The Science of Learning

MISCONCEPTIONS,
EVIDENCE FOR INNOVATION,
AND PRINCIPLES IN PRACTICE

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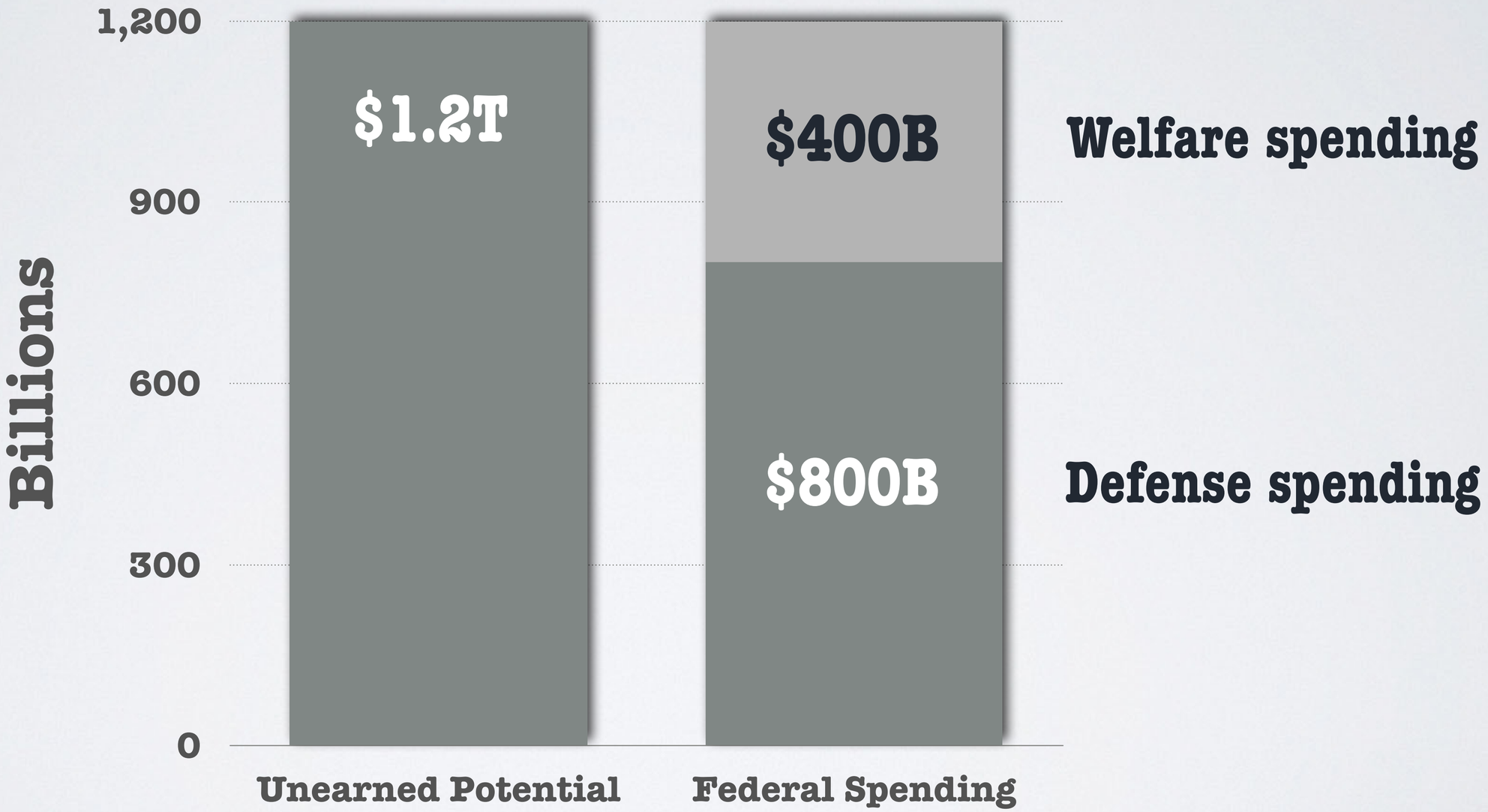
INSTITUTE FOR
APPLIED NEUROSCIENCE
BRAIN SCIENCE FOR GOOD


1 student drops out every 26 sec
138 students will drop out during this talk
Each will make $200,000 less than their high school graduating peers
Each will make $1 million less than their college graduating peers
That's $138 million in unearned potential lost, during this talk alone

1,200,000 students drop out every year

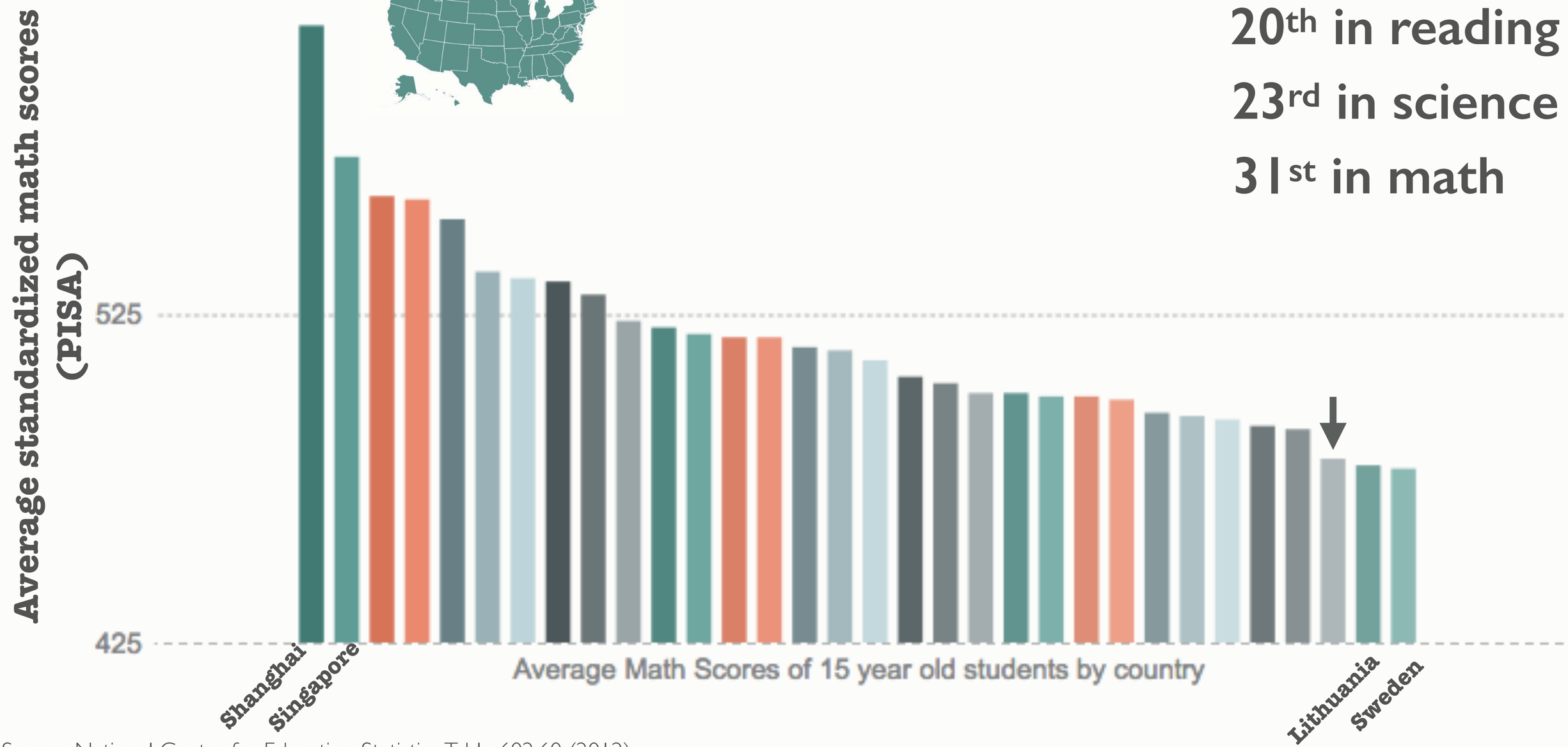
$1.2T Unearned potential lost every year



Source: U.S. Government Publishing Office (FY17: https://www.gpo.gov/fdsys/browse/collection.action?collectionCode=BUDGET)

What about kids who stay in school?

On average, below most developed nations



20th in reading

23rd in science

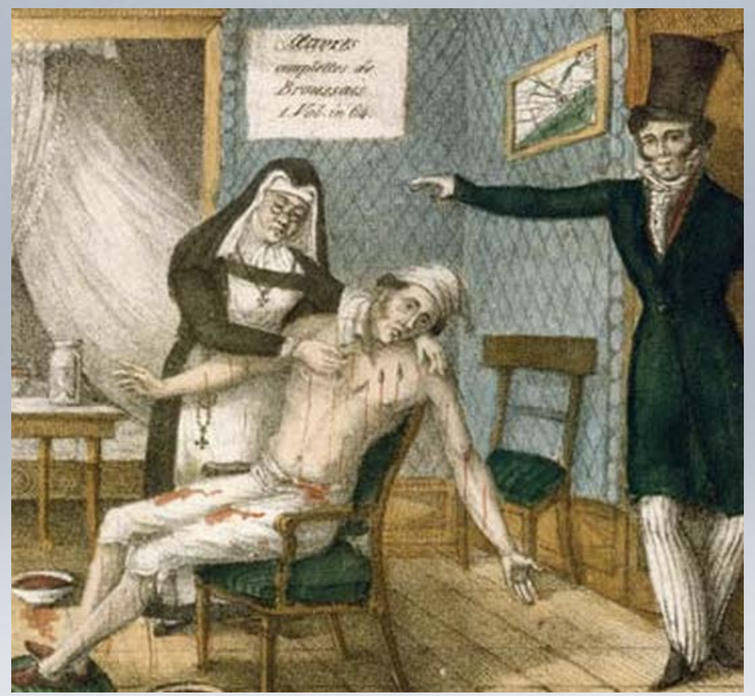
31st in math

Source: National Center for Education Statistics, Table 602.60 (2012)

Solving the problem with learning science?

Analogy with medicine

- Medicine used to operate independently from science
- Physicians didn't have a ground truth about what worked



- Rapidly improved after synching with science

Education is an applied science: future of education will benefit from being grounded in a scientific understanding of how the brain learns

What could this look like?

Co-creative process:

Learning Scientists

Cognitive scientists

Learning Engineer?

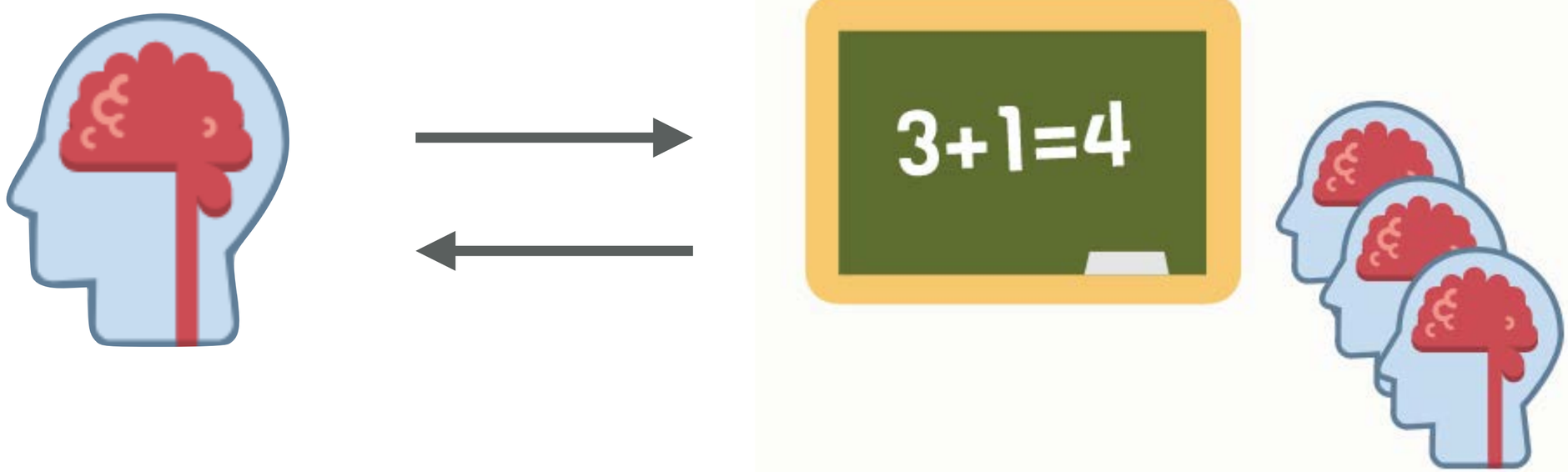
Educators

Instructional designers

An understanding of HOW learning works gives us guiding principles around which to innovate

What is a Learning Engineer?

Takes the research and turns it into something you can use



Helps researchers ask better questions

What does a Learning Engineer do?

1. Builds Research-Practice Partnerships (RPPs)

Researchers

-Processes
-Platforms

Practitioners

What does a Learning Engineer do?

1. Builds Research-Practice Partnerships (RPPs)
2. **Builds Education Innovation Clusters (EICs)**

Researchers

-Processes
-Platforms

Practitioners

How do we start?

Synching EDUCATION with EVIDENCE for transformative teaching

- Two-pronged approach:

Program 1

With Educators

Arm teachers with the science of learning:

INSTITUTE FOR APPLIED NEUROSCIENCE

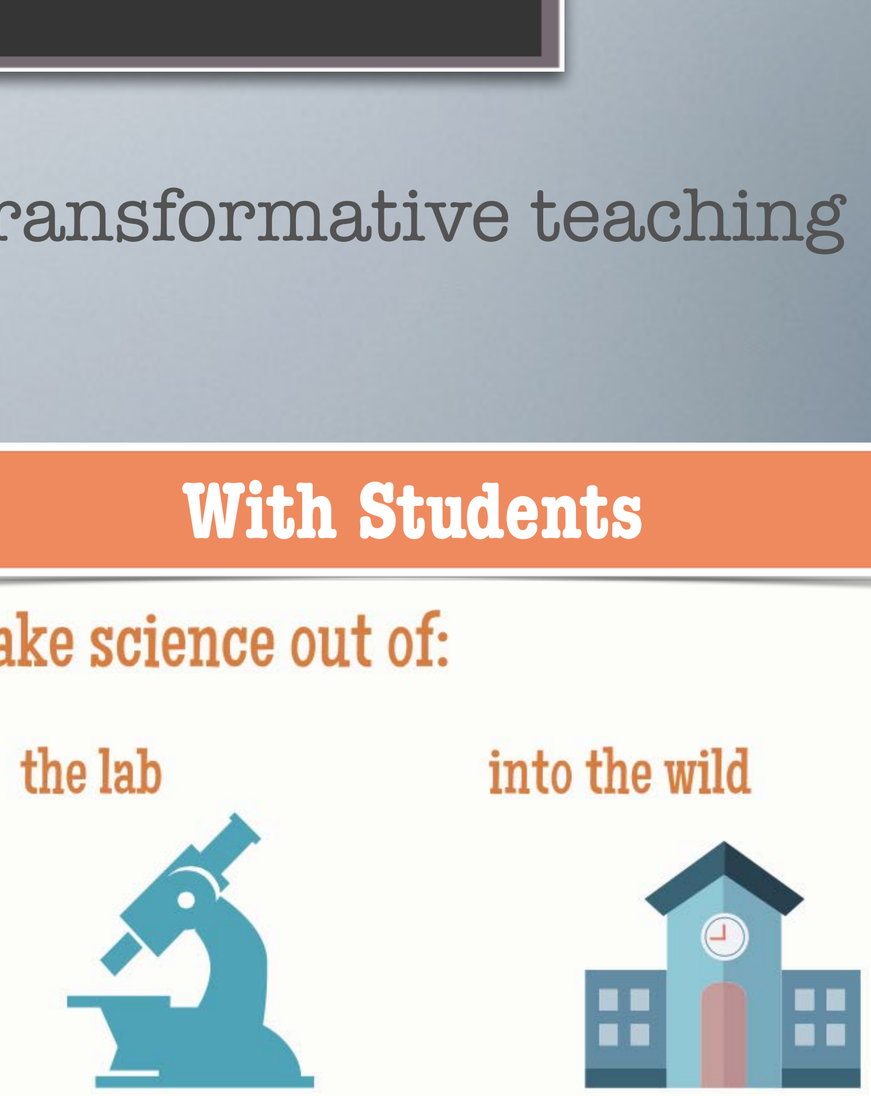
BRAIN SCIENCE FOR GOOD

scienceforgood.org

Program 2

With Students

Take science out of:



UCSF

University of California San Francisco

neuroscape.ucsf.edu

Learning Engineering

Program 1

With Educators

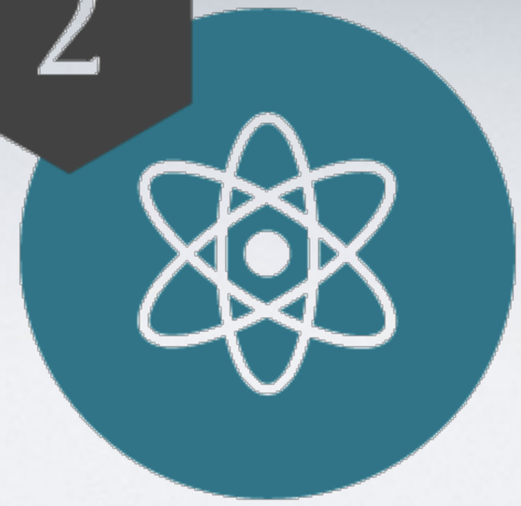
Arm teachers with the science of learning:

WILL

SKILL

1 Debunk

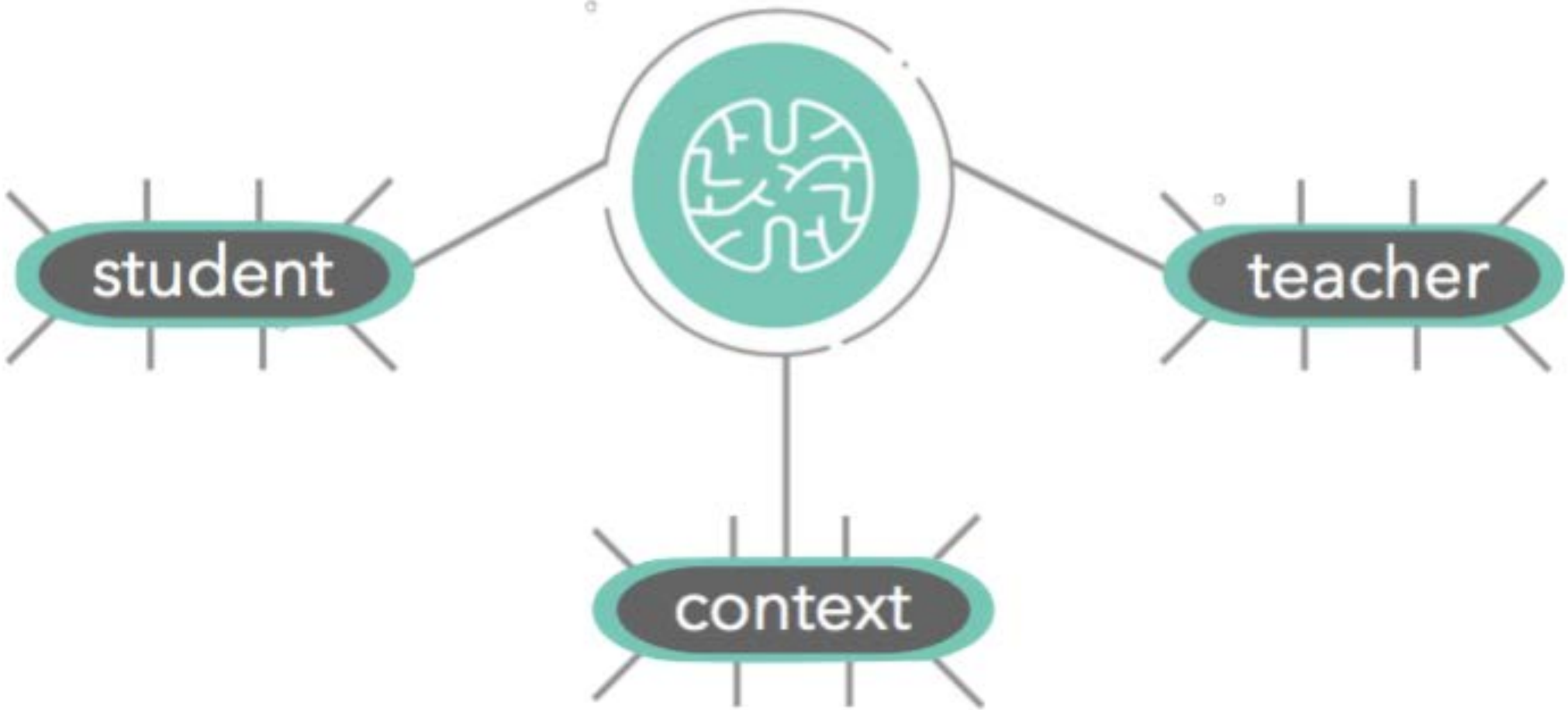
2 Reframe



3 Apply

Mindmap: your mental model of how students learn

Learning is a shared responsibility between the **student**, **teacher**, and **context**. Map out the factors you think each player contributes to learning, to reveal your mental model of how students learn.

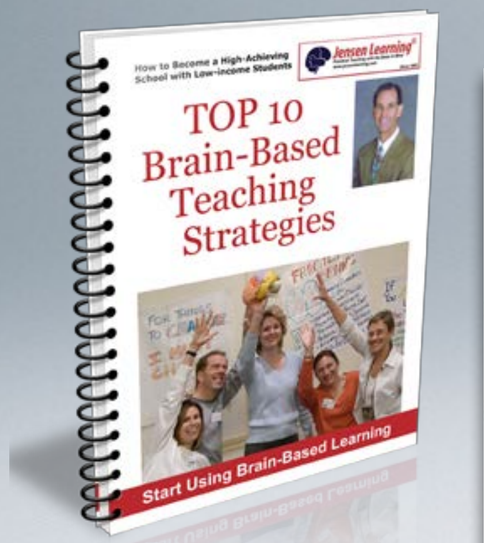


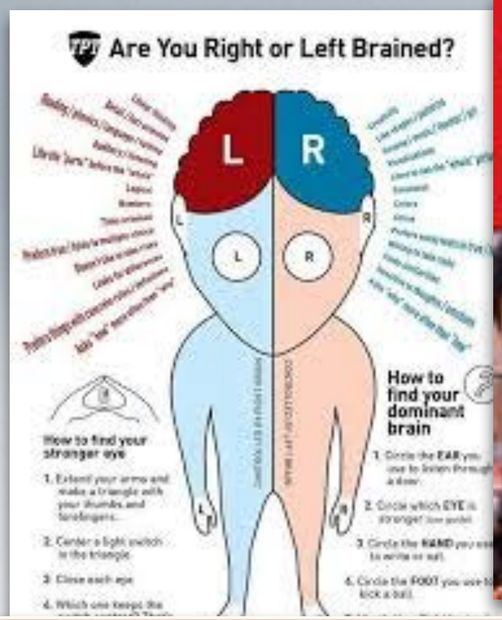
Debunking common myths

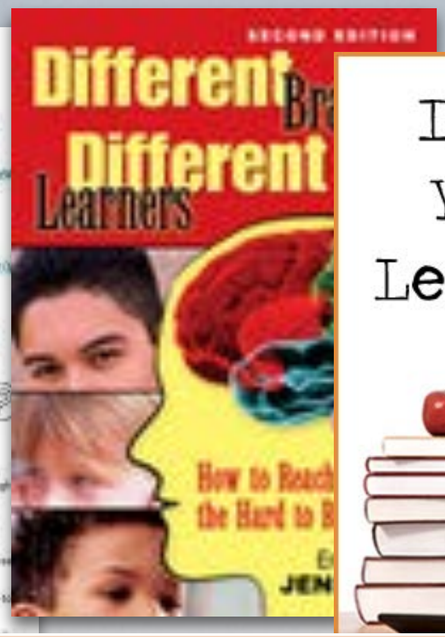
1 Debunk

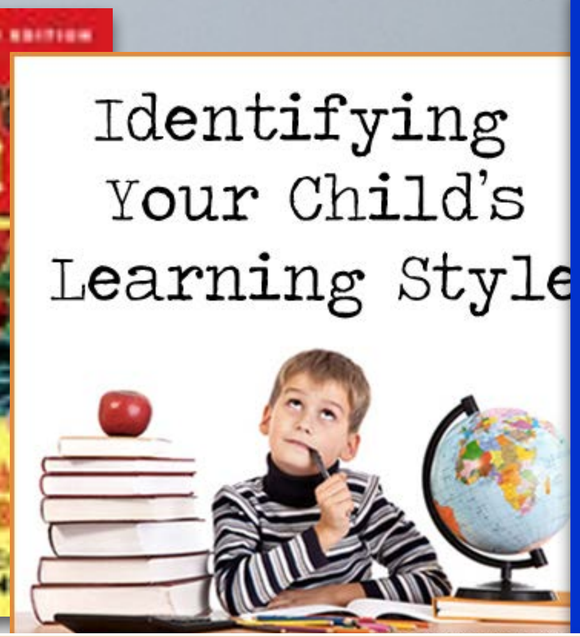
Many myths of learning and brain commonly believed

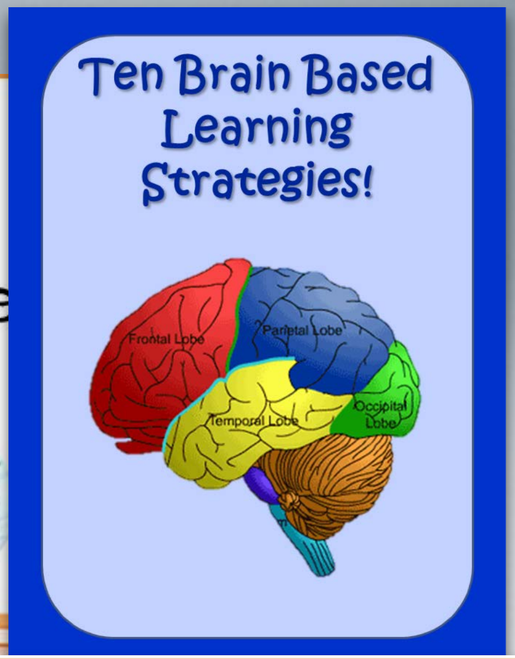
- Harmful if replace effective teaching practices
- Can misappropriate resources to ineffective programs











Which are the leeches and which are the penicillin?

What's the harm?

Threat of class-action lawsuit in 2009

TV exposure in 1-3 yr olds associated with attention problems

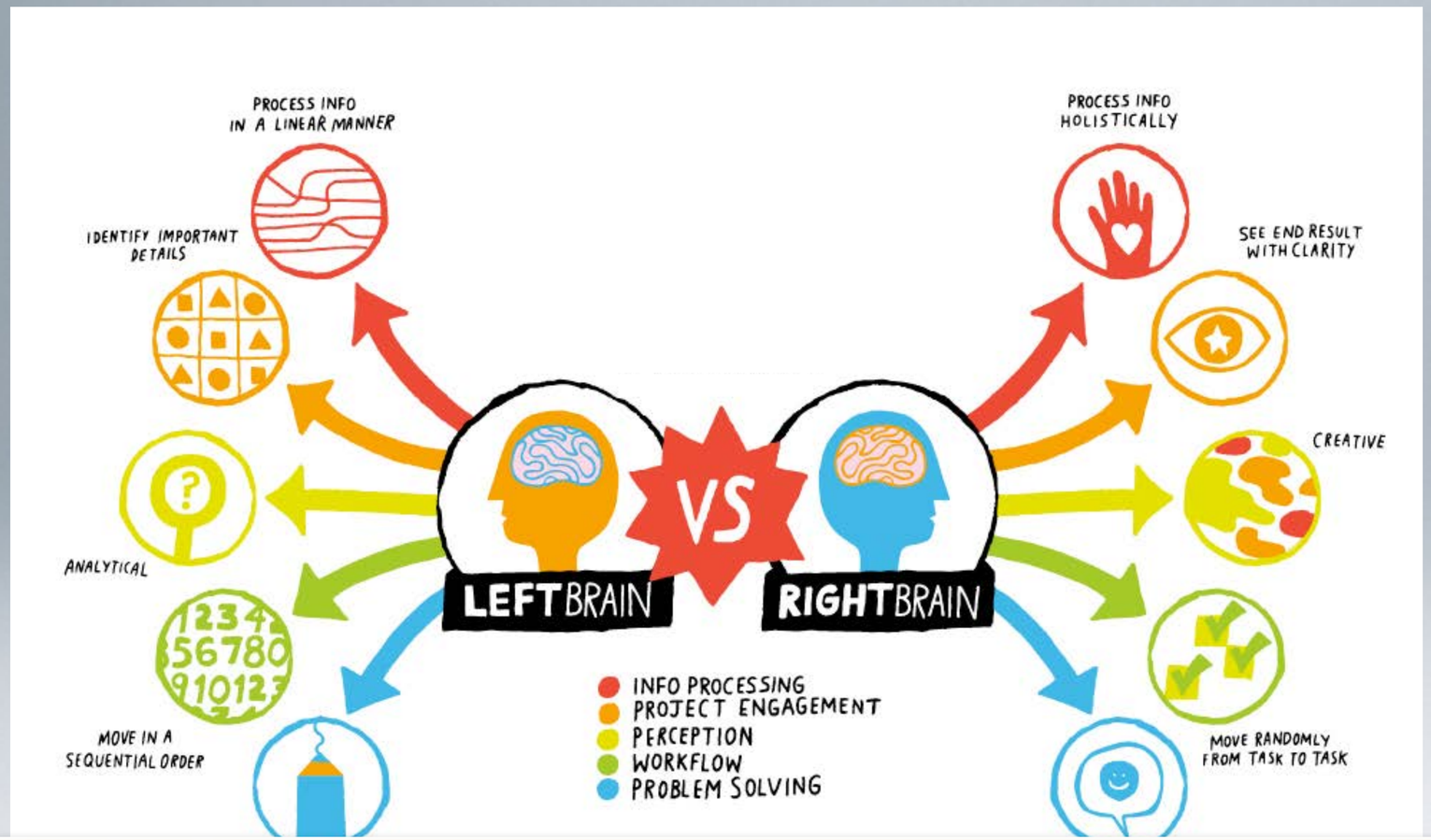
Exposure to Baby Einstein correlated with reduced language abilities

Zimmerman, Christakis, Meltzoff (2007) *J Pediatrics*

Empirical testing is crucial (like in clinical trials)

Neuromyths and learning myths

Myth of left-brain vs. right-brain learners



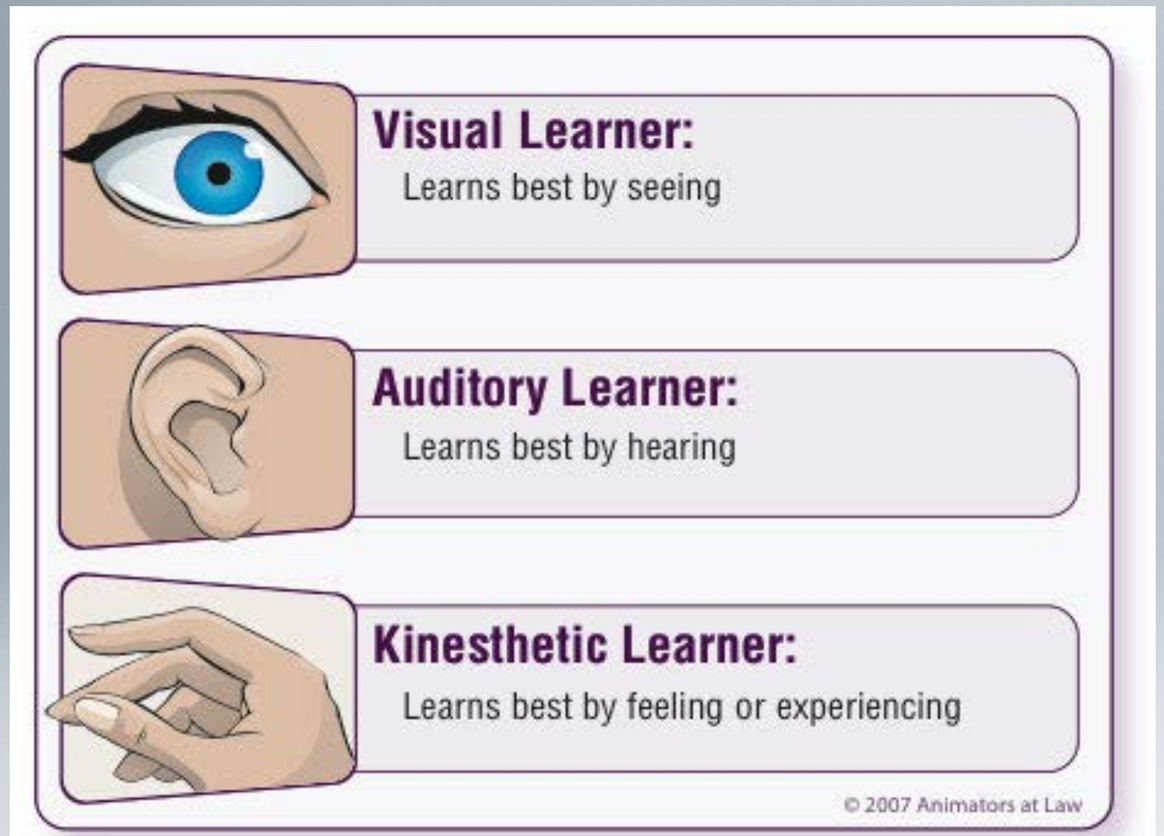
~80% teachers around world believe this myth

Howard-Jones (2014) *Nature Neuroscience*

No such thing as 'left-brained' or 'right-brained' learner (we use all of our brain!)

Neuromyths and learning myths

Myth of learning styles



~96% teachers around world believe this myth

Howard-Jones (2014) *Nature Neuroscience*

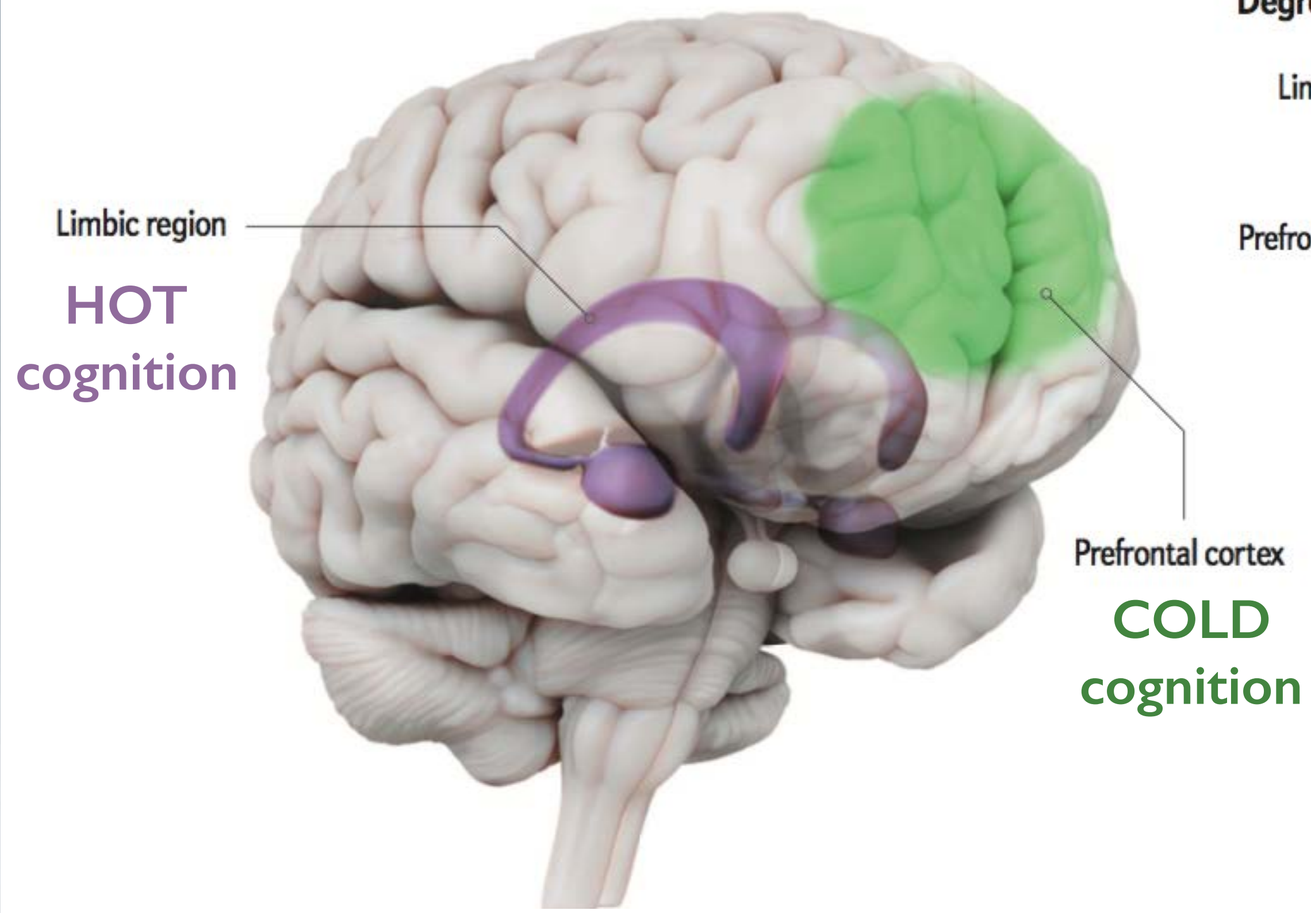
Describes how kids may prefer to perceive, not learn

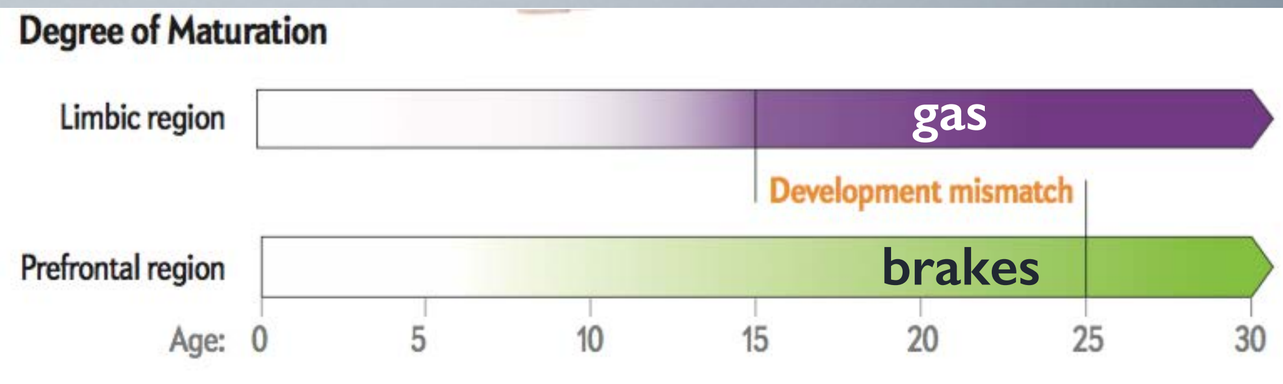
Need to translate perceiving into understanding

Understanding how students make MEANING may be a better way to think about individual differences

Neuromyths and learning myths

Myth of the half-baked teen brain





Teens can make decisions like adults
UNDER CERTAIN CONDITIONS!

- *Abstract reasoning, memory, planning mature by ~15-16yo*
- *Judgments during **emotional arousal**, **social** or **time pressure** not mature until mid-20s*

Mo

Our expectations should be developmentally informed
We may be able to shorten the mismatch with self-regulation training

Neuromyths and learning myths

Myth that we cannot do anything about trauma

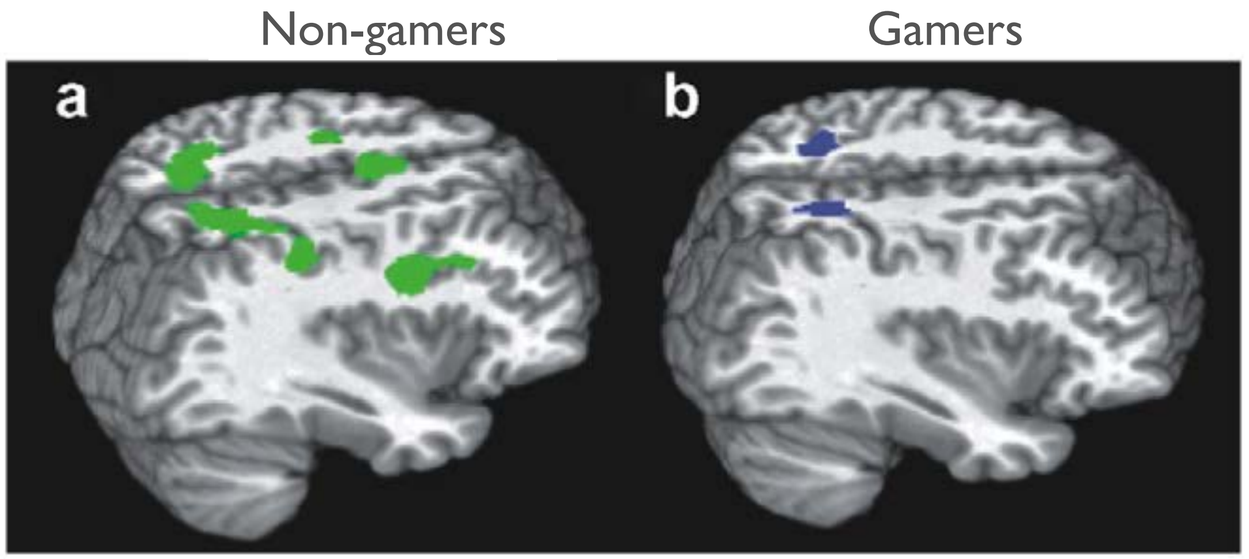
Single common factor for children who develop resilience is at least one **stable & committed relationship with a supportive adult**

At least one stable, supportive adult can change the course of trauma

https://www.cdc.gov/violenceprevention/acestudy/about.html

Neuromyths and learning myths

Myth that action video game play is bad for the brain



Bavelier et al. (2012) *Vision Research*

Action gamers have:

- more efficient executive control systems
- better pattern recognition ('learning-to-learn')

Encourage students to look for and understand patterns

Learning Engineering

Program 1

With Educators

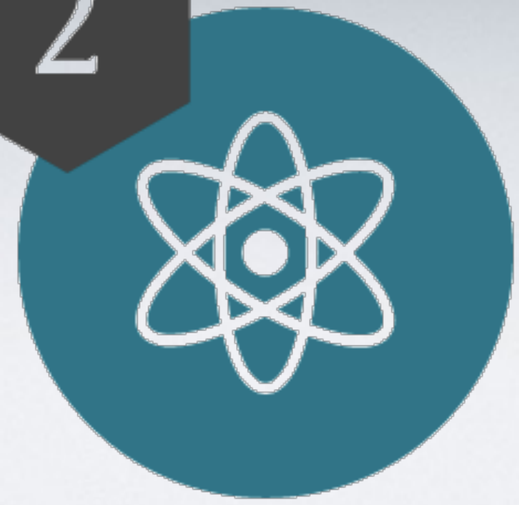
Arm teachers with the science of learning:

WILL

SKILL

1 Debunk

2 Reframe



3 Apply

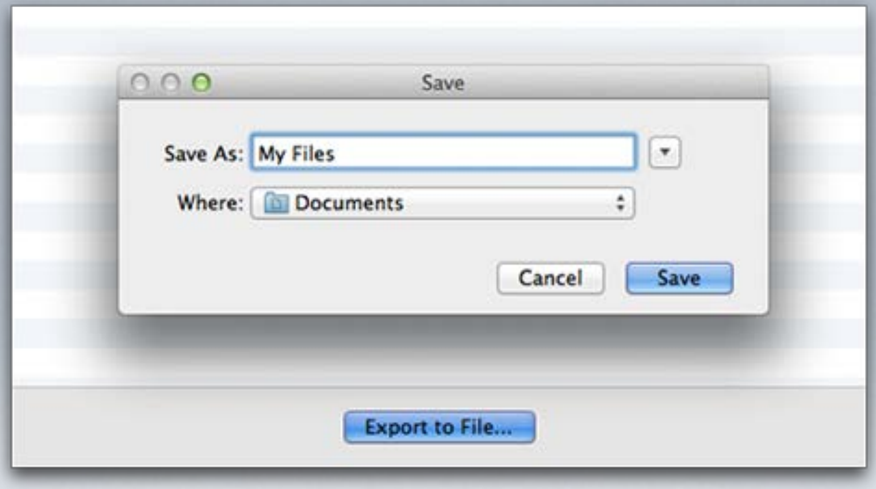
Learning in the brain

What does learning look like in the brain?

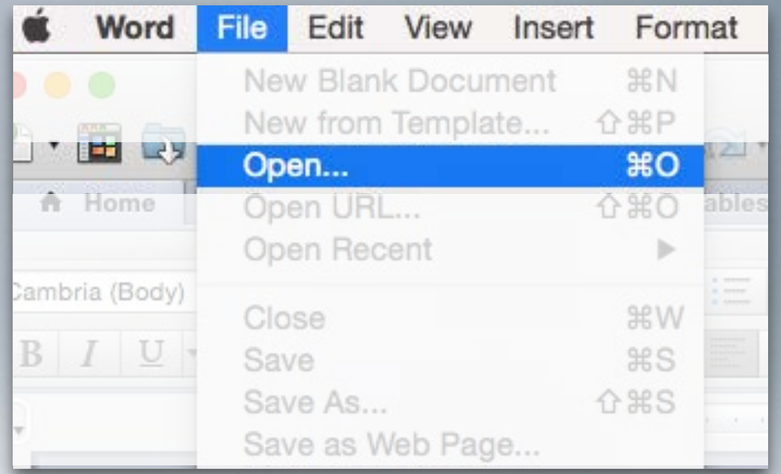
- Three stages:

Encoding

Storage



Retrieval



Learning in the brain

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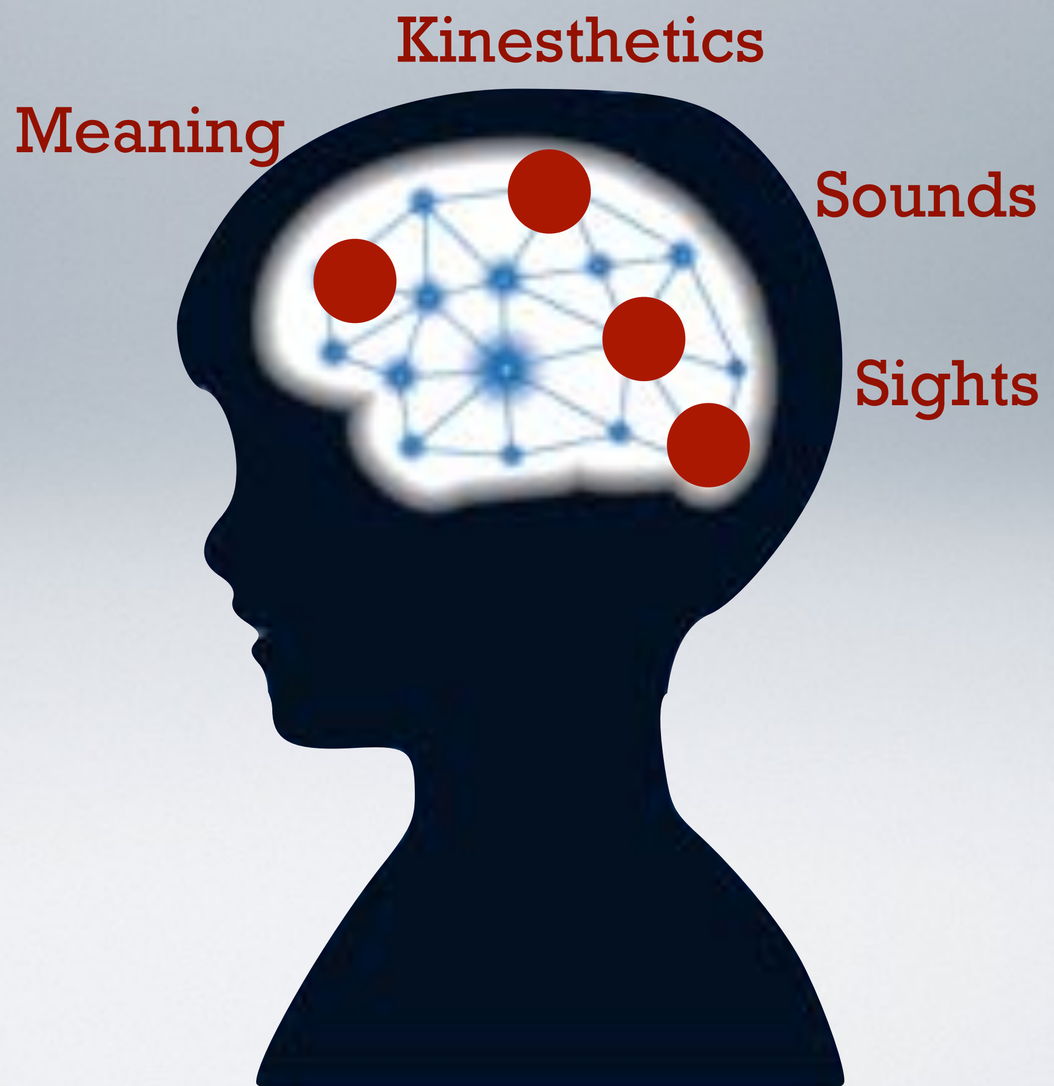

Learning in the brain

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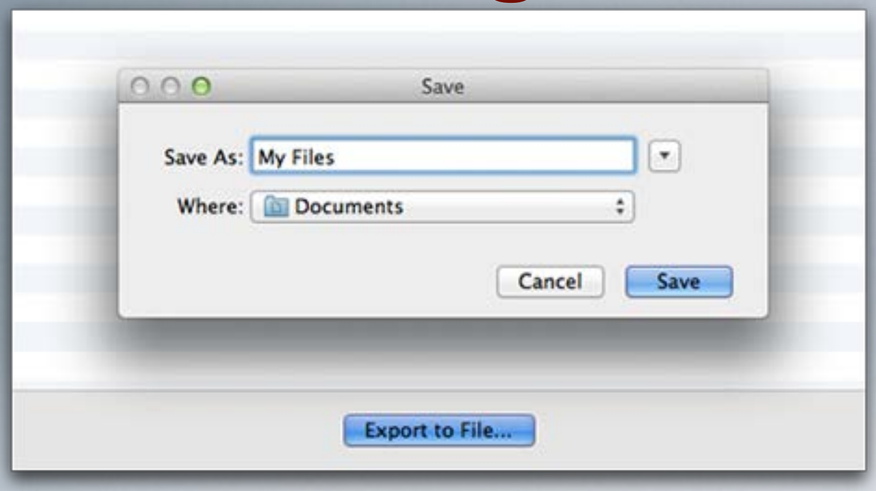
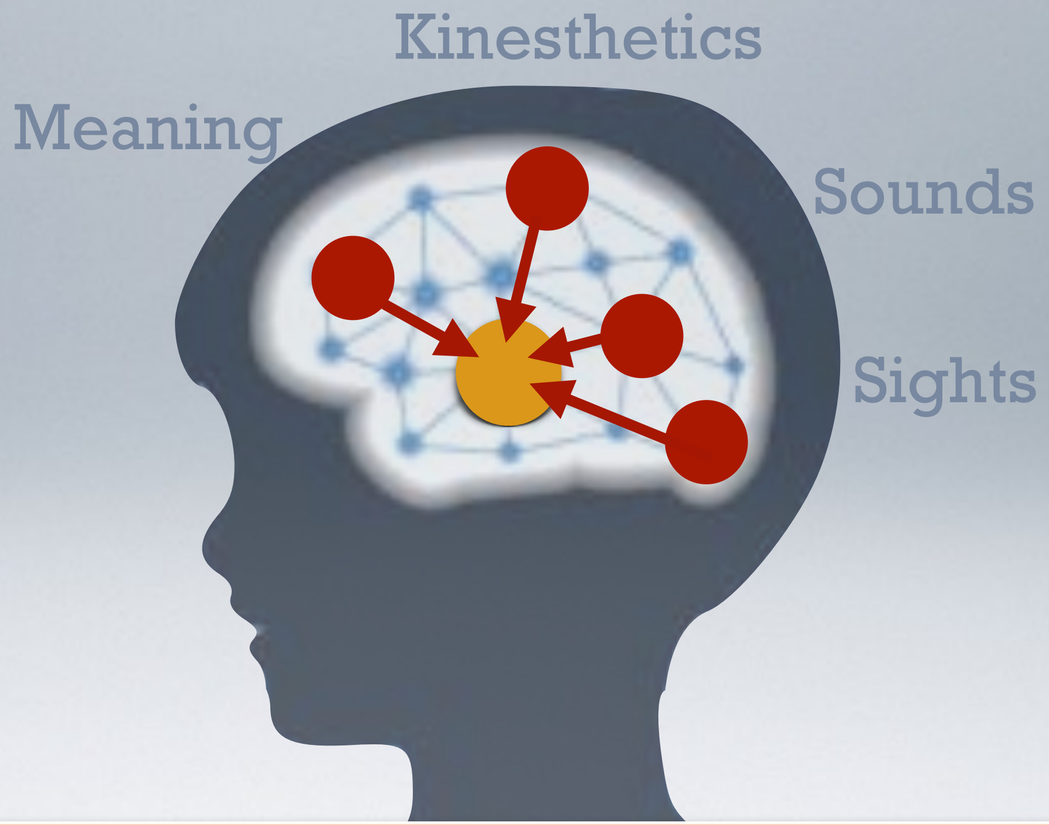


Hippocampus



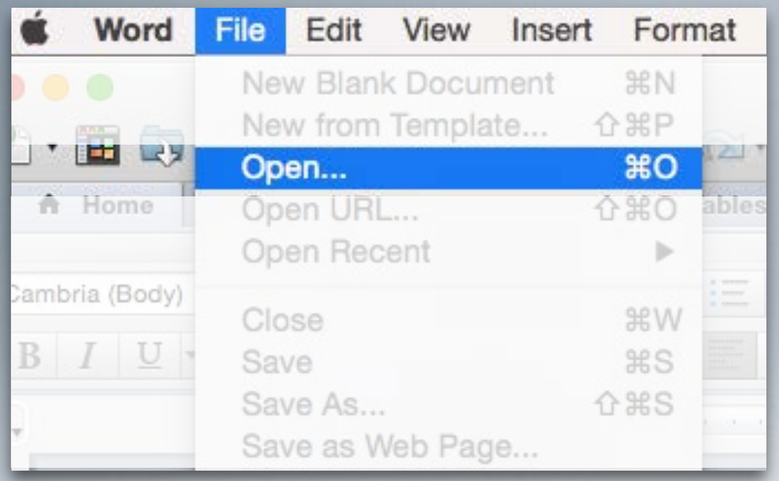
Learning is the ‘residue of experience’ and hippocampus stores that activity

Learning in the brain

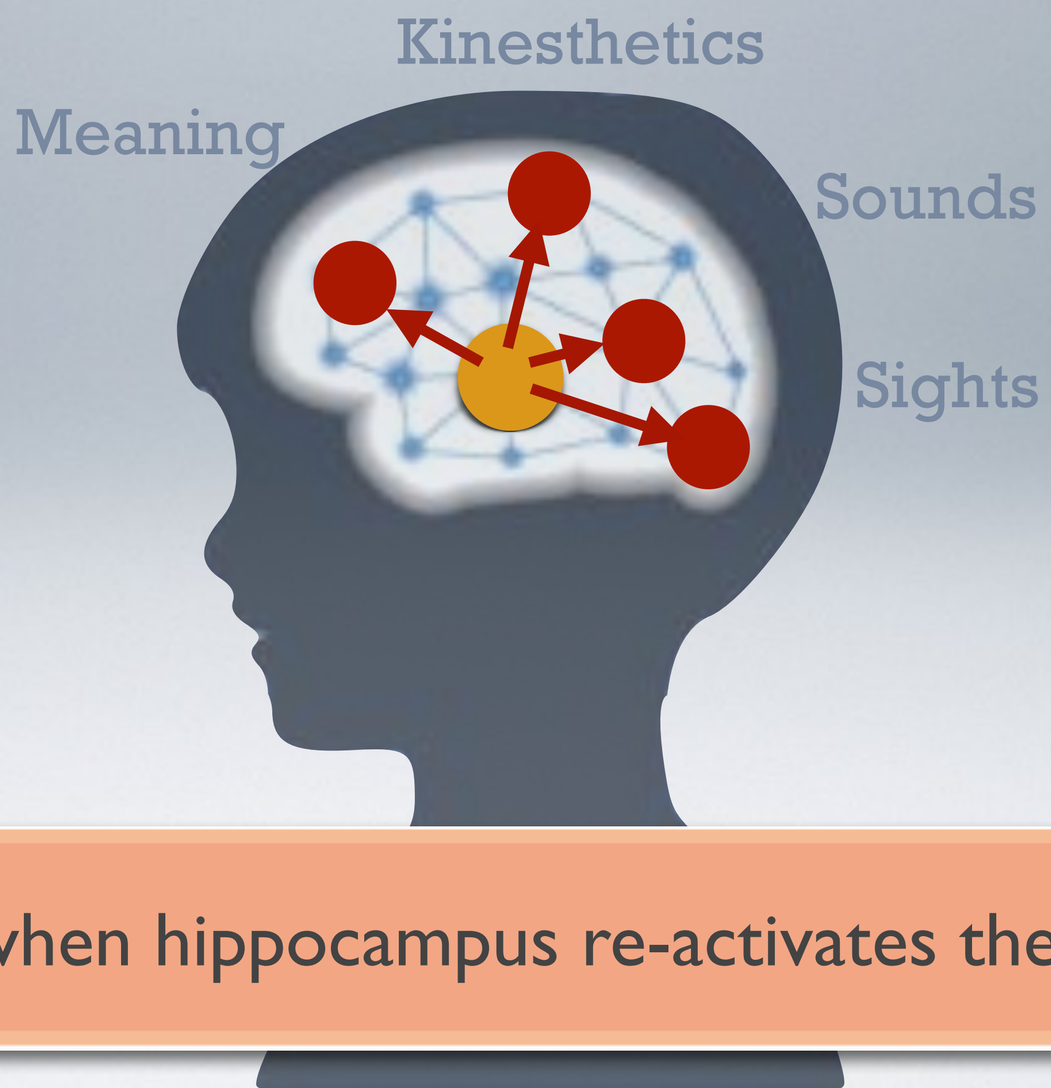
What does learning look like in the brain?

- Three stages:

Retrieval



Hippocampus



Learning is accessed when hippocampus re-activates the experience

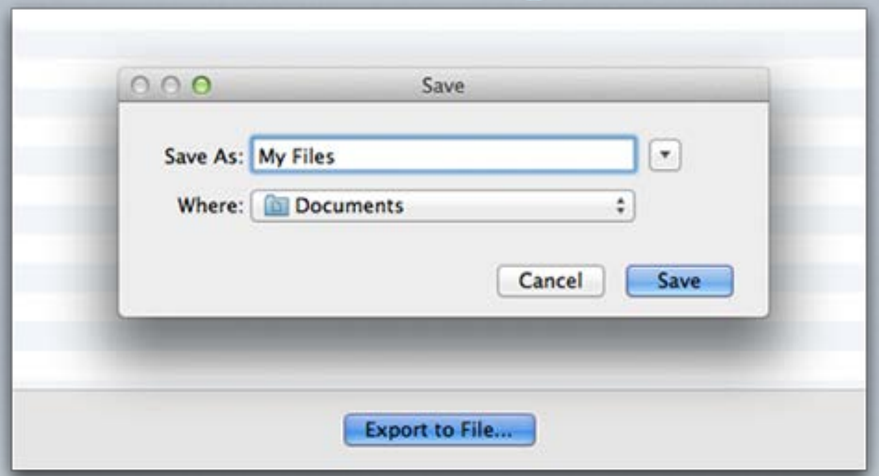
Learning in the brain

This means we can leverage **practices at each stage**

Encoding

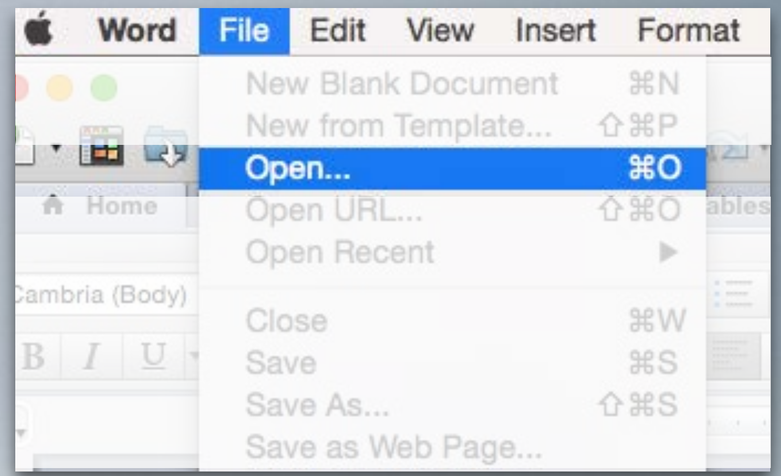
Practices to **lay down** strong memories

Storage



Practices to **store** those memories deeply

Retrieval



Practices to **access** those memories easily, and when useful

Learning Engineering

Program 1

Translate

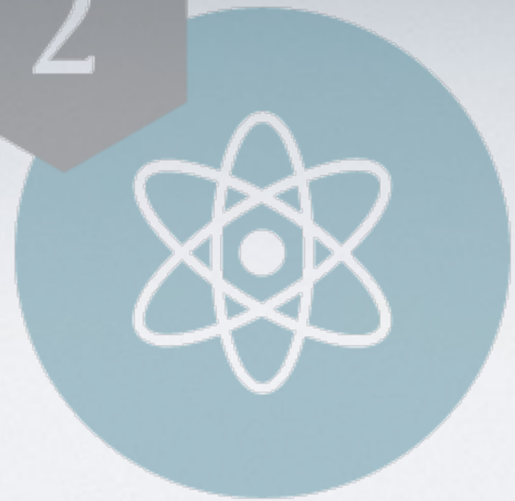
Arm teachers with the science of learning:

WILL

SKILL

1 Debunk

2 Reframe

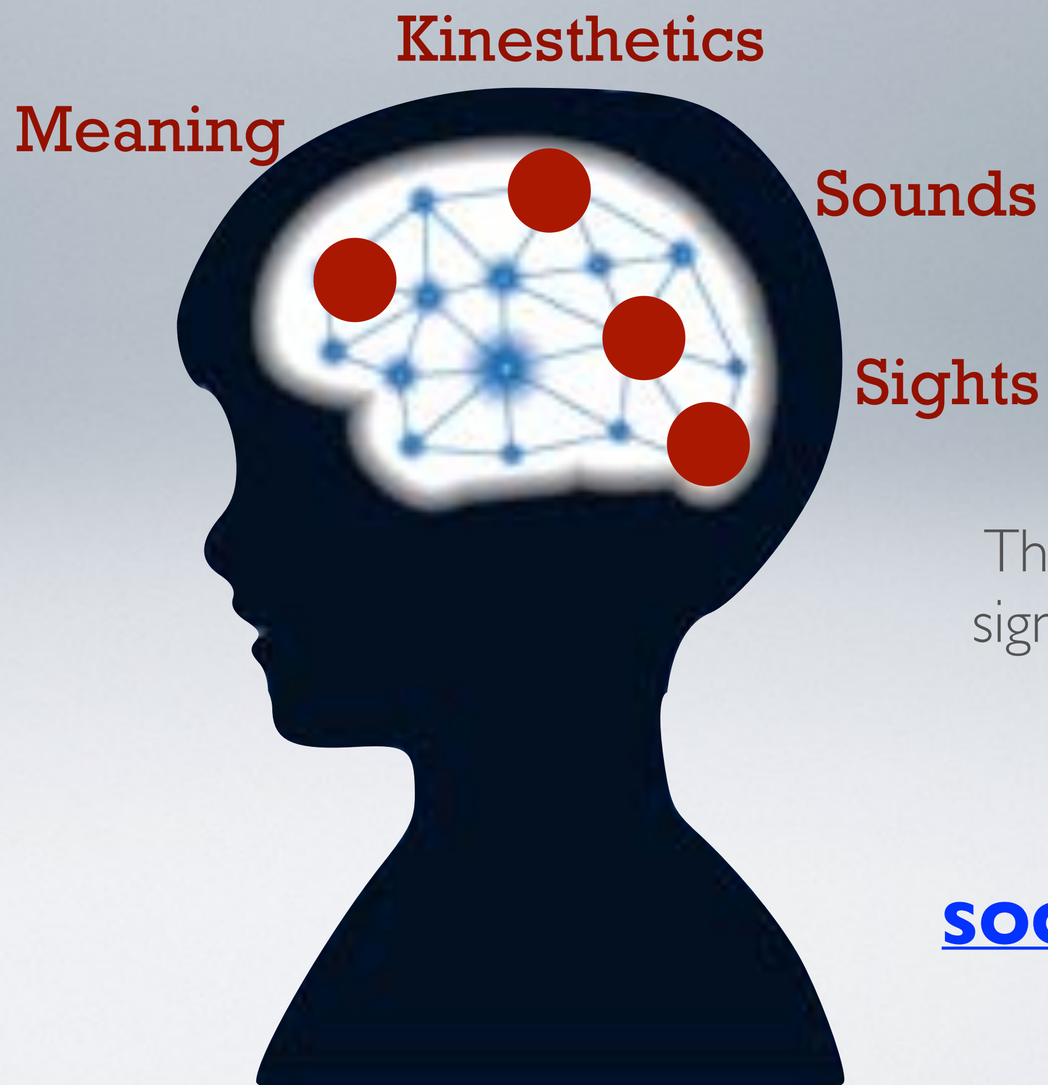


3 Apply

Learning in the brain

Encoding

Practices to **lay down** strong memories



Things that makes these signals **stronger** will be encoded better

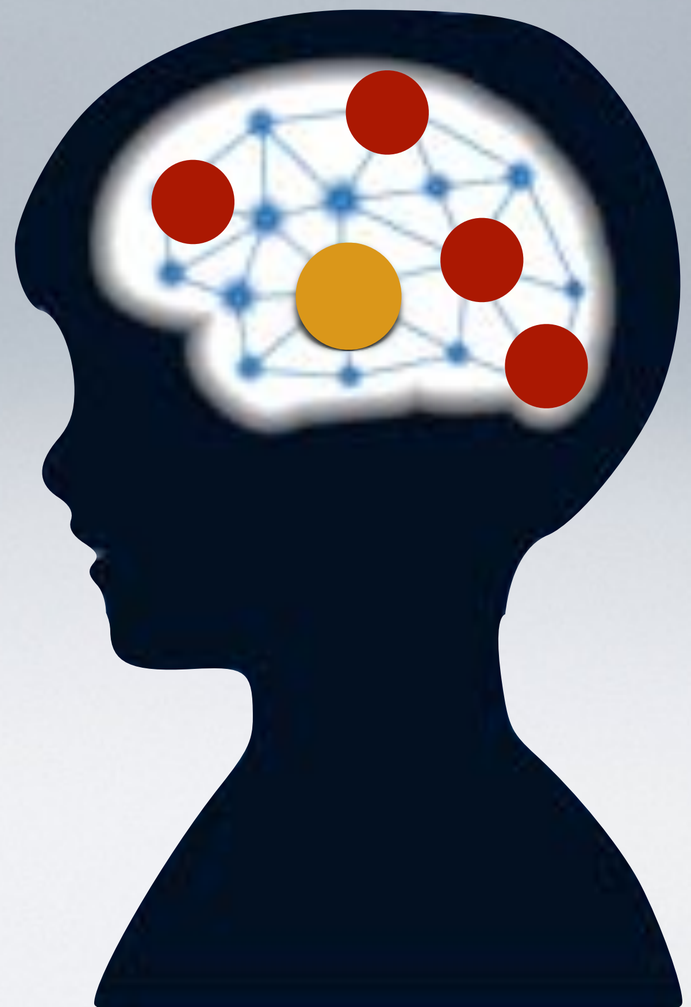
ATTENTION, MEANING, SOCIAL RELEVANCE

Learning in the brain

Keep in mind…

- **When learning is <u>easy</u>, it is often soon forgotten**

Hippocampus
doesn't have much signal to record



When learning is <u>easy</u>, engages the brain less

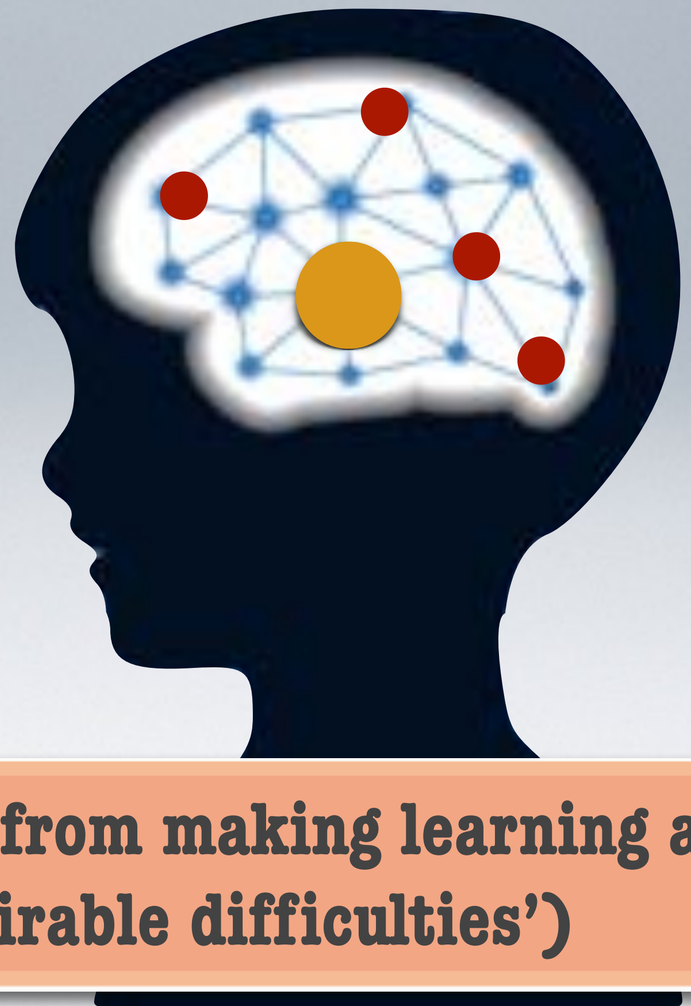
↓

<u>Weak</u> memories

Learning in the brain

Keep in mind…

- When learning is <u>easy</u>, it is often soon forgotten
- **When learning is <u>harder</u>, it creates more durable memories**



Hippocampus
has lots signal to record

When learning is <u>harder</u>, engages the brain more

↓

<u>Stronger</u> memories

Stronger learning comes from making learning a bit challenging ('desirable difficulties')

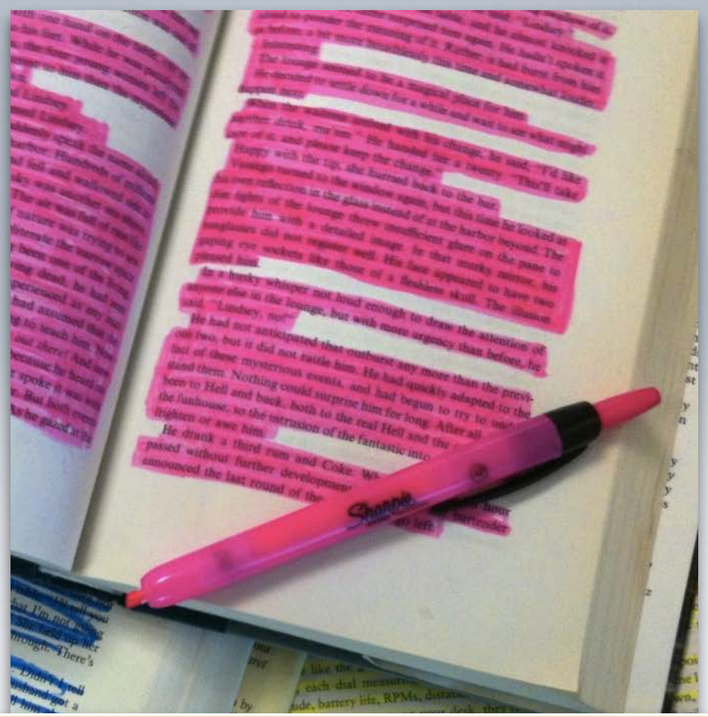
Another learning myth…

Myth of fluency

- Many things make students feel like they know information better than they do

Re-reading

Highlighting



Cramming

Creates short-lived, weak memories

Some strategies that may enhance **encoding**

Encoding

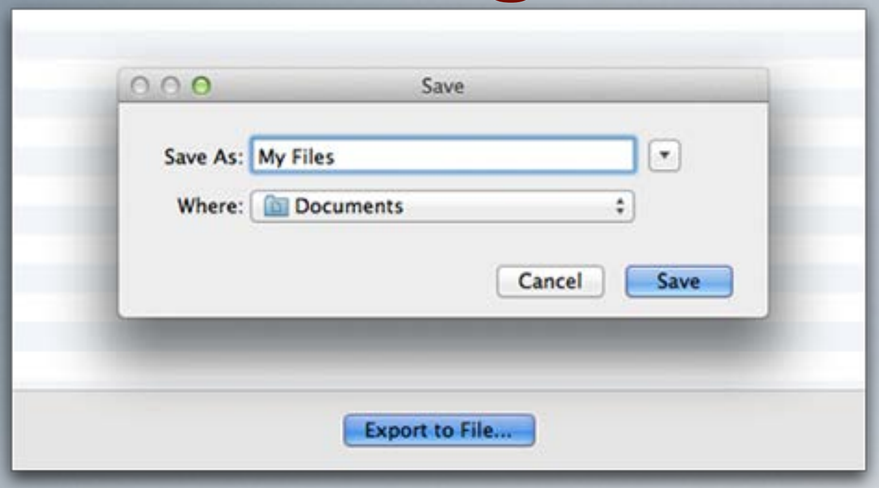
Practices to **lay down** strong memories

Build stronger memories

- Self-quizzing
  - *Creating self-quiz material encourages deeper learning*
- Elaborate on material
  - *Make relevant to self, to prior knowledge, to everyday experiences via analogy and metaphor*
- Interleave different material
  - *Highlights relationships and differences between concepts*
- Increase internal motivation to learn
  - *Dopamine boosts learning!*
  - *Playful, social activities; make clear why material is relevant to them; make connections to topics that interest them*
- Reduce barriers to motivation
  - *Mindset (students & instructors), belonging, affirmation interventions*
- Minimize non-learning digital devices in class
  - *Handwriting benefits, social distraction, multitasking*
- Access to natural light
  - *Tells hypothalamus to wake up, increasing alertness during learning*

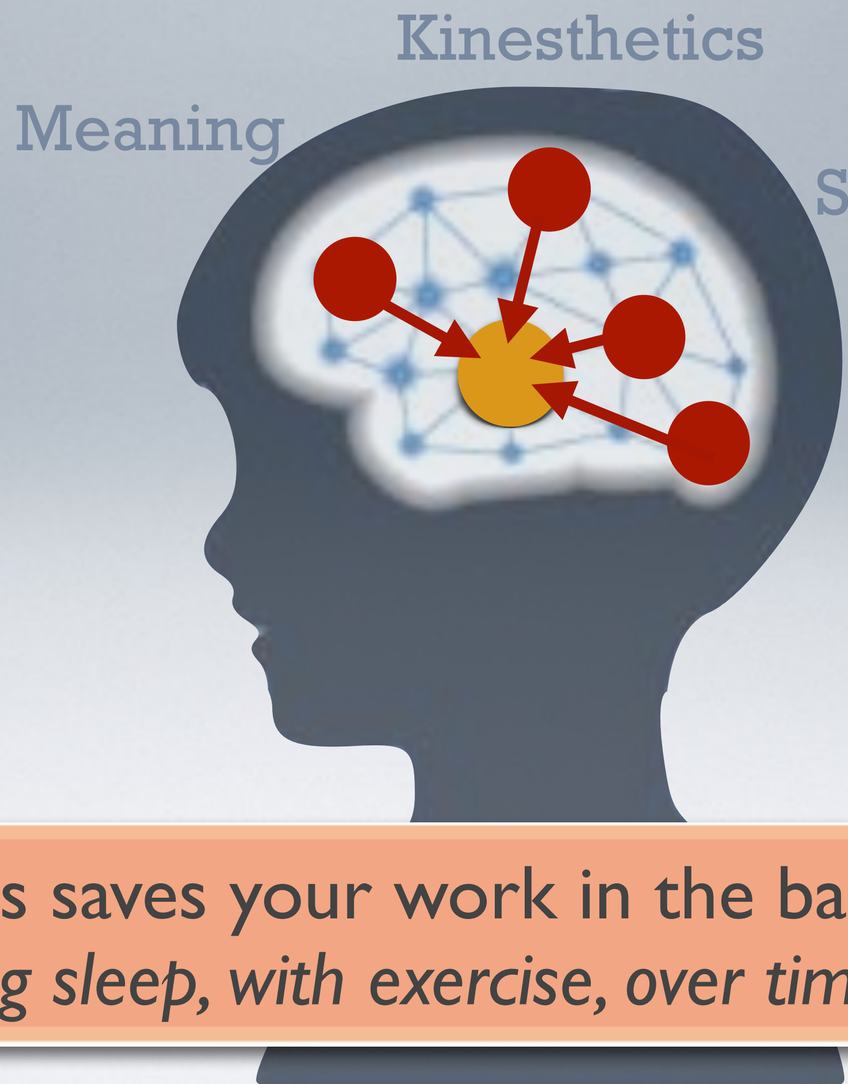
Learning in the brain

Storage



Practices to **store** those memories deeply

Hippocampus



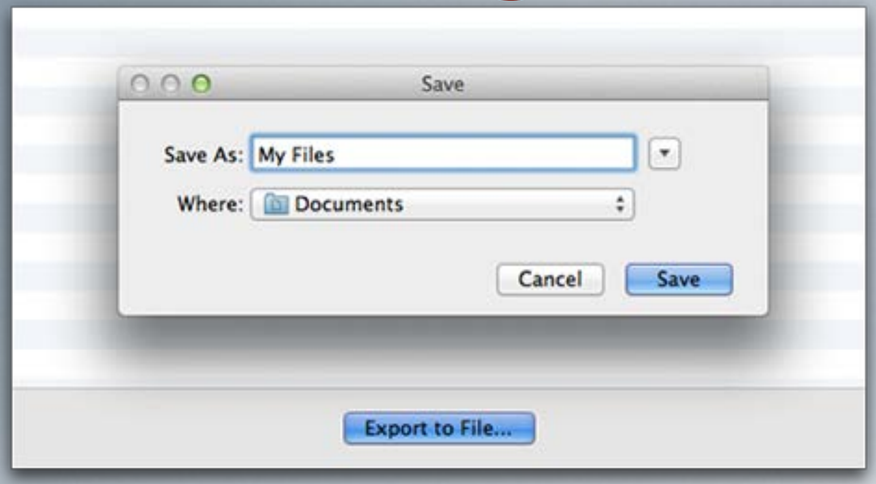
Things that support hippocampal function can lead to better learning

SLEEP, EXERCISE, TIME

Hippocampus saves your work in the background
(during sleep, with exercise, over time)

Some strategies that may enhance **storage**

Storage



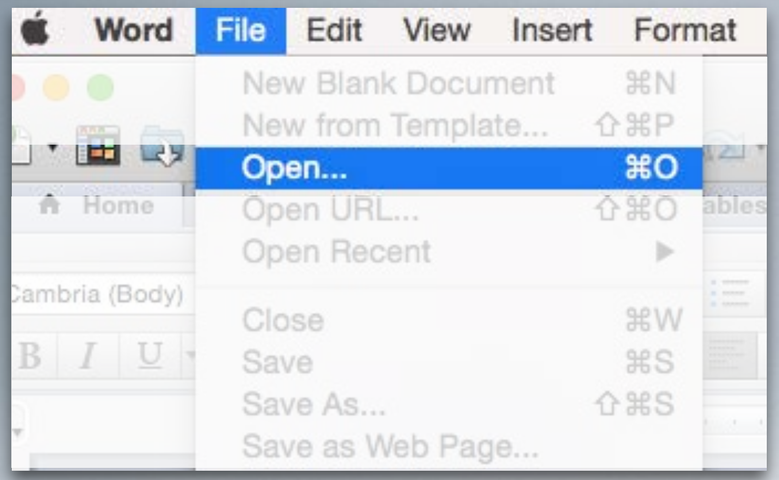
Practices to **store** those memories deeply

STORE stronger memories

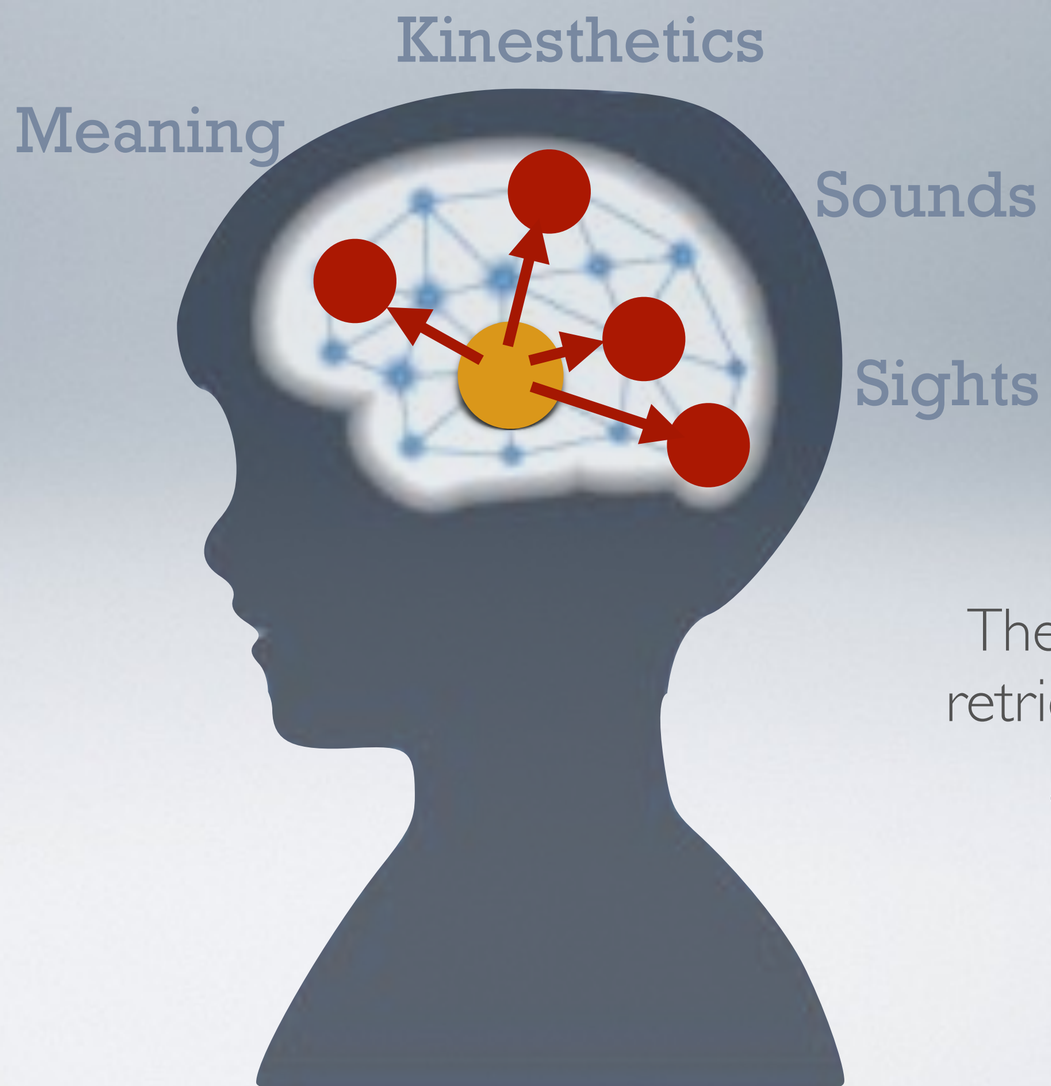
- Prioritize sleep
  - *Strengthens learning from the day*
  - *Allows students to be more awake and alert during learning*
- Later school start times for adolescents?
  - *Allows students to be more awake and alert during learning*
- Reduce blue light before bed
  - *Blue light interrupts circadian rhythms and interferes with sleep architecture*
- Prioritize exercise
  - *Stimulates new cells in hippocampus, new connections*
- Space topics out in course material
  - *Re-loading after some forgetting leads to stronger memories*

Learning in the brain

Retrieval



Practices to **access** those memories easily, and when useful

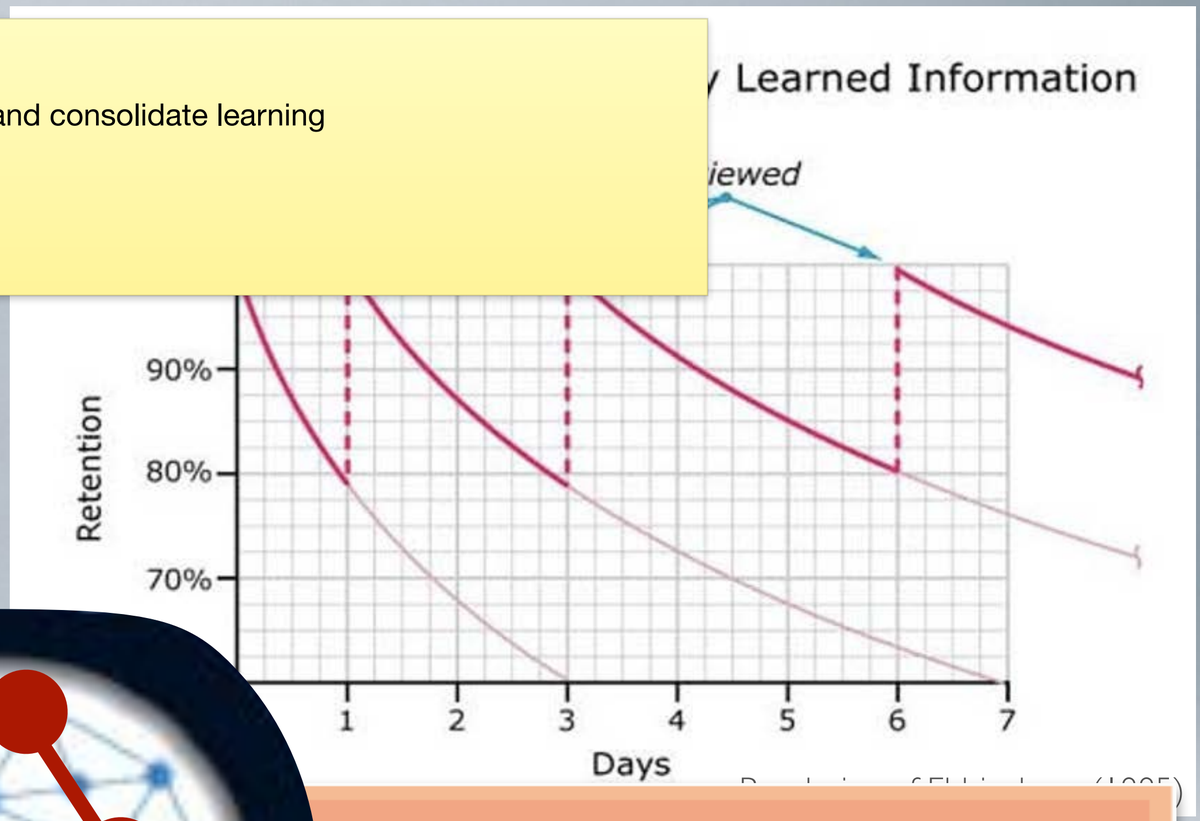


The more you practice retrieving, the better you get at retrieving!

Learning in the brain

Retrieval practice

ting and consolidate learning

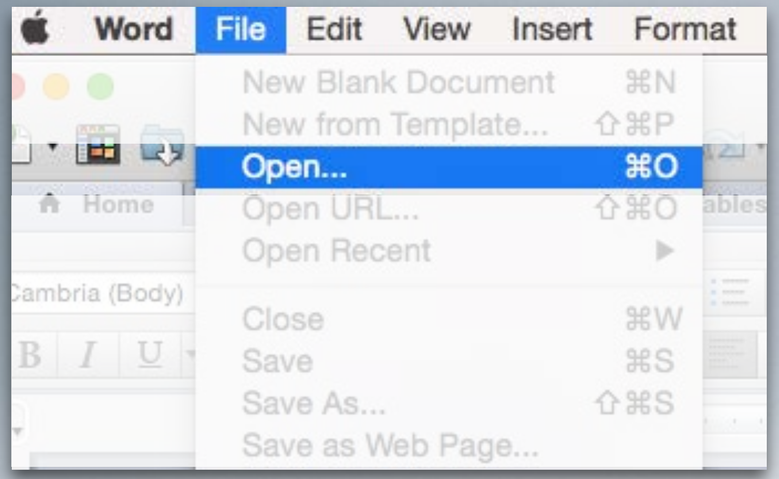


Frequent [illegible] forgetting

Frequent retrieval also <u>changes</u> the nature of the learning

Some strategies that may enhance **retrieval**

Retrieval

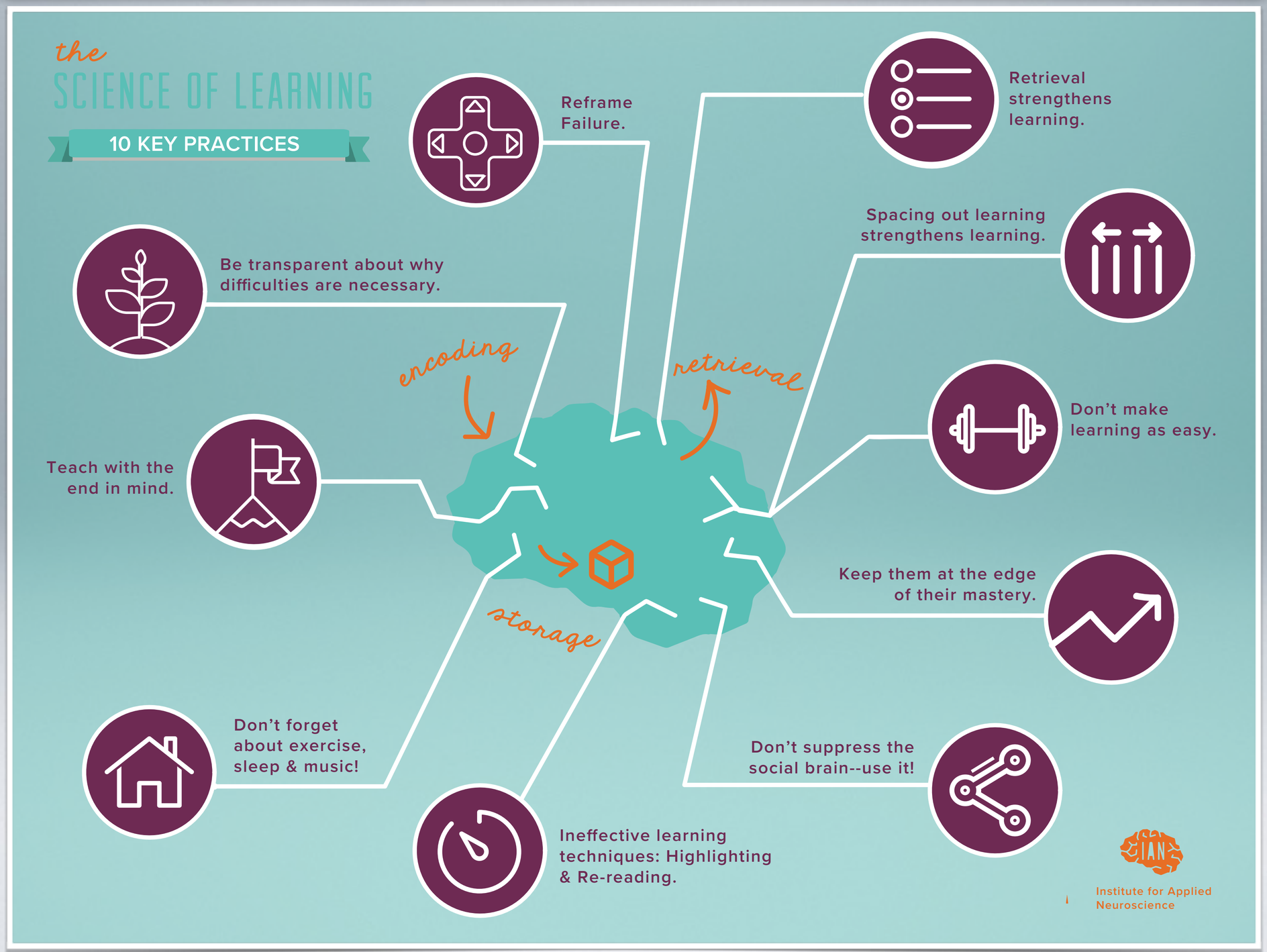


Practices to **access** those memories easily, and when useful

Better access to memories

- Frequent, low-stakes quizzing
  - *Re-loading consolidates learning, interrupts forgetting*
  - *No feedback necessary for benefits; must count toward grade*
- Practice tests that students can do on own
  - *Calibrate their judgments of what they know and do not*
- Ask students questions in class, without notes
  - *Increased attention, more re-loading*
  - *Can make it social by asking them to vote on 3 possible answers, then discuss with someone who voted differently*
- Writing exercises that encourage generation
  - *Take 5-10 min at end of class to recall material*
- Ask students to puzzle through question prior to giving answer
  - *Generativity encourages deeper learning*
- Design quizzes/exercises to reach back to prior concepts
  - *Allows for deeper conceptual knowledge (mental models)*

Poster of Strategies for teachers and students



Learning Engineering

Program 1

With Educators

Arm teachers with the science of learning:

WILL

SKILL

Program 2

With Students

Take science out of:

the lab

into the wild

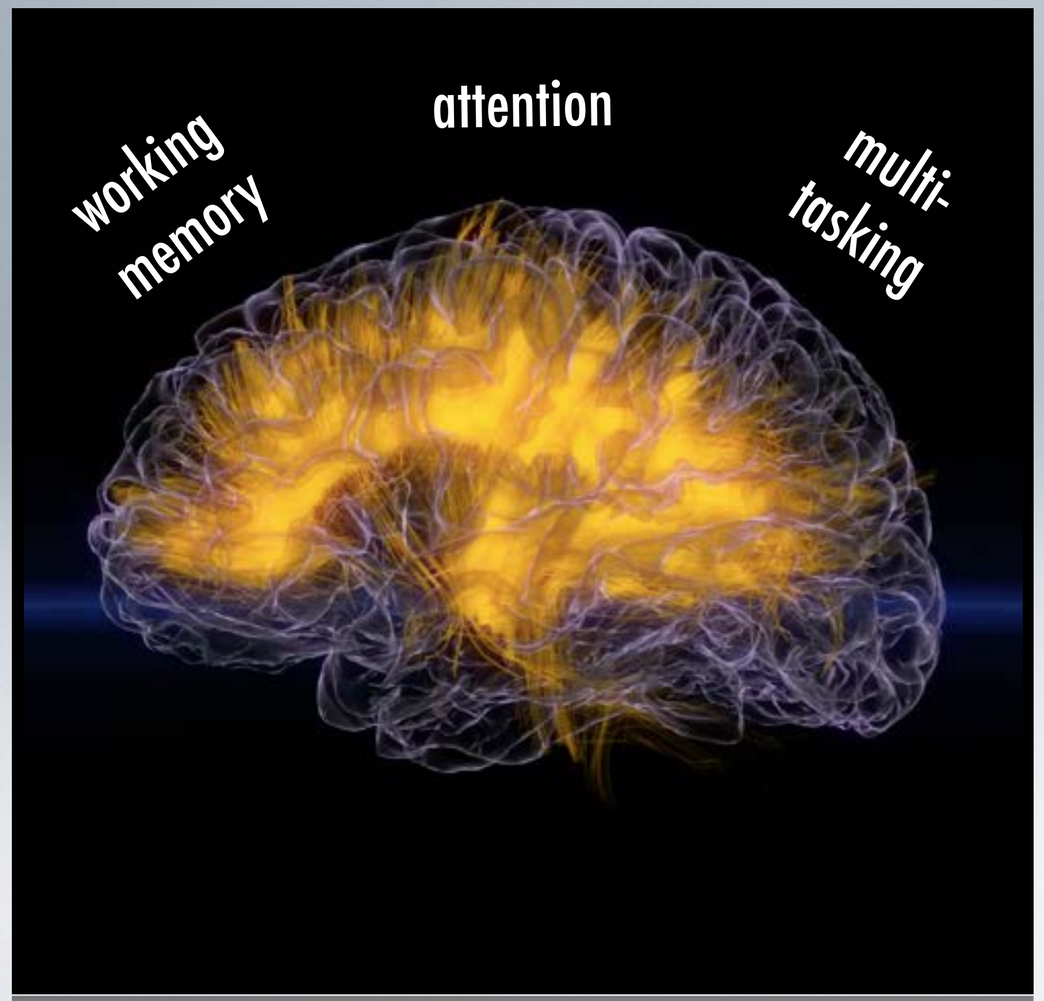
UCSF

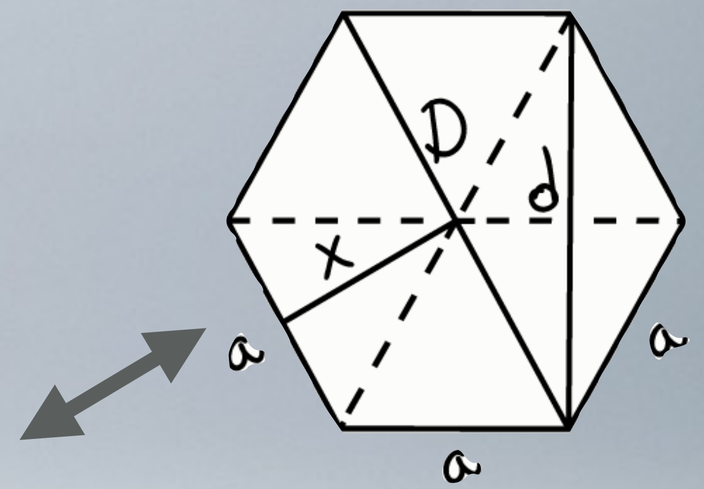
University of California
San Francisco

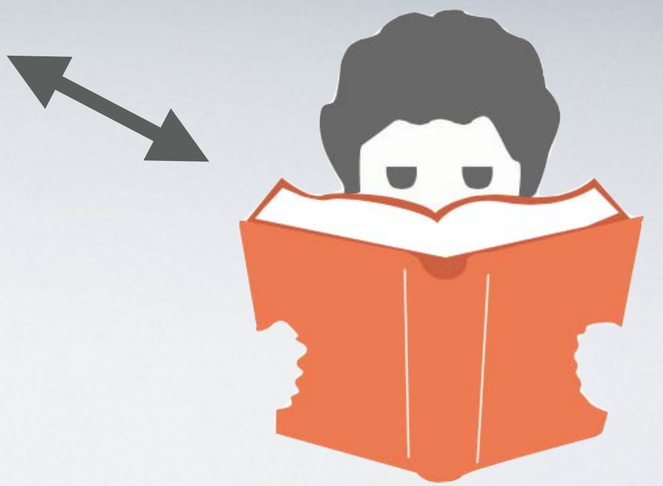
neuroscape.ucsf.edu

Executive Function and Learning

Executive functioning: core capacities that allow us to pursue our goals

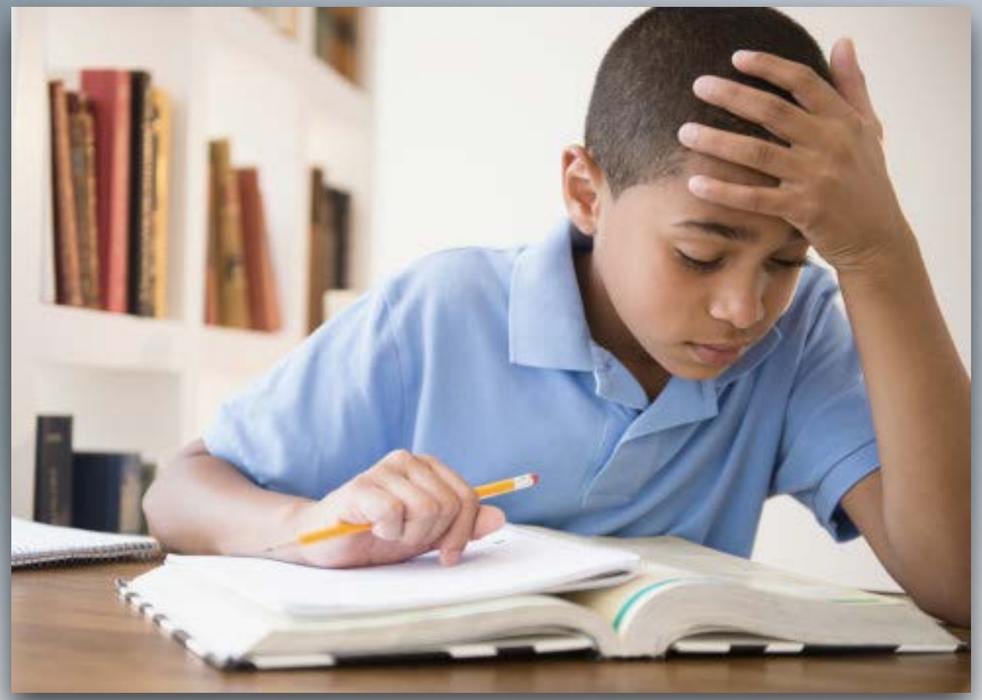






Executive Function and Learning

Executive functioning may be the key to academic success



EFs predict academic outcomes

- School readiness (e.g. McClelland et al., 2007)
- Successful transition to K (e.g. Blair & Razza 2007)
- School performance and social competence in adolescence (e.g. Mischel et al., 1989)

…life outcomes in adulthood

- Better physical health
- Higher socio-economic status
- Fewer drug-related problems
- Fewer criminal convictions

(e.g. Moffitt et al., 2011)

Executive Function & Academic Achievement

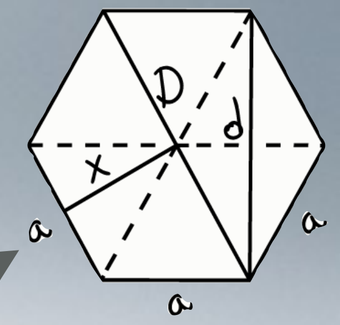
Executive functioning study in 1,258 students in Bay Area

Measure

Personalized Assessment

Train

Personalized Training



EFs may be key to understanding how students learn, and what to do to optimize learning

Learning Engineering

Synching EDUCATION with EVIDENCE for transformative teaching

Program 1

With Educators

Arm teachers with the science of learning:

WILL

SKILL

Program 2

With Students

Take science out of:

the lab

into the wild

Take-Home Messages

Treating education as an applied science may result in rapid improvements, as with medicine

- The future of innovation in education depends on solving hard problems–with science?
- When teaching is grounded in the science of learning, can use SoL principles as *axes of innovation*
- This may require a new job description: a **Learning Engineer**

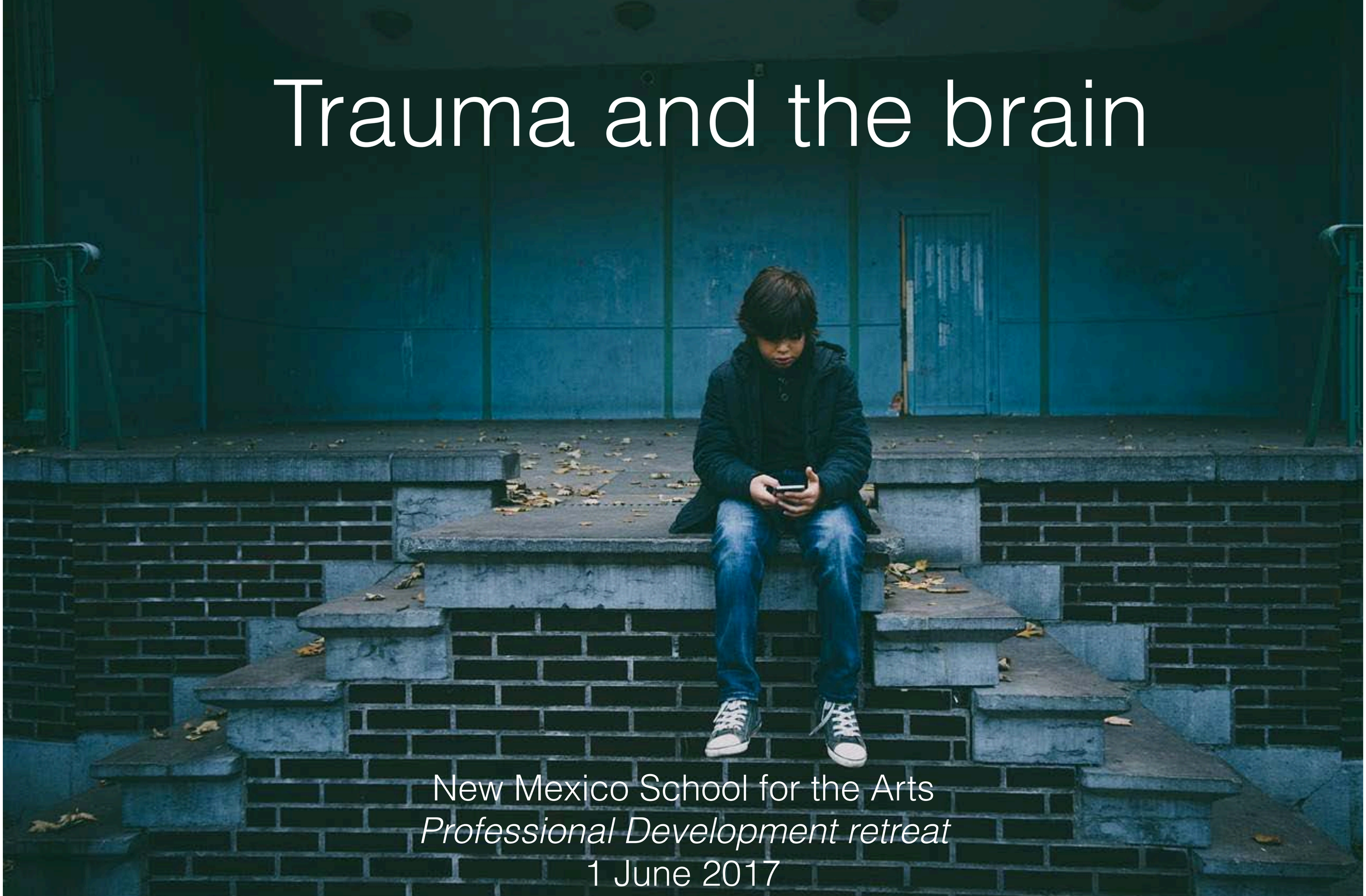
Learning Scientists

Learning Engineer

Educators

Thank you!

Trauma and the brain

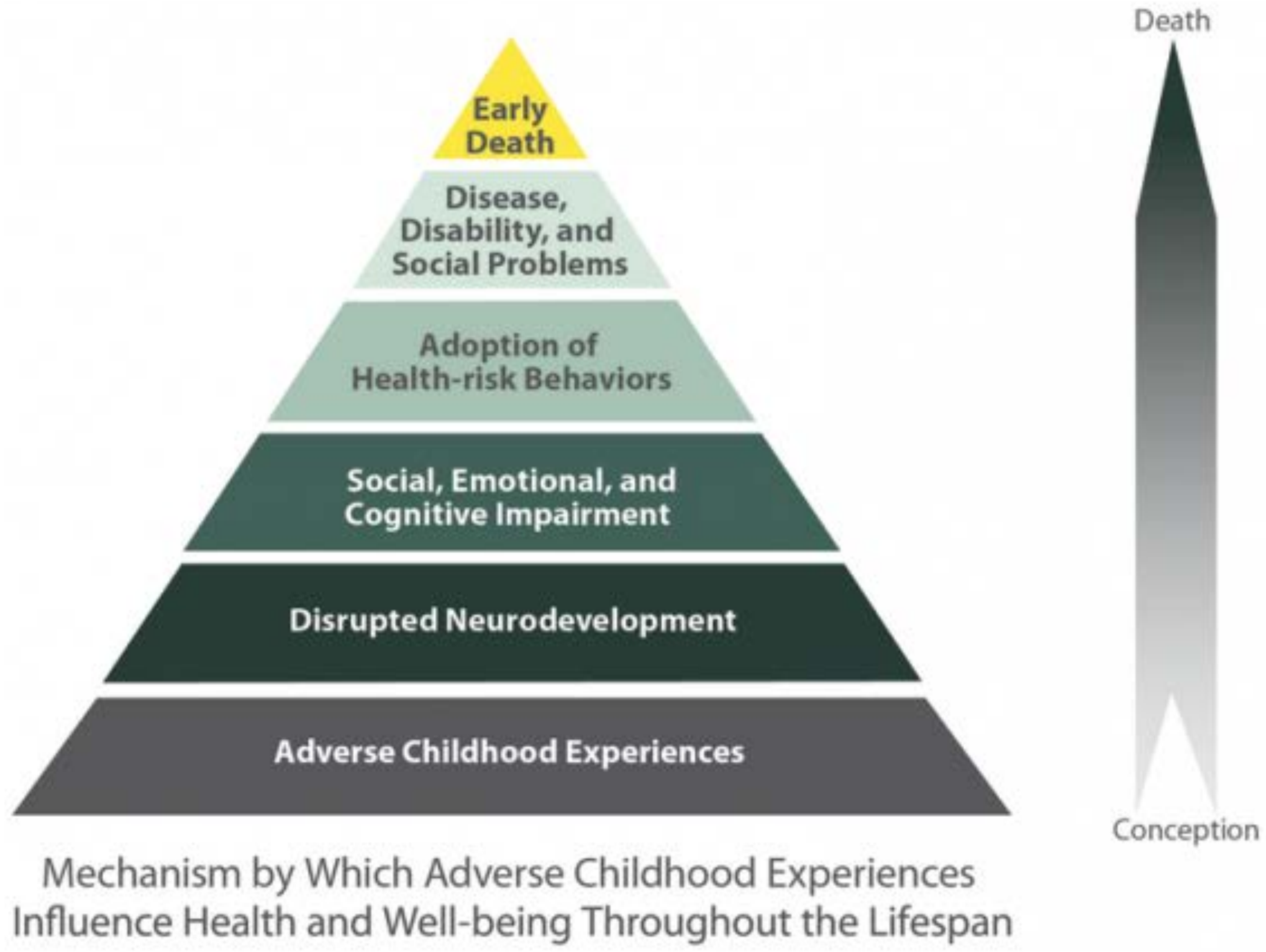


New Mexico School for the Arts

Professional Development retreat

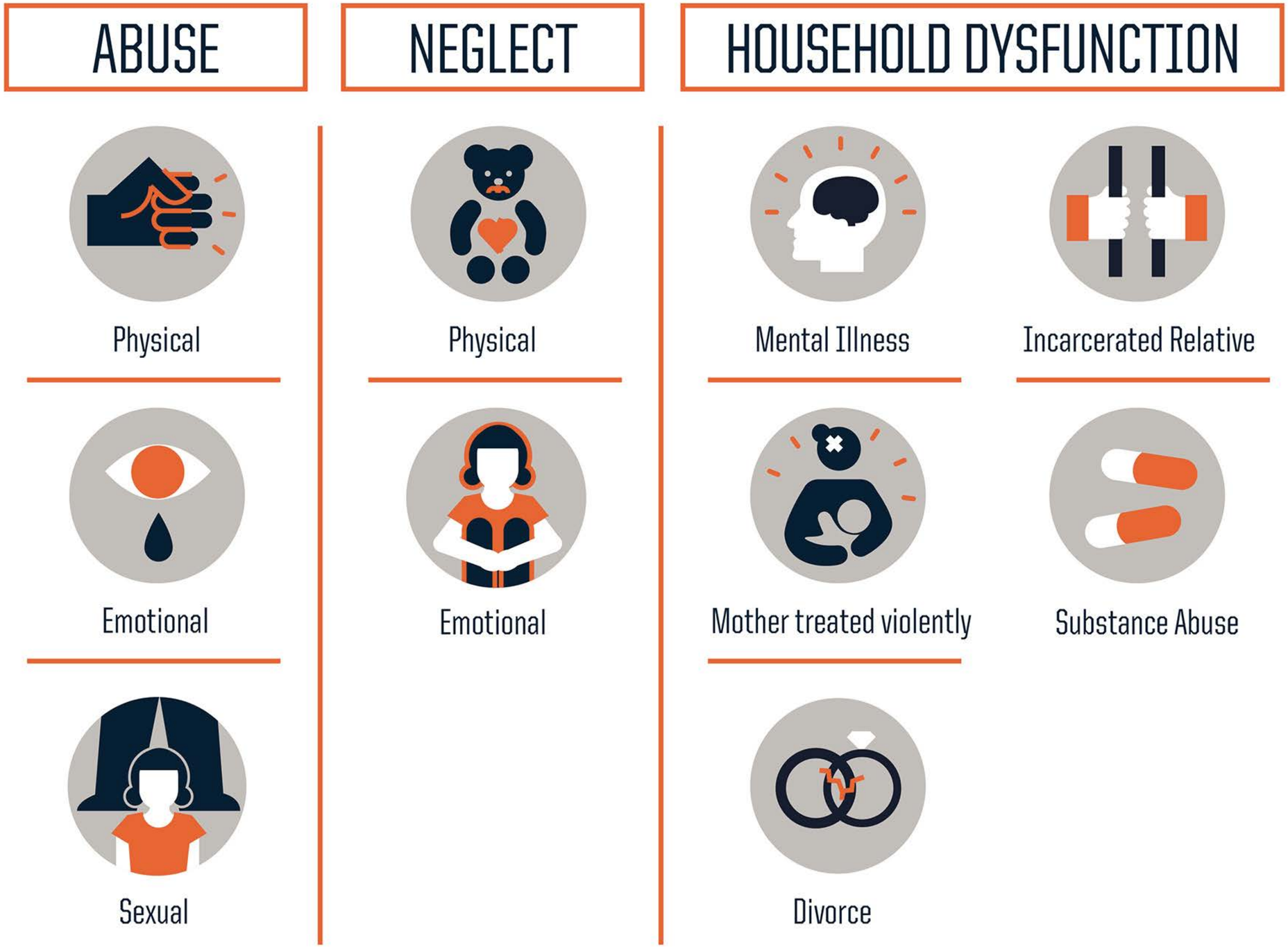
1 June 2017

The Trauma Pyramid



https://www.cdc.gov/violenceprevention/acestudy/about.html

Adverse Childhood Experiences



Infographic credit: Robert Wood Johnson Foundation

Adverse Childhood Experiences

All ACE questions refer to the respondent's first 18 years of life.

1. Abuse

- ***Emotional abuse***: A parent, stepparent, or adult living in your home swore at you, insulted you, put you down, or acted in a way that made you afraid that you might be physically hurt.
- ***Physical abuse***: A parent, stepparent, or adult living in your home pushed, grabbed, slapped, threw something at you, or hit you so hard that you had marks or were injured.
- ***Sexual abuse***: An adult, relative, family friend, or stranger who was at least 5 years older than you ever touched or fondled your body in a sexual way, made you touch his/her body in a sexual way, attempted to have any type of sexual intercourse with you.

2. Household Challenges

- ***Mother treated violently***: Your mother or stepmother was pushed, grabbed, slapped, had something thrown at her, kicked, bitten, hit with a fist, hit with something hard, repeatedly hit for over at least a few minutes, or ever threatened or hurt by a knife or gun by your father (or stepfather) or mother's boyfriend.
- ***Household substance abuse***: A household member was a problem drinker or alcoholic or a household member used street drugs.
- ***Mental illness in household***: A household member was depressed or mentally ill or a household member attempted suicide.
- ***Parental separation or divorce***: Your parents were ever separated or divorced.
- ***Criminal household member***: A household member went to prison.

3. Neglect

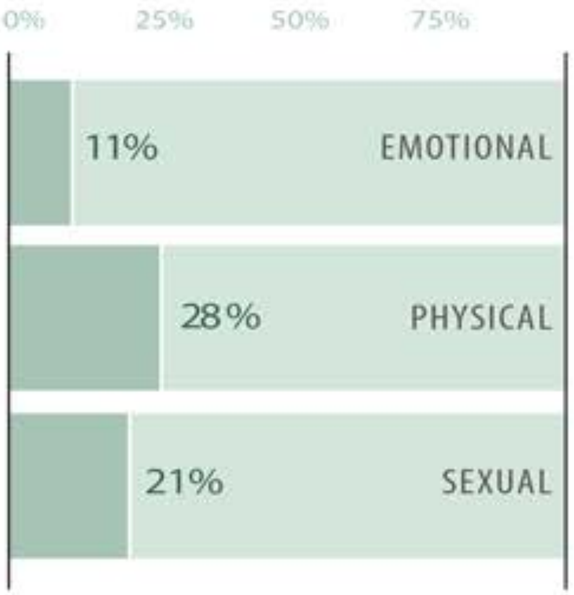
- ***Emotional neglect***: Someone in your family helped you feel important or special, you felt loved, people in your family looked out for each other and felt close to each other, and your family was a source of strength and support.
- ***Physical neglect***: There was someone to take care of you, protect you, and take you to the doctor if you needed it, you didn't have enough to eat, your parents were too drunk or too high to take care of you, and you had to wear dirty clothes.

"Relationship of Childhood Abuse and Household Dysfunction to Many of the Leading Causes of Death in Adults," (1998) Am J Preventive Medicine

TYPES *of* ACES

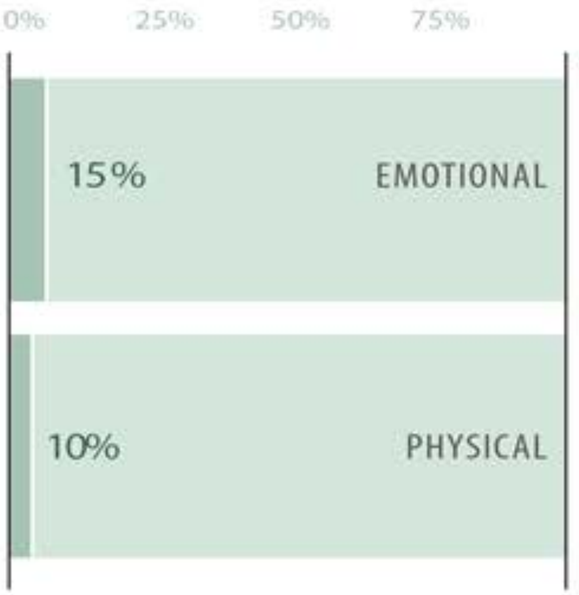
The ACE study looked at three categories of adverse experience: **childhood abuse**, which included emotional, physical, and sexual abuse; **neglect**, including both physical and emotional neglect; and **household challenges**, which included growing up in a household were there was substance abuse, mental illness, violent treatment of a mother or stepmother, parental separation/divorce or had a member of the household go to prison. Respondents were given an **ACE score** between 0 and 10 based on how many of these 10 types of adverse experience to which they reported being exposed.

ABUSE



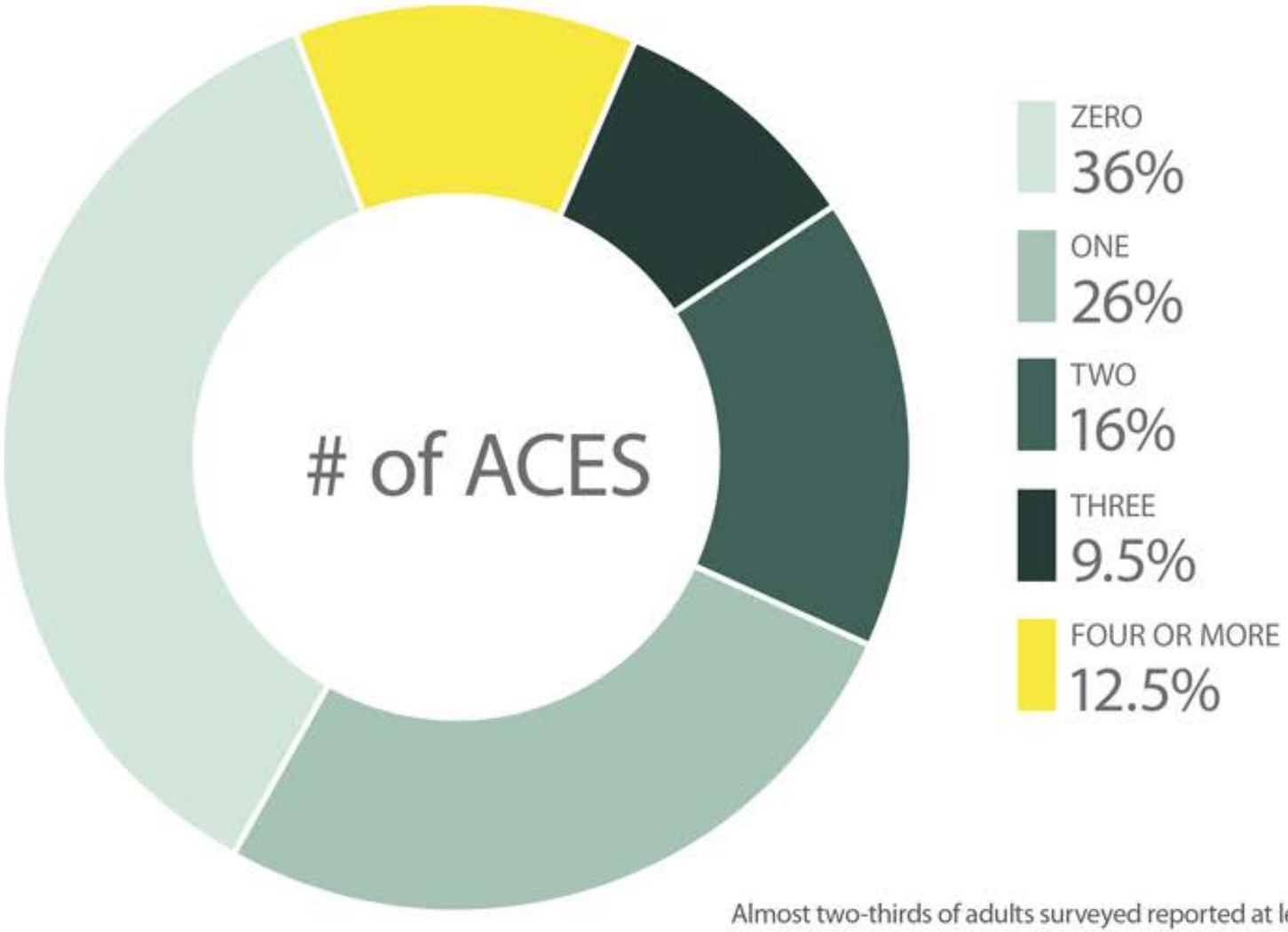
HOUSEHOLD CHALLENGES

NEGLECT



http://vetoviolence.cdc.gov/apps/phl/resource_center_infographic.html

HOW COMMON ARE ACES?



Almost two-thirds of adults surveyed reported at least one Adverse Childhood Experience – and the majority of respondents who reported at least one ACE reported more than one.

http://vetoviolence.cdc.gov/apps/phl/resource_center_infographic.html

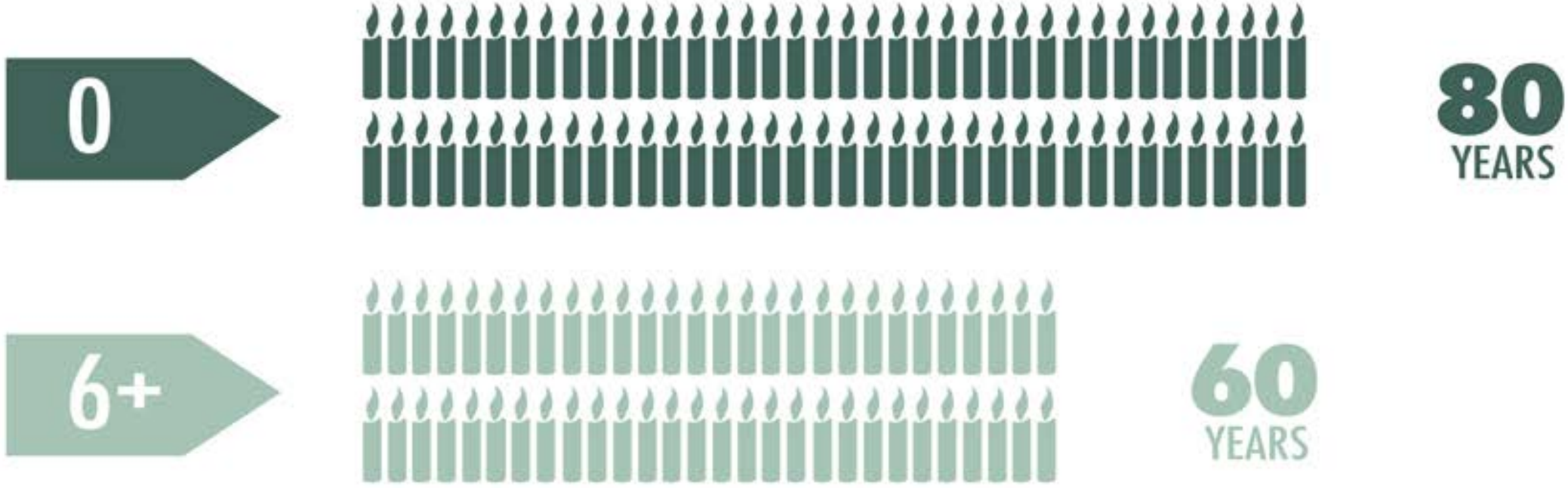
HOW DO **ACES** AFFECT OUR LIVES?

ACES CAN HAVE LASTING EFFECTS ON BEHAVIOR & HEALTH...

Simply put, our childhood experiences have a tremendous, lifelong impact on our health and the quality of our lives. The ACE Study showed dramatic links between adverse childhood experiences and risky behavior, psychological issues, serious illness and **the leading causes of death**.

LIFE EXPECTANCY

People with six or more ACEs died nearly **20 years earlier on average** than those without ACEs.



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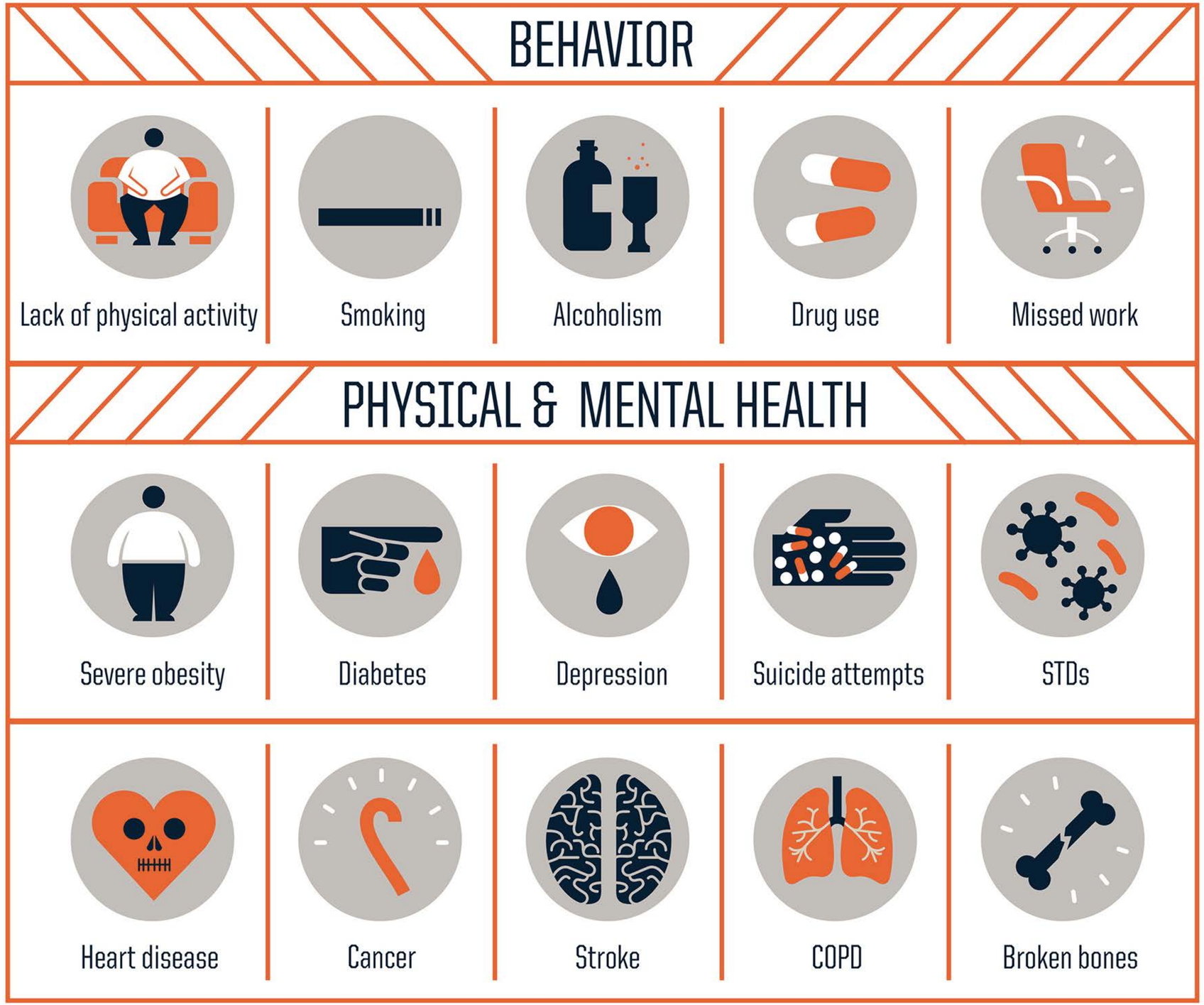


Infographic credit: Robert Wood Johnson Foundation

ECONOMIC TOLL

The Centers for Disease Control and Prevention (CDC) estimates the lifetime costs associated with child maltreatment at **$124 billion.**

http://vetoviolence.cdc.gov/apps/phl/resource_center_infographic.html

What about the brain?

Exposure to early ACEs can lead to structural and functional changes in the brain

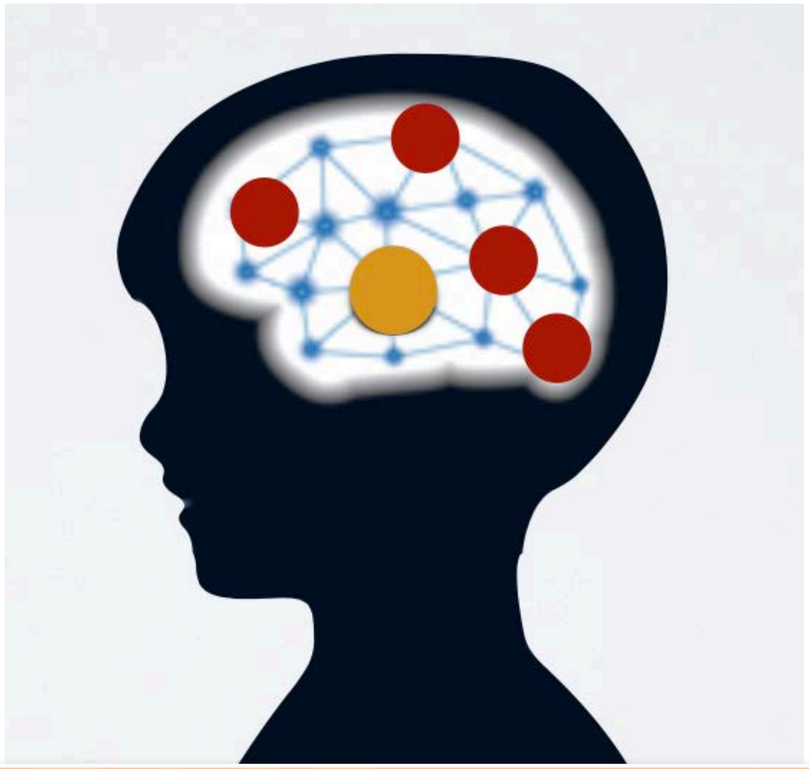
Can affect neural circuits for:

- Language
- Executive Function
- Learning and memory
- Social-emotional processing

Reviewed in Merz & Noble (2017) *Neural Development in Context: Differences in Structure and Function Associated with ACEs*

Remember the hippocampus?

The hippocampus is <u>critical</u> for new learning



Smaller hippocampus found in kids with:

- Lower family income
- Lower parental education
- Lower SES

But all is not lost! Remember that the hippocampus is one of the only brain regions that grows new neurons throughout life!

Reviewed in Merz & Noble (2017) *Neural Development in Context: Differences in Structure and Function Associated with ACEs*

What *can* Be Done About ACES?

Single most common factor for children who develop resilience is at least one **stable & committed relationship with a supportive adult**

Trusted adult can provide:

- personalized responsiveness
- scaffolding
- protection

…that buffer children from developmental disruption

Build key capacities:

- ability to plan
- monitor
- regulate behavior

…that enable children to respond adaptively to adversity and thrive

http://developingchild.harvard.edu/science/key-concepts/resilience/

Are there protective factors?

Yes! Children who do well in the face of serious hardship typically have a biological resistance to adversity and strong relationships with the important adults in their life

Biology

Social Environment

*Resilience is the result of a **combination** of protective factors*

http://developingchild.harvard.edu/science/key-concepts/resilience/

How to optimize resilience

Research has identified a common set of factors that predispose children to positive outcomes in the face of significant adversity:

1 Supportive adult-child relationships

2 Build sense of self-efficacy & perceived control

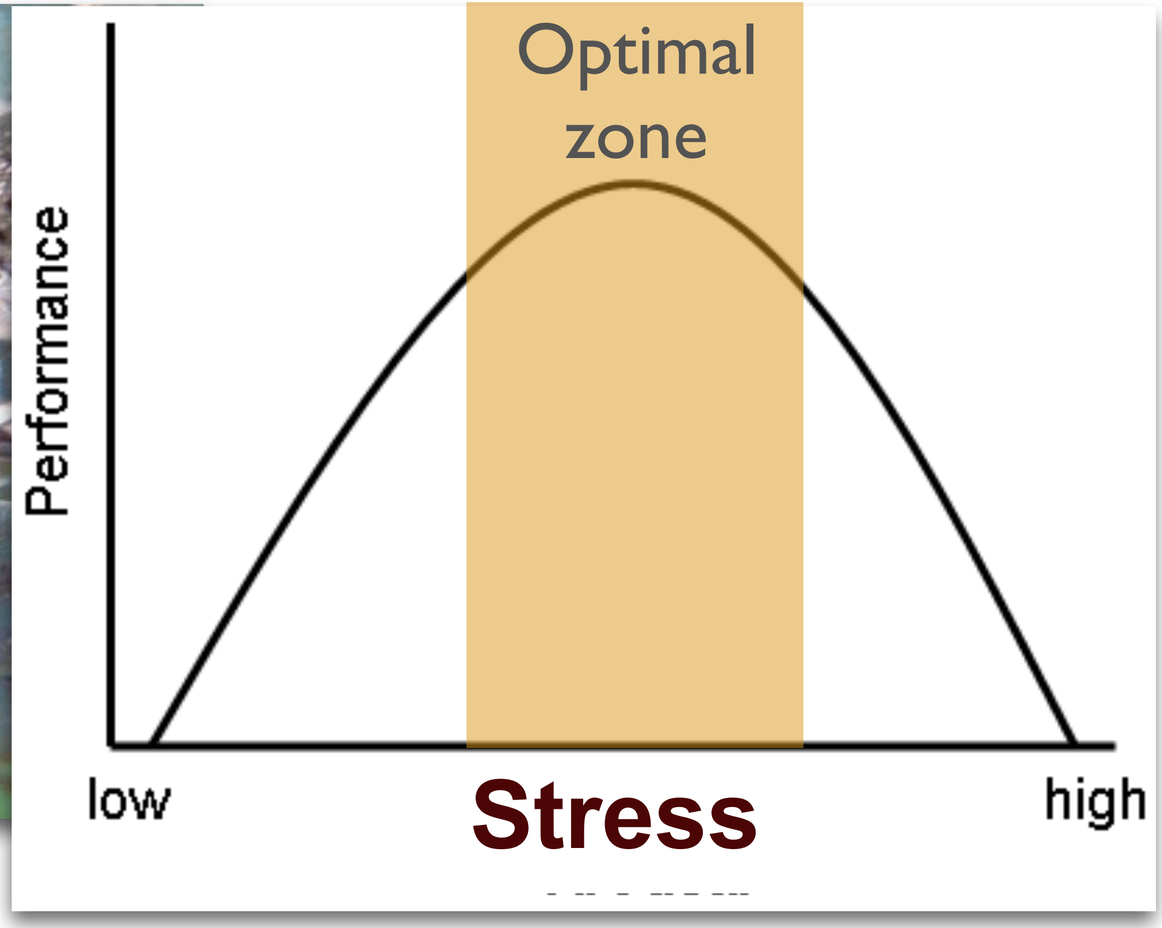
3 Self-regulation opportunities

4 Mobilize sources of faith, hope, cultural tradition

http://developingchild.harvard.edu/science/key-concepts/resilience/

Reframing stress

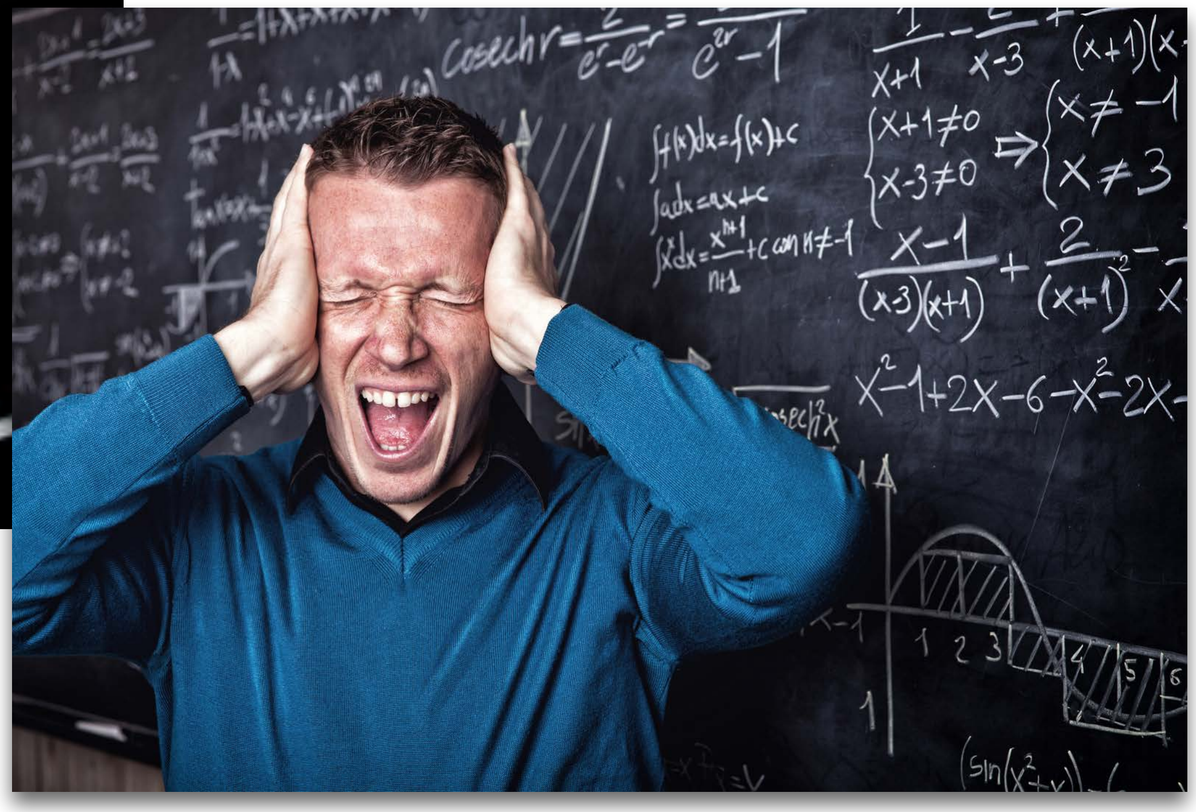
Not all stress is harmful!



Reframing stress can move you into the optimal zone

It’s never too late

Resilience can be developed at any age



Modeling healthy behavior can improve students’ capacities