# NEUROSCIENCE AND THE BRAIN-EFFECTS OF EARLY READING

# AGENDA

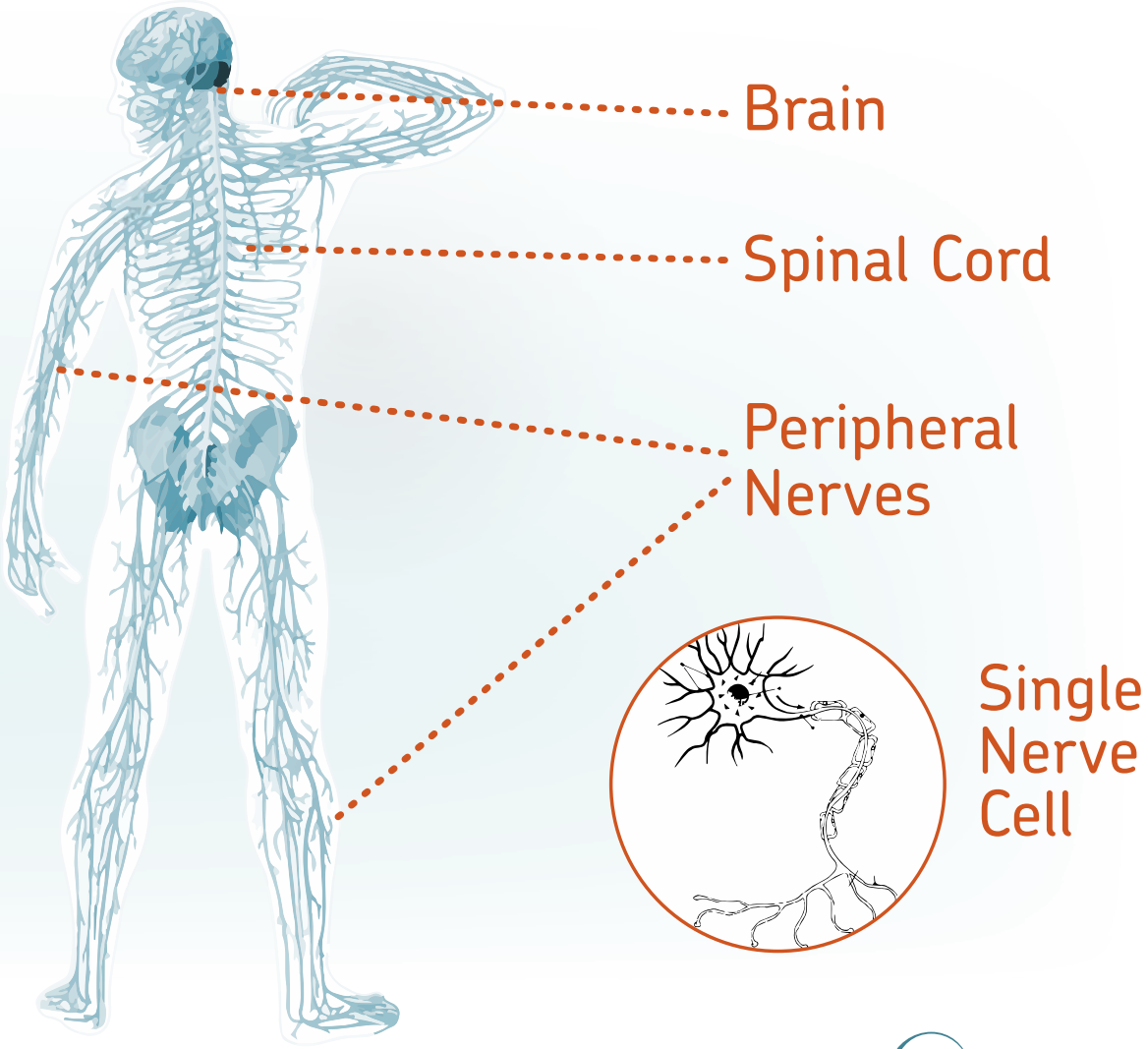
- Brain Development Basics
- The Intersection of Neuroscience and Reading
- Prevention, Intervention and Innovation

# BRAIN DEVELOPMENT BASICS

# HUMAN NERVOUS SYSTEM

Nervous system
ORCHESTRATES BODY
**FUNCTIONS & PERCEPTIONS**

Neuroscience
HELPS US UNDERSTAND WHY
**A C E s**
ARE SO POWERFUL



# THE EARLIEST YEARS ARE CRITICAL FOR HEALTHY BRAIN DEVELOPMENT

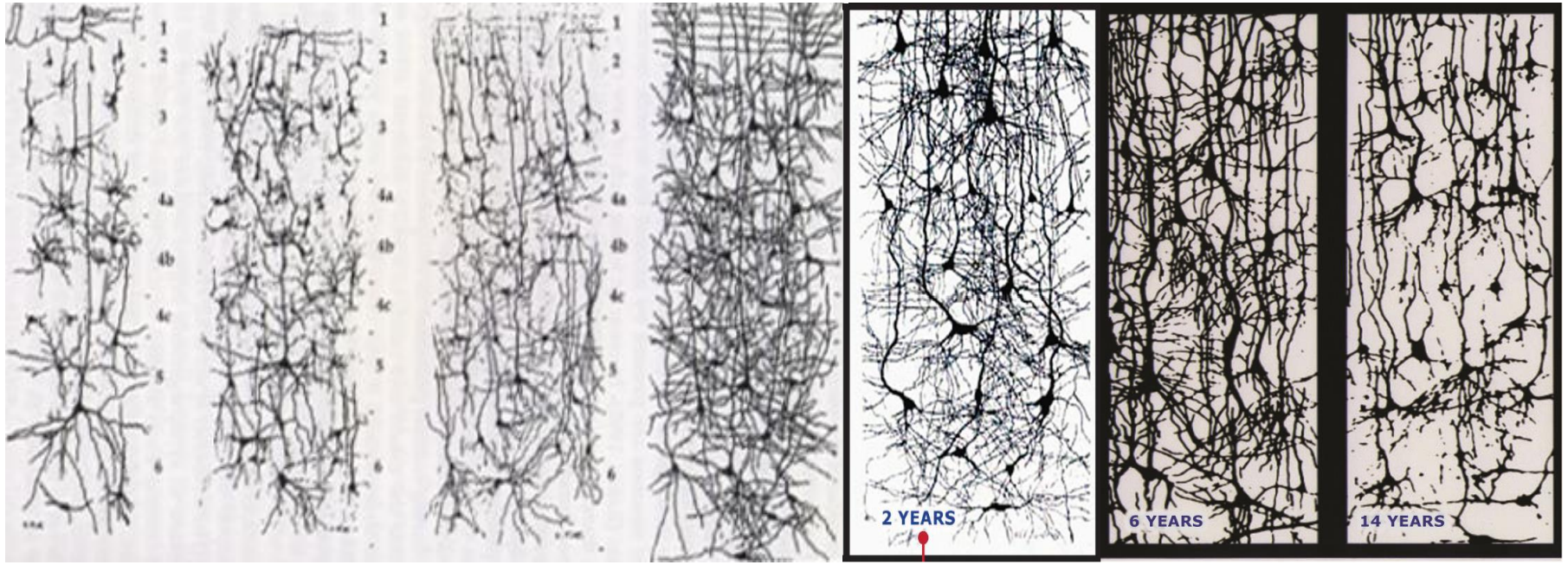
We know from science that brains are built from the bottom up.

During the first three years of life, the brain undergoes its most dramatic development, and children acquire the ability to think, speak, learn, and reason.

The early experiences of young children will shape the architecture of their brains in enduring ways and build the foundation – whether strong or weak – for their future development.

# +1,000,000,000

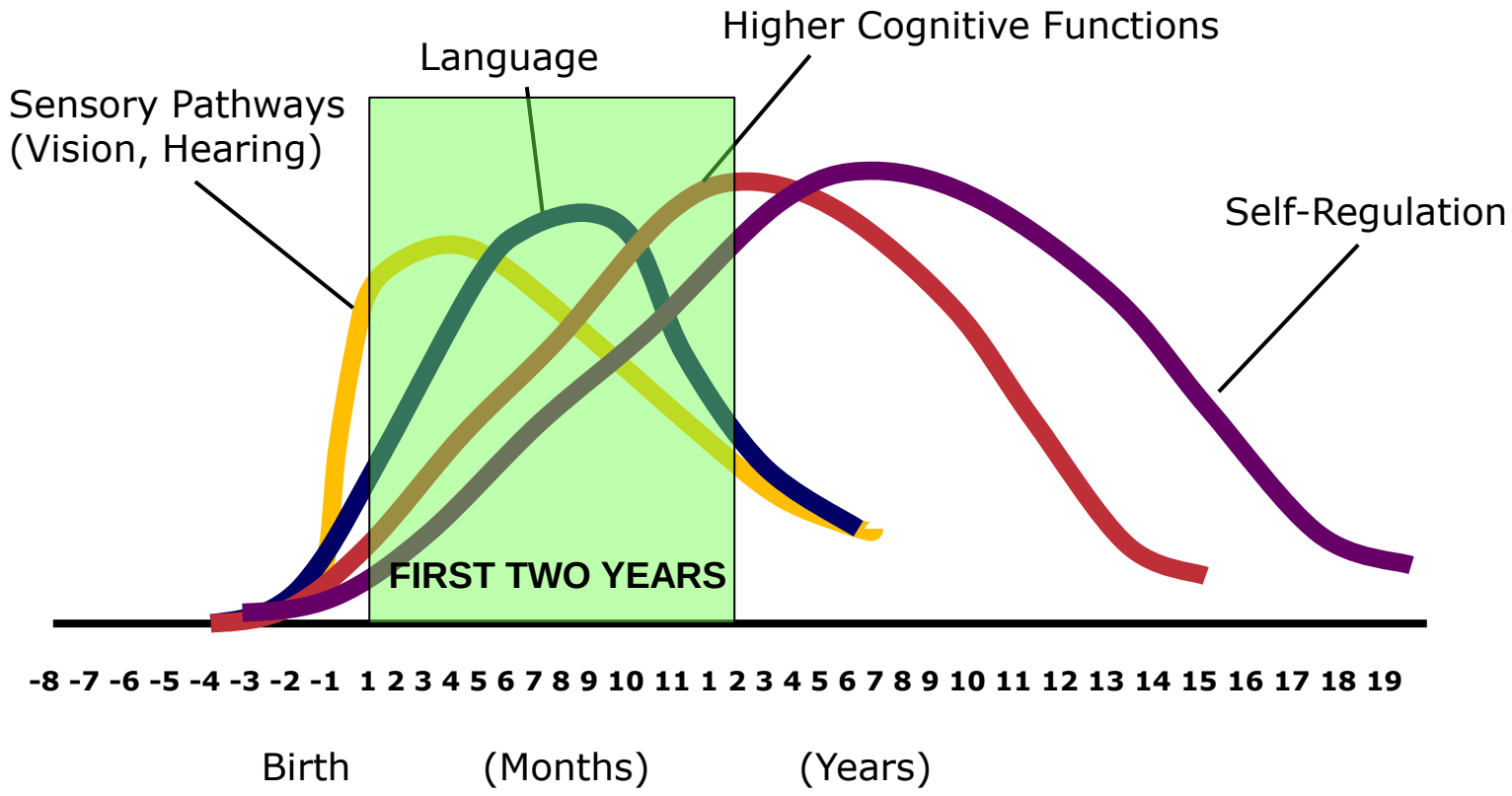
## MORE THAN 1 MILLION NEW NEURAL CONNECTIONS PER SECOND




Images source: Conel, JL. The postnatal development of the human cerebral cortex. Cambridge, Mass: Harvard University Press, 1959.

Brains are built from the bottom up. Like building a house, they need to start with a strong foundation.

# DEVELOPMENT OF NEURAL CONNECTIONS FOR DIFFERENT FUNCTIONS PEAKS IN EARLY YEARS, LAYING CRITICAL FOUNDATIONS FOR LEARNING



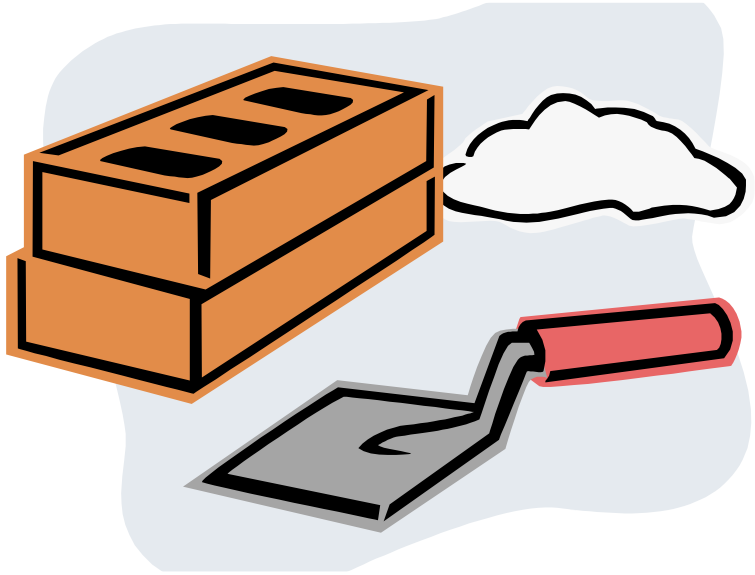

Slide courtesy of Ross A. Thompson

Source: C. Nelson (2000)

# TWO BASIC INGREDIENTS AFFECT BRAIN CONSTRUCTION – WHICH CONNECTIONS ARE STRENGTHENED OR LOST?

- Early **experiences** shape brain architecture. Babies learn through:
  - Quantity, quality, and complexity of language
  - Understanding emotions
  - Eye gaze and imitation
  - Back-and-forth interactions
  - Building one skill on top of another

- Experiences don't just happen. They unfold within **relationships** with trusted adults in safe and respectful **environments**:
  - Teach us who we are and how the world works
  - Affect how we trust and interact with people
  - Give us the confidence to explore and learn



***How we think and understand***
(cognitive development)

+

***How we relate to others***
(social-emotional development)

=

**The *bricks and mortar* of brain construction**

Institute of Medicine. *From Neurons to Neighborhoods*. 2000

# THE FOUNDATION FOR ALL LEARNING THAT FOLLOWS DEPENDS ON THE QUALITY OF THESE "MATERIALS"

## *Strong…*

- ***Connections for important skills are reinforced*** *through nurturing relationships that facilitate enjoyable everyday activities (e.g., talking, playing, reading) and encourage exploration.*

## *Or fragile…*

- ***Important connections are lost*** *when children lacks positive experiences to reinforce them (no language-rich activities, opportunities to play and explore) and has negative experiences with caregivers (e.g., cries are ignored, no one smiles or talks, or talk is harsh) that stifle confidence and curiosity needed for learning.*

CONCEPTION

Danger

Fight
Flight
Freeze

Survive
Worst
Conditions

Childhood Experience

Adaptation

Adult Functioning

Safety

People
Process
Possibility

Survive Best
Conditions –
*Vulnerable in
Worst*


What kind of situations might be a good match for a person who tends to be edgy, hypervigilant, emotionally detached, or quick to act?

# ADAPTATIONS VS EXPECTATIONS

WHEN BIOLOGY
collides
WITH SOCIAL
EXPECTATIONS
we run into
**TROUBLE**

# EFFECTS OF MALTREATMENT

type of maltreatment

GENDER

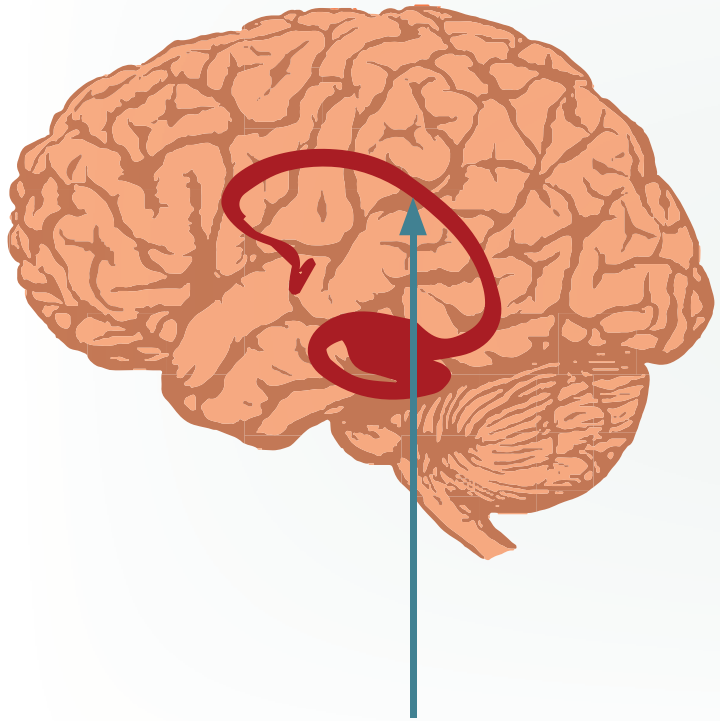
**A G E**

EXPERIENCE & ADAPTATION

sensitive periods

# Cause-Effect

# THE LIMBIC SYSTEM

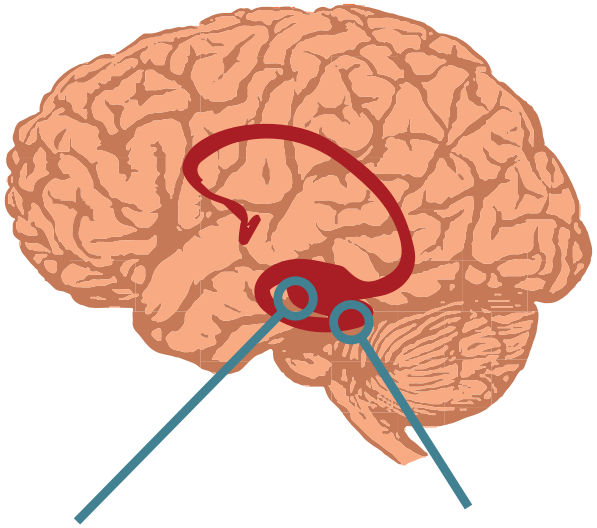



FIGHT
or
FLIGHT

**vital for**
LEARNING
MEMORY
REWARD
REINFORCEMENT

**regulates**
HORMONES
MOOD
HEARTBEAT
SEXUAL BEHAVIOR

# THE HIPPOCAMPUS AND AMYGDALA



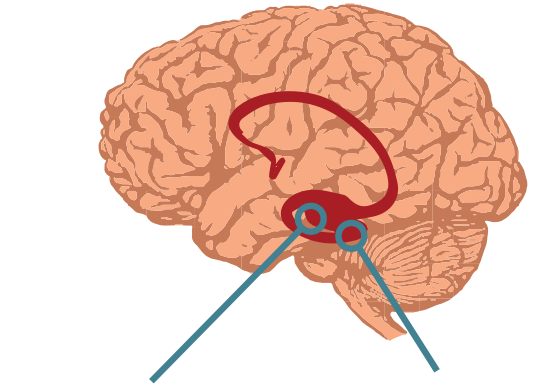
Amygdala Hippocampus

**VITAL for RELATIONSHIPS**

Panic & Fear | Attention | Memory | Social Cues

# MALTREATMENT
## 0-3

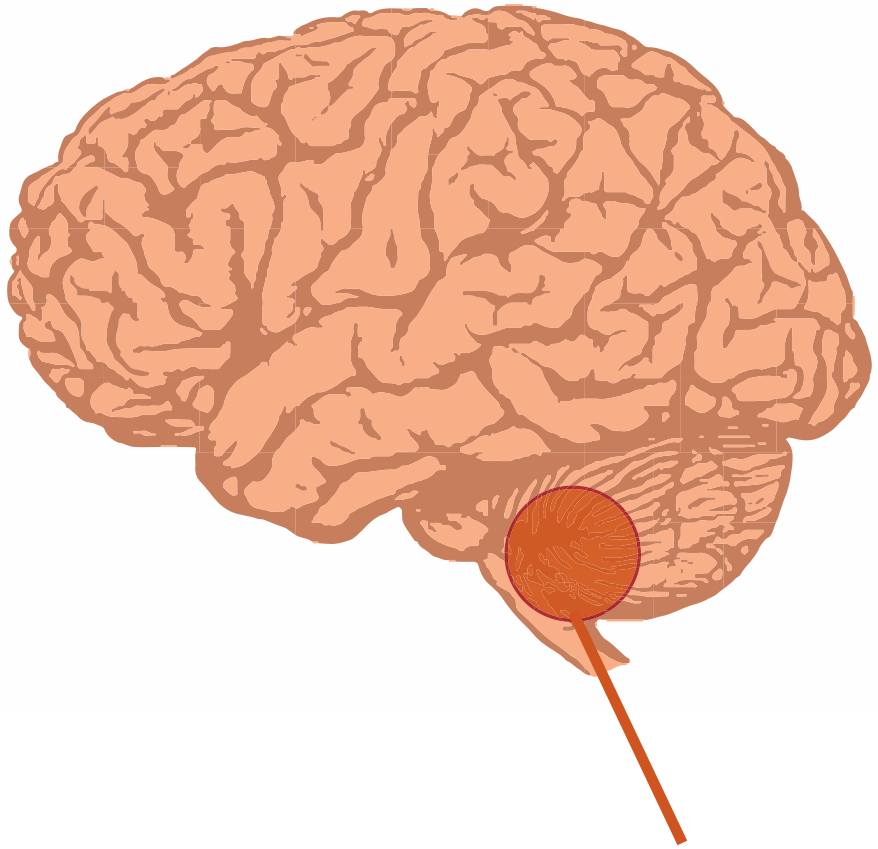
## SEXUAL ABUSE
## Age 0-5




**POSITIVE FEELINGS**

Perception

**Attention**



**ADDICTION**

Attention Problems

**Mental Illness**

# Cerebellar Vermis

# Cerebellar Vermis

## BIOLOGICAL CONNECTIONS

between trauma-induced adaptations in the Vermis

and

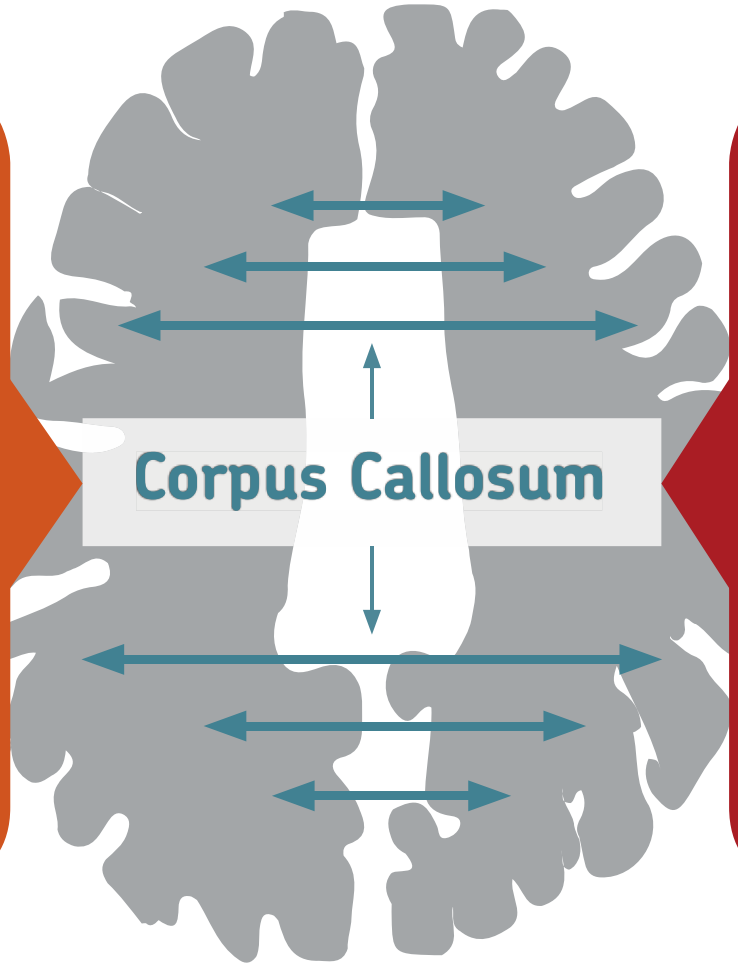
serious and persistent

## MENTAL ILLNESS

# The Corpus Callosum

**LEFT HEMISPHERE**

- Spatial Patterns
- Math Calculation & Fact Retrieval
- Grammar & Vocabulary
- Processing Routine Situations

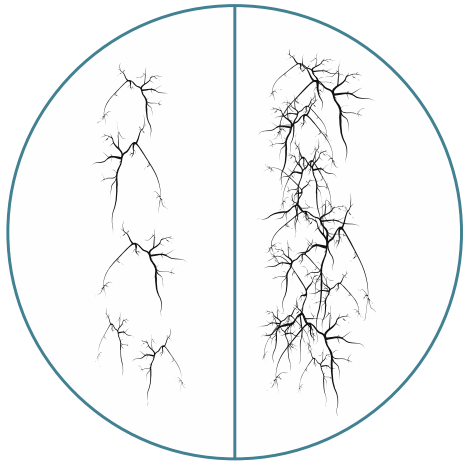


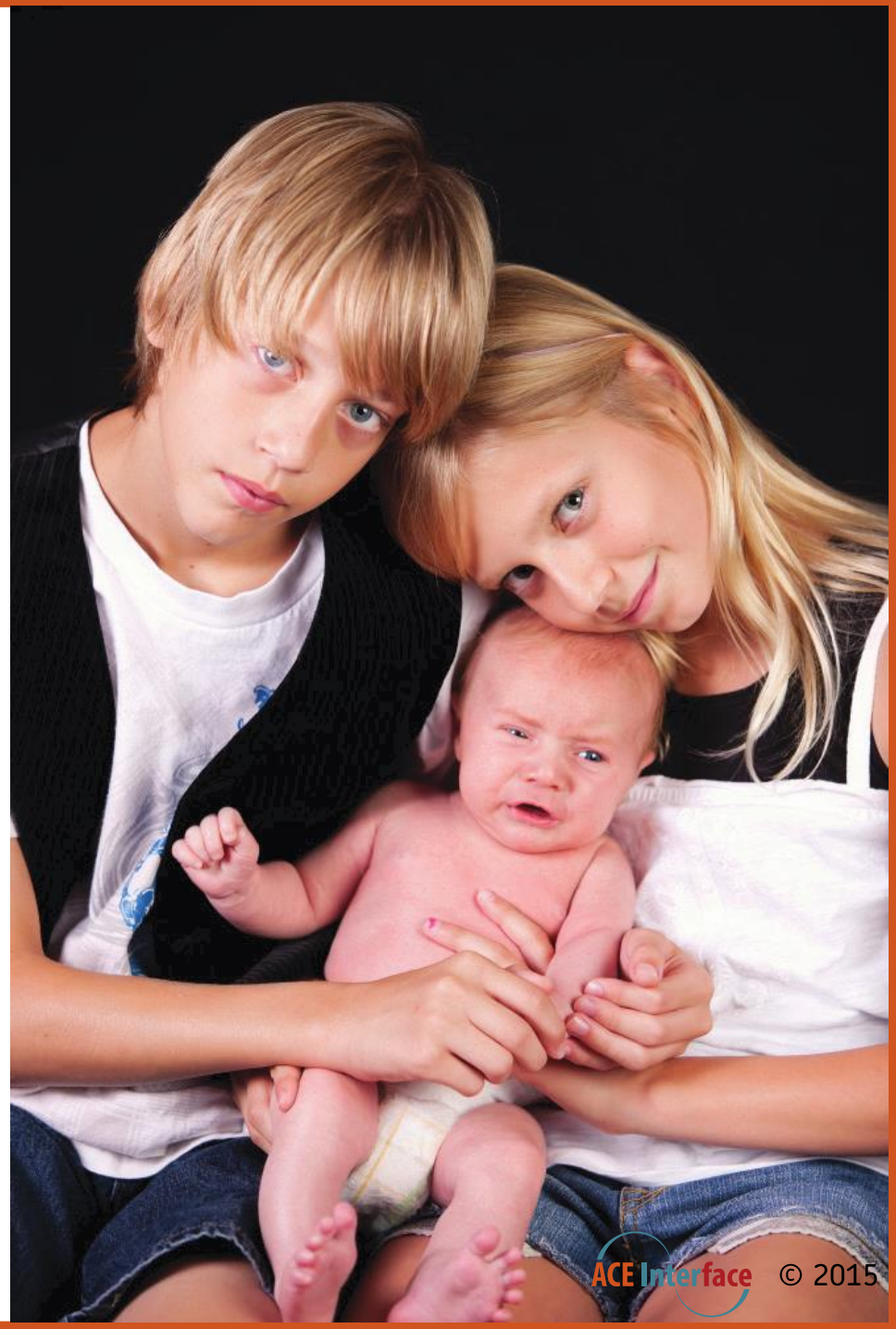

**RIGHT HEMISPHERE**

- Visual & Auditory Processing
- Prosaic Language
- Facial Perception
- Processing Novel Situations

# NEGLECT in Infancy

# SEXUAL ABUSE Age 9-10



# STRESS

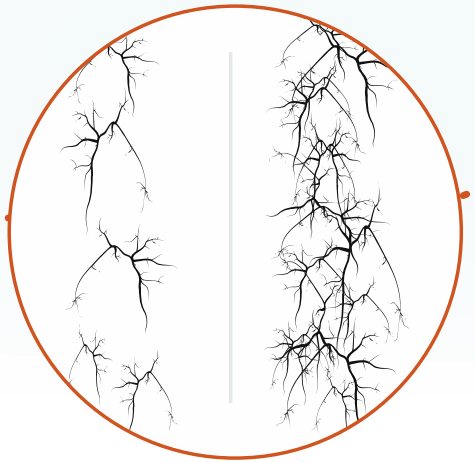
Interpretations Can Differ

set points in place by

EARLY ADULTHOOD

At Birth

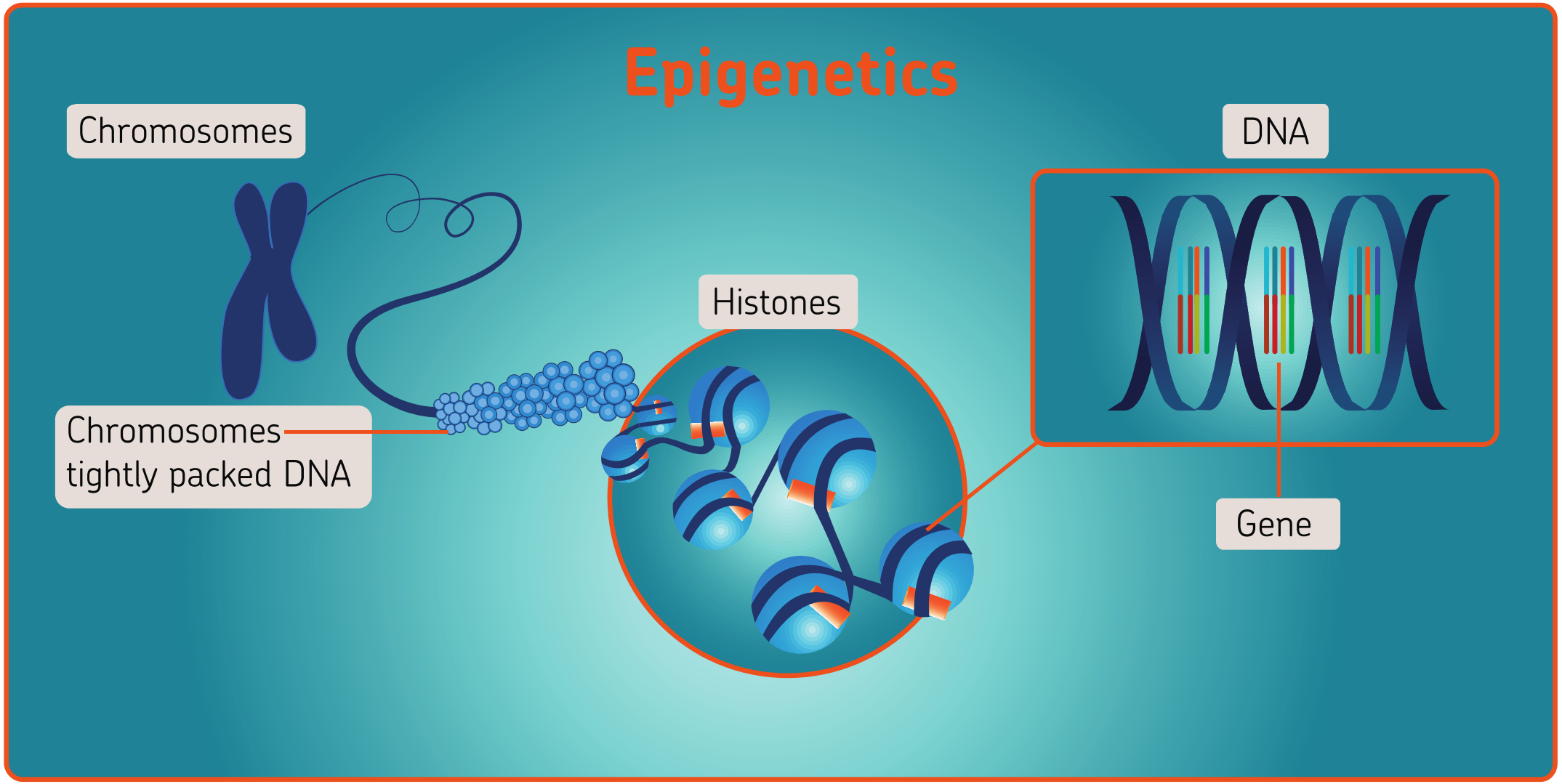
SYNAPTIC DENSITY



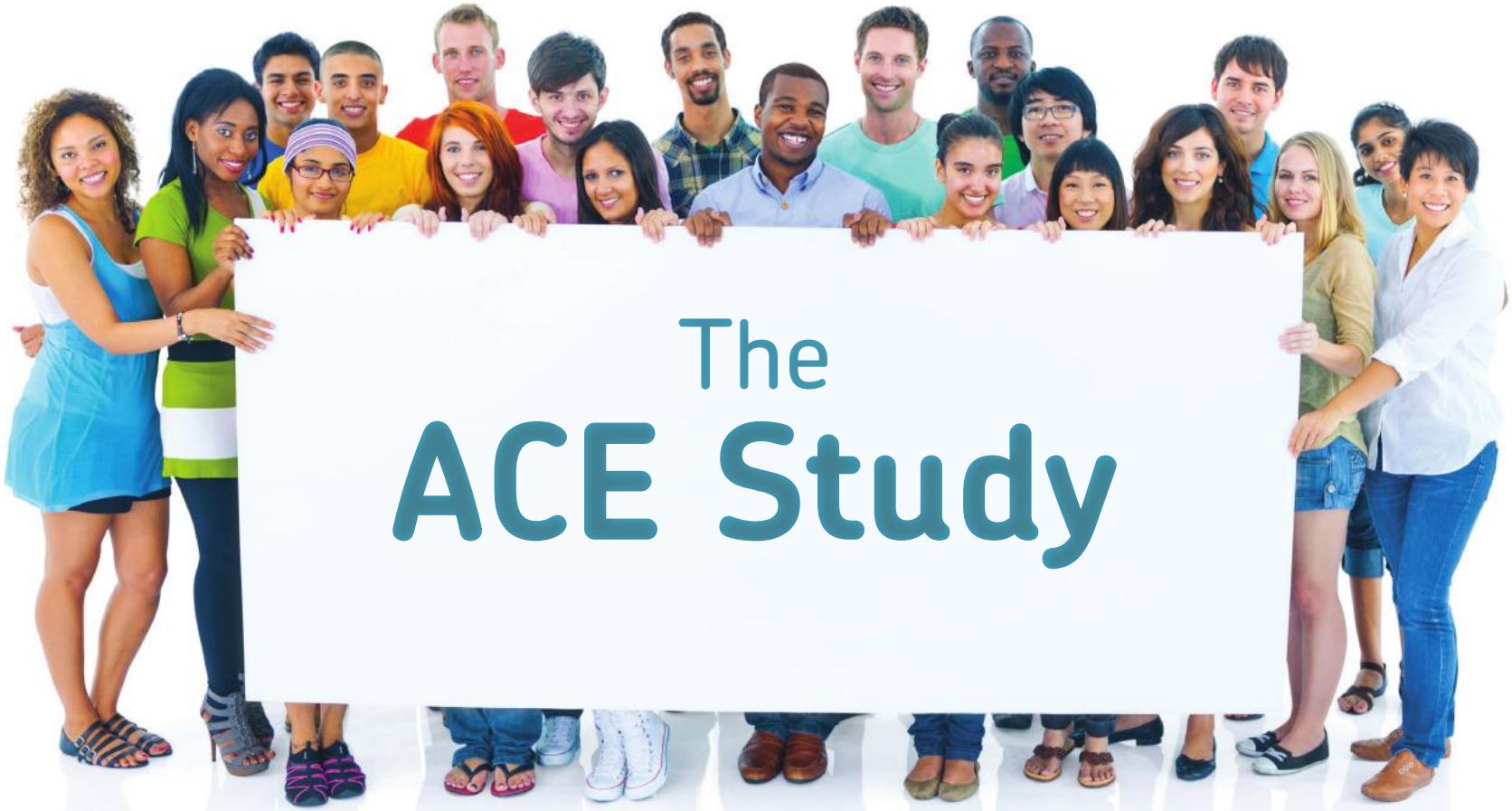
Elementary Age

# Memory of our experiences
# IS STORED IN OUR BODY

# ACEs Influence Gene Expression



# Epigenetics & Enduring Health



# FINDING MORE CONNECTIONS

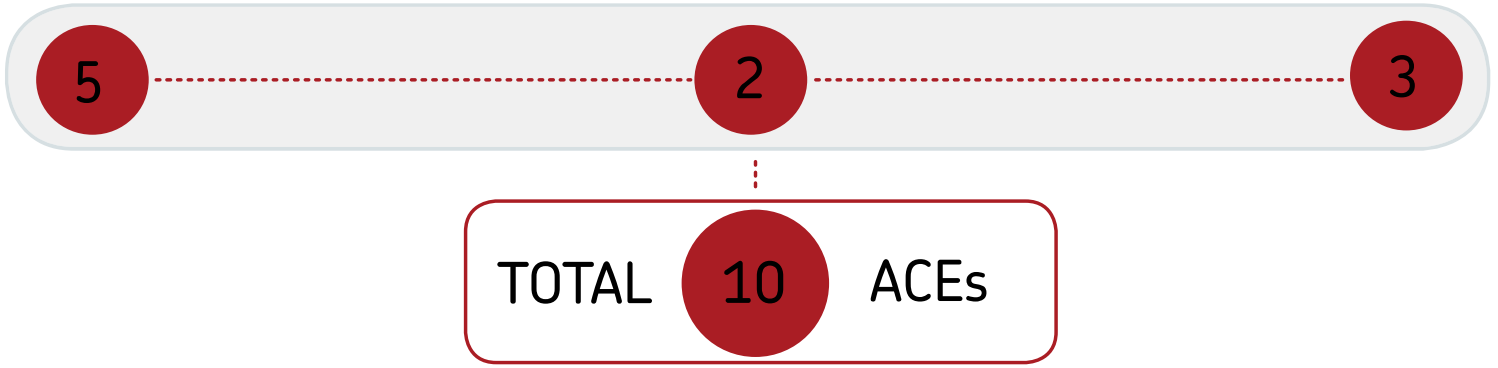
how multiple forms of **childhood adversity** can affect many important **PUBLIC HEALTH PROBLEMS**

# Adverse Childhood Experiences
# ARE COMMON

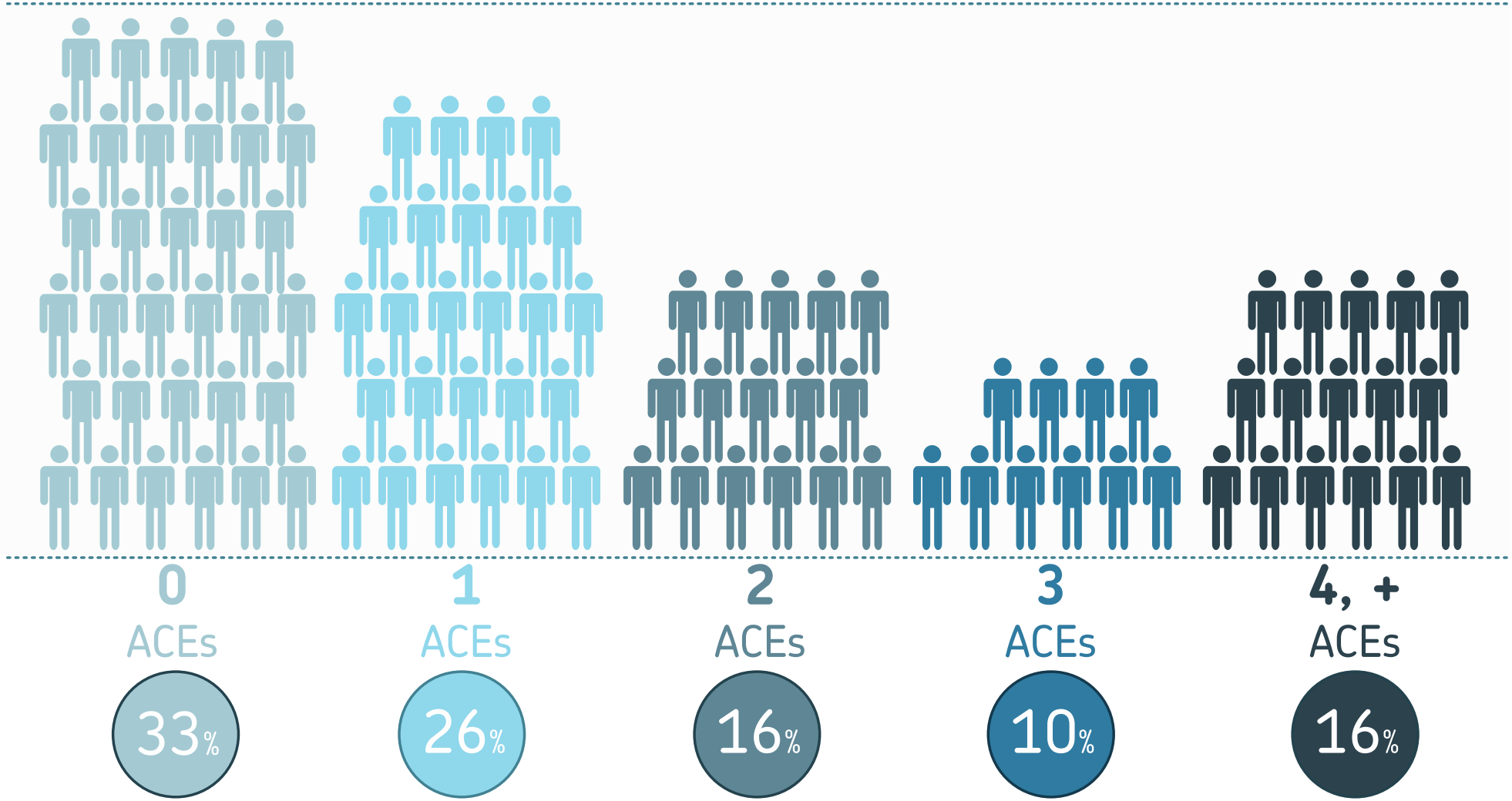
| Household Dysfunction | |
|---|---|
| Substance Abuse | 27% |
| Parental Sep/Divorce | 23% |
| Mental Illness | 17% |
| Battered Mothers | 13% |
| Criminal Behavior | 6% |

| Neglect | |
|---|---|
| Emotional | 15% |
| Physical | 10% |

| Abuse | |
|---|---|
| Emotional | 11% |
| Physical | 28% |
| Sexual | 21% |

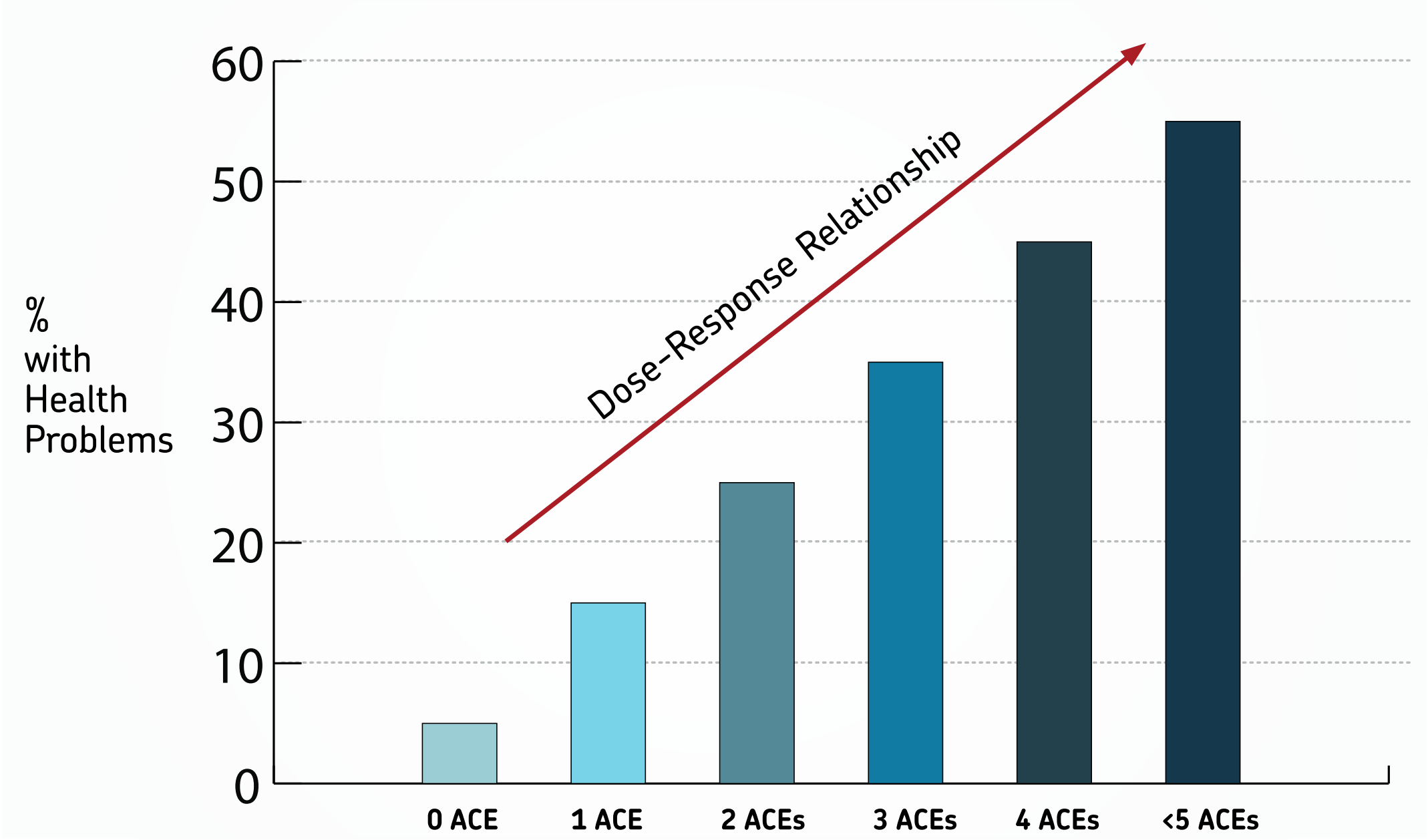


# ACE Score = Number of ACE Categories




ACE Scores Reliably Predict Challenges During the Life Course

# ACE Score and Health Problems

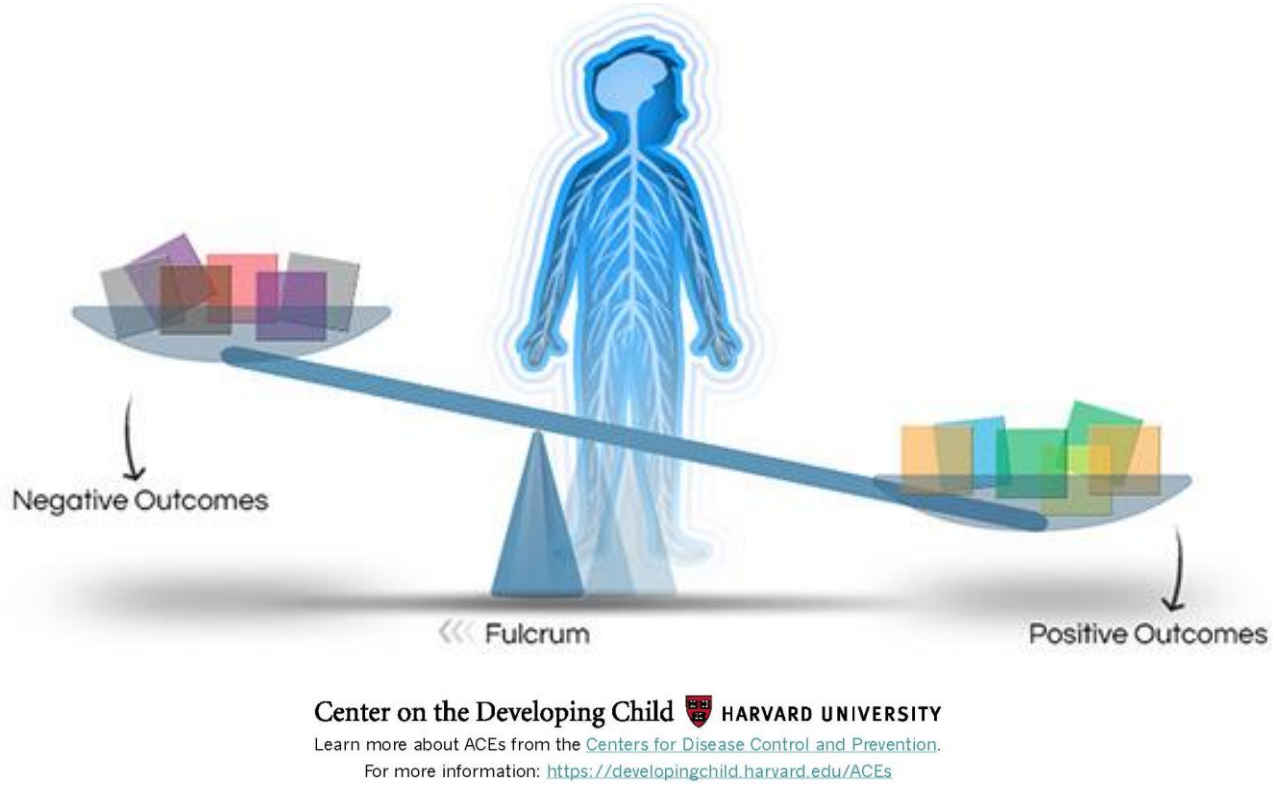


We

have a collective

**CHOICE**

# Resilience


Negative Outcomes
Fulcrum
Positive Outcomes
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Learn more about ACEs from the Centers for Disease Control and Prevention.
For more information: https://developingchild.harvard.edu/ACEs

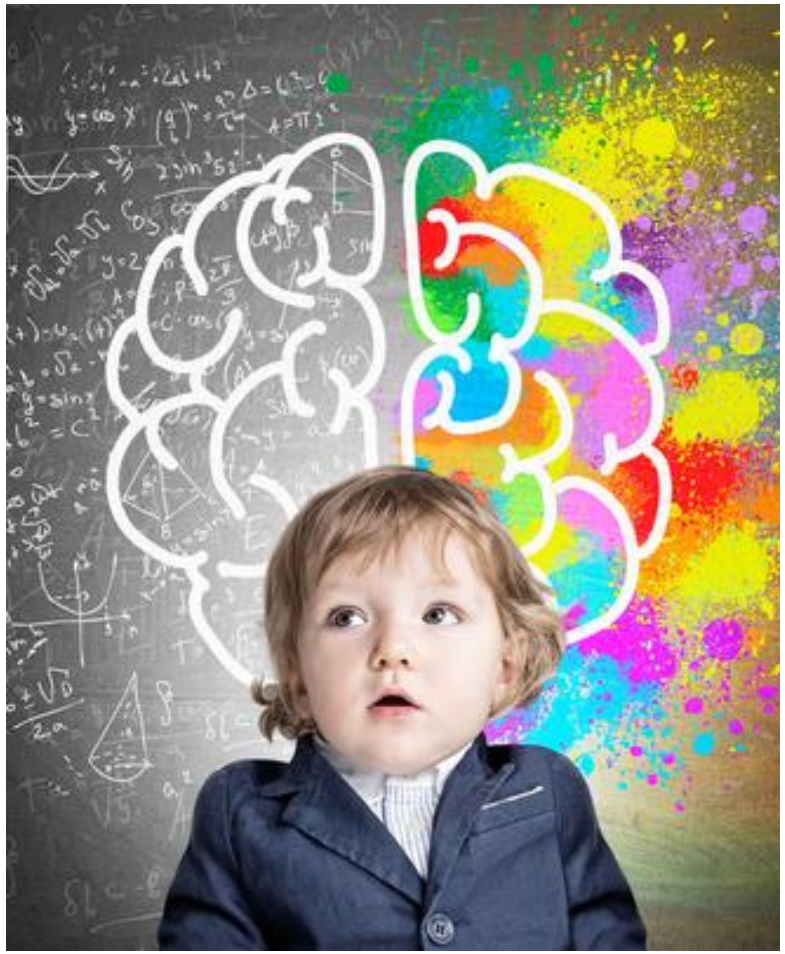
# Resilience

- Resilience requires supportive relationships and opportunities for skill-building.
- Resilience results from a dynamic interaction between internal predispositions and external experiences.
- Learning to cope with manageable threats to our physical and social well-being is critical for the development of resilience.
- Some children respond in more extreme ways to both negative and positive experiences.
- Resilience can be developed at any age, but earlier is better.

# THE INTERSECTION OF NEUROSCIENCE AND READING

- In the debate about nature versus nurture for developing reading skills, neuroscientists have a clear message:  both matter.

- From infancy, children have a neural scaffolding in place upon which environmental factors refine and build reading skills.
  - Babies as young as 3 months old have an underlying infrastructure that helps predict success in reading years later.
  - An infant's brain is programmed to perceive all the different sounds and speech patterns of all languages in the world; this is the result of genetics. But the brain's wiring is shaped in response to the language or languages spoken in the home; this is the result of the environment.
  - Children are not a clean slate for reading experience. Reading depends on experiences and brain connections that develop over time.



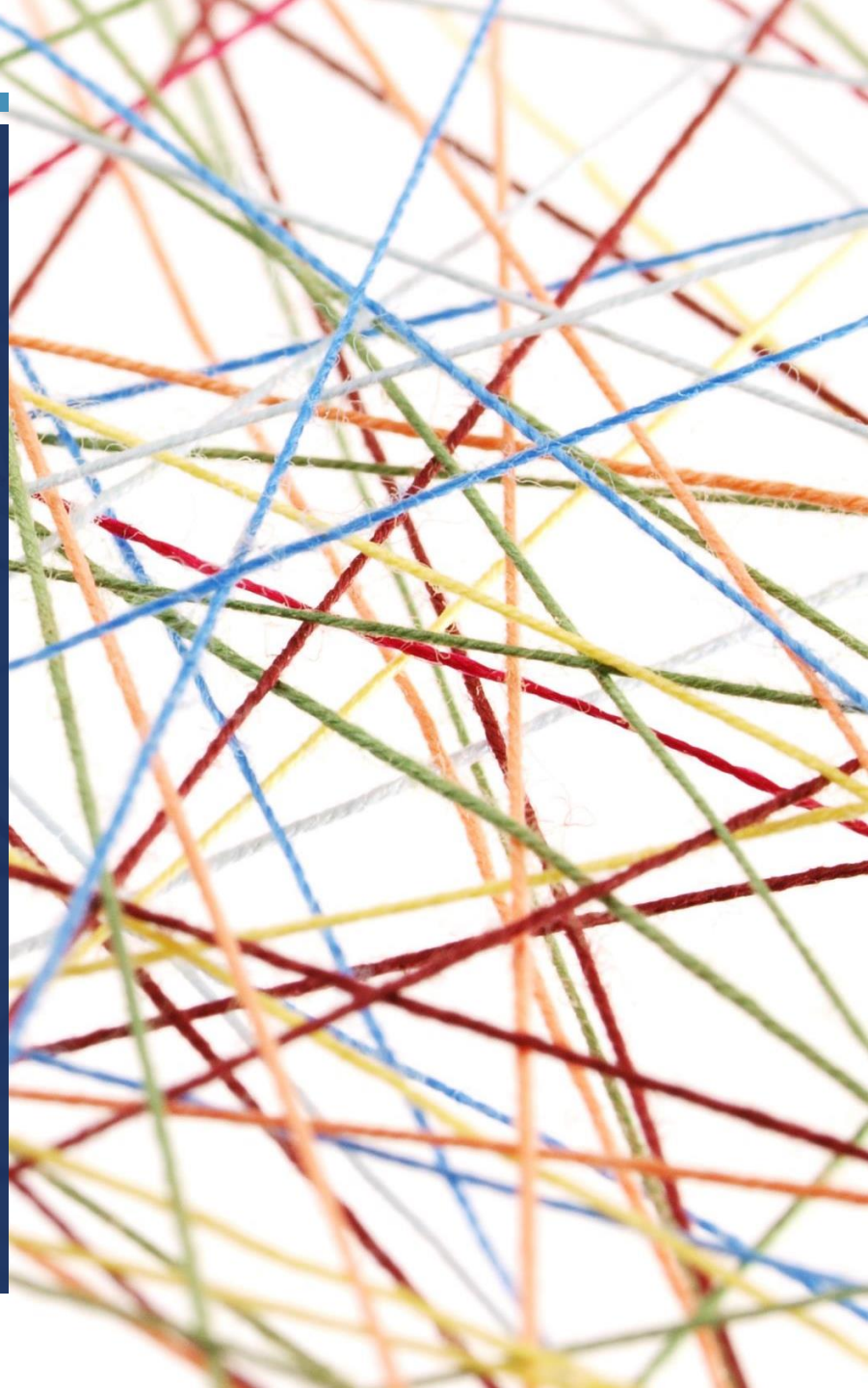
# READING DEPENDS ON BRAIN INTERCONNECTIVITY

- Reading begins with the activation of the brain at the presentation of a printed word.
  - The decoding takes place within 400 milliseconds.
- It is immediately followed by the word identification process.
- Two simultaneous processes come next:
  - Identification of the grammatical function and the grammatical interrelationship of words in a clause or sentence
  - Identification of the indicative intention of words and phrases, and their intentional relationship to the other words in the clause or sentence
- Comprehension, then, takes places beyond the level of a single-word processing. It takes place on the sentence level of neural mechanism.
  - Meaning is not directly extracted from every word on the printed image, but from the combined meaning of individual words, and the context to produce a coherent meaning.

# READING DEPENDS ON BRAIN INTERCONNECTIVITY: ATTENTION, EMOTION AND MEMORY

- A holistic approach to reaching cannot and must not separate the interplay between attention, emotion and cognition!
- Affection or emotional is a cerebral process centralized in the limbic system, especially for attention, problem solving and support relationships.
  - Emotion influences the deployment and operation of attention.
  - Without attention, a reader cannot translate print into speech, and it is crucial for achieving fluent and automatic reading.
  - The emotional networks in the brain facilitate the processing of close relationships and meaning associations – they help children make connections about what they are reading.
- Besides regulating emotion, the limbic system also regulates memory.
  - Some stress is essential for meeting challenges and can lead to better cognition and learning, but beyond a certain level, stress can be counter-productive.
  - Cognitive performance will certainly suffer when there is excessive stress and intensive fear in learning. When we spend too much time on reading drill work, we see an increase in behavioral outbursts and child anxiety that affects learning and retention.
- **This is the key evidence that shows the importance of emotional development for literacy achievement, especially for children and adolescents.**

We must be mindful of the home and extended relationships,  environments and experiences that affect the brain circuits of children. In particular – executive functions, language, visual processing, and social emotional development.



# EXECUTIVE FUNCTION AND SELF-REGULATION

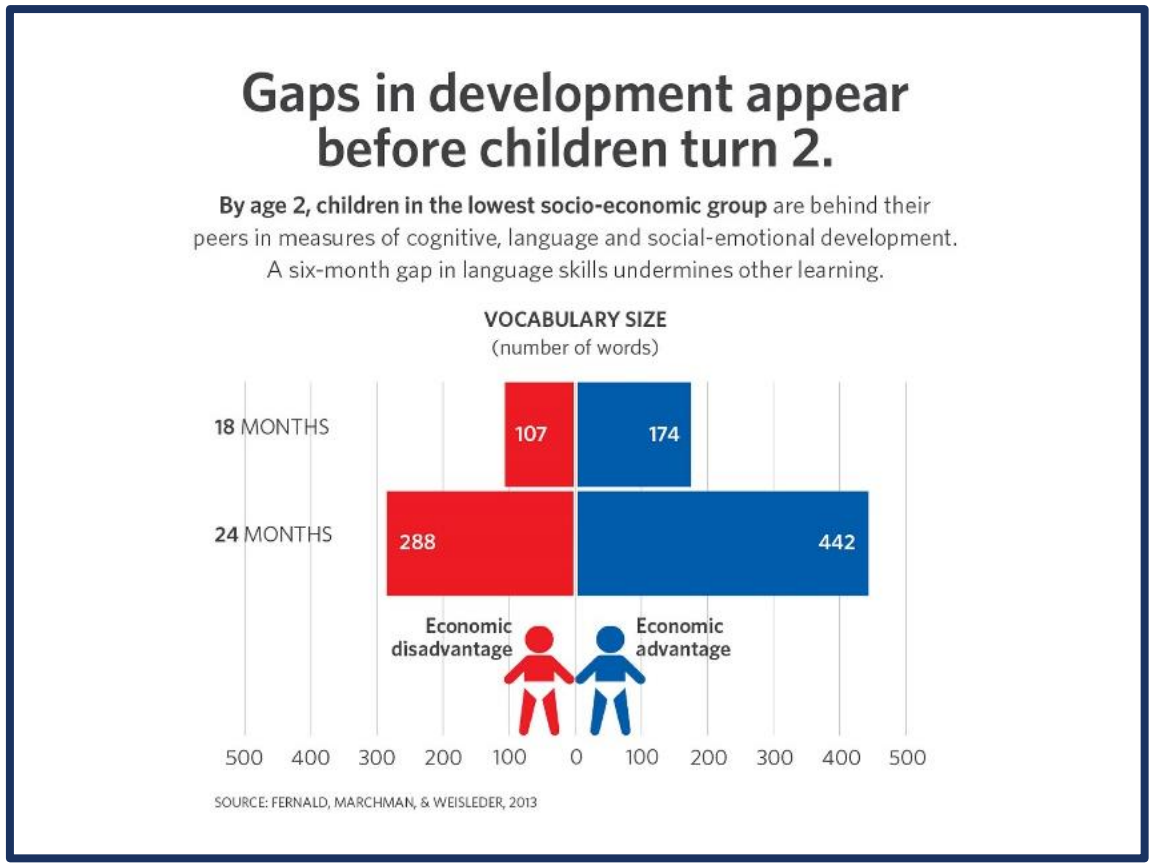
- Executive function and self-regulation skills are like an air traffic control system in the brain.
  - Working memory governs our ability to retain and manipulate distinct pieces of information over short periods of time.
  - Mental flexibility helps us to sustain or shift attention in response to different demands or to apply different rules in different settings.
  - Self-control enables us to set priorities and resist impulsive actions or responses.

- We need these skills at every stage of life, and while no one is born with them, we are all born with the potential to develop them.

# LANGUAGE

- The first 3 years of life, when the brain is developing and maturing, is the most intensive period for acquiring speech and language skills. These skills develop best in a world that is rich with sounds, sights, and consistent exposure to the speech and language of others.
- Human language involves both receptive and productive use.
  - Receptive language use occurs during the comprehension or understanding of words and sentences.
  - Productive language use involves idea generation and the articulation of words in speech.
- Children tend to produce their first words sometime between nine and twelve months.
  - 6-month-olds recognize the basic sounds of their native language.
  - One-year-olds have about 5 words in their vocabulary on average
  - Two-year-olds have an average vocabulary size of more than 150 words
  - Six-year-olds possess a vocabulary of about 14,000 words
  - Adults have an estimated average of 40,000 words in their working vocabulary at age forty.
- One of the best predictors of a child's vocabulary development is the amount and diversity of input the child receives.

# DIFFERENT OPPORTUNITIES = DISPARITIES IN DEVELOPMENT THE "WORD GAP" IS ONE EXAMPLE




- Strong language skills at age 3 predict academic success in grade 3. When children lack this key to learning, they cannot easily master academic content presented in school.

# VISUAL PROCESSING

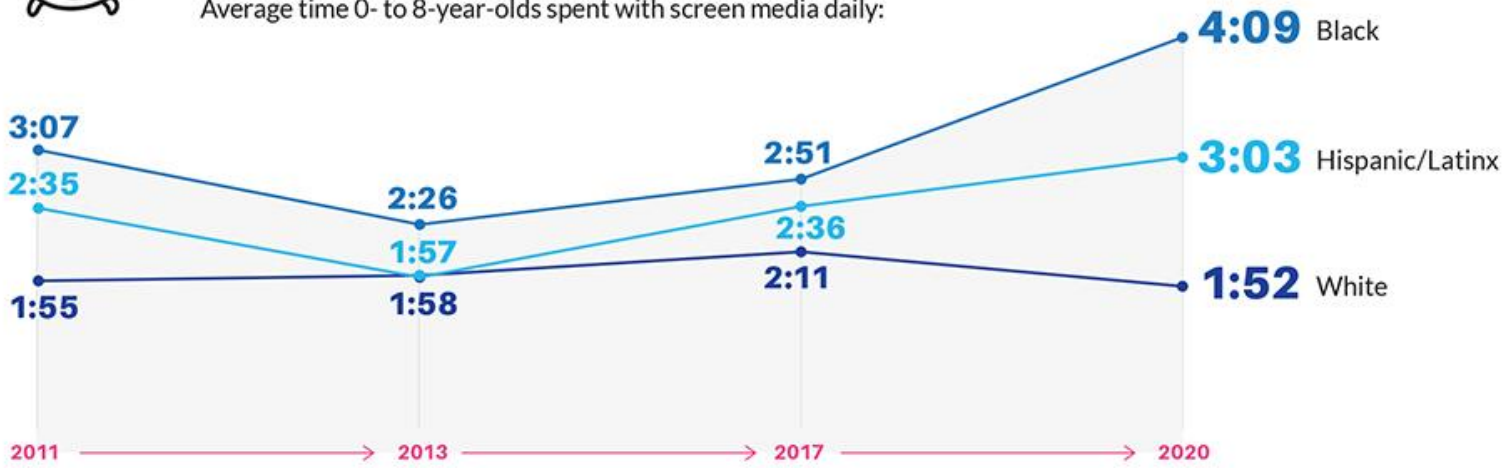
- Visual processing skills are what our brain uses to make sense of what we see in the world around us. Good visual perceptual skills are important for many every day skills such as reading, writing, completing puzzles, cutting, drawing, completing math problems, dressing as well as many other skills.
- Visual processing is not the same as visual acuity, which refers to how clearly a person sees. A person can have perfect vision and still have problems with visual perceptual processing.
  - Attention, discrimination, memory, relationships, constancy, closure
- Prenatal development yields a visual system that is richly structured and organized. All neurons are in place, and connections with other sensory systems are present and partly refined. At birth, babies can't see as well as older children or adults. Their eyes and visual system aren't fully developed.
  - **Newborns:** Can see large shapes and faces, as well as bright colors.
  - **By 3 to 4 months:** Most babies can focus on a variety of smaller objects and tell the difference between colors (especially red and green).
  - **By 4 months**: A baby's eyes should be working together. This is when babies begin to develop depth perception (binocular vision).
  - **By 12 months:** A child's vision reaches normal adult levels while he continues to learn about and understand what he sees.

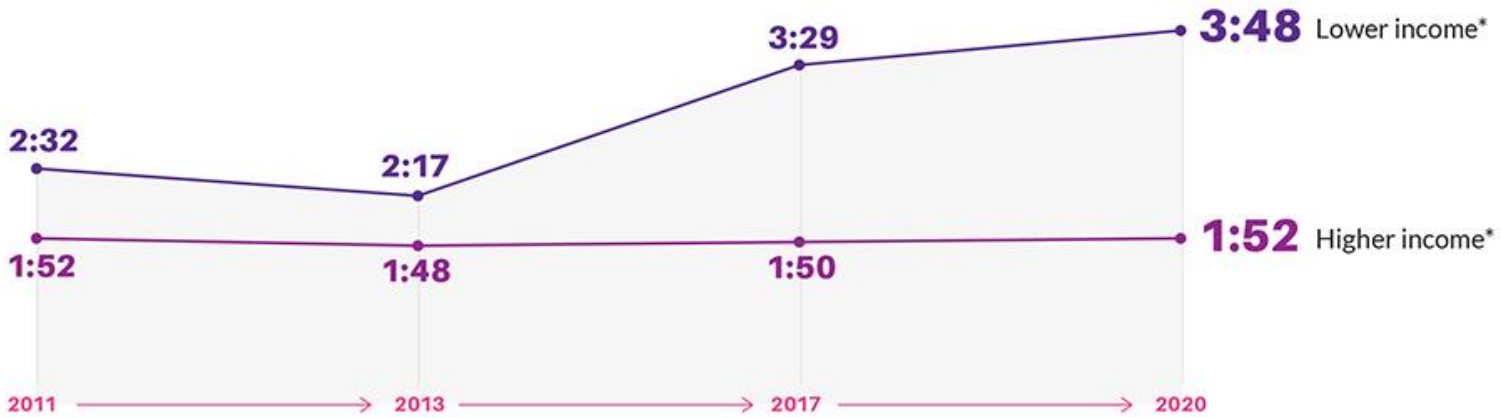
# SCREEN TIME

- The American Academy of Pediatrics recommends limits on screen time:
  - Discourages media use by children younger than 18-24 months,
    - Average 49 minutes/day
  - Limits screen time to 1 hour a day of high-quality programming for children 2-5
    - Average 2 hours and 30 minutes per day
  - Limits screen time to 1 to 1.5 hours per day for children 6-10
    - Average 3 hours and 5 minutes per day
- Screen-based media use beyond the American Academy of Pediatrics guidelines was associated with lower language and emergent literacy skills in prekindergarten children.
- The basic pattern that has been found in dozens of studies is that children learn better from a person who is with them face-to-face than from a person on a screen, even if it's the exact same person doing the exact same thing.
  - Listening to stories through screens is not similar to joint reading when seeking to nurture the developing brain.
- Differences in screen time by race/ethnicity and income continue to expand.

# Differences in screen time by race/ethnicity and income continue to expand.

Average time 0- to 8-year-olds spent with screen media daily:



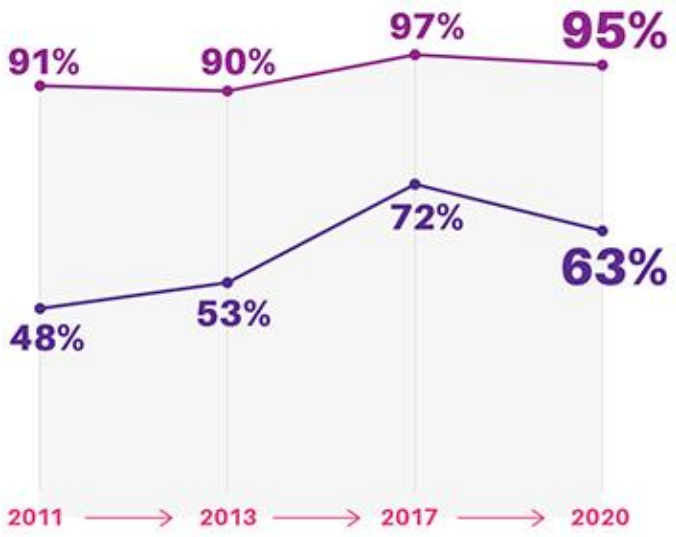




Rideout, V., & Robb, M. B. (2020). *The Common Sense census: Media use by kids age zero to eight, 2020*. San Francisco, CA: Common Sense Media.

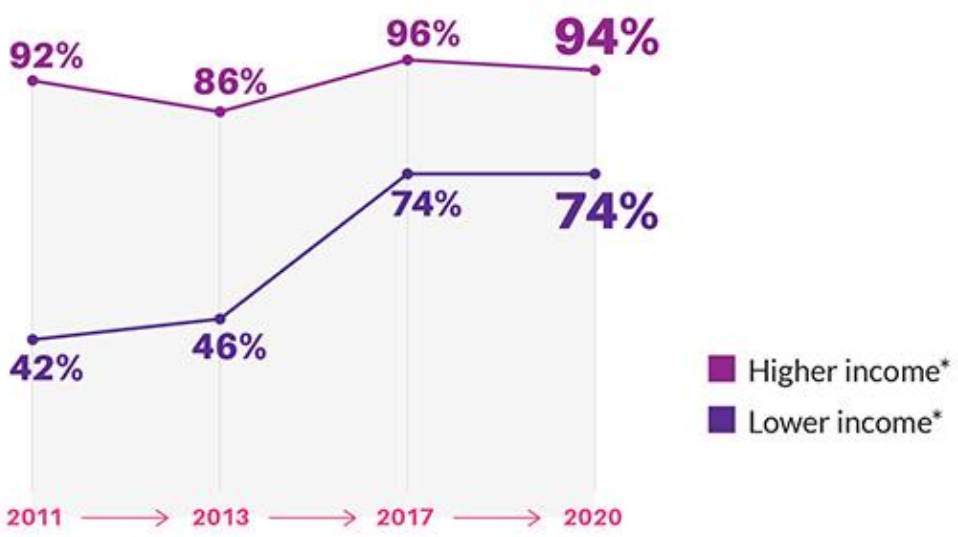
common sense

# Children need computers and internet access more than ever, but many in lower-income families still lack access at home.

Home **computer** access among 0- to 8-year-olds:




Home **internet** access among 0- to 8-year-olds:




Higher income*
Lower income*

* "Lower income" is less than $30,000 a year; "higher income" is more than $75,000 a year.

Rideout, V., & Robb, M. B. (2020). *The Common Sense census: Media use by kids age zero to eight, 2020*. San Francisco, CA: Common Sense Media.

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# READING DEPENDS ON BRAIN INTERCONNECTIVITY

- It is unclear how or why some individuals develop reading difficulties, and whether there are subgroups of children with reading difficulties due to distinct casual factors.

- Successful reading has many components – oral language skills to word reding to comprehension. Difficulties may arise in any one of those components or subsystems. The origins of those difficulties may be clear or unclear.

# STRATEGIES THAT USE NEUROSCIENCE TO FOSTER READING SKILLS

# PRINCIPLES

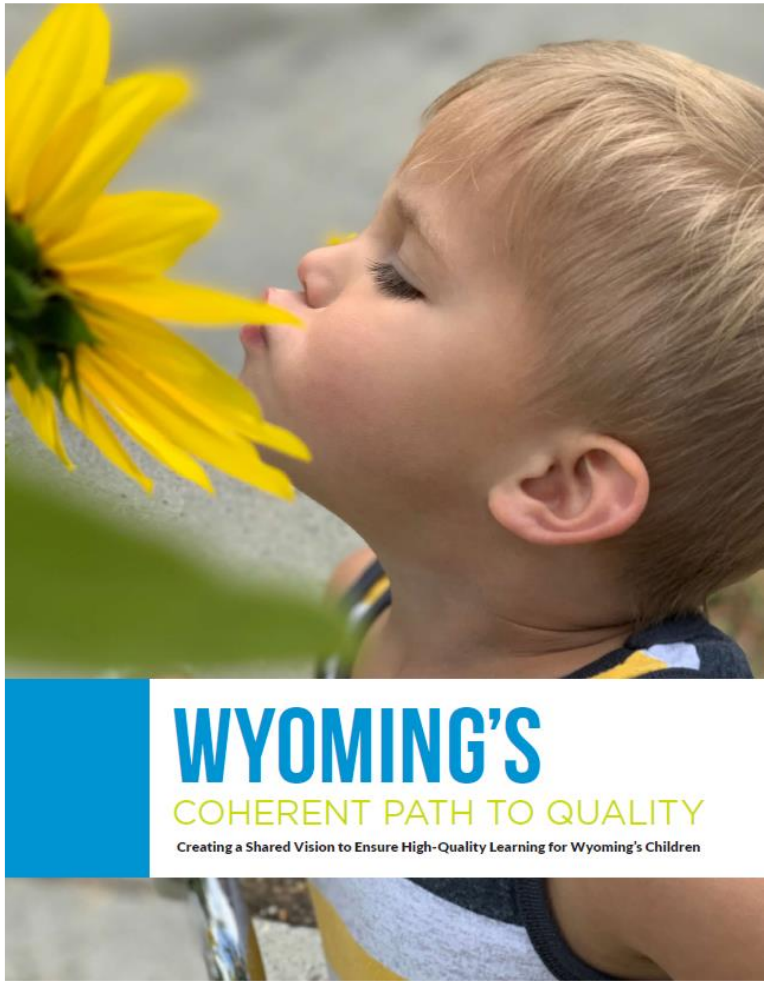
- Recognize the role that families and communities play in helping children grow, develop and learn.
- Start early – before birth! But recognize that brains develop from the bottom up and over time – do not rush!
- Invest in quality.
- Reach the populations who are most at-risk or vulnerable.
- Both prevention and intervention is necessary to support young readers.

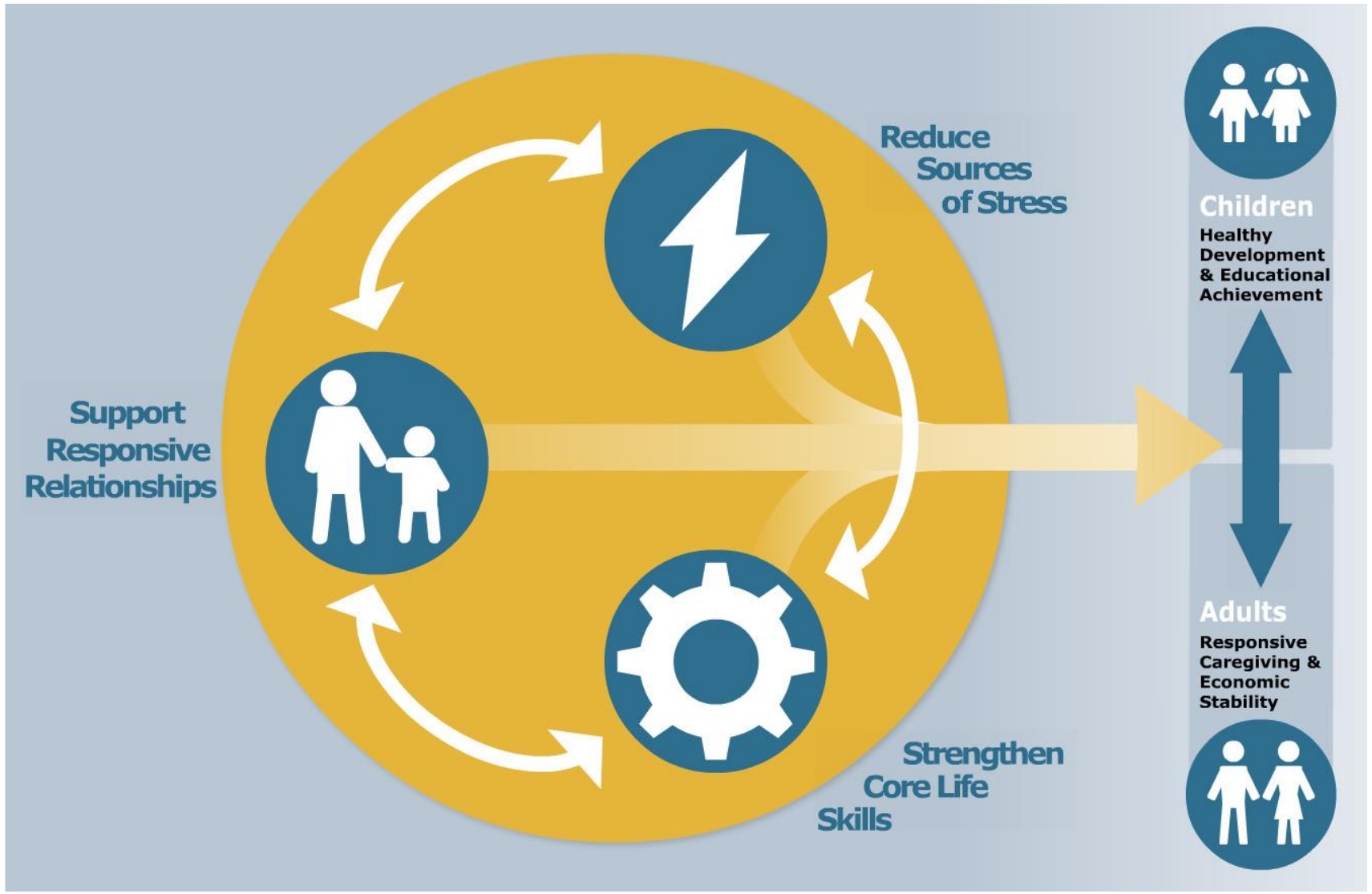
# CONNECT HEALTH AND LEARNING

- Adult-child relationships, environmental exposures and early experiences influence child well-being
  - The conditions and environments in which children develop affect lifelong health as well as education achievement
- The foundations of health and learning are built early
  - What happens prenatally and during the first few years after birth can have substantial effects on shot- and long-term outcomes in learning, behavior, and physical and mental health

# PROVIDE THE RIGHT INGREDIENTS UP FRONT

- **Relationships and Interactions**
  - Authentic
  - Responsive
  - Reciprocal
  - Consistent
- **Emotional and Physical Environments**
  - Safe
  - Respectful
  - Predictable
  - Accessible
- **Experiences**
  - Meaningful
  - Exploratory
  - Actionable



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Learn more about ACEs from the Centers for Disease Control and Prevention.

For more information: https://developingchild.harvard.edu/ACEs

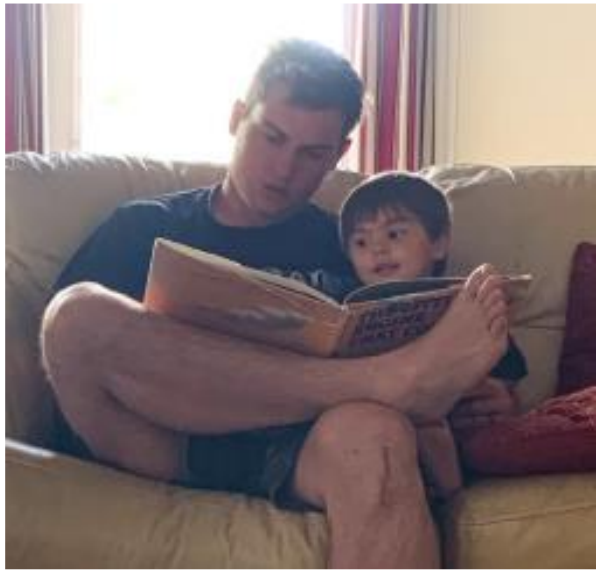
# EXECUTIVE FUNCTION KEY IDEAS

- Provide the support that children need to build executive function skills at home, in early care and education programs, and in other settings.
- Growth-promoting environments provide children with "scaffolding" that helps them practice necessary skills before they must perform them alone.
  - Adults can facilitate the development of a child's executive function skills by establishing routines, modeling social behavior, and creating and maintaining supportive, reliable relationships.
- It is also important for children to exercise their developing skills through activities that foster creative play and social connection, teach them how to cope with stress, involve vigorous exercise, and over time, provide opportunities for directing their own actions with decreasing adult supervision.
  - Initiative and curiosity
  - Persistence and attention
  - Cooperation

# LANGUAGE DEVELOPMENT KEY IDEAS

- Language development is the key to learning across all domains.
- Children need opportunities to grow their language abilities, learn new vocabulary, and better communicate their thoughts and ideas.
  - Receptive language
  - Expressive language
- Dual language learners and those who use alternative forms of communication (sign language or communication devices) need to have opportunities to develop language in the same way as typical language learners.
- Talk. Read. Sing. Play. Create.

# LITERACY KNOWLEDGE AND SKILLS KEY IDEAS



- Literacy knowledge and skills lay the foundation for reading and writing.
- Book appreciation and knowledge.
  - The interest in books and their features, and the ability to understand and get meaning from stories and information from books and other texts.
- Print concepts and conventions.
  - The concepts about print and early decoding (identifying letter-sound relationships).
- Phonological awareness.
  - An awareness that language can be broken into words, syllables and smaller pieces of sound.
- Alphabetical skills.
  - The names and sounds associated with letters.
- Early writing.
  - The familiarity with writing tools, conventions and emerging skills to communicate through written presentations, symbols and letters.

# SOCIAL AND EMOTIONAL DEVELOPMENT KEY IDEAS

- Social and emotional development refers to the skills necessary to foster secure attachment with adults, maintain healthy relationships, regulate one's behavior and emotions, and develop a healthy concept of personal identity.
- Predictive of favorable social, behavioral and academic adjustment into elementary school, middle childhood and adolescence.
- Social relationships
  - The healthy relationships and interactions with adults and peers.
- Self-concept and self-efficacy
  - The perception that one is capable of successfully making decisions, accomplishing tasks, and meeting goals.
- Self-regulation
  - The ability to recognize and regulate emotions, attention, impulses and behavior.
- Emotional and behavioral health
  - A healthy range of emotional expression and learning positive alternatives to aggressive or isolating behaviors.

# RECAP

- Development is a highly interactive process, and life outcomes are not determined solely by genes. Experiences matter!
- Adversity disrupts brain development. We must reduce sources of stress for children and adults alike.
- Resilience requires relationships.
- While attachment to their parents are primary, young children benefit significantly from relationships with other responsive caregivers both within and outside the family.
- Brains are built from the bottom-up and over time. Reading requires the brain to work in a richly coordinated fashion within and across the body. Pushing reading fluency work on young children is akin to asking a baby to run. The brain may not be ready!
- Executive functions, language, visual processing and social emotional development in young children lay a foundation for later reading success. That development in inextricably linked to other development, and relies on relationships and interactions, physical and emotional environments, and experiences.

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# THANK YOU