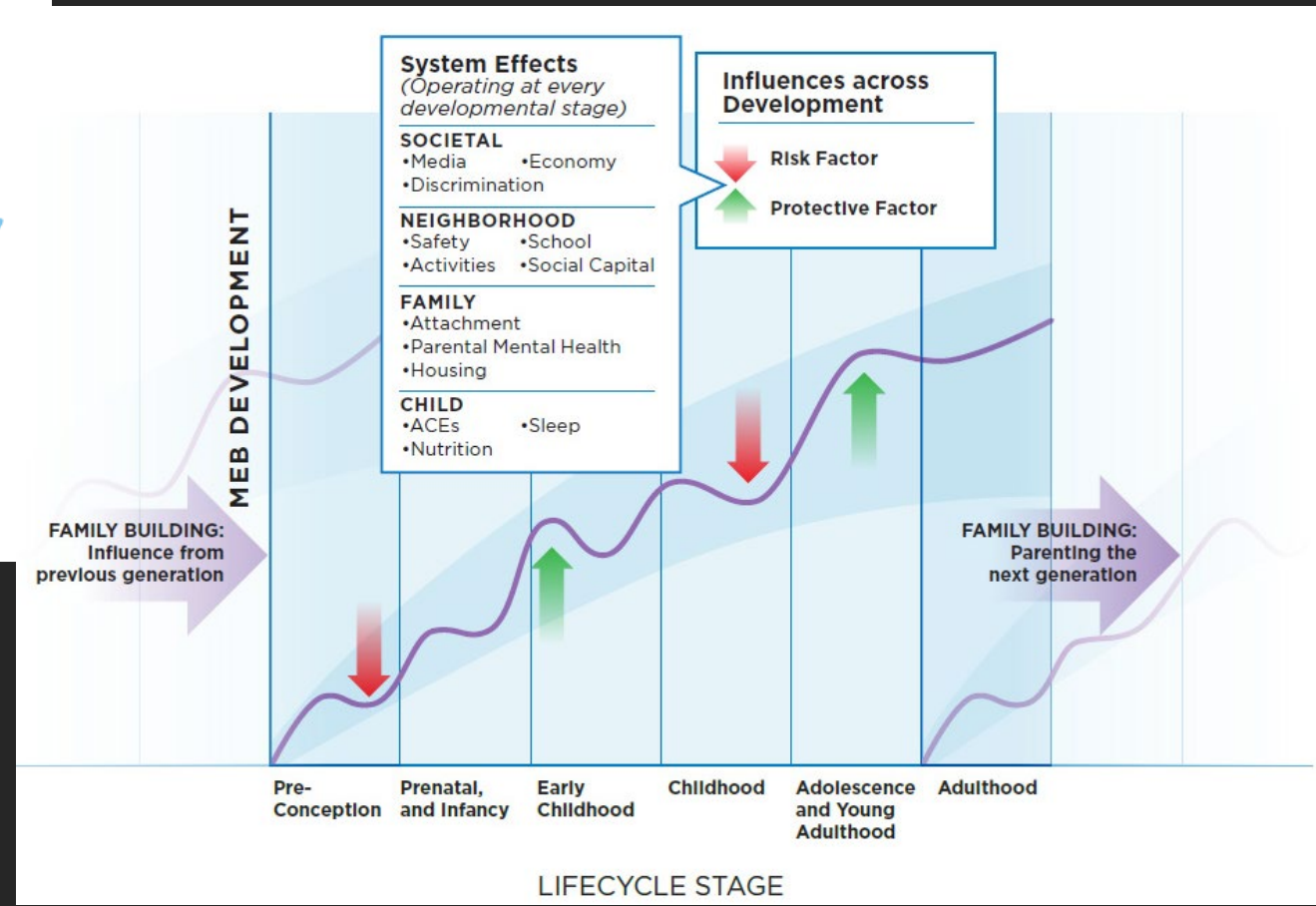
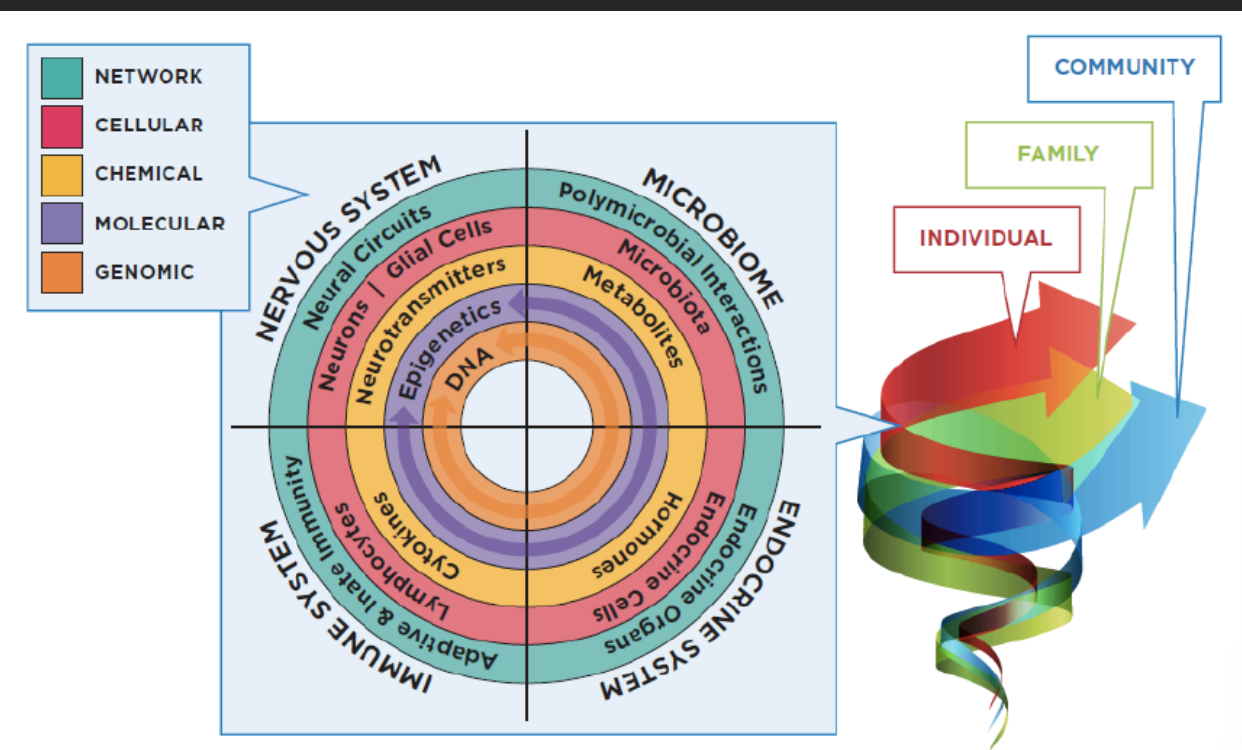


# A LIFECOURSE APPROACH TO WELL CHILD DEVELOPMENT FOR PREVENTION OF YOUTH PSYCHOPATHOLOGY

Identifying Protective and Risk Factors

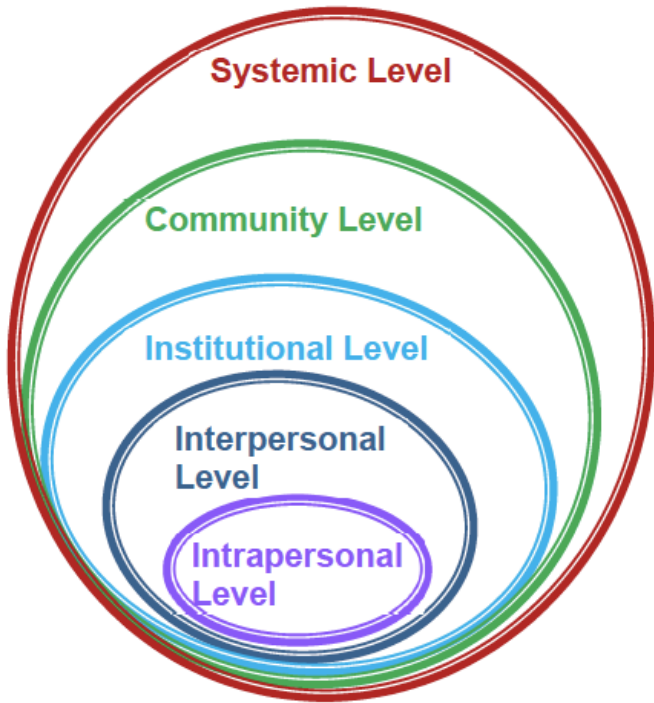


# Mapping Biological, Psychological, Social, and Environmental Factors That Operate At Every Developmental Stage for Individual Children.



# A LIFECOURSE APPROACH TO WELL CHILD DEVELOPMENT FOR PREVENTION OF YOUTH PSYCHOPATHOLOGY

## • IDENTIFYING PROTECTIVE AND RISK FACTORS



### Systemic Level

- Immigration policies
- Incarceration policies
- Civil rights
- Predatory banking

### Community Level

- Differential resource allocation
- Racially or class segregated schools

### Institutional Level

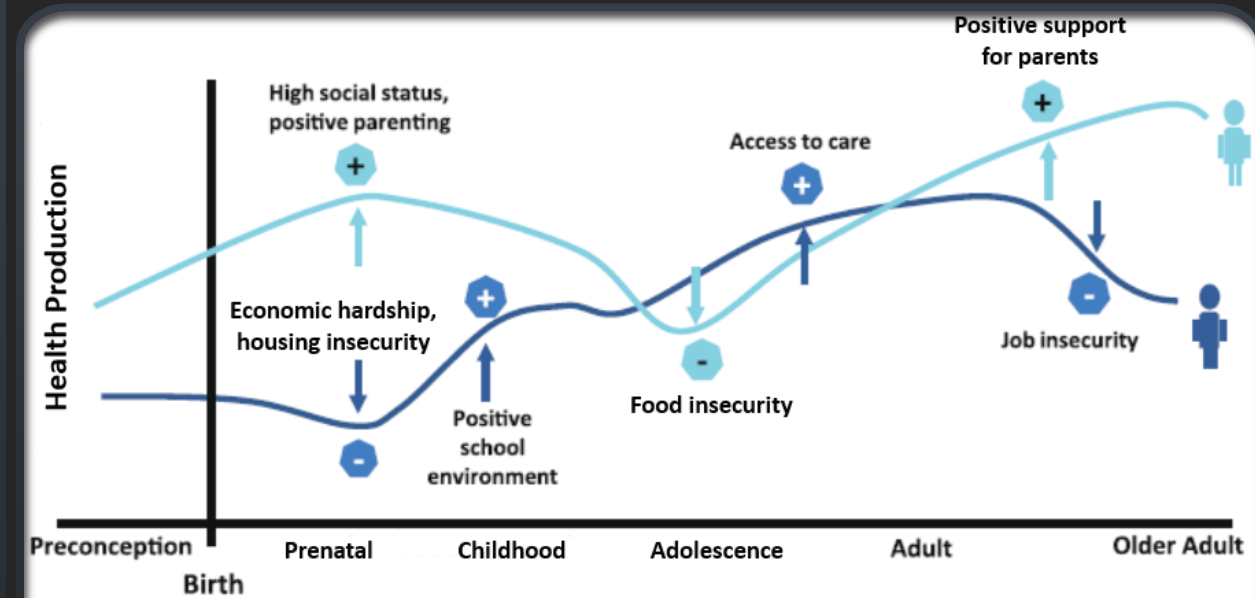
- Hiring and promotion practices
- Under- or over-valuation of contributions

### Interpersonal Level

- Overt discrimination
- Implicit bias

### Intrapersonal Level

- Internalized racism
- Stereotype threat
- Embodiment inequities



# Recommendation: Mapping Assets/Strengths And Risk Factors For Individual Youth

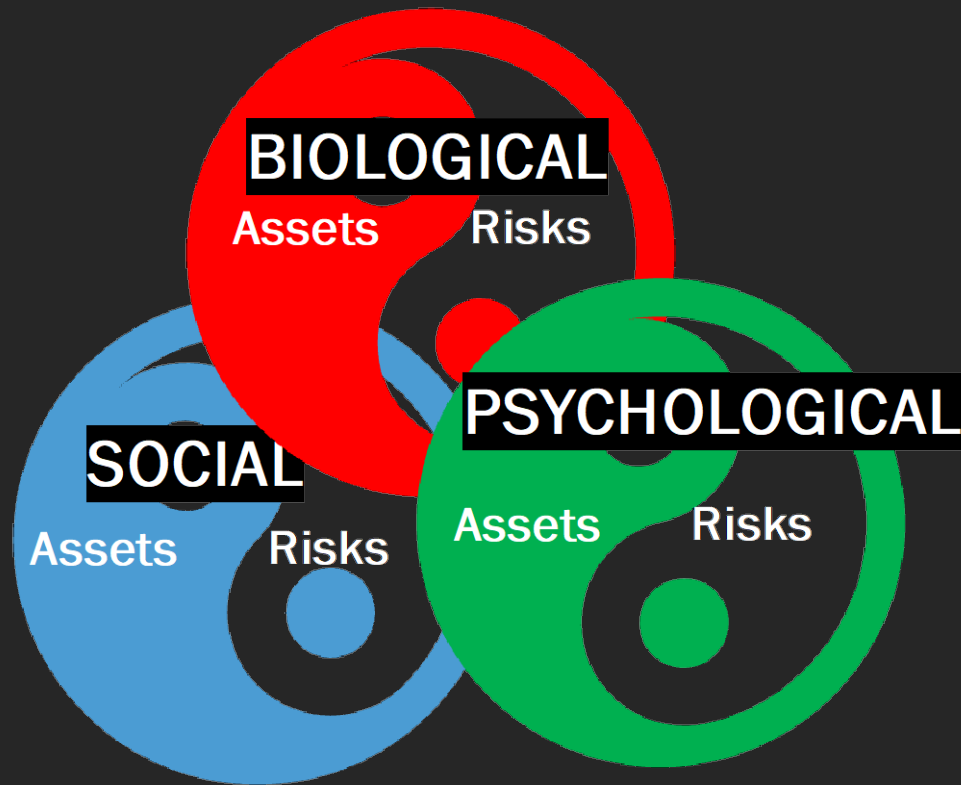
**ASSETS**



**RISKS**

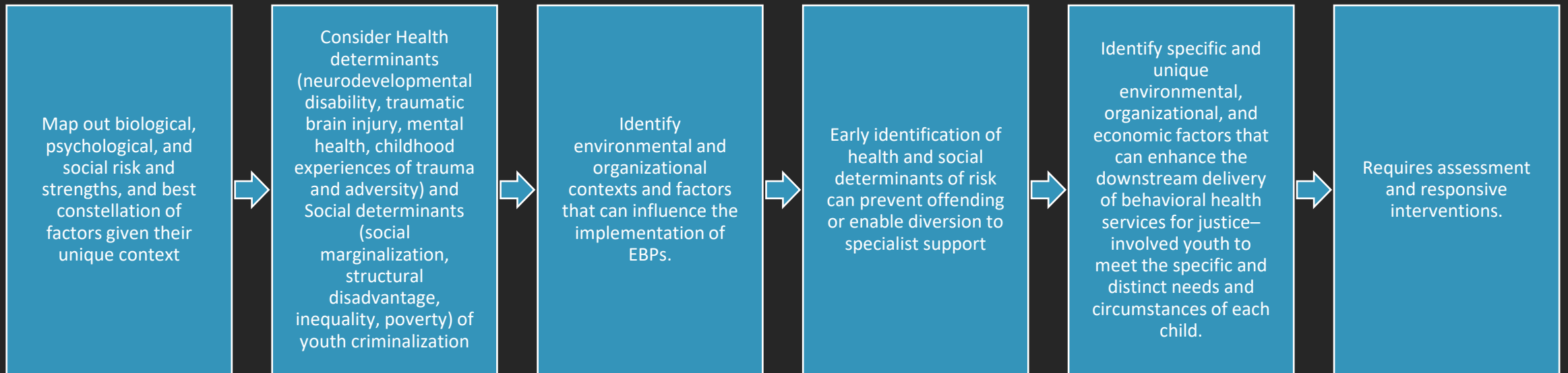


# Mapping Assets/Strengths And Risk Factors For Youth Re-entry



Systems Levels	Risks	Strengths
SOCIETAL: (Media, Economy, Discrimination, Migration, Violence, Poverty)		
NEIGHBORHOOD - COMMUNITY (Safety, Activity, School, Social Capital)		
FAMILY (Attachment, Parental Mental Health, Housing)		
CHILD (ACEs, Sleep, Nutrition, Disability)		

# For Individual Youth



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# Health and Social Determinants

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Strong and consistent evidence shows the existence of important health determinants of criminal justice involvement in adolescence, with an increased risk of engagement in the criminal justice system for young people who have had neurodevelopmental disability, mental health difficulties, ACEs, or trauma.

Substantial numbers of young people are therefore left vulnerable to criminal behavior and criminalization because of a combination of health difficulties and social disadvantage. Furthermore, the adolescent population engaged by criminal justice systems has a considerable prevalence of complex needs

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# Health and Social Determinants

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Transition age youth (16-25): High prevalence of substance abuse compounding disruptive behavior (highest rates of onset of problematic substance use and substance use disorders (i.e., abuse, dependence) (Chassin, et al., 2004; Delucchi, et al., 2008; SAMSHA, 2009)

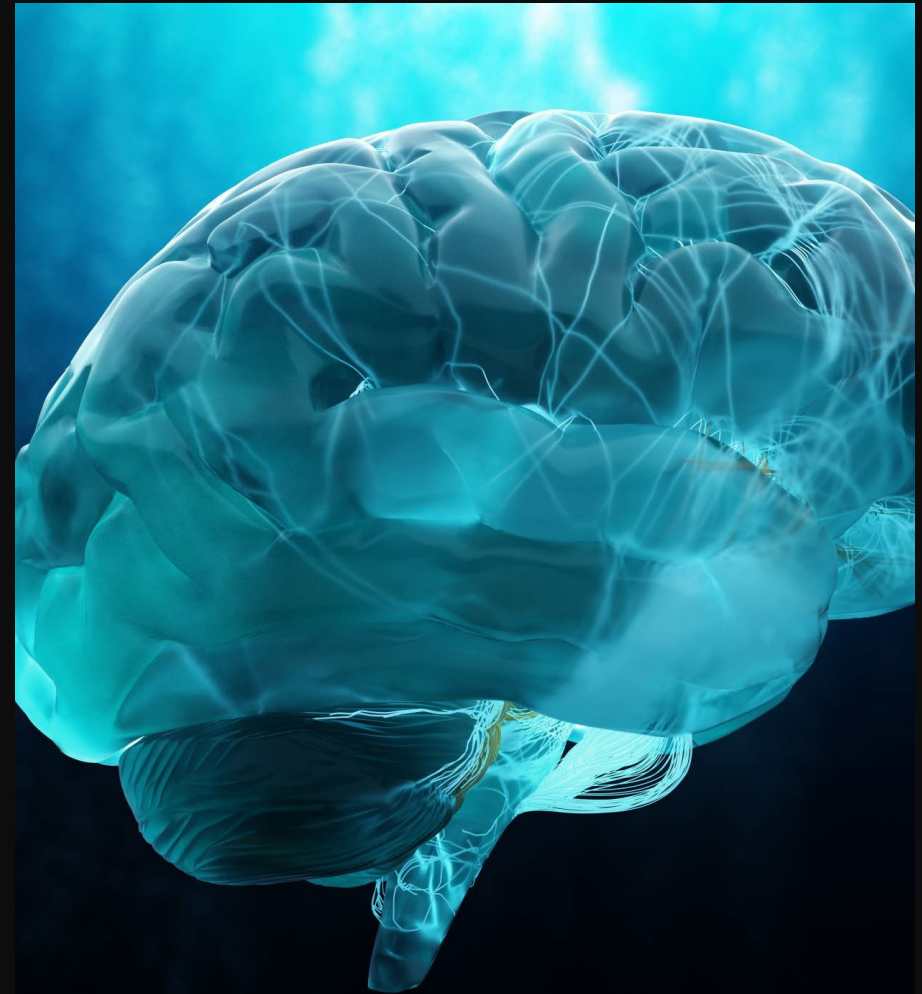
This risk of criminal justice engagement appears to be amplified by experiences of social marginalization and inequality. Youth with accumulated disadvantage often includes poverty, poor relationships with parents and other family members, school failure and/or dropout, negative peer groups, and the lack of adult role models.

Re-entry programs for youth with mental health problems are often inappropriate or insufficient, as they are mostly designed for adults: lack of peer groups, family support, educational support, financial support, effective mental health interventions,

# Key Take-aways

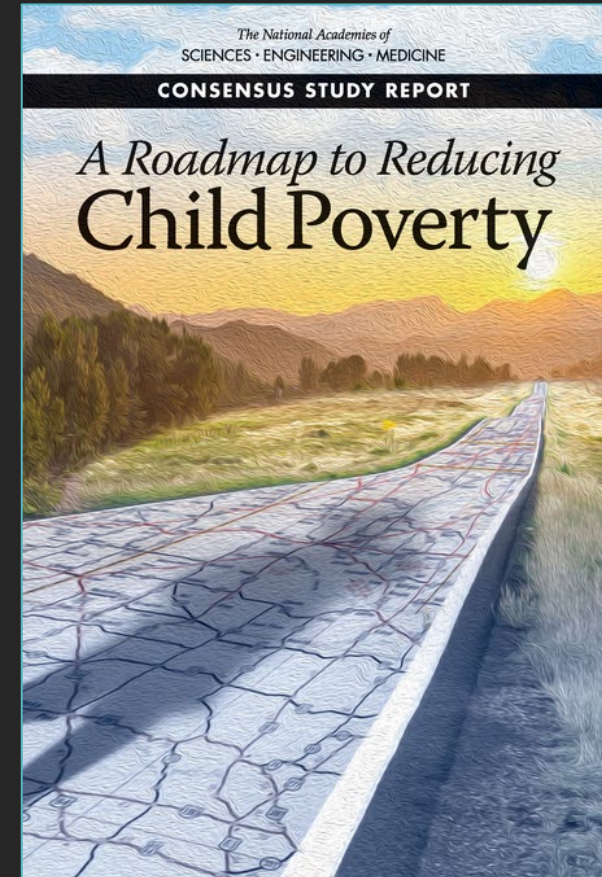
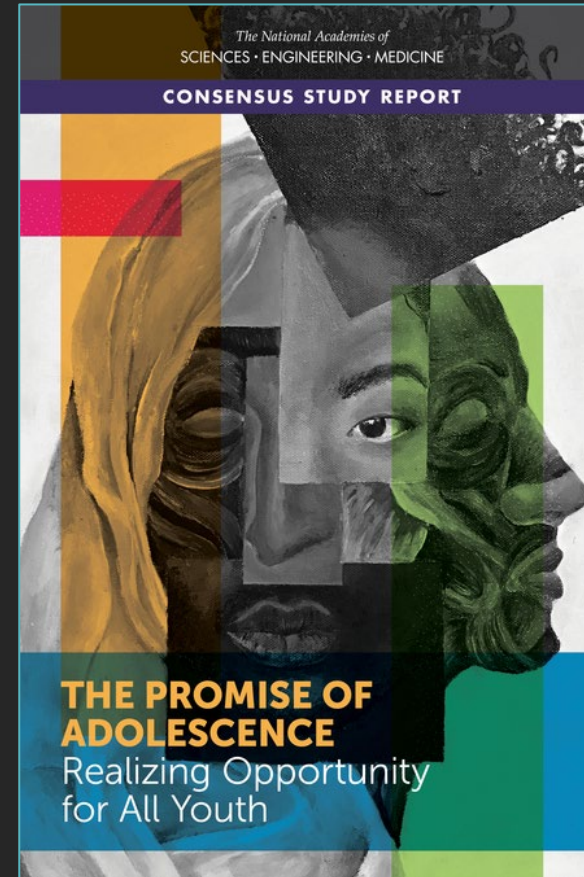
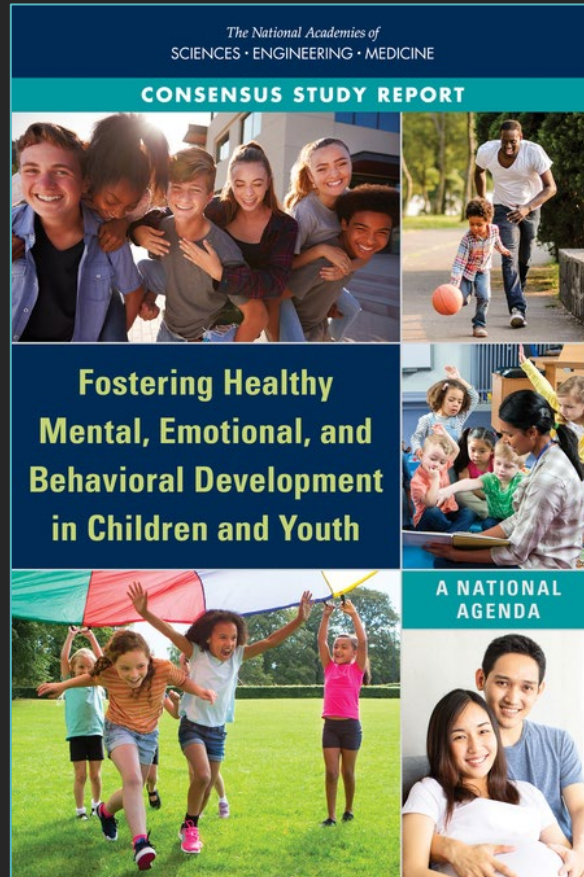
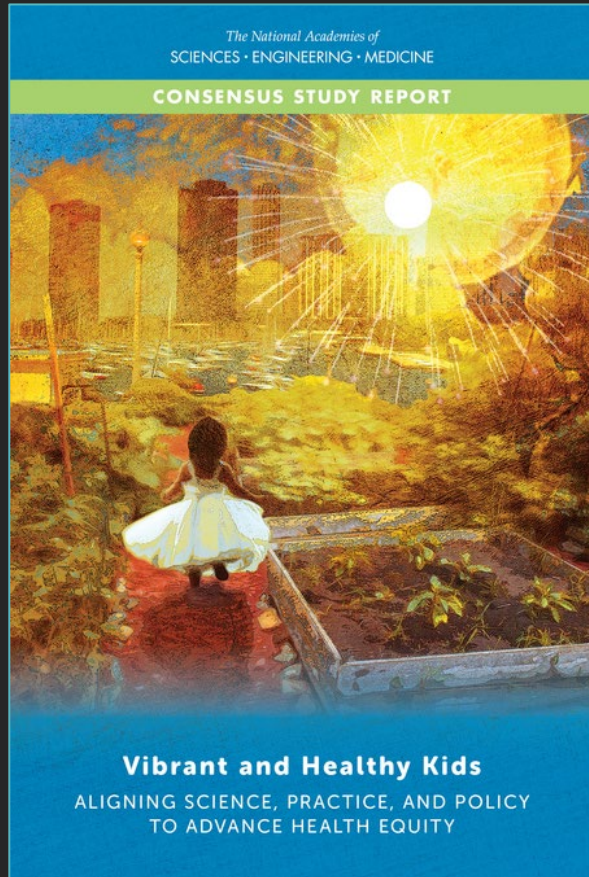
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- Adolescence is a critical period of brain development with unique risk and opportunities
  - Traumatic life experiences, including physical, emotional, psychological adverse events alter brain development, increasing risk for psychopathology
  - Developmental trajectory is a product of its biological/genetic make-up and environmental modulators , creating a constant recalibration of their risk and resilience
  - Early identification of constellation of factors that contribute to onset and severity of mental health and behavioral problems is critical for prevention of continued offending and recidivism, to increase their chances to develop into a healthy and non-criminal future and protect society from further crime.
  - Assessing positive and negative pressure points and identifying rescue or strength factors for individual children is necessary for planning effective interventions and actions, beyond weekly psychotherapy and medication.
  - Charting risk (exposure to trauma, social isolation, further exposure to risky environments and behaviors, management through correction systems) and resilience factors (community-based interventions, effective targeted interventions, identification of specialized needs) for individual children.
- 





# Integrating Evidence-Based Practices – NAS Reports



Thank You!