The Brain and Executive Function

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BRAIN FACTS

- Most complex object in the known universe
- 100 billion neurons (nerve cells)
- Each neuron has 5,000 to 10,000 connections to other neurons
- Fully developed, there are 100 trillion interconnections among neurons
- The way the connections are organized into networks is most important
- Most sensitive part of fetal growth

DEFINITIONS

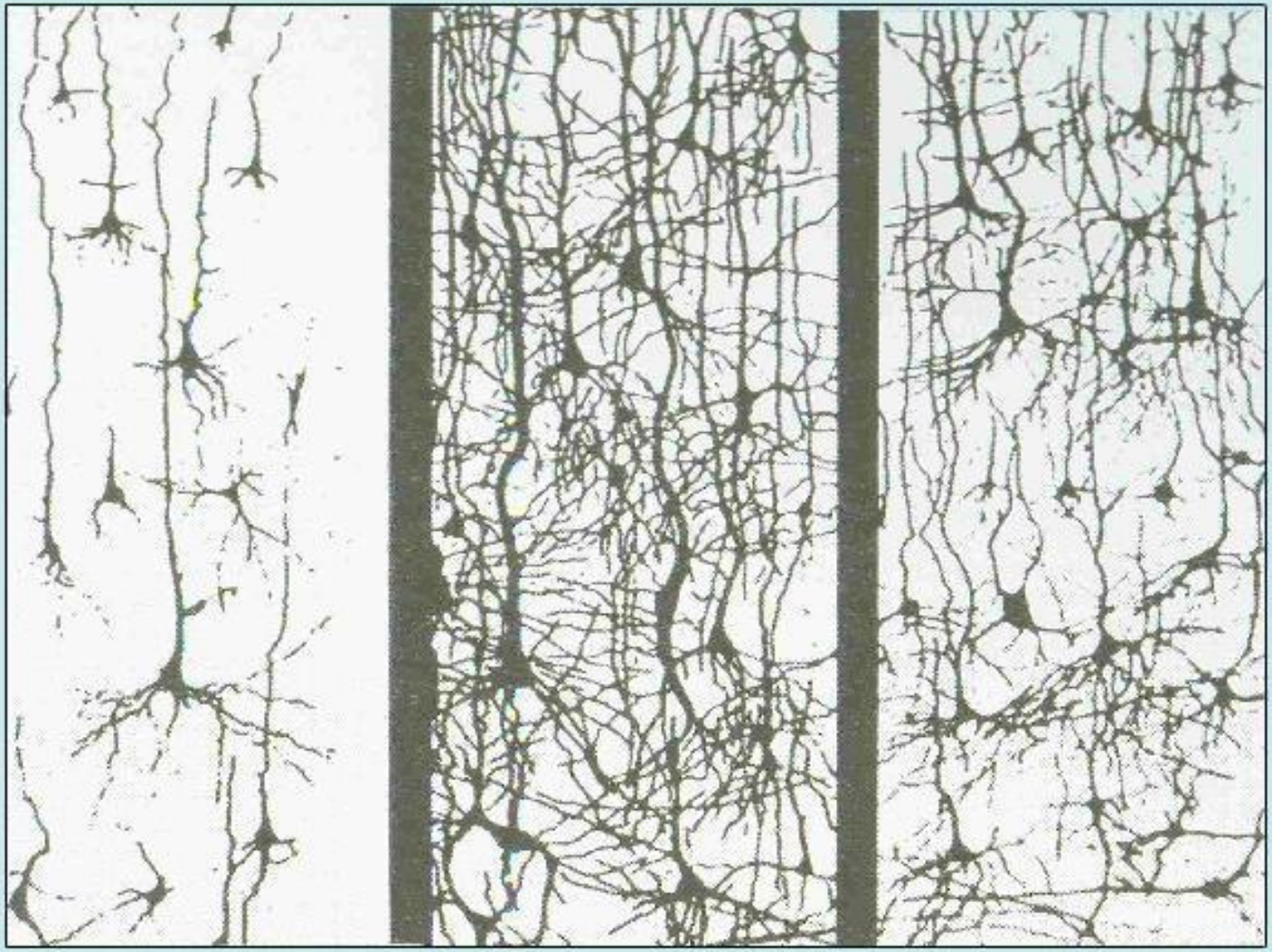
- **Action Potential**: A nervous impulse -- the transmission of an electric change along the membrane of a neuron beginning at the point of stimulus.
- **Axon**: The fiber like extension of a neuron by which it sends information to target cells.
- **Dendrite**: A tree-like extension of the neuron cell body. The dendrite is the primary site for receiving and integrating information from other neurons.
- **Myelin**: Compact fatty material that surrounds and insulates the axons of some neurons.
- **Synapse**: A physical gap between two neurons that functions as the site of information transfer from one neuron to another.

BRAIN GROWTH AFTER BIRTH

- Neurons develop until 18 months
- Dendrites produced until 10 years
- Myelination of axons continues into adolescence
- Explosion of synaptogenesis just before and after birth -- connections between axons and neurons -- and again in puberty
- Consists of much redundancy and some randomness in the connections
- Some connections, not stimulated, will die. Brain becomes organized through "Blooming" and "Pruning"

Synaptic Density

At birth | 6 years old | 14 years old



Source: Rethinking the Brain, Families and Work Institute, Rima Shore, 1997; Founders Network slide

PRUNING

- **"USE IT OR LOSE IT"–** Reading, sports, music, video games, x-box, hanging out—whatever a child/teen is doing—these are the neural synapses that will be retained
- How children/teens spend their time is **CRUCIAL** to brain development since their activities guide the structure of the brain

LEARNING

- Learning begins in utero
- Brain organizes itself in response to stimulation received
- When same experiences happen again and again those connections are strong
- Other initial connections, not stimulated, retract or die
- Brain highly dependent on regular patterns
- Children ACTIVELY try to make sense of "messy" data

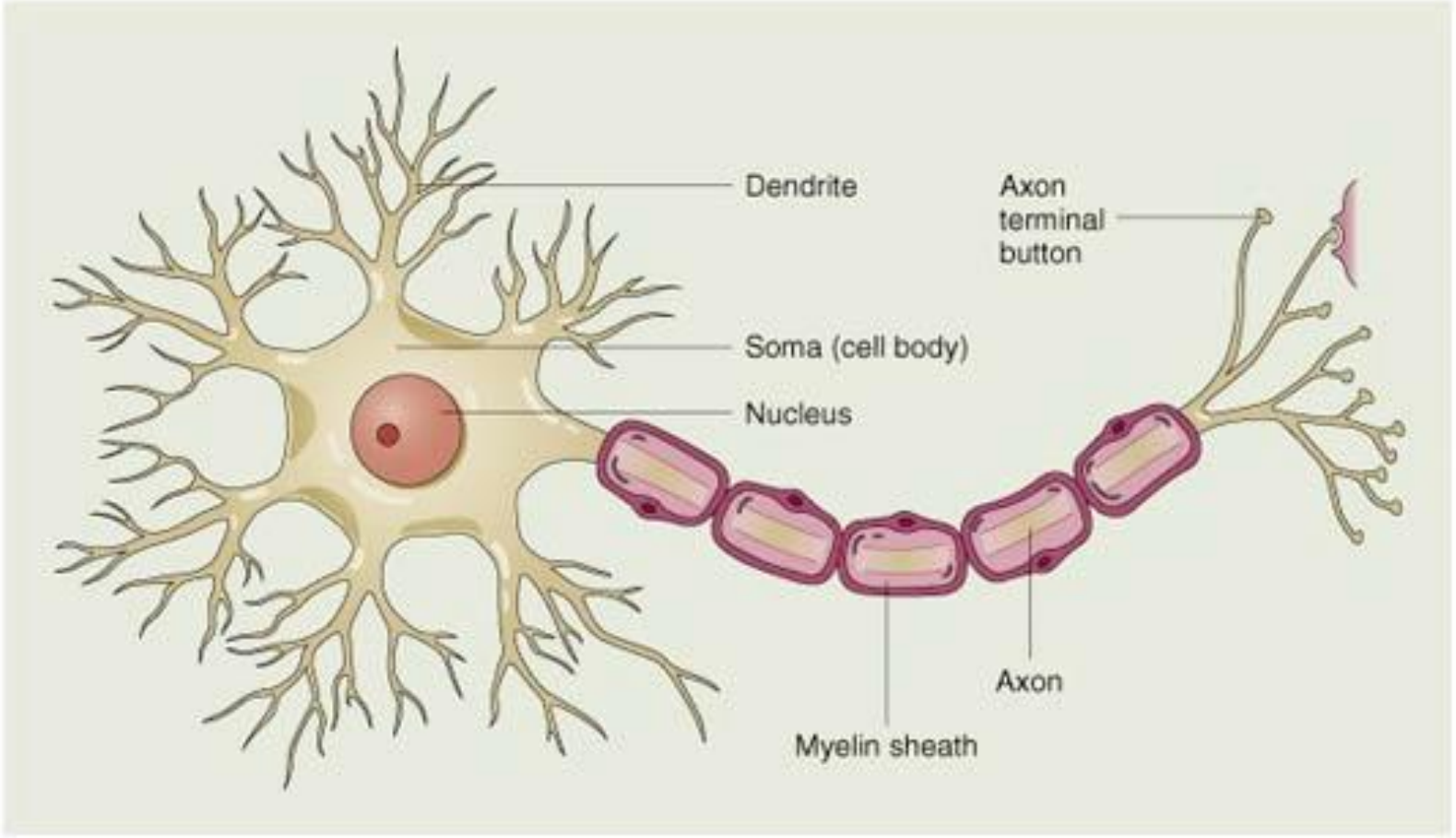
TWO TYPES OF CONNECTIONS IN RESPONSE TO EXPERIENCE

- Experience-Expectant Synaptogenesis
  - ***Species typical environments***
  - ***Early, critical periods***
- Experience-Dependent Synaptogenesis
  - ***Individually specific environments***
  - ***Learning through life***
  - ***Novel situations require a lot of brain activity***
  - ***The better something is known the less activity is necessary***

CRITICAL PERIODS IN DEVELOPMENT

- Definitions
  - "Window of opportunity"
  - Decreasing plasticity over time
  - Societally imposed competency requirements
  - Different learning pathways at different times
- Strict "critical periods" found only for *experience-expectant* learning
- *Experience-dependent* learning more complex with gradual reductions in responsivity

Neuron

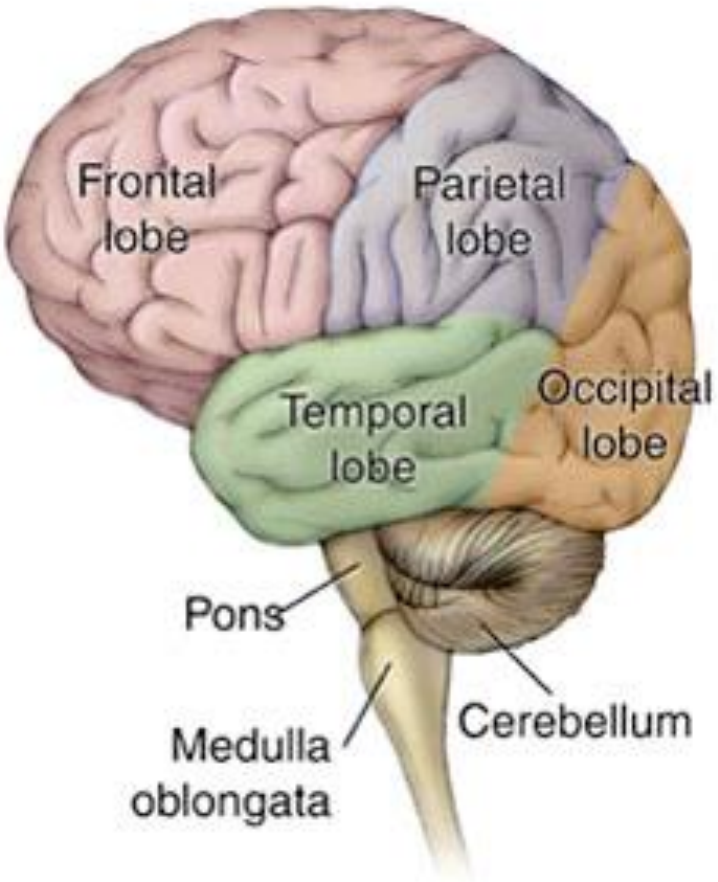


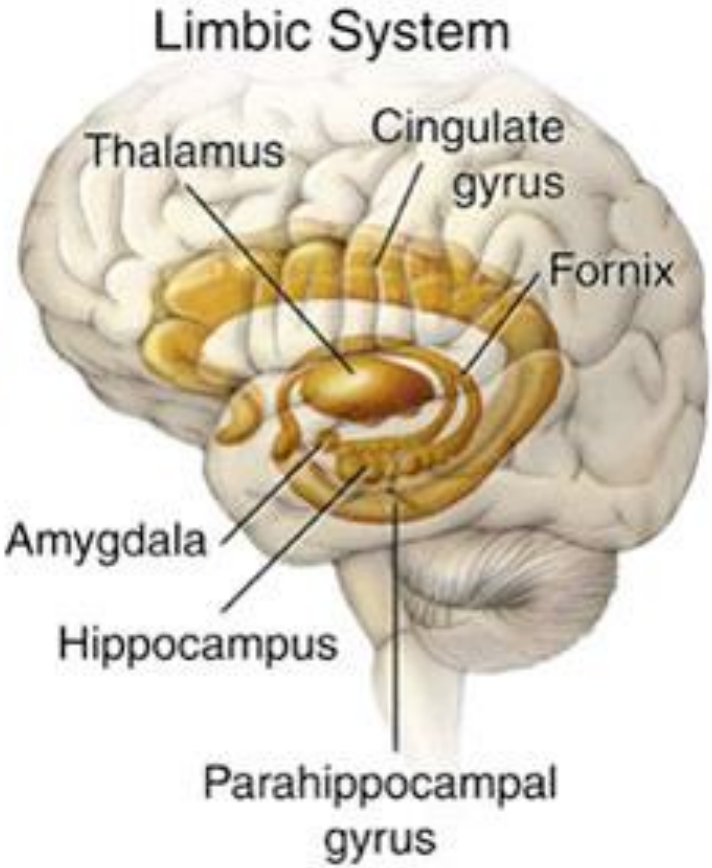
MYELINATION

- Visual, auditory, and somesthetic cortex myelinate before birth
- Higher brain centers that integrate information are not completely myelinated until after puberty
- Myelination means more automated learning

- **Gray Matter**
  - Nerve cells
  - Synapses
- **White nerve fibers**
  - Carry signals between nerve cells and other parts of the brain and body
  - Myelination makes them white

The Brain


Frontal lobe
Parietal lobe
Temporal lobe
Occipital lobe
Pons
Medulla oblongata
Cerebellum

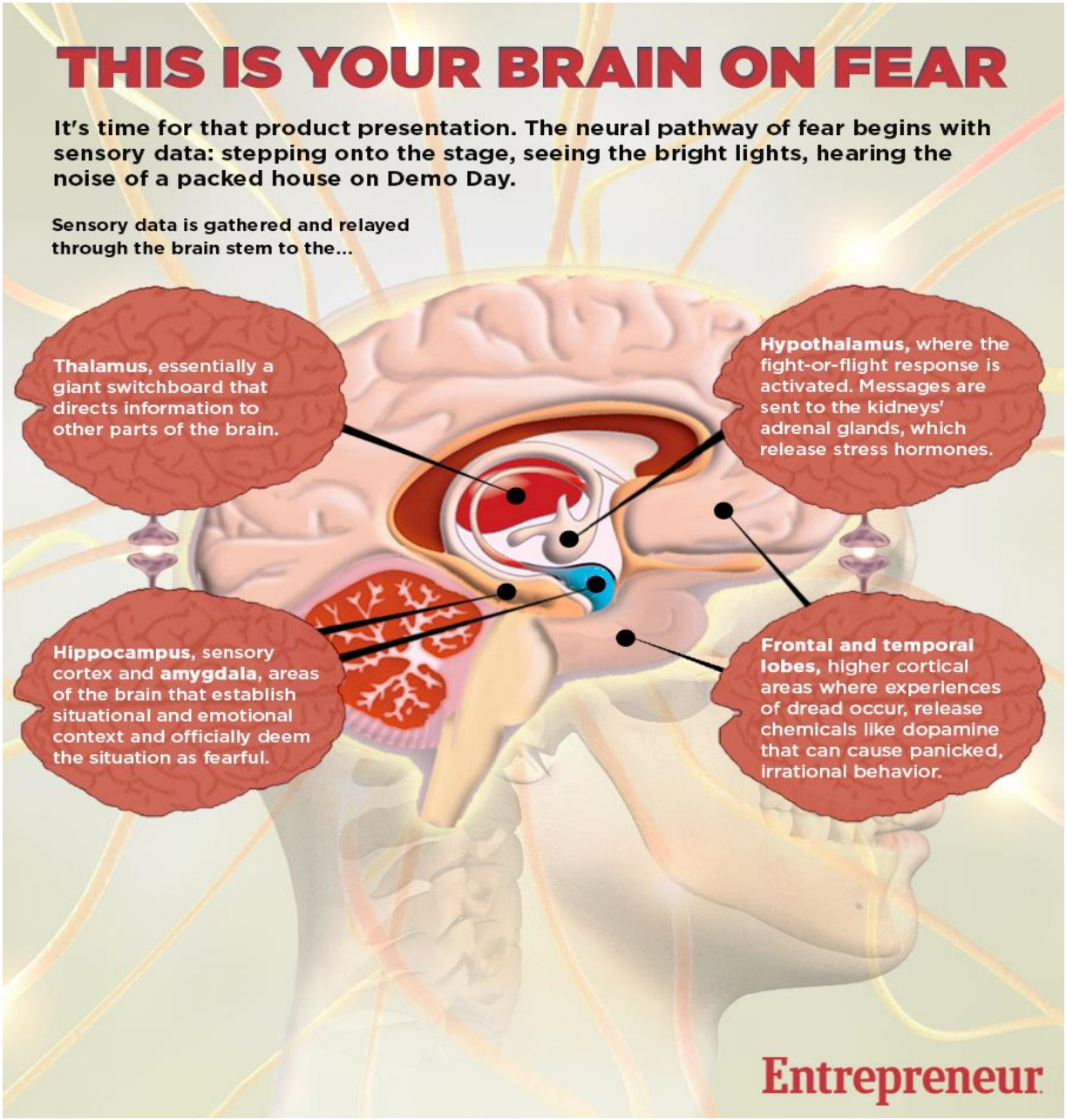

Limbic System
Thalamus
Cingulate gyrus
Fornix
Amygdala
Hippocampus
Parahippocampal gyrus

MAJOR AREAS OF THE BRAIN

- **Cerebellum** – governs movement.
- **Frontal lobe** – helps control skilled muscle movements, mood, planning for the future, setting goals and judging priorities.
- **Occipital lobe** – helps process visual information.
- **Parietal lobe** – receives and processes information about temperature, taste, touch, and movement coming from the rest of the body. Reading and arithmetic are also processed in this region.
- **Temporal lobe** – processes hearing, memory and language functions.

LIMBIC SYSTEM

- **Limbic system** – a group of interconnected structures that mediate emotions, learning and memory.
  - **Amygdala** – limbic structure involved in many brain functions, including emotion, learning and memory. It is part of a system that processes "reflexive" emotions like fear and anxiety.
  - **Hippocampus** – plays a significant role in the formation of long-term and autobiographical memories.
  - **Parahippocampal gyrus** – an important connecting pathway of the limbic system
  - **Thalamus** – a major relay station between the senses and the cortex (the outer layer of the brain consisting of the parietal, occipital, frontal and temporal lobes).


THIS IS YOUR BRAIN ON FEAR
It's time for that product presentation. The neural pathway of fear begins with sensory data: stepping onto the stage, seeing the bright lights, hearing the noise of a packed house on Demo Day.
Sensory data is gathered and relayed through the brain stem to the...
Thalamus, essentially a giant switchboard that directs information to other parts of the brain.
Hypothalamus, where the fight-or-flight response is activated. Messages are sent to the kidneys' adrenal glands, which release stress hormones.
Hippocampus, sensory cortex and amygdala, areas of the brain that establish situational and emotional context and officially deem the situation as fearful.
Frontal and temporal lobes, higher cortical areas where experiences of dread occur, release chemicals like dopamine that can cause panicked, irrational behavior.
Entrepreneur

PRE-FRONTAL CORTEX

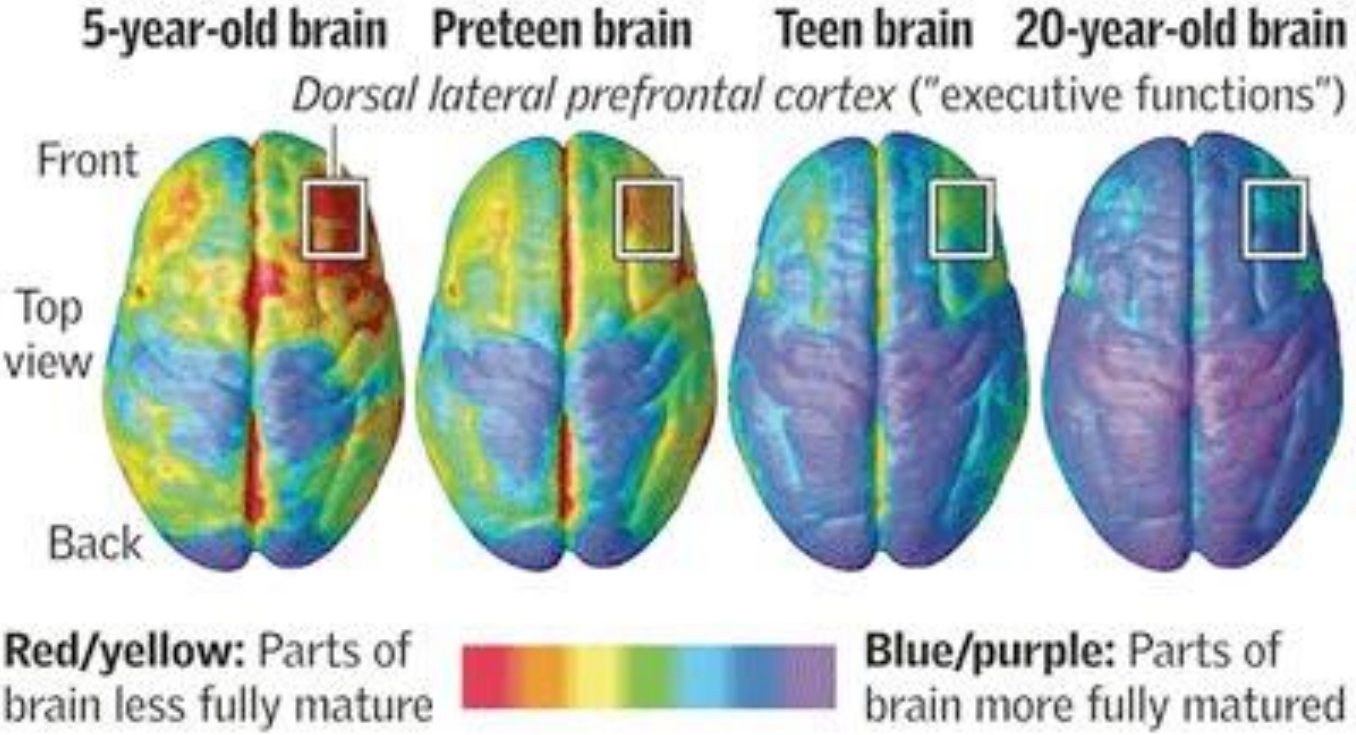
- Sits just behind the forehead
- Acts as the "CEO" of the brain controlling
  - Planning
  - Working memory
  - Organization
  - Modulating mood
  - Called "the area of sober second thought"
- **Second wave of synapse formation begins in frontal cortex just before puberty, pruning back in adolescence (wrapping white matter around connections to stabilize them)**

EXECUTIVE FUNCTION: ASSOCIATED WITH FRONTAL LOBE

- Capacity to control and coordinate thoughts and behavior
  - Selective attention
  - Decision-making
  - Response inhibition
  - Working memory
- Prospective Memory
  - Holding in mind intention to carry out an action at a future time
  - At puberty there is a *decline* in performance that does not return to usual levels until age 16
- Sudden proliferation of synapses at puberty makes cognitive performance less efficient

Judgment last to develop

The area of the brain that controls "executive functions" — including weighing long-term consequences and controlling impulses — is among the last to fully mature. Brain development from childhood to adulthood:



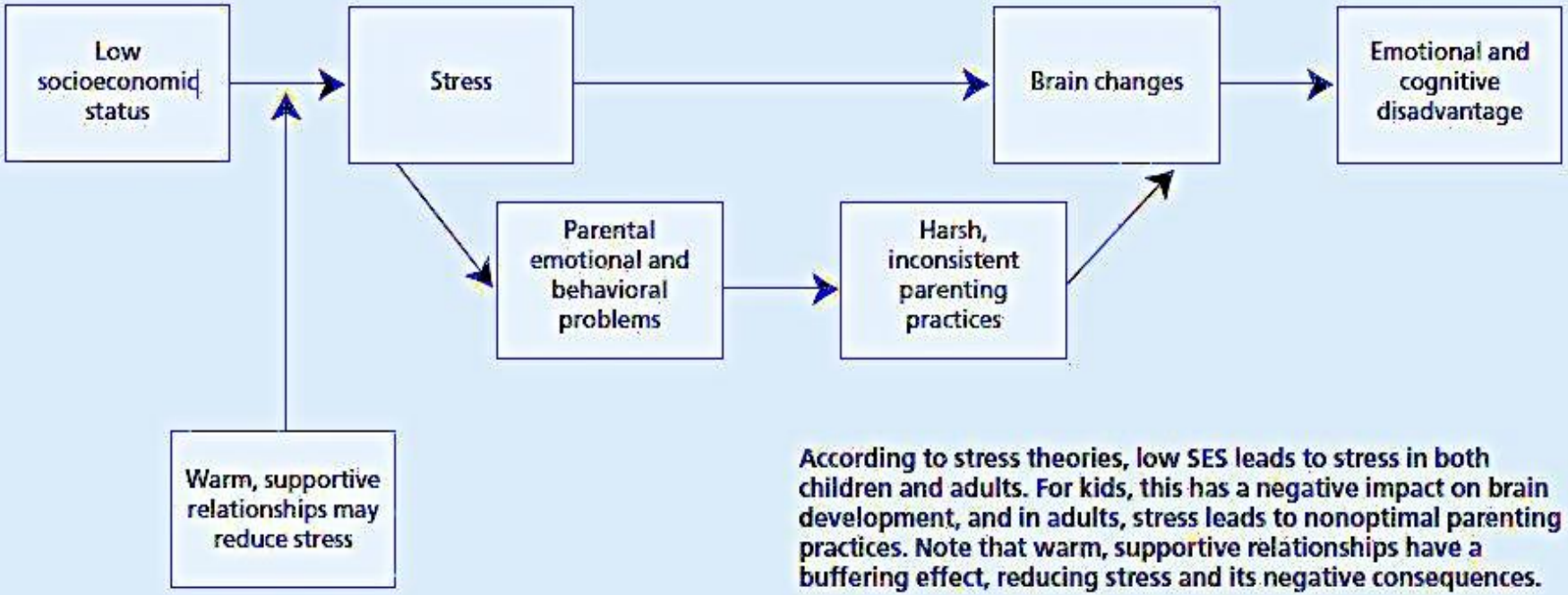
Sources: National Institute of Mental Health; Paul Thompson, Ph.D., UCLA Laboratory of Neuro Imaging

Thomas McKay | The Denver Post

OTHER FRONTAL LOBE FUNCTIONS

- Social Cognition
  - What is perceived in the social world – emotional intelligence
- Perspective taking
  - First person perspective and third person perspective
  - Undergoes "perturbation" during puberty
- Inhibiting responses (thinking before acting)
  - Depletion of self control
- Emotion processing and cognitive appraisal systems

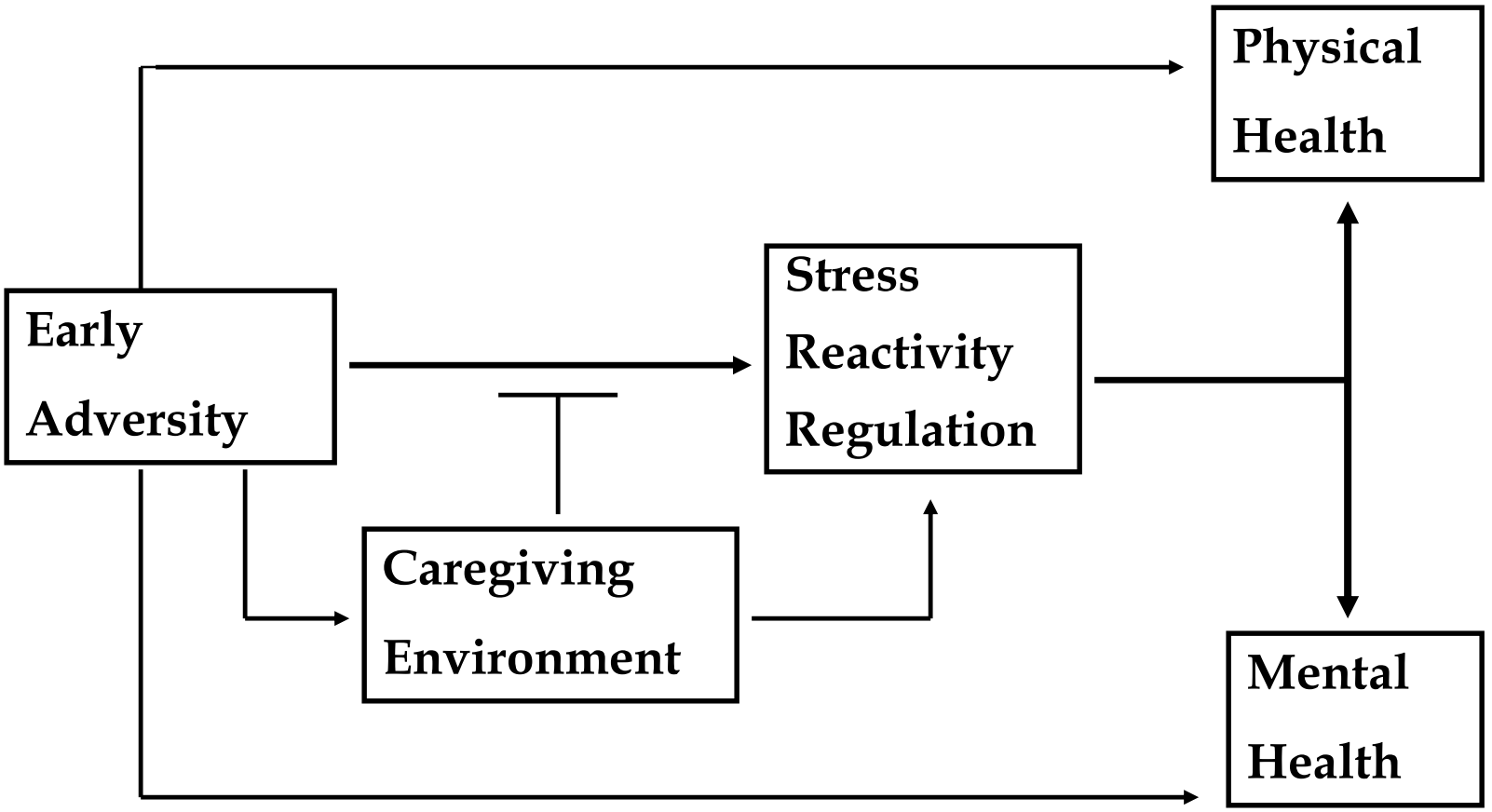
How Chronic Stress Affects Performance



According to stress theories, low SES leads to stress in both children and adults. For kids, this has a negative impact on brain development, and in adults, stress leads to nonoptimal parenting practices. Note that warm, supportive relationships have a buffering effect, reducing stress and its negative consequences.

Stress Sensitive Physiological System

(from Gunner, 2000)



STRESS REGULATION

- Depends on
  - Perceptions of control over stimulation
  - Responsive interactions
- Affected by quality of interactions with adults
  - Nurturance more important than stimulation
  - Short term (group care situations)
  - Group interactions in school
- Important effects on ability to learn in new situations
  - Classrooms
  - New jobs
- Dysregulation difficult to handle in classroom or job setting

VENTRAL STRIATUM

- Brain's "reward center"
- Adolescence is period of strengthening connections between reasoning and emotion-related areas
- When connections weak, stronger rewards required to be motivated
- Leads to greater susceptibility to alcohol and drug dependency….and more willingness to experiment

LEARNING TO CONTROL IMPULSES

- When amygdala and the limbic system within the prefrontal cortex dominate the prefrontal cortex functions– a decrease in reasoned thinking and an increase in impulsiveness
- Immature brains do not handle social pressure, instinctual urges, and other stresses well
- A major part of adolescence is learning how to assess risk and consequences — adolescents are not yet skilled at these tasks
- Self control learned in childhood predicts adolescent risk taking ("snares" according to Moffitt, 2011) that in turn predicts adult health, wealth, marital status and job stability.

REWARD SYSTEM

- Drugs of abuse activate the reward system in the limbic area of the brain—producing powerful feelings of pleasure
- Desire to repeat drug using behavior is strong
- Drugs of abuse can/do exert powerful control over behavior because they act directly on the more primitive, survival limbic structures— override the frontal cortex in controlling adolescent/adult behavior

CONCLUSIONS

BRAINS AND LEARNING

- Learning begins in utero and continues over a long period of time
- The longer a person stays in a particular environment the more committed the neural system is to particular patterns of learning and ways of responding to stress
- To make changes in behavior and learning at later ages, the stimulation must be more intense
- Learning later likely also involves changing the emotional basis for learning, a long process

"Possibly the single most important understanding regarding neurological development in recent years has been the appreciation of the degree to which it is experience driven" (Kuhn, 2006, p. 64)

Brains are Sturdy but They Require Looking After… When Children are Most Vulnerable