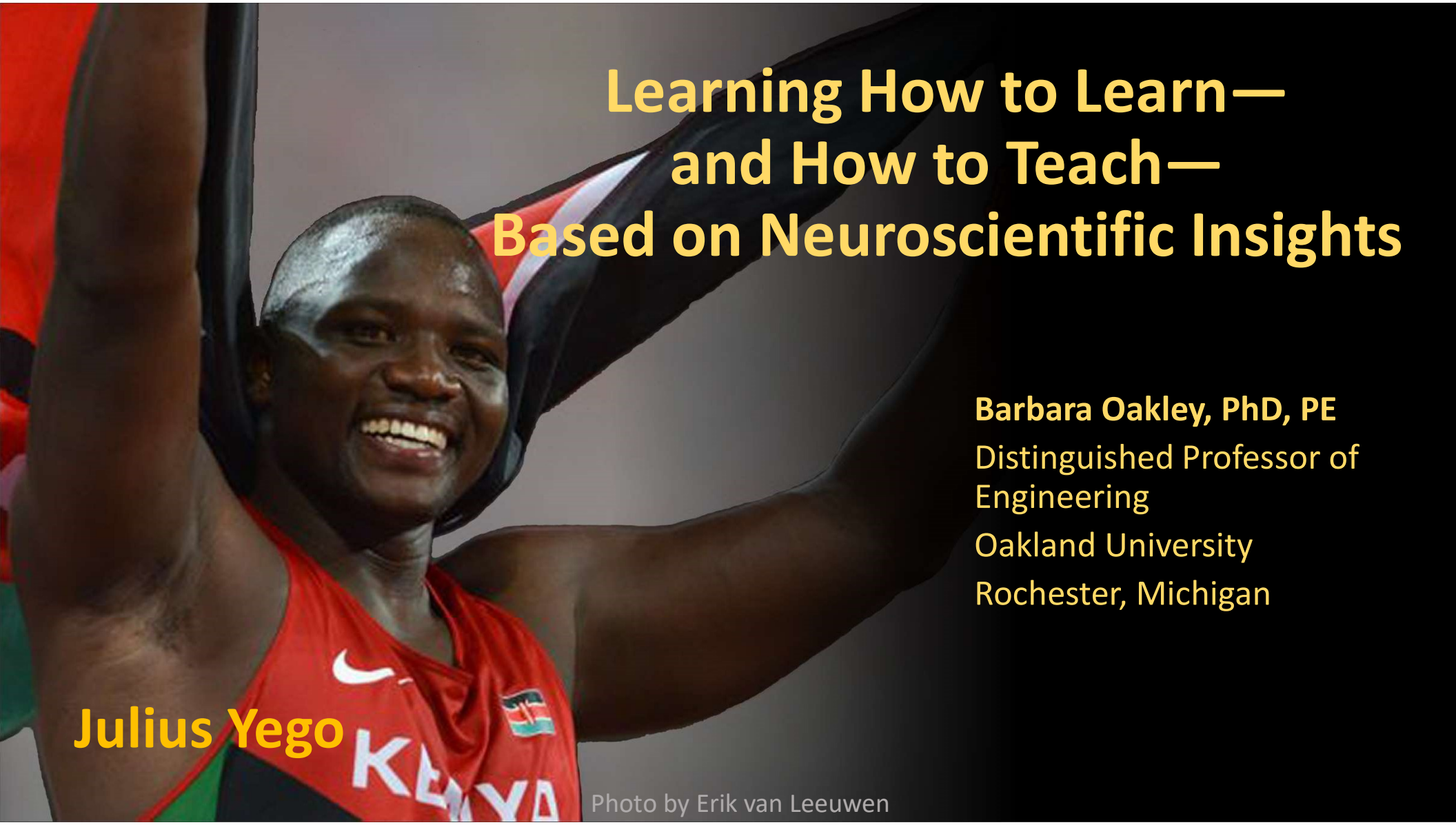

Learning How to Learn—and How to Teach—Based on Neuroscientific Insights

Barbara Oakley, PhD, PE
Distinguished Professor of Engineering
Oakland University
Rochester, Michigan

Julius Yego

Photo by Erik van Leeuwen

Watch how the PowerPoints are constructed

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Houston
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Chihuahua
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Gulf of Mexico
Miami
THE BAHAMAS
Nassau
Monterrey
★ National capital
U.S. State
State capital
Scale 1:13,500,000
Albers Equal-Area Projection
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500 Kilometers
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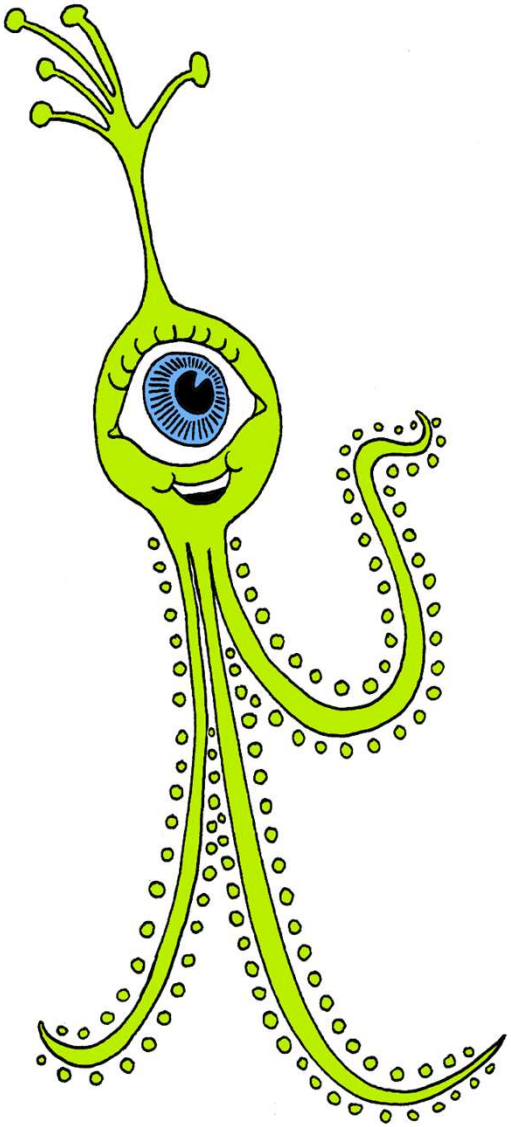
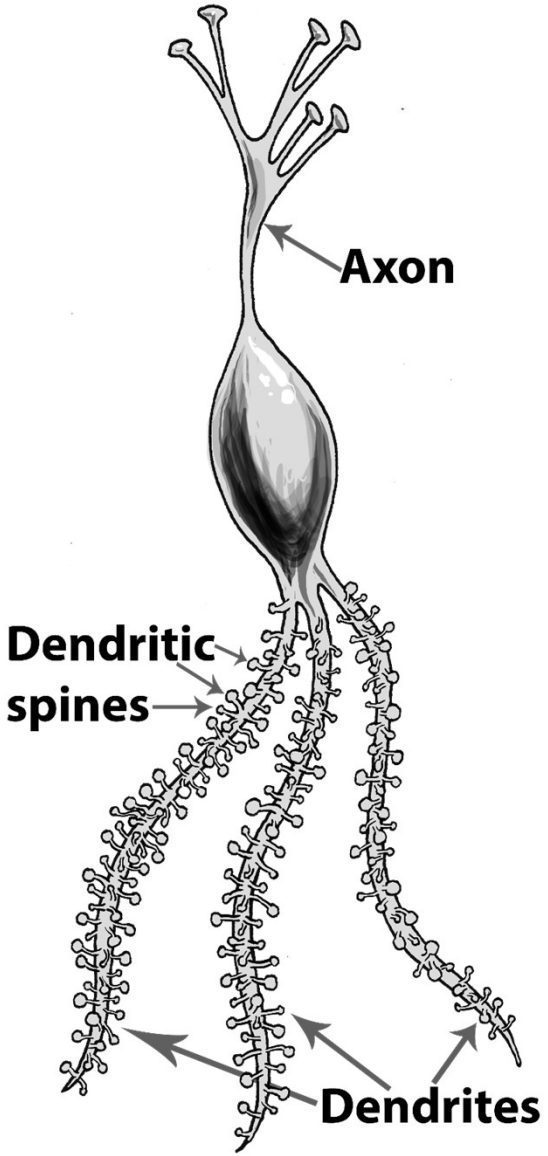
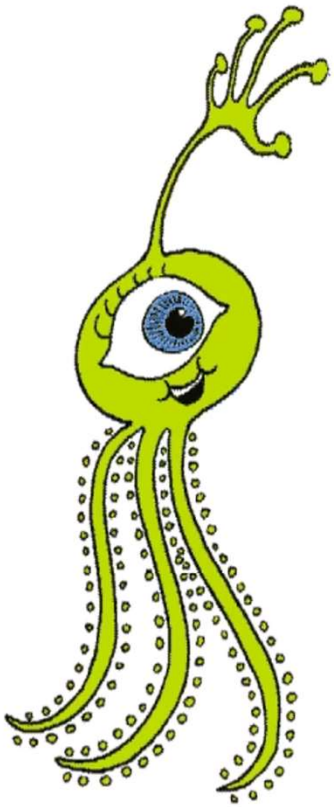
500 Miles

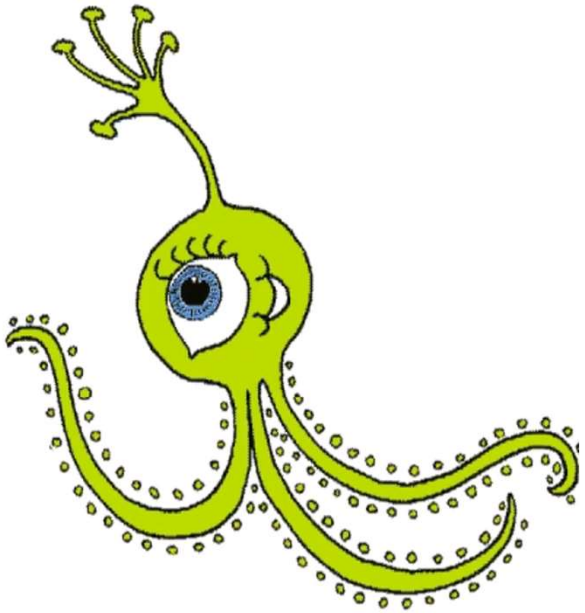
Philip Oakley

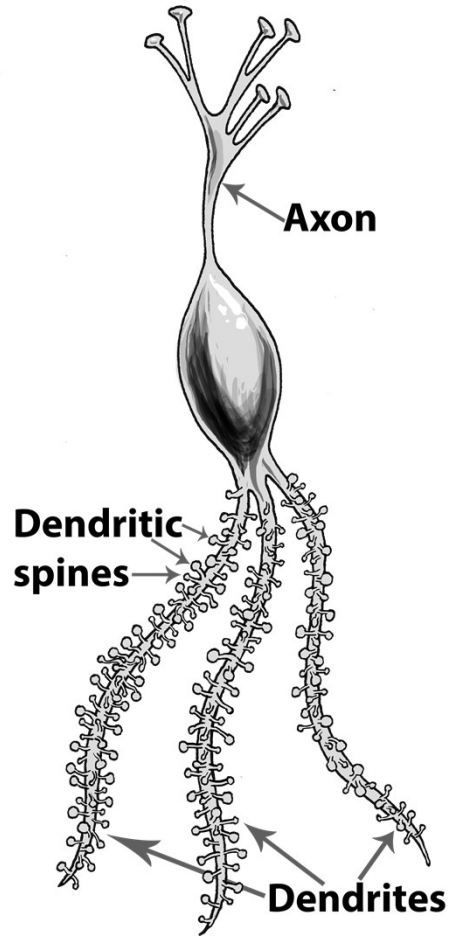
Axon
Dendritic
0:06

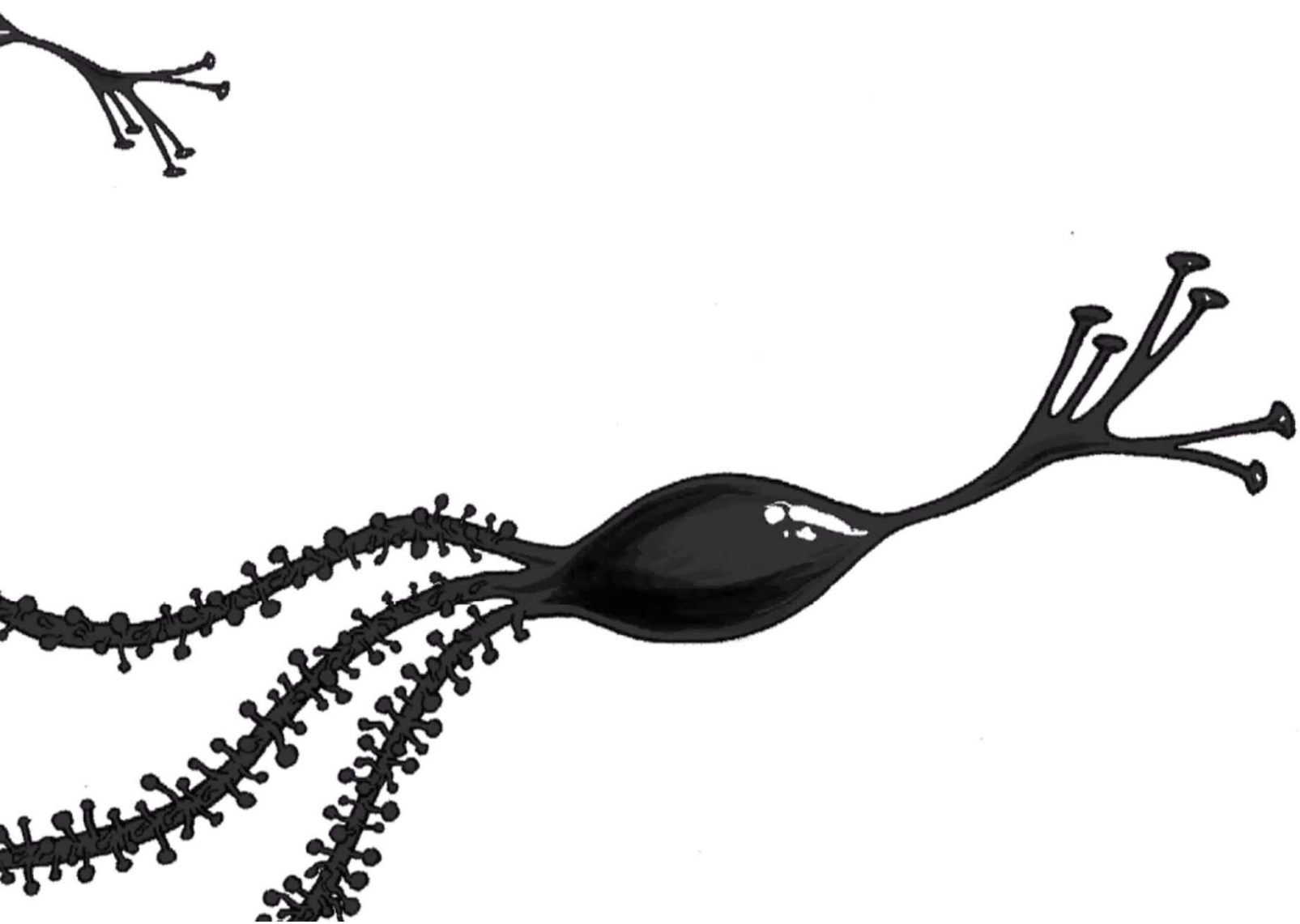



Axon
Dendritic
spines
Dendrites



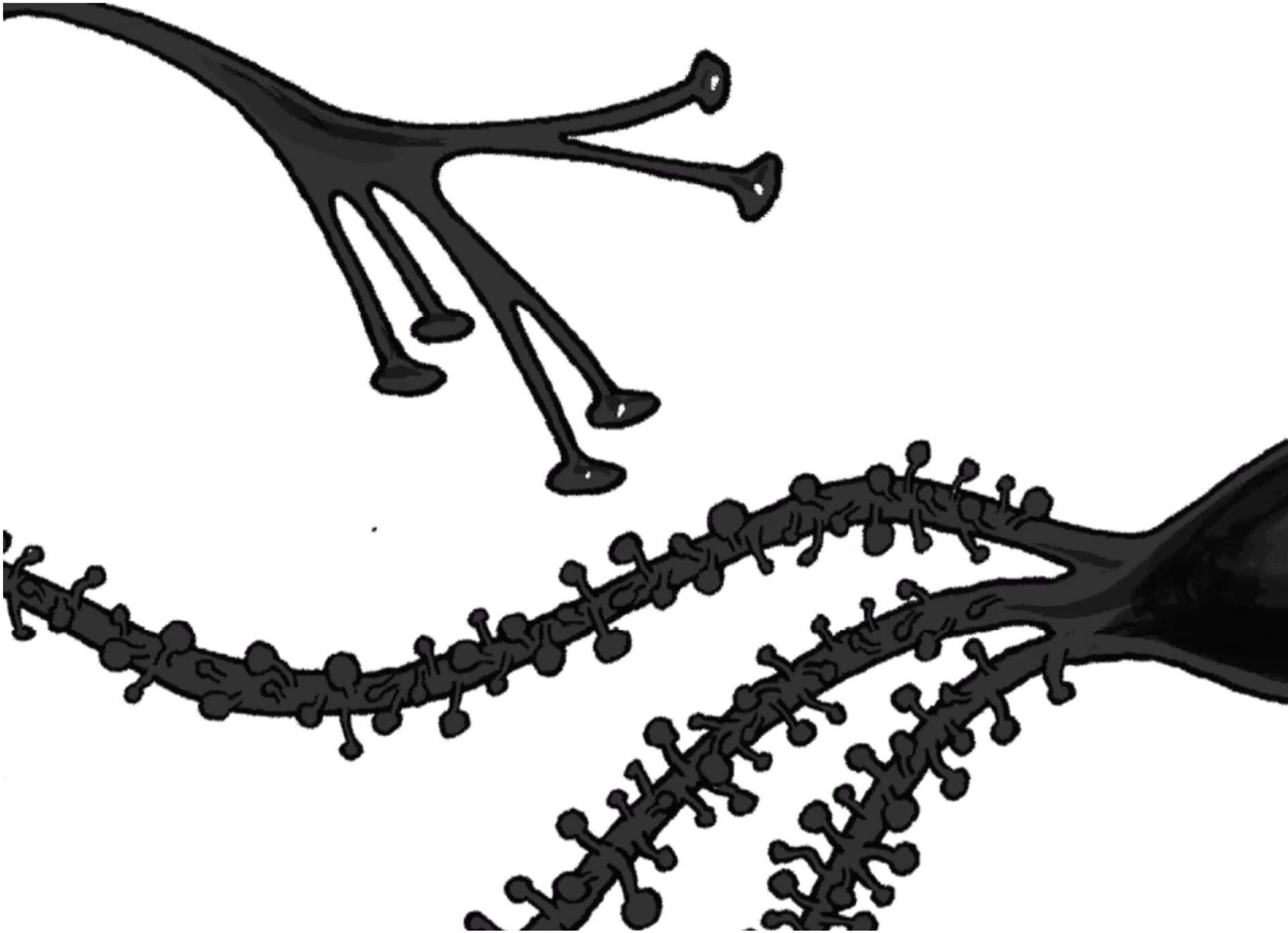



Axon
Dendritic spines
Dendrites

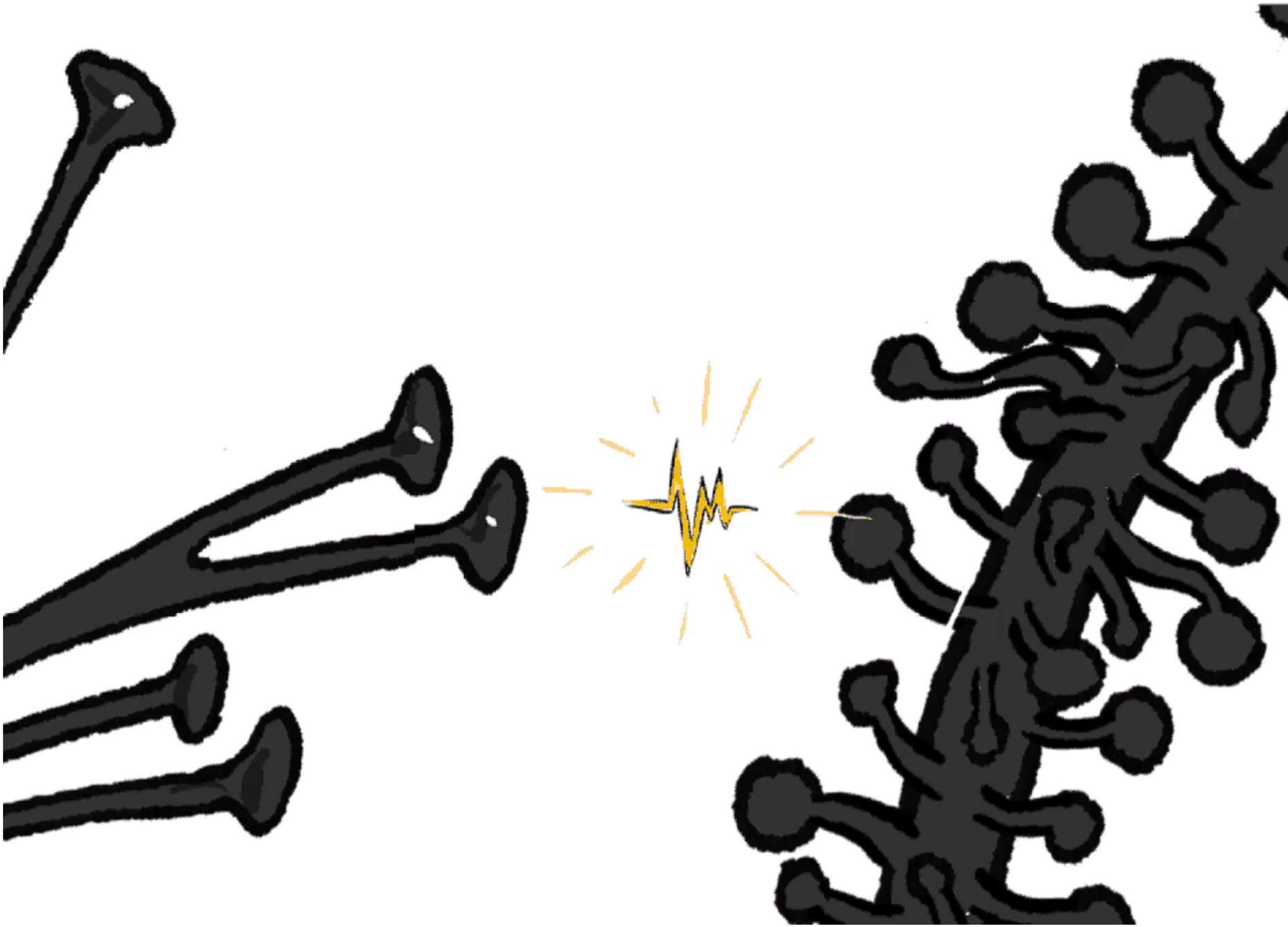


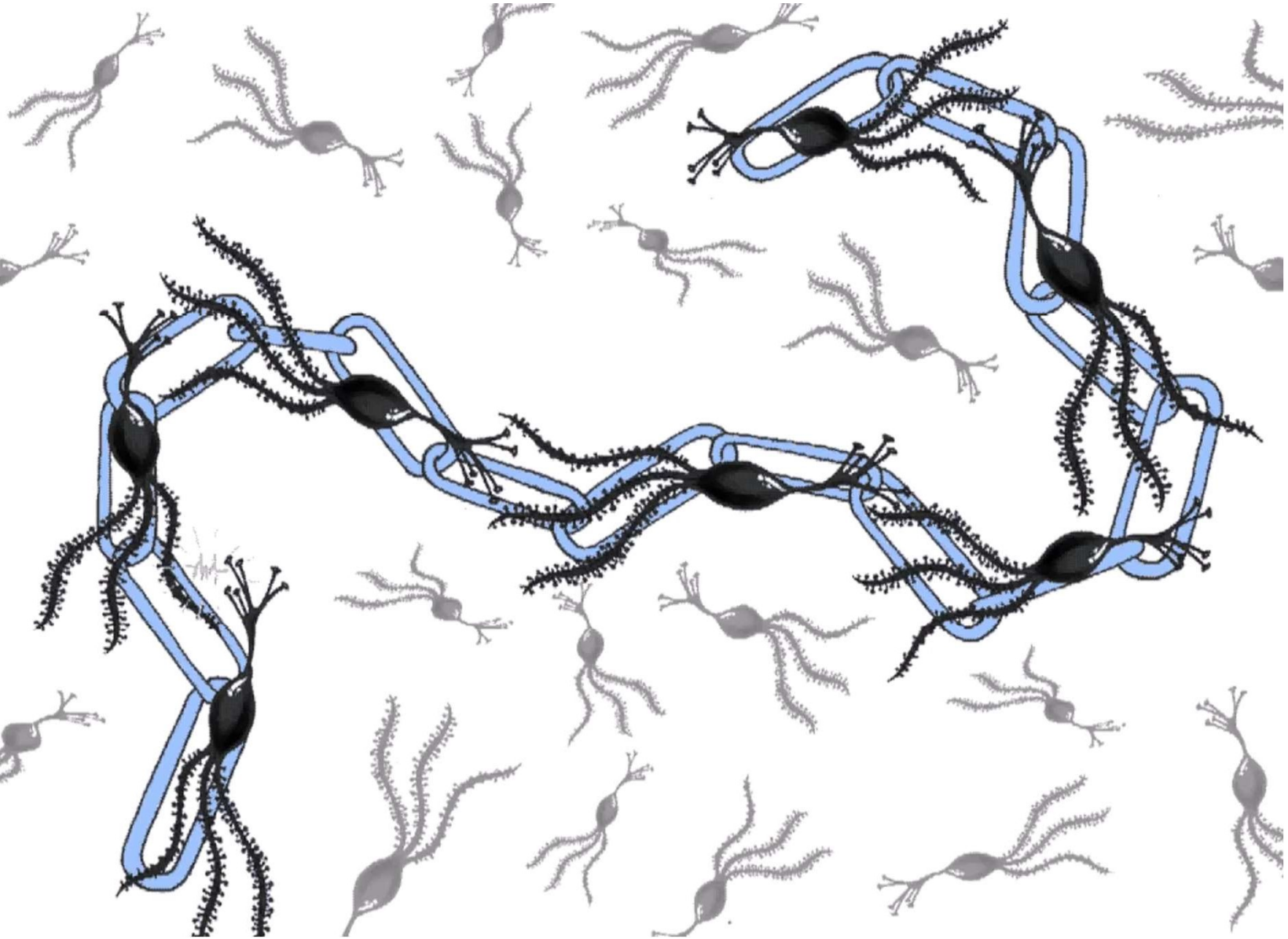
Neurons send signals

Neurons create sets of links when you learn something.



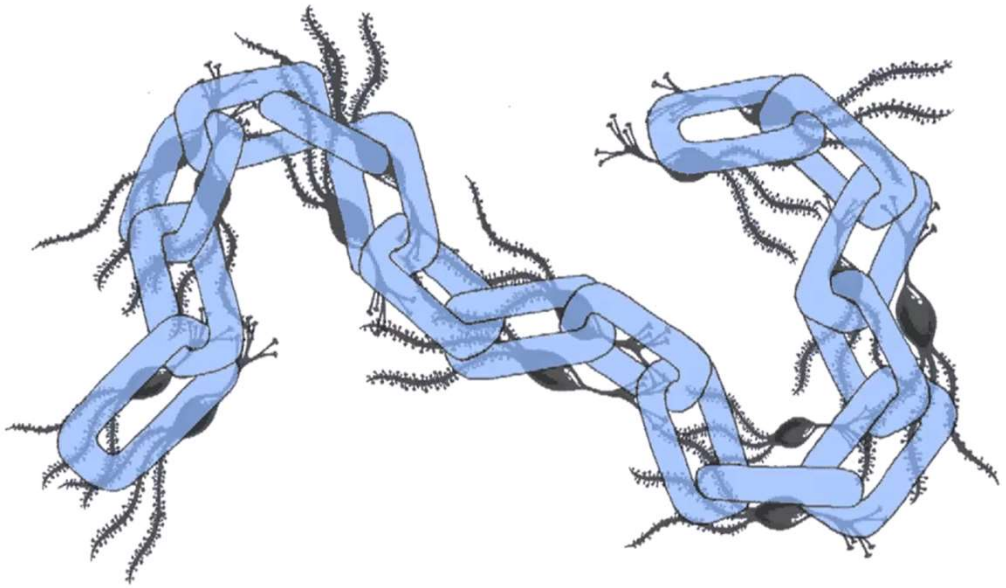
Connections strengthen with practice





These are like sets of links in a chain.

The value of metaphor



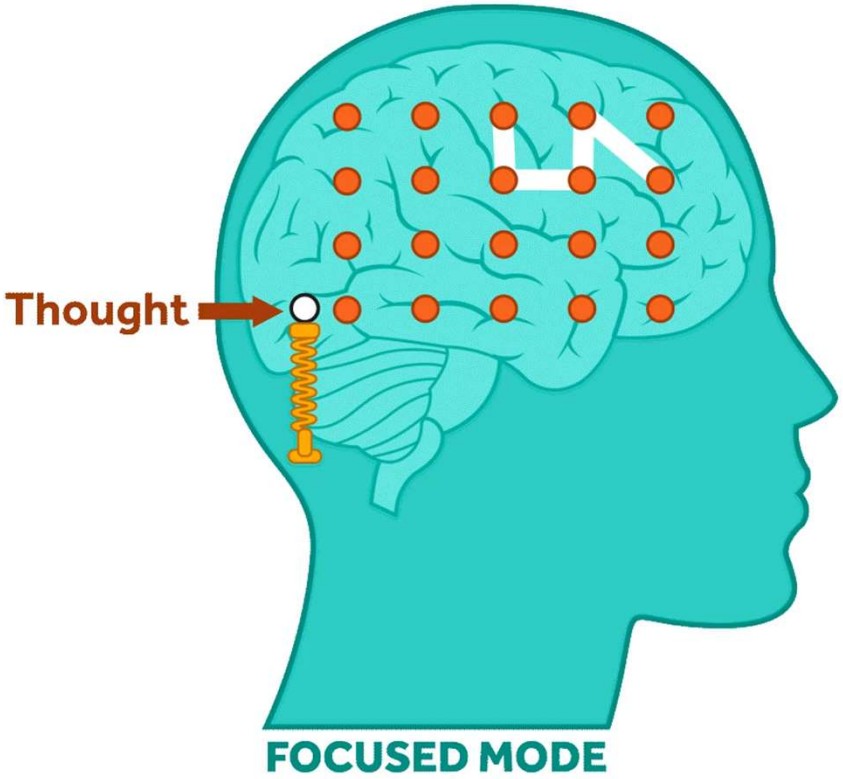
BROKEN METAPHOR
Good Meta phor

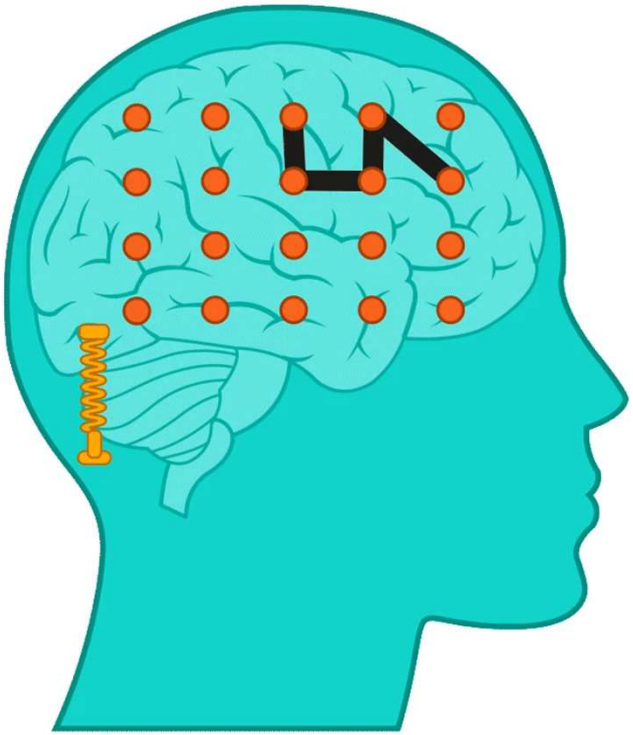
Focused mode

Diffuse mode

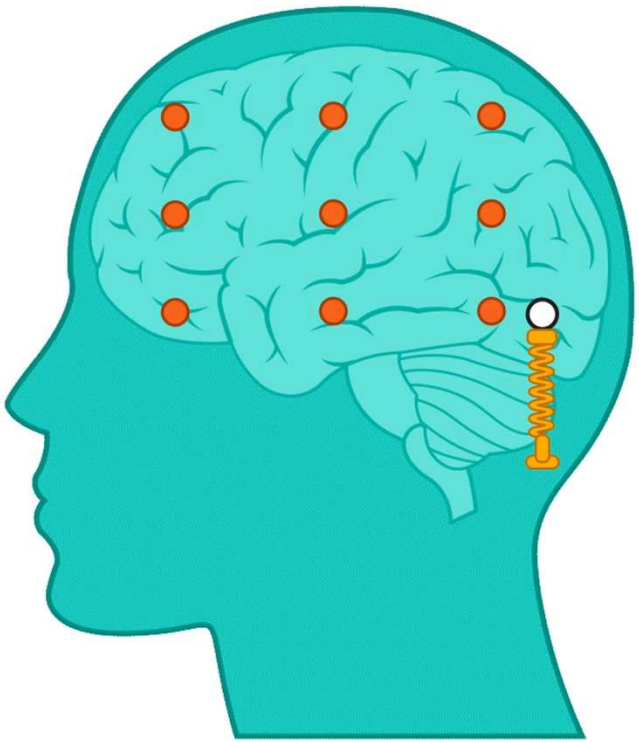
PINBALL
PINBALL
PINBALL

PINBALL
PINBALL
PINBALL


Thought
FOCUSED MODE



FOCUSED MODE



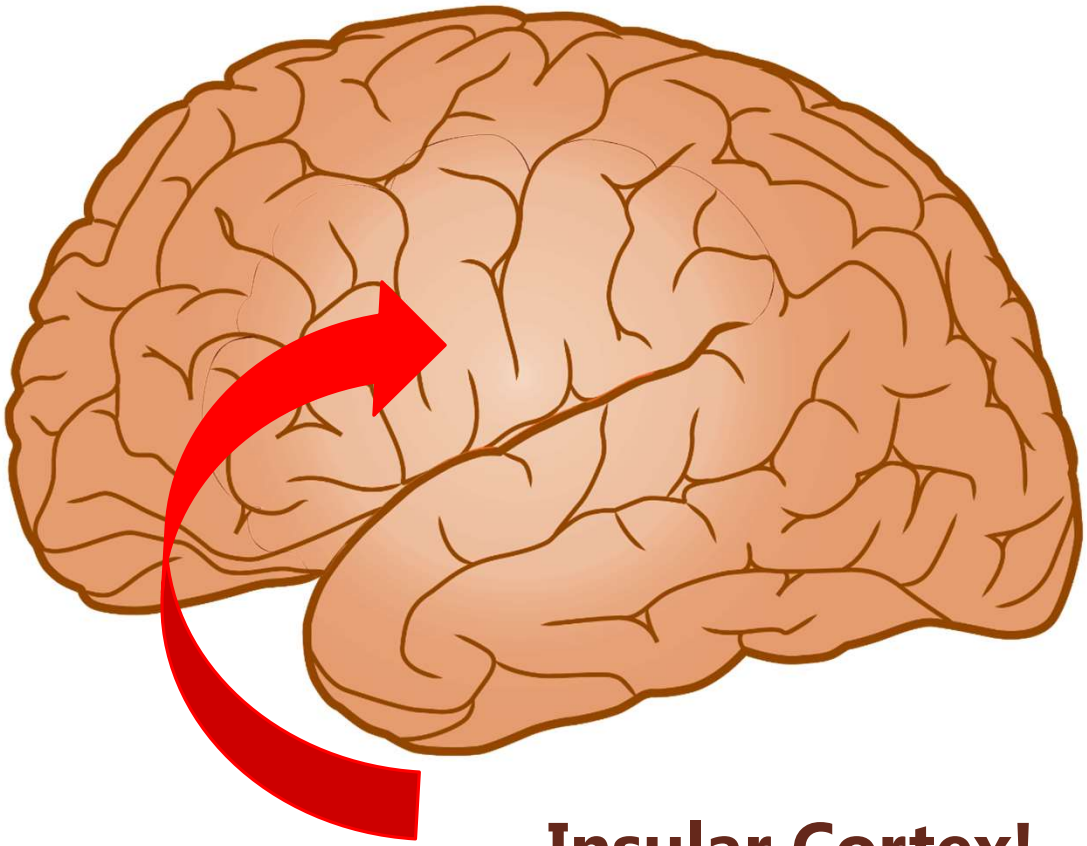
DIFFUSE MODE

Break Out Groups (5 minutes)

- Explain *focused* versus *diffuse* mode
- Describe examples of each mode

Procrastination

Procrastination



Insular Cortex!

3

Feel happy (temporarily)

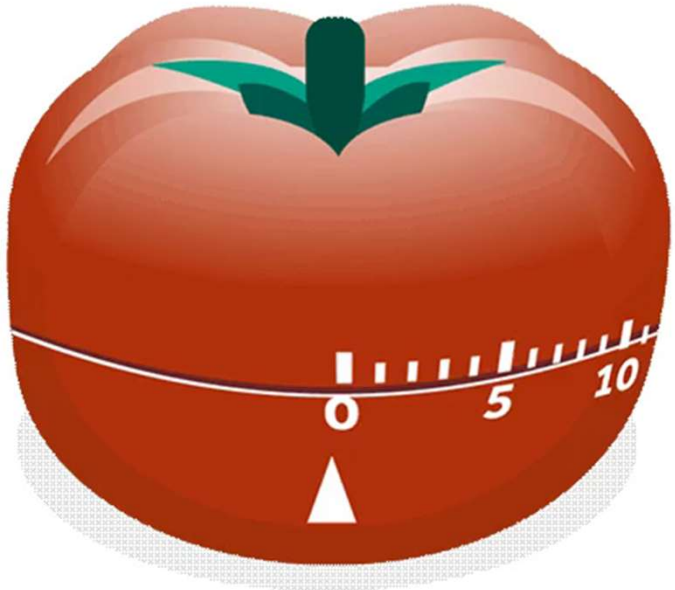
2

Turn your attention to something more pleasant

Zombie Tube

1

Unhappy feeling

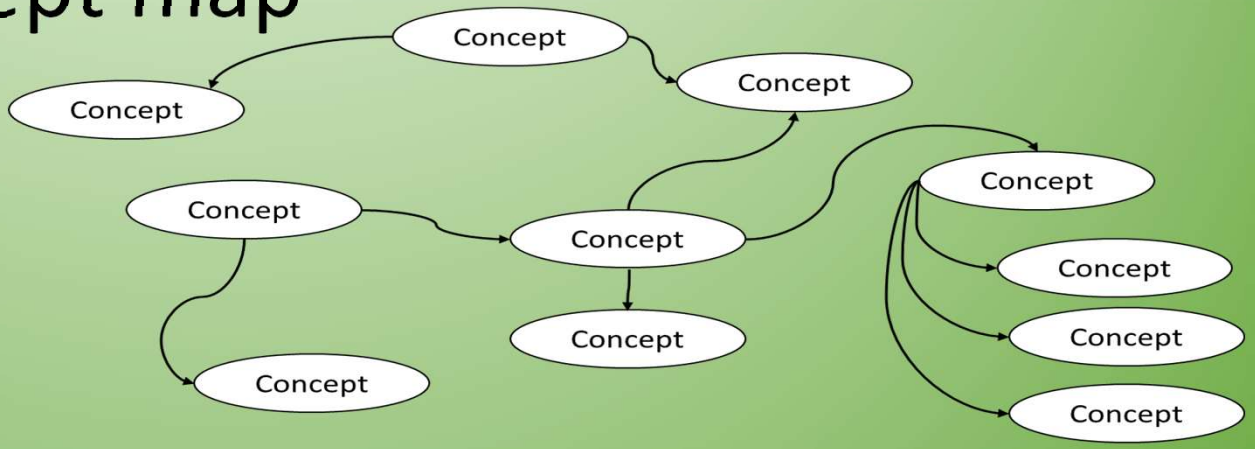


- **Turn off all distractions**
- **Set timer for 25 minutes**
- **Focus**
- ***Reward!***

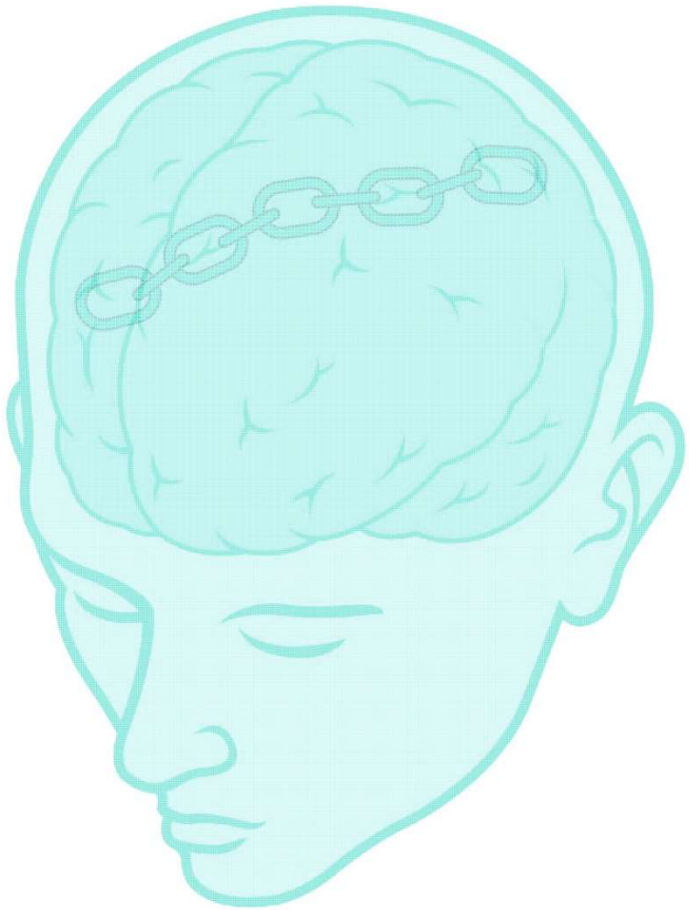
Pomodoro Technique

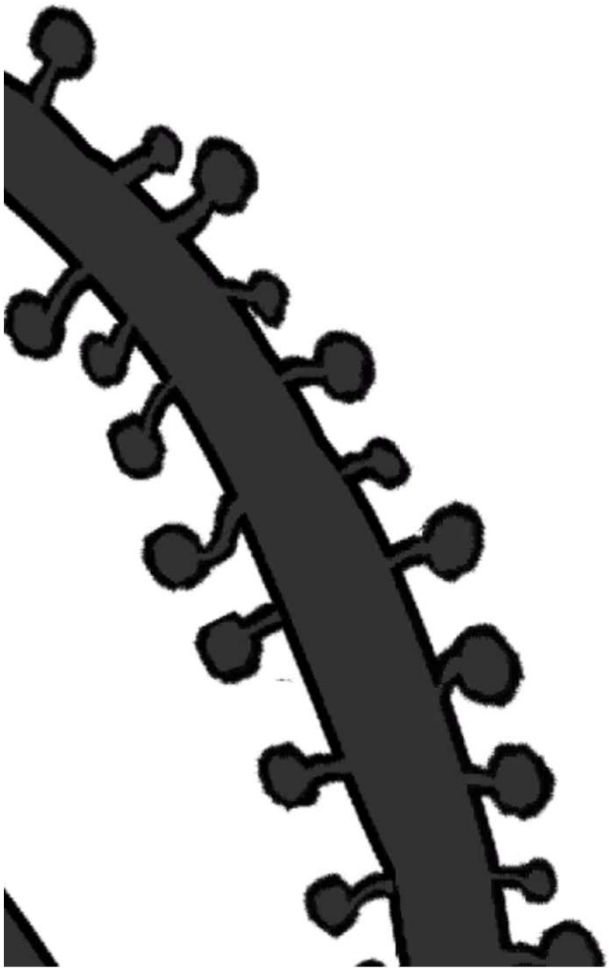
What is the most powerful technique to help you learn most efficiently?

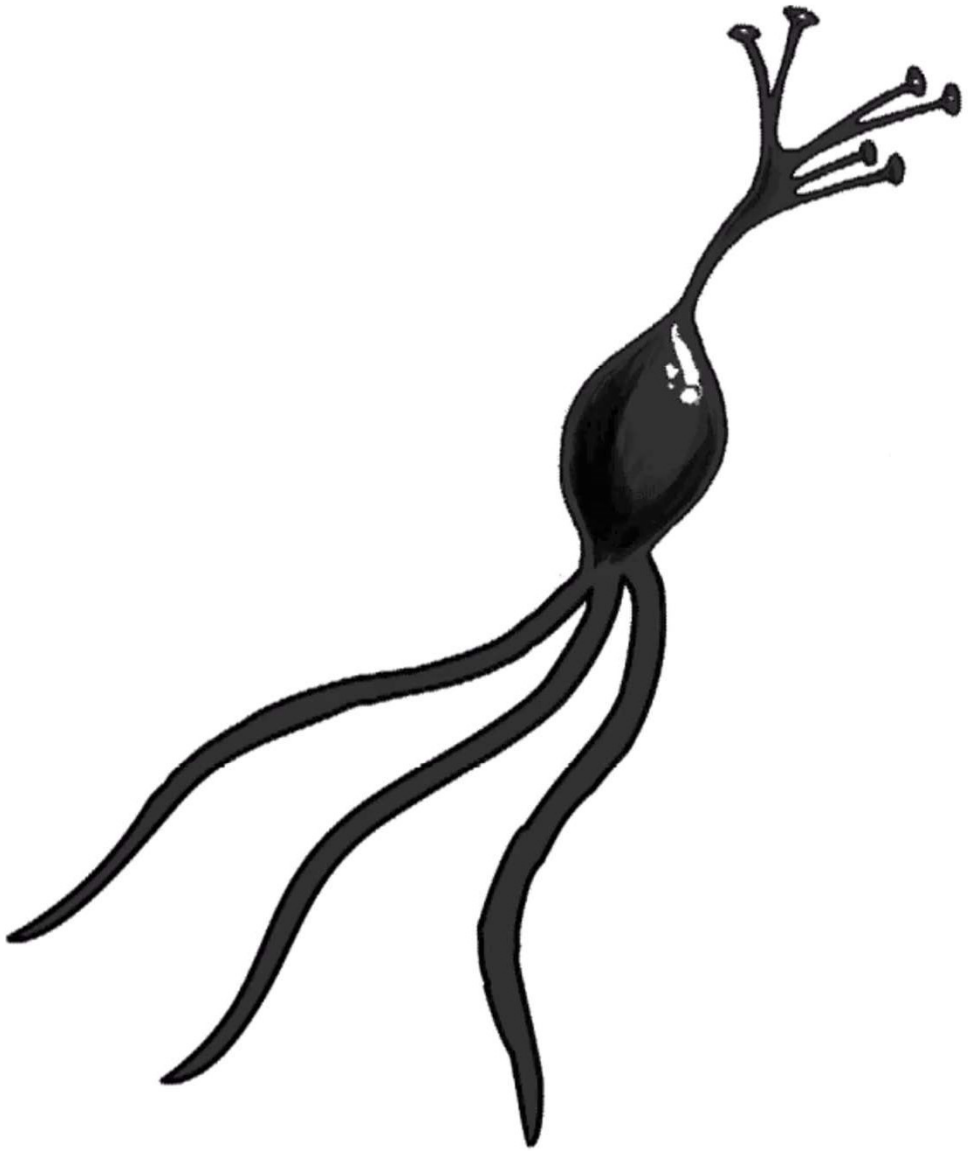
- Reread
- Highlight or underline
- Retrieval practice (“recall”)
- Create a concept map



Retrieval Practice

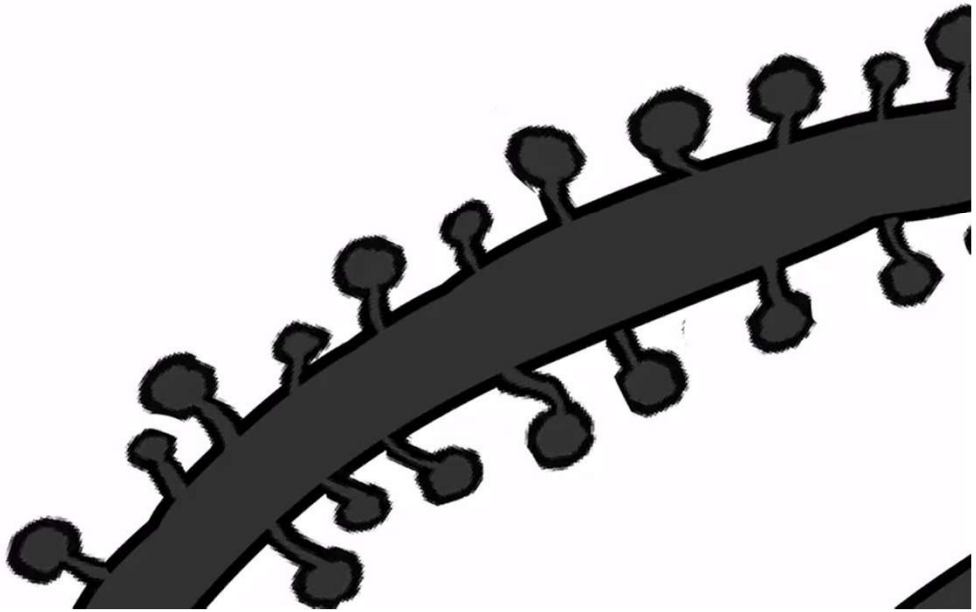






Active learning (with sleep in between!)

Active learning (with sleep in between!)



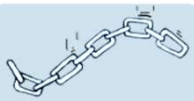
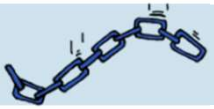
Before learning and before sleep

Images courtesy Guang Yang, NYU Langone

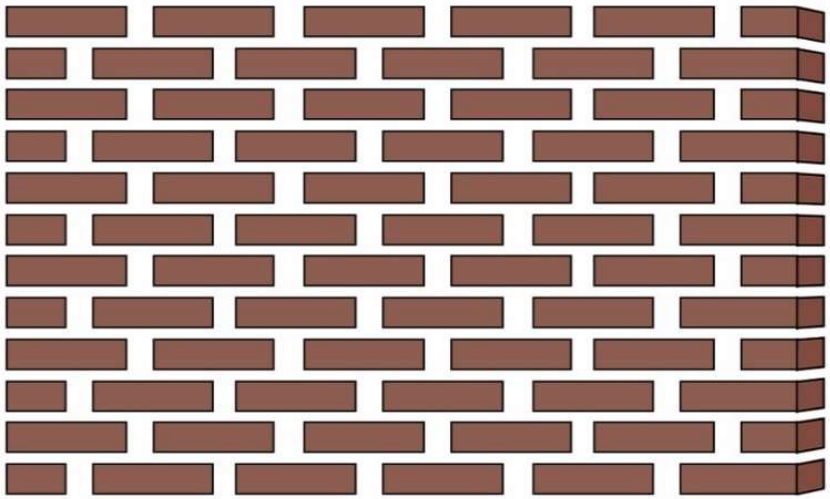
Before learning and before sleep

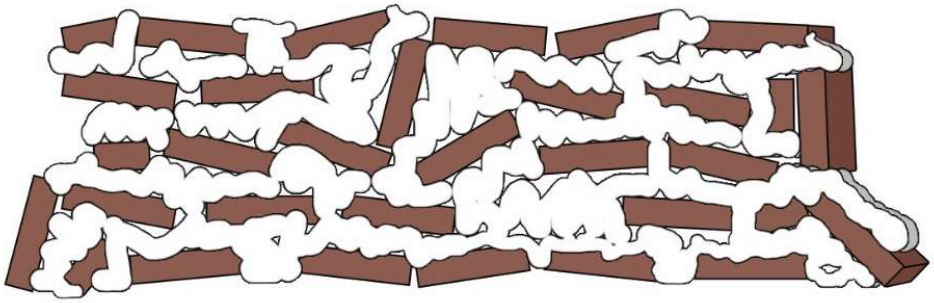
After learning and after sleep

Images courtesy Guang Yang, NYU Langone

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
						

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

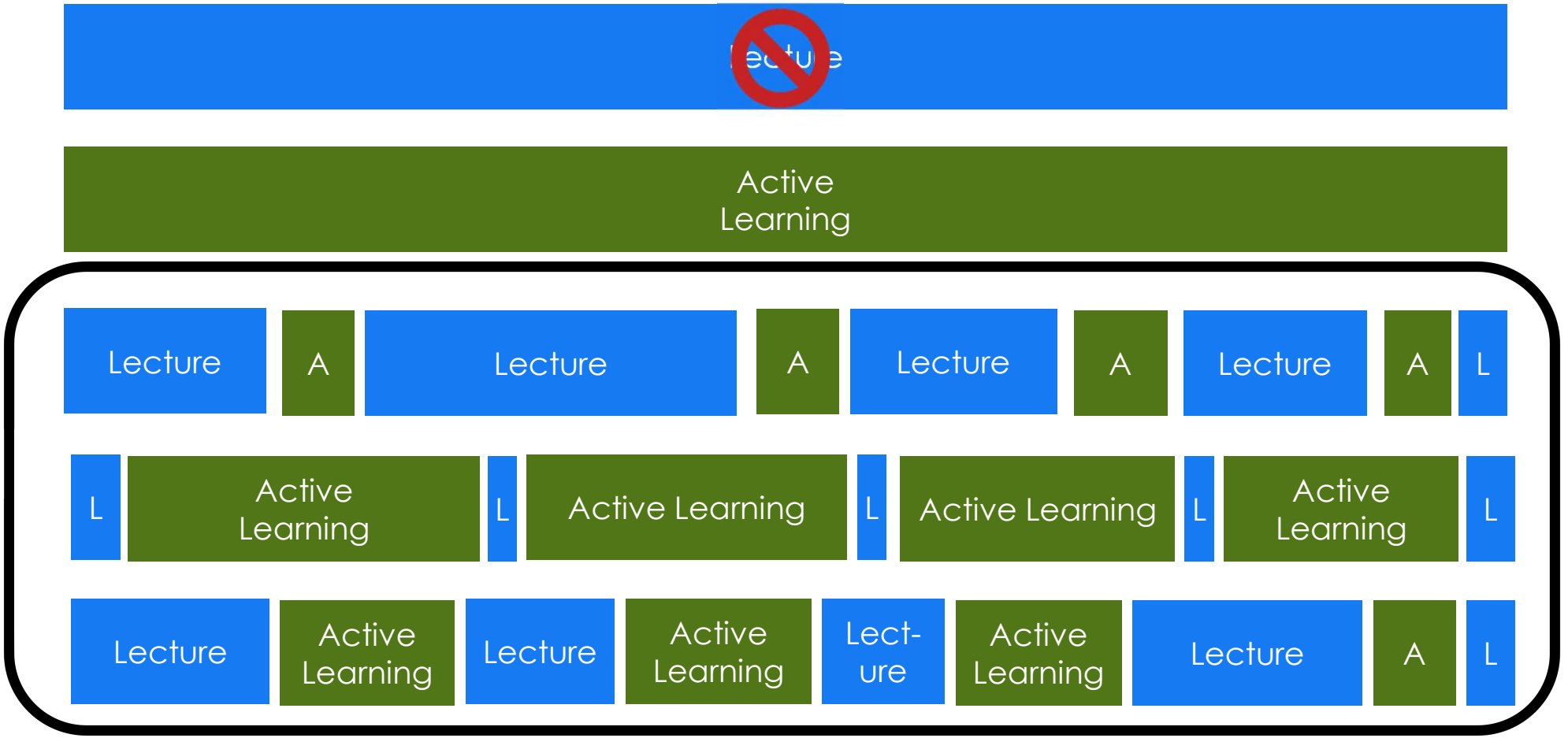




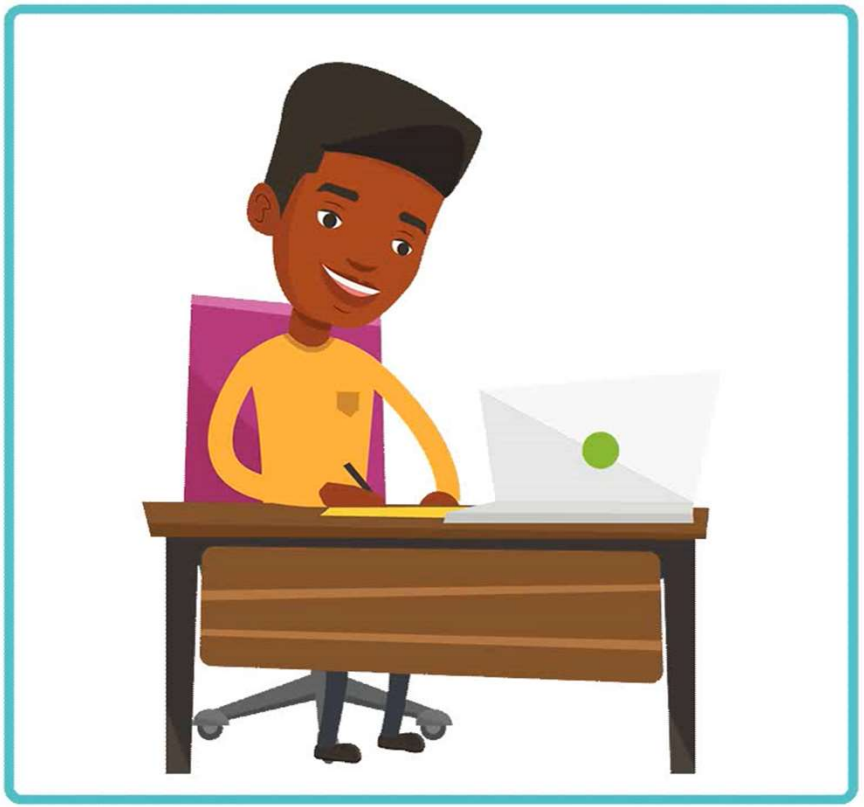
It takes time

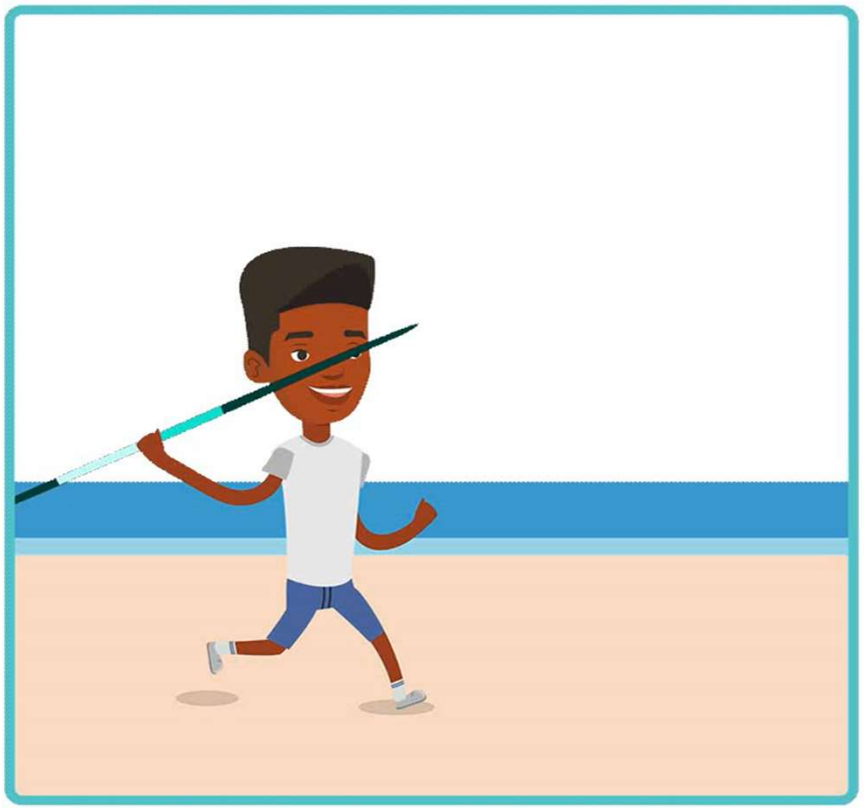
Weight lifter Sultan Rakhmanov, RIA Novosti

Julius Yego

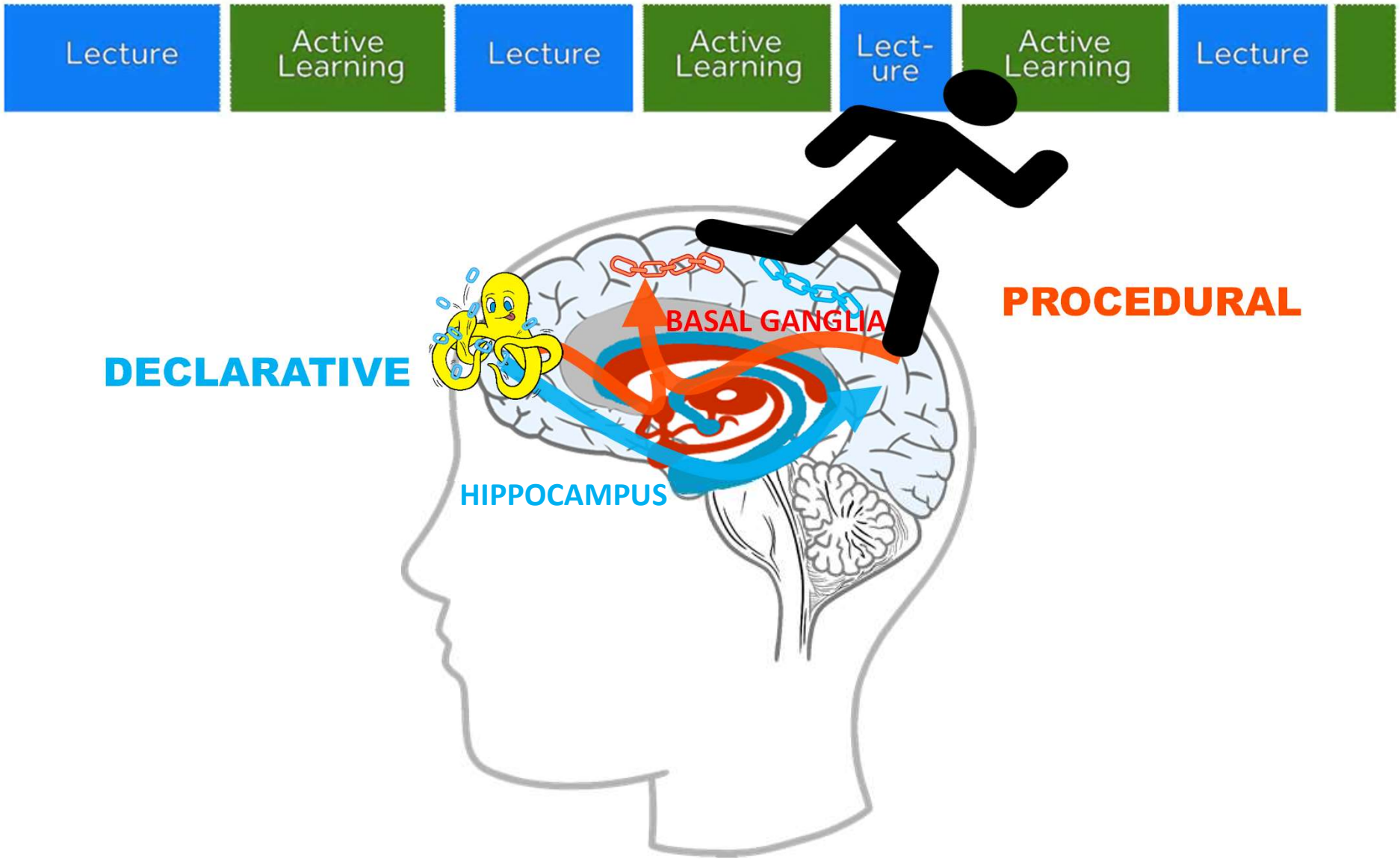


Direct instruction





Lecture	Active Learning	Lecture	Active Learning	Lect-ure	Active Learning	Lecture	


Lecture
Active Learning
Lecture
Active Learning
Lect-ure
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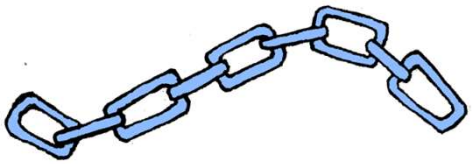
Lecture
DECLARATIVE
BASAL GANGLIA
PROCEDURAL
HIPPOCAMPUS

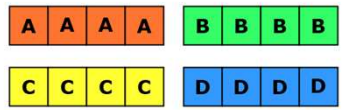


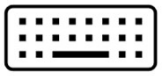
Declarative

- You're mostly conscious of it
- Develops through explicit instruction

- You can explain it.
- Involves sequential tasks.
- Fast to learn, slow to use.
- Flexible

Procedural

- You're not conscious of it
- Develops through *practice*, especially:
  - Spaced repetition
  - Interleaving 

- You can't explain it (or not easily)
- Involves complex patterns
- Slow to learn, fast to use $\frac{1}{1/k} = k$
- Inflexible 

See if you can put declarative and procedural descriptions in the appropriate box

https://barbaraoakley.h5p.com/content/1291071574160675978

DECLARATIVE

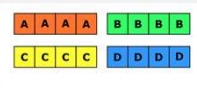
PROCEDURAL

RETRIEVAL PRACTICE

SPACED REPETITION

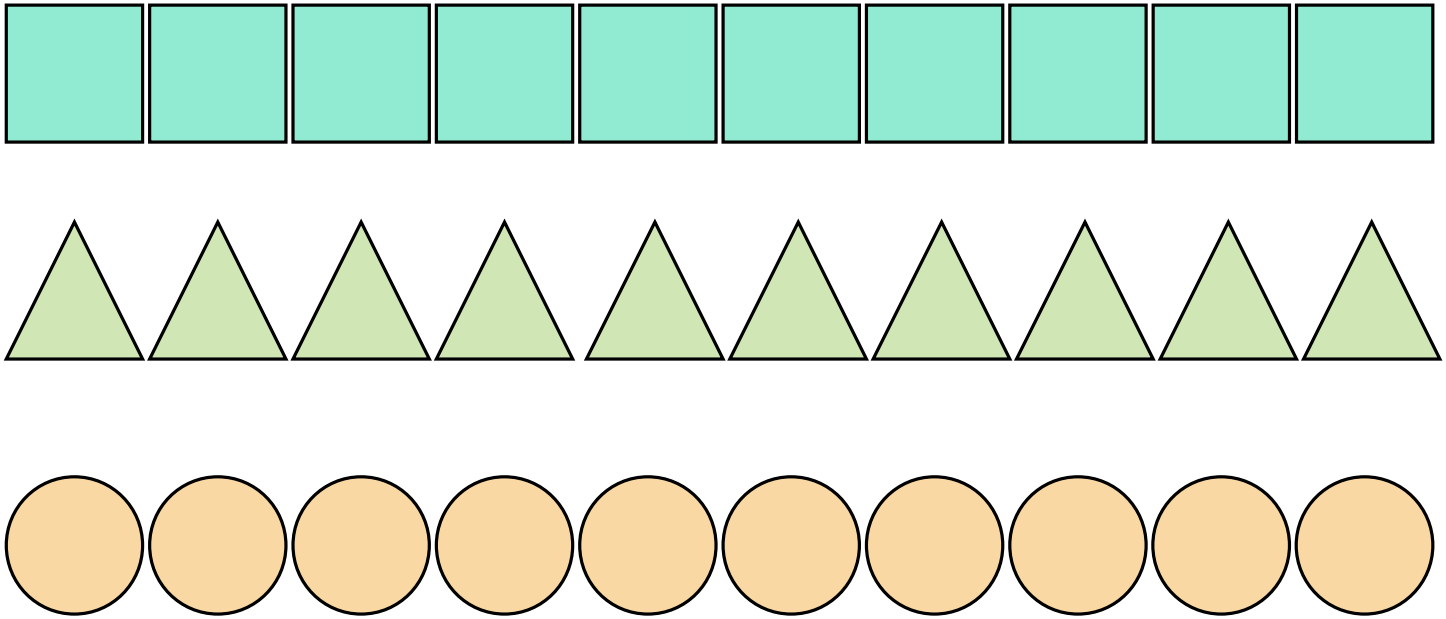
EXPLANATION

INTERLEAVING

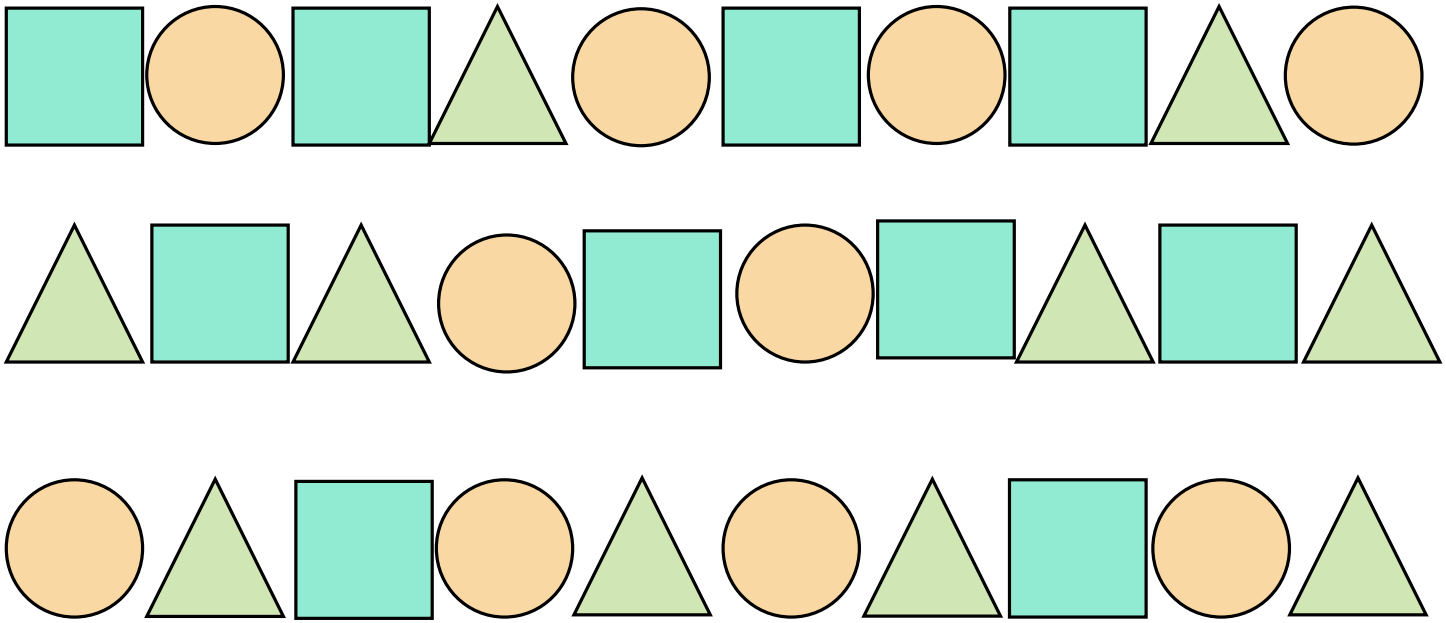


VARIED PRACTICE

Blocking



INTERLEAVING



Interleaving

Plain Assignment

Topic 7 problem 4

Topic 7 problem 9

Topic 7 problem 15

Topic 7 problem 17

Topic 7 problem 22

Interleaved Assignment

Topic 7 problem 4

Topic 4 problem 8

Topic 7 problem 9

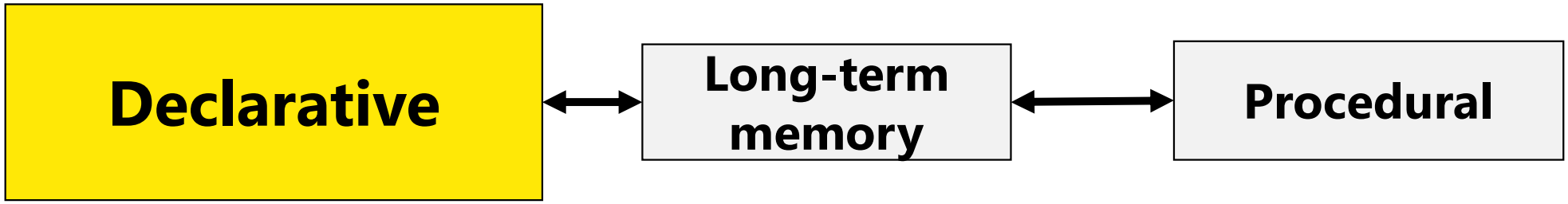
Topic 6 problem 26

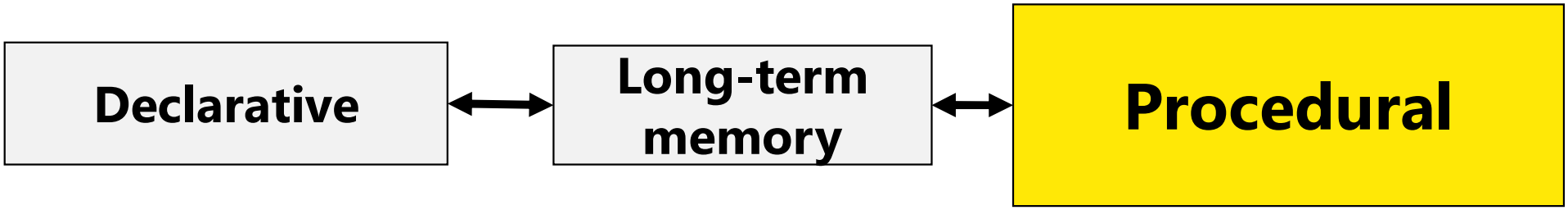
Topic 7 problem 15

Topic 5 problem 18

Topic 7 problem 17

Declarative
Long-term memory
Procedural


Declarative
Long-term memory
Procedural

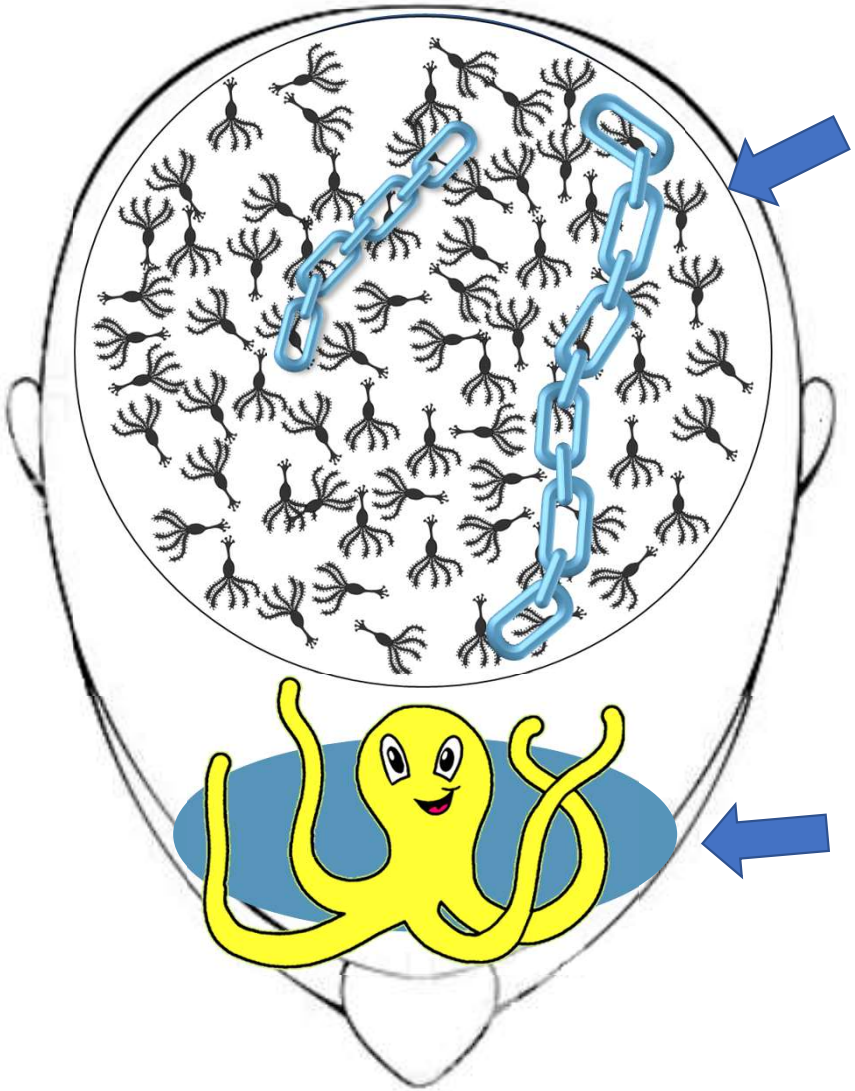

Declarative
Long-term memory
Procedural

Declarative ↔ **Long-term memory** ↔ **Procedural**

When you eliminate rote learning ("Drill and kill")

You eliminate the easiest, best way the brain has to handle routine learning tasks.

Drill to skill!



LONG-TERM MEMORY

WORKING MEMORY

Working memory capacities vary

WORKING MEMORY TEST

Daneman, M., & Carpenter, P. A. (1980). "Individual differences in working memory and reading." *Journal of Verbal Learning and Verbal Behavior*, 19(4), 450-466.

wmt.supers.no

Working Memory Test

Write down as many of the 8 words that you remember and press "submit".

word word word word

(Word order and capitalization is not important, but spelling is!)

Submit

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. Journal of verbal learning and verbal behavior, 19(4), 450-466.

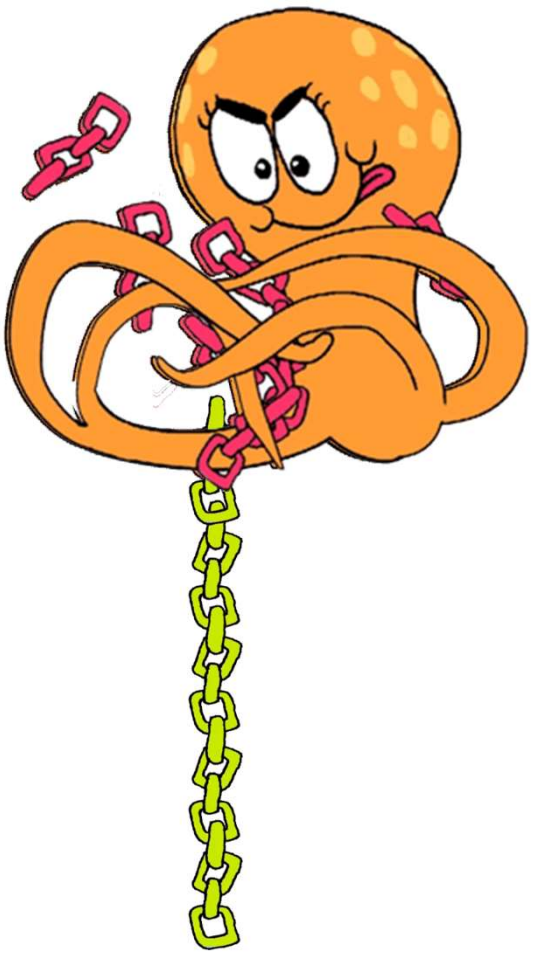
Example:

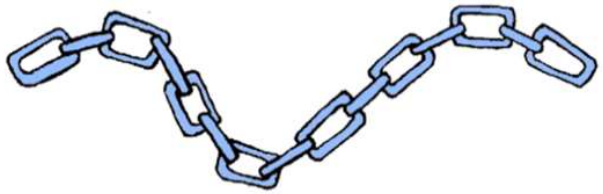
- He was reading a blue book.
- Fourteen people were inside the supermarket.

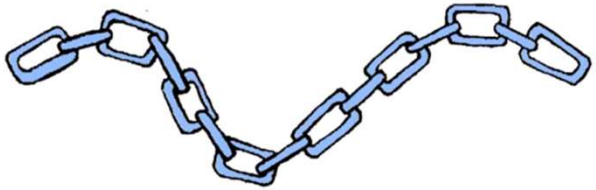
- We had been waiting for a long time.
- It was interesting, but difficult to understand.
- No one was carrying a backpack.
- We had just arrived when it started to rain.
- The office was just a small room.
- The coffee arrived late, and it was cold.
- There were many bushes in the garden.
- He asked and he asked, but received no offer.

Race car learners

Hiker learners

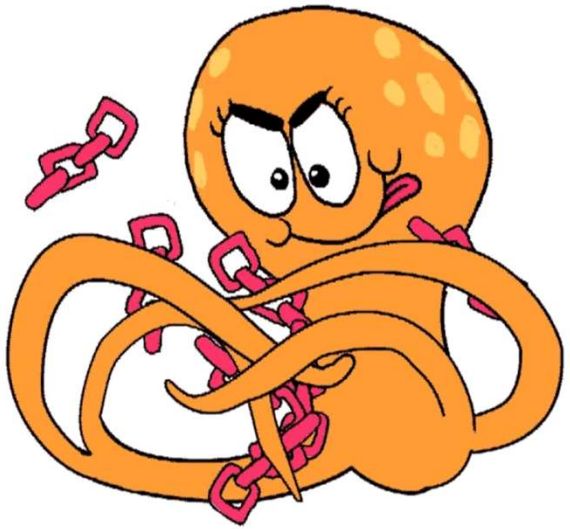




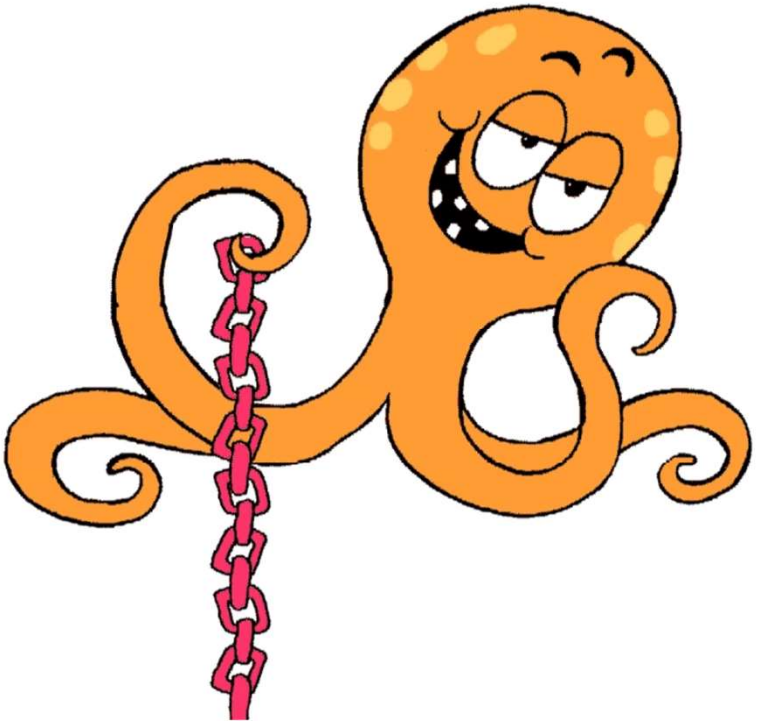


25 focused tangled octopus-20180922113485772-001.zip

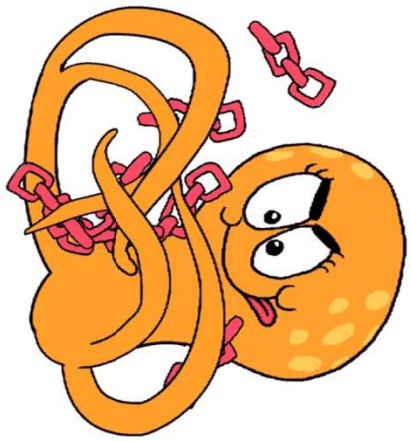
25 focused tangled octopus-20180922113485ZZ-001.zip

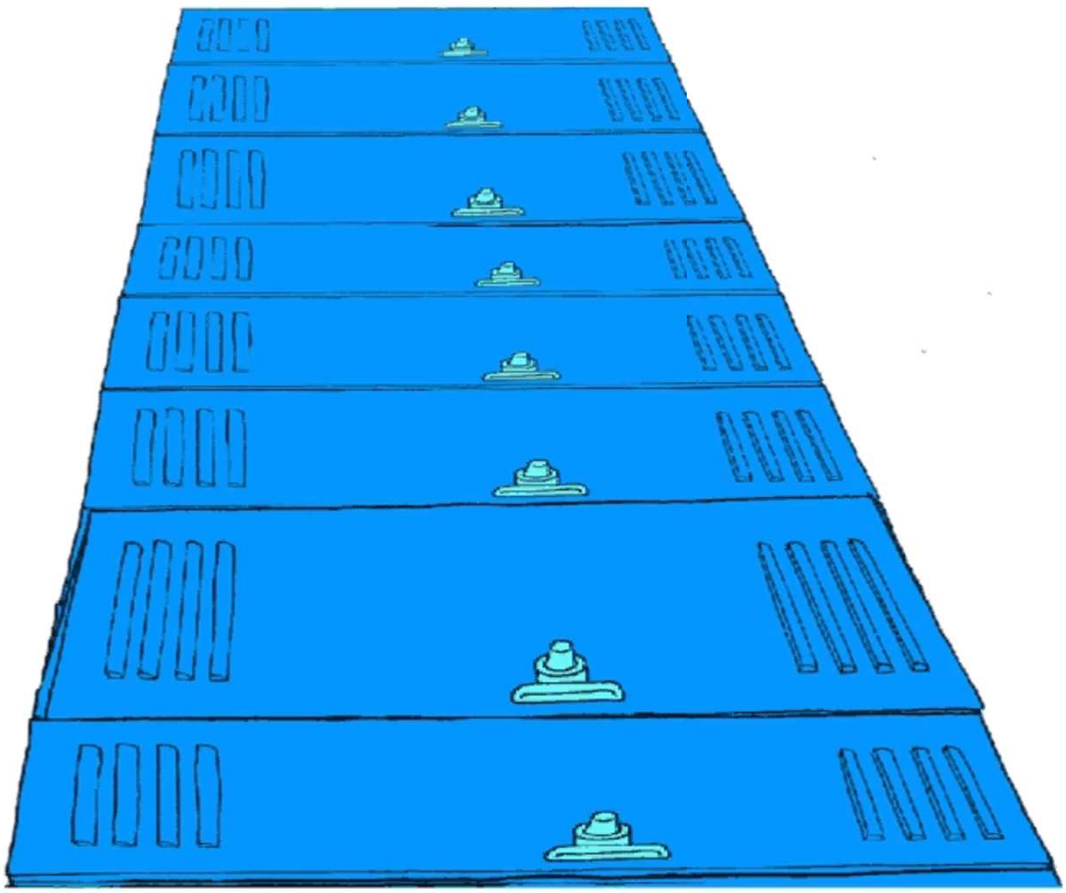


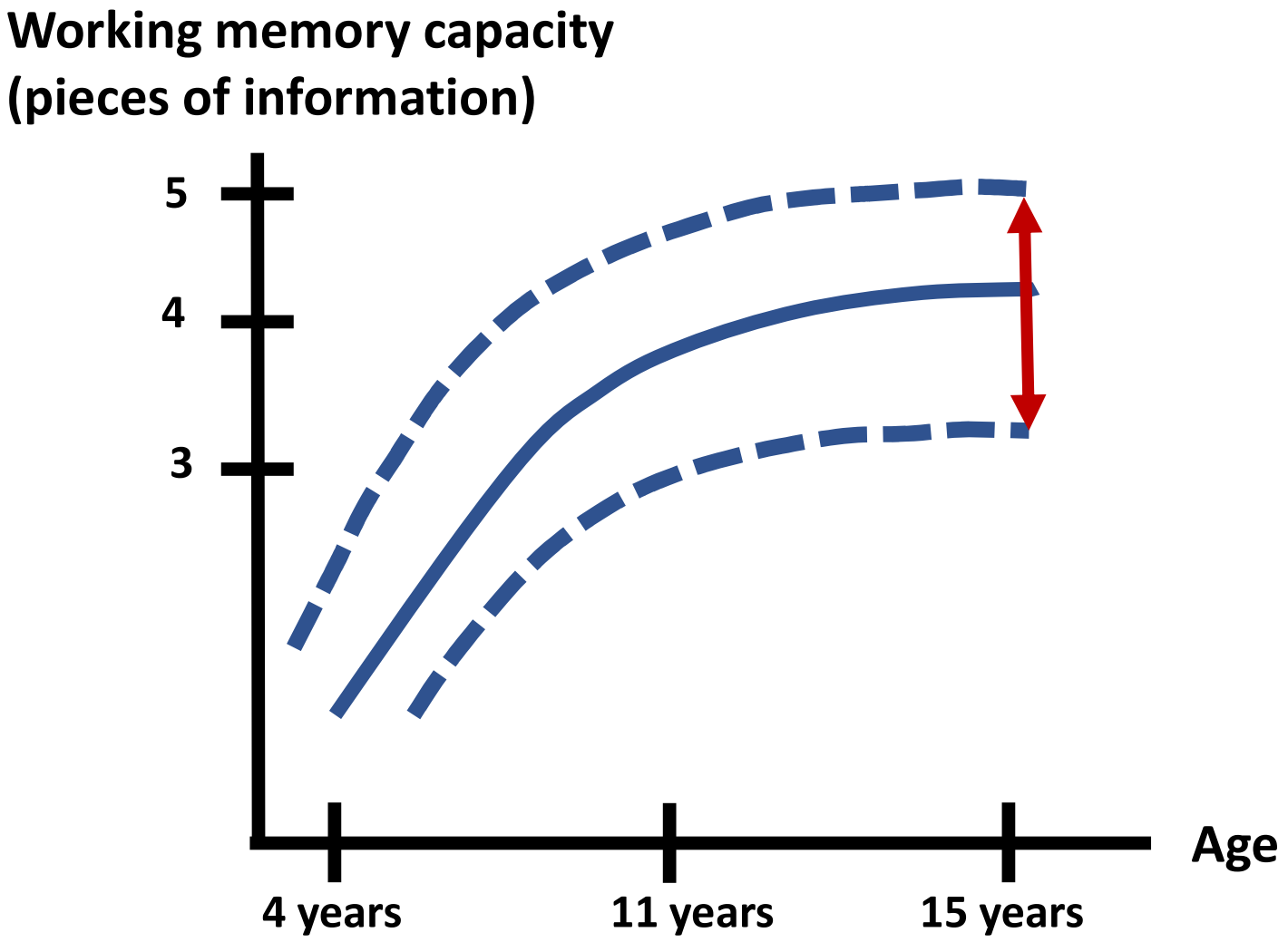
- Heavy cognitive load
- No working memory is available for anything else



- Light cognitive load!
- Working memory is available for more complex thinking

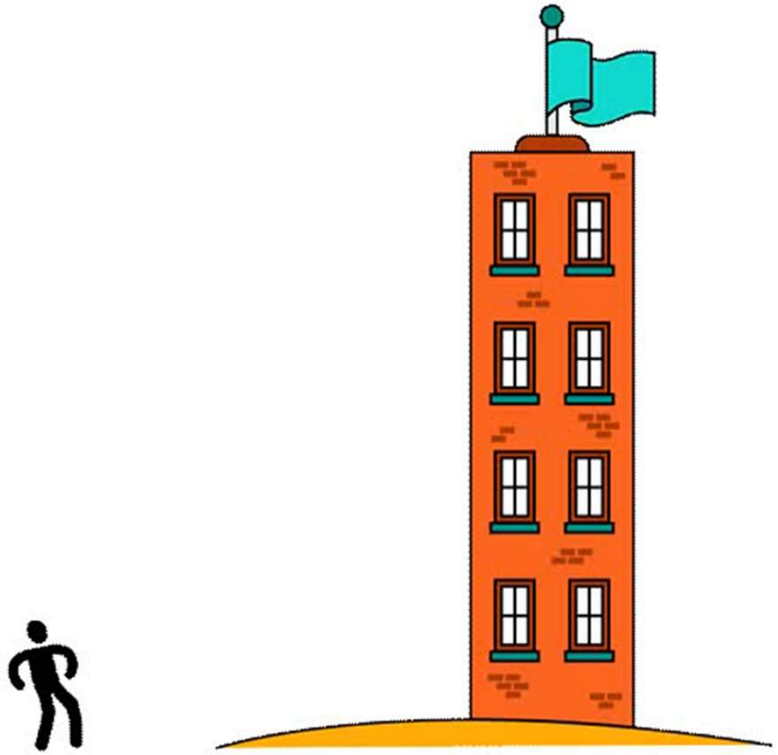






Changes in working memory capacity with age

The value of scaffolding



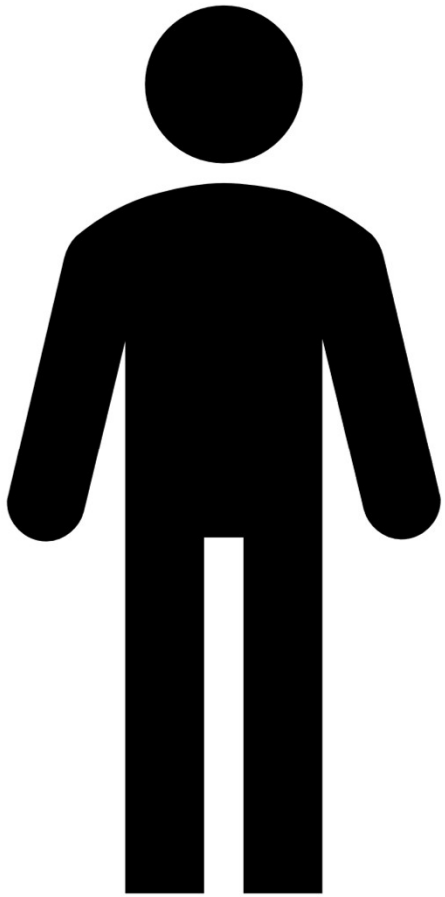
- Small chunks
- Practice

Break Out Groups (5 minutes)

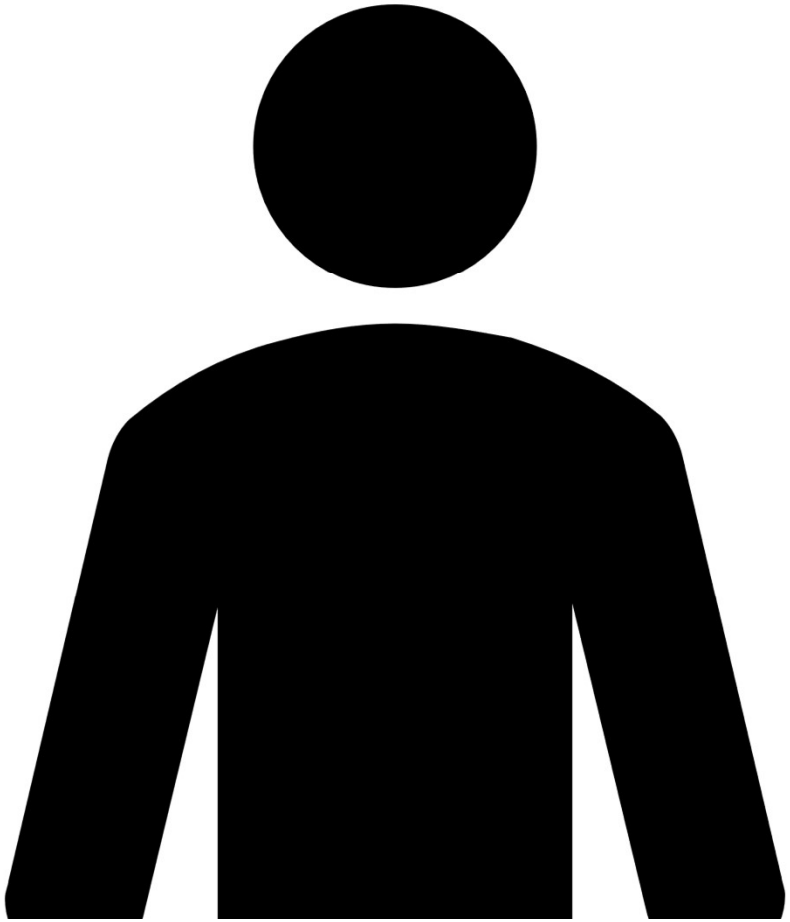
- What is particularly effective about the Powerpoints in this presentation to help with learning?
- What could you do with your own PowerPoints to make them more effective?

Why Learning Via Video is so Valuable

The value of looming motion



The value of looming motion

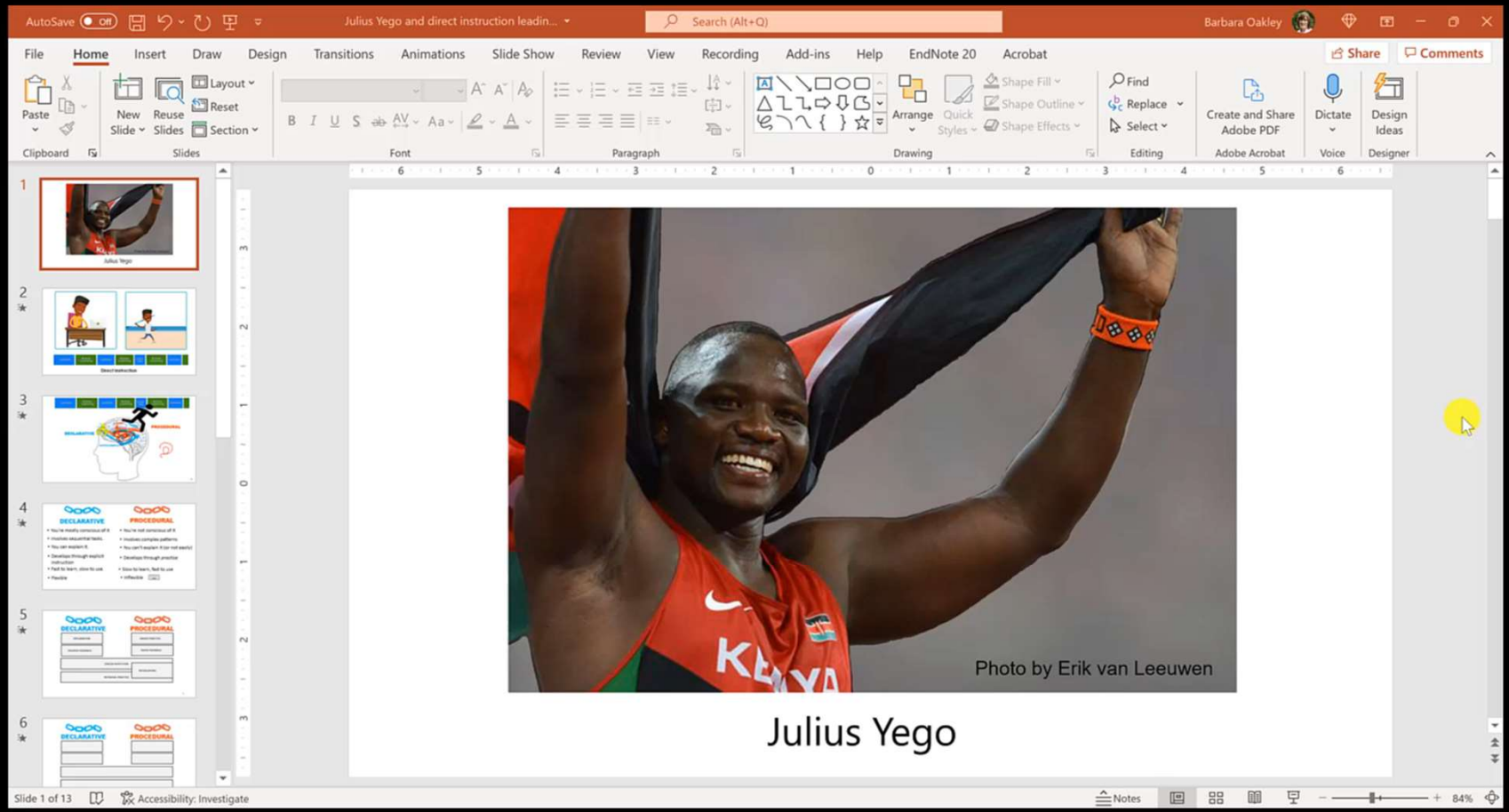


Engaging Your Students

- Students in online courses look first at the videos.
- But we want them to *engage*.

“Zero-ith” Rule of Making Engaging Online Courses

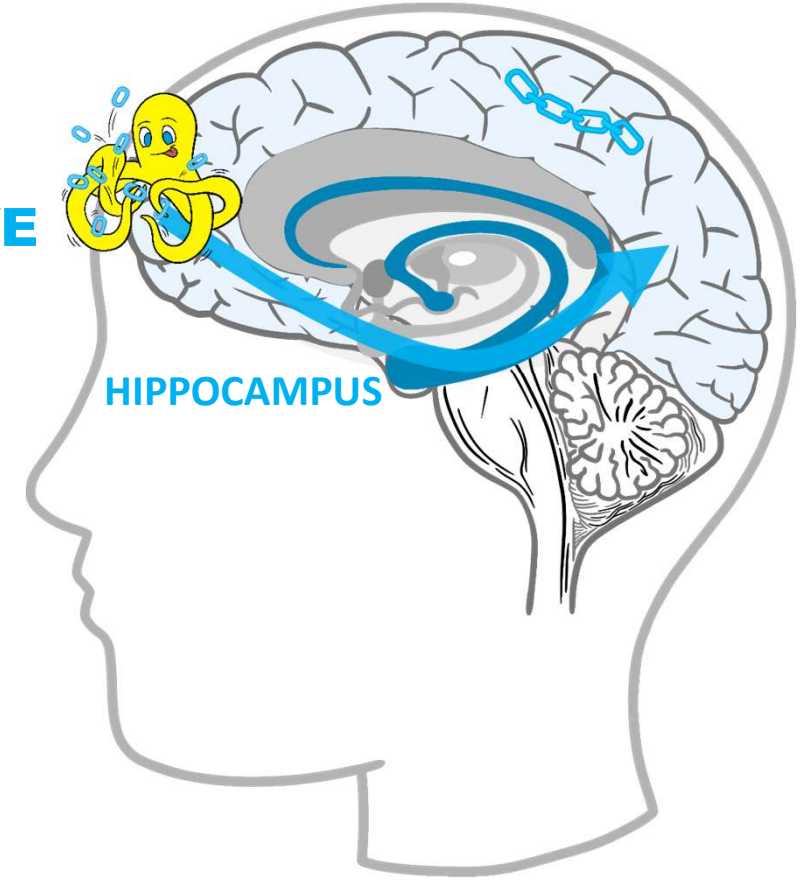
Make a BAD video

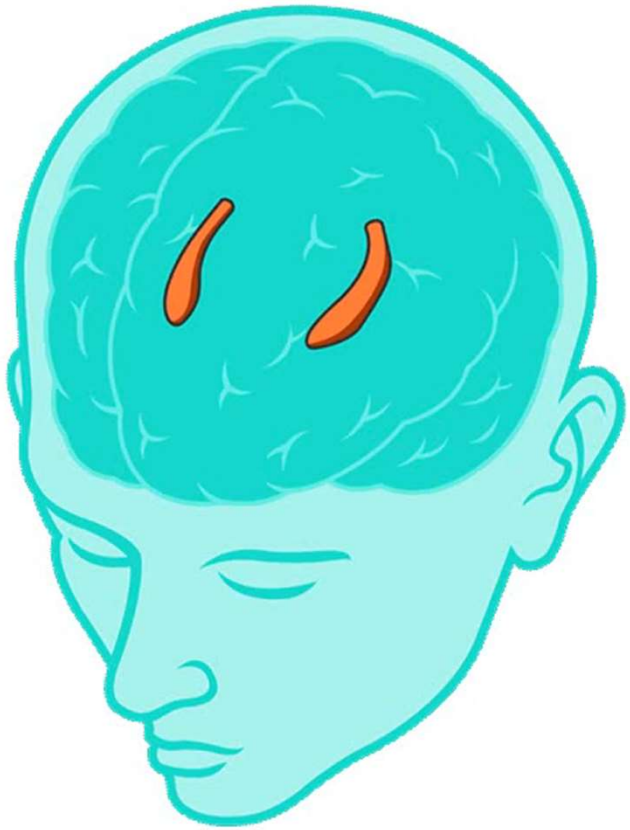

AutoSave
Julius Yego and direct instruction leadin...
Search (Alt+Q)
Barbara Oakley
File
Home
Insert
Draw
Design
Transitions
Animations
Slide Show
Review
View
Recording
Add-ins
Help
EndNote 20
Acrobat
Share
Comments
Paste
New Slide
Reuse Slides
Layout
Reset
Section
Clipboard
Slides
Font
Paragraph
Arrange
Quick Styles
Shape Fill
Shape Outline
Shape Effects
Drawing
Find
Replace
Select
Editing
Create and Share Adobe PDF
Adobe Acrobat
Dictate
Voice
Design Ideas
Designer
Photo by Erik van Leeuwen
Julius Yego
Slide 1 of 13
Accessibility: Investigate
Notes
84%

Plan your videos just as you plan your PowerPoints

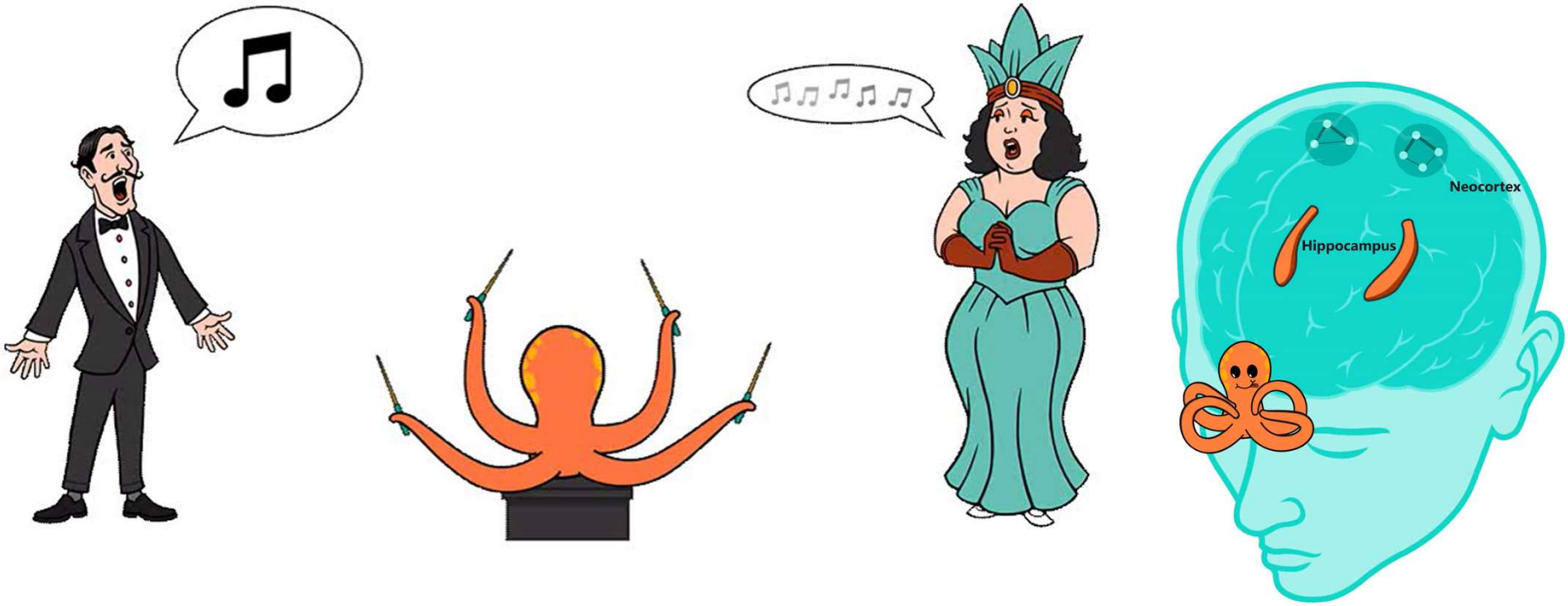
- Avoid too much text!
- Use enhancing videos whenever possible.

DECLARATIVE

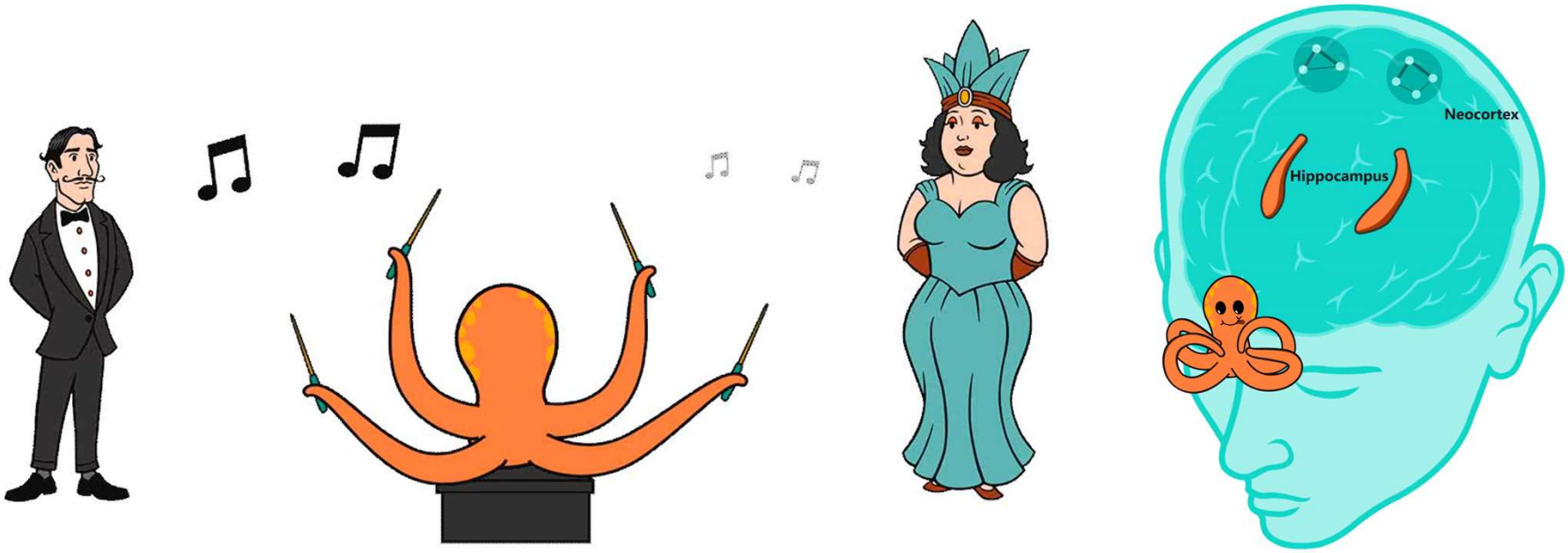




The Declarative Pathway

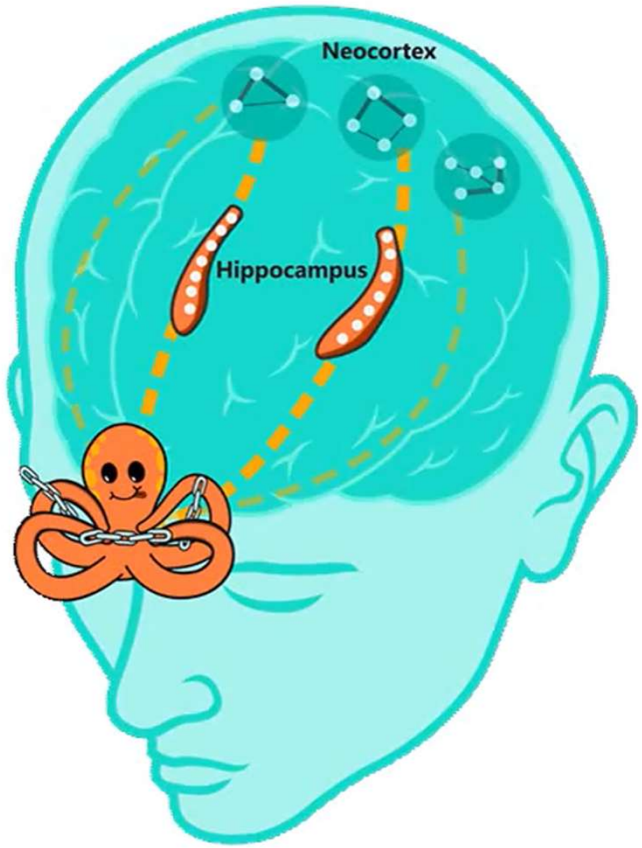


The Declarative Pathway



The Declarative Pathway

Why cramming is bad



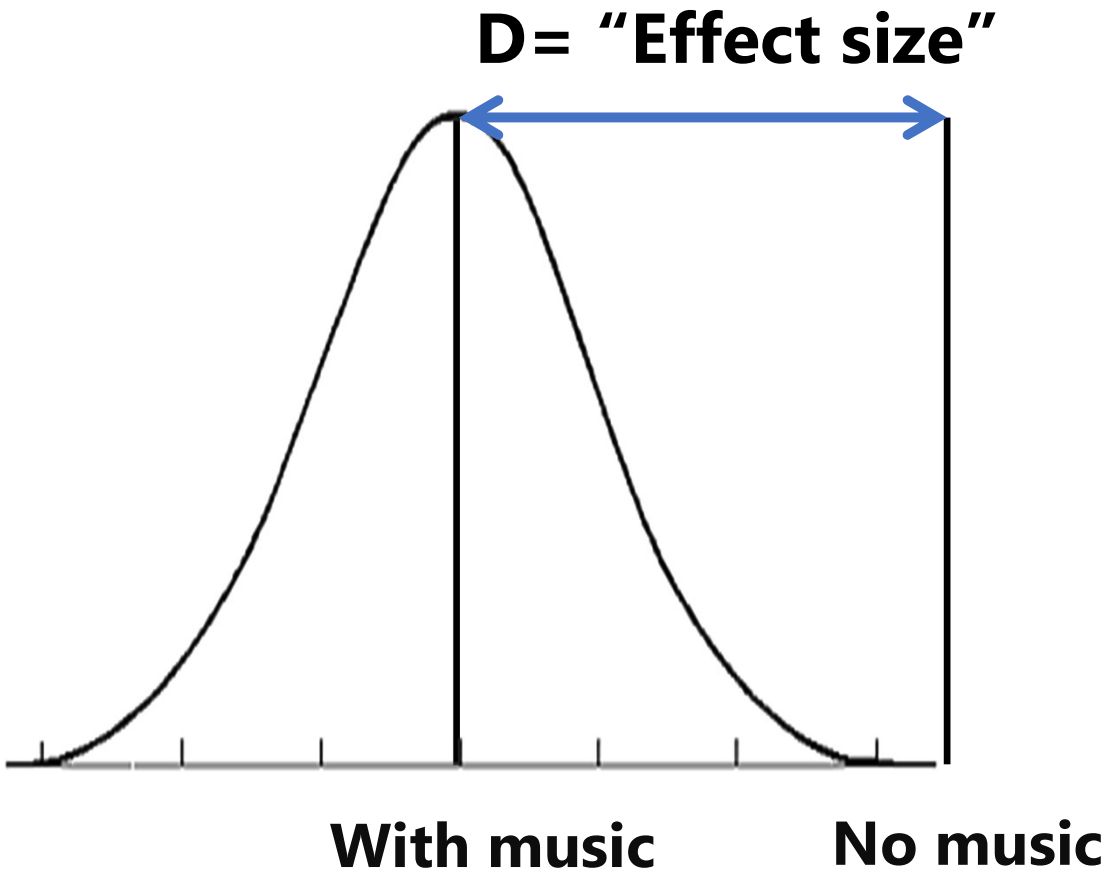
Research supports short breaks or lighter tasks

This helps the hippocampus offload and refresh itself, while strengthening links in the neocortex

- Runyan, J. D., Moore, A. N., & Dash, P. K. (2019). Coordinating what we've learned about memory consolidation: Revisiting a unified theory. *Neuroscience & Biobehavioral Reviews, 100*, 77-84.
- Wamsley, E. J. (2019). Memory consolidation during waking rest. *Trends in Cognitive Sciences, 23*(3), 171-173.
- Dewar, M., Alber, J., Butler, C., Cowan, N., & Della Sala, S. (2012). Brief wakeful resting boosts new memories over the long term. *Psychol Sci, 23*(9), 955-960.
- Tambini, A., Ketz, N., & Davachi, L. (2010). Enhanced brain correlations during rest are related to memory for recent experiences. *Neuron, 65*(2), 280-290.

- **Cooperative exercises**
- **Humor**

Does Music Matter?

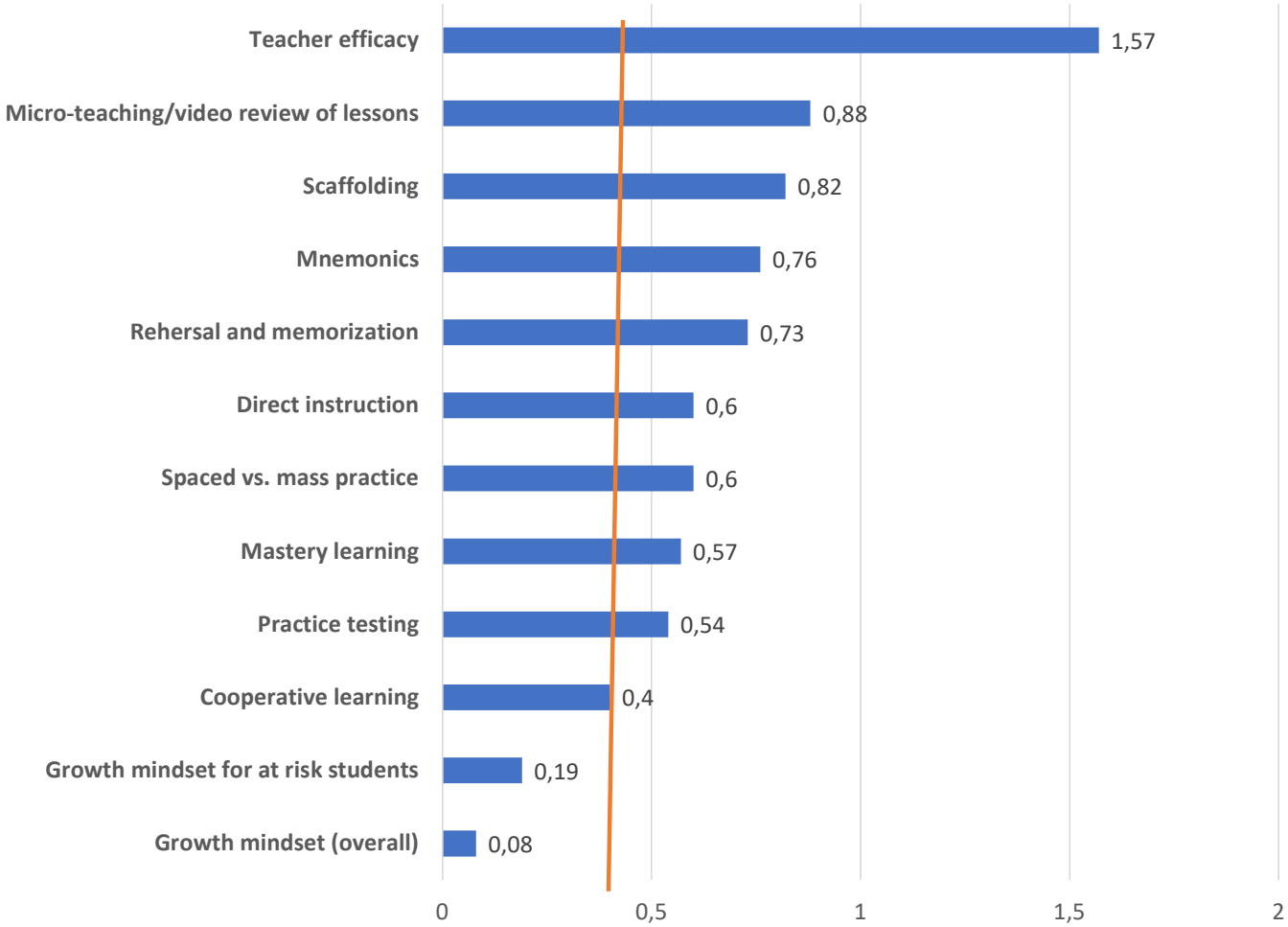


John Hattie's *Visible Learning*

- **Hattie Ranking:** 252 influences and effect sizes related to student achievement

- D = 0.4 The "hinge point"

Effect size for different factors



Source: https://visible-learning.org/hattie-ranking-influences-effect-sizes-learning-achievement/

The Replicability Crisis

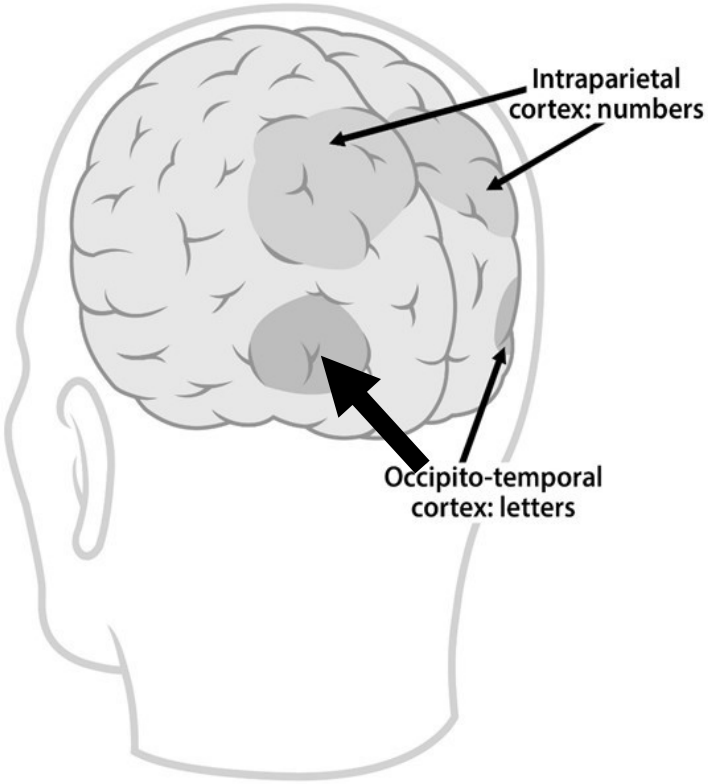
Different types of knowledge

Easy stuff (Biologically primary knowledge)

- Recognize faces
- Listen to and speak a first language
- Acquired easily without explicit instruction

Hard stuff (Biologically secondary knowledge)

- Reading and writing
- Mathematics
- Not evolved to acquire—
  need to repurpose other neural circuits



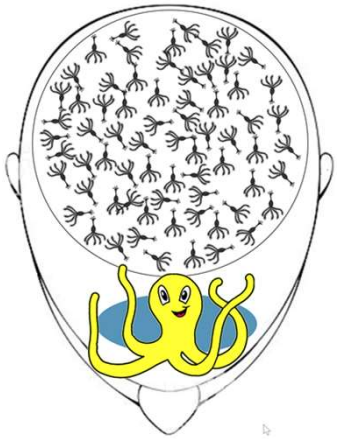
Type of material being learned

Extrapolating from: Evolutionary Perspectives on Child Development and Education
edited by David C. Geary, Daniel B. Berch, p. 240

(Teacher-centered) High

Amount of direct instruction

(Student-centered) Low



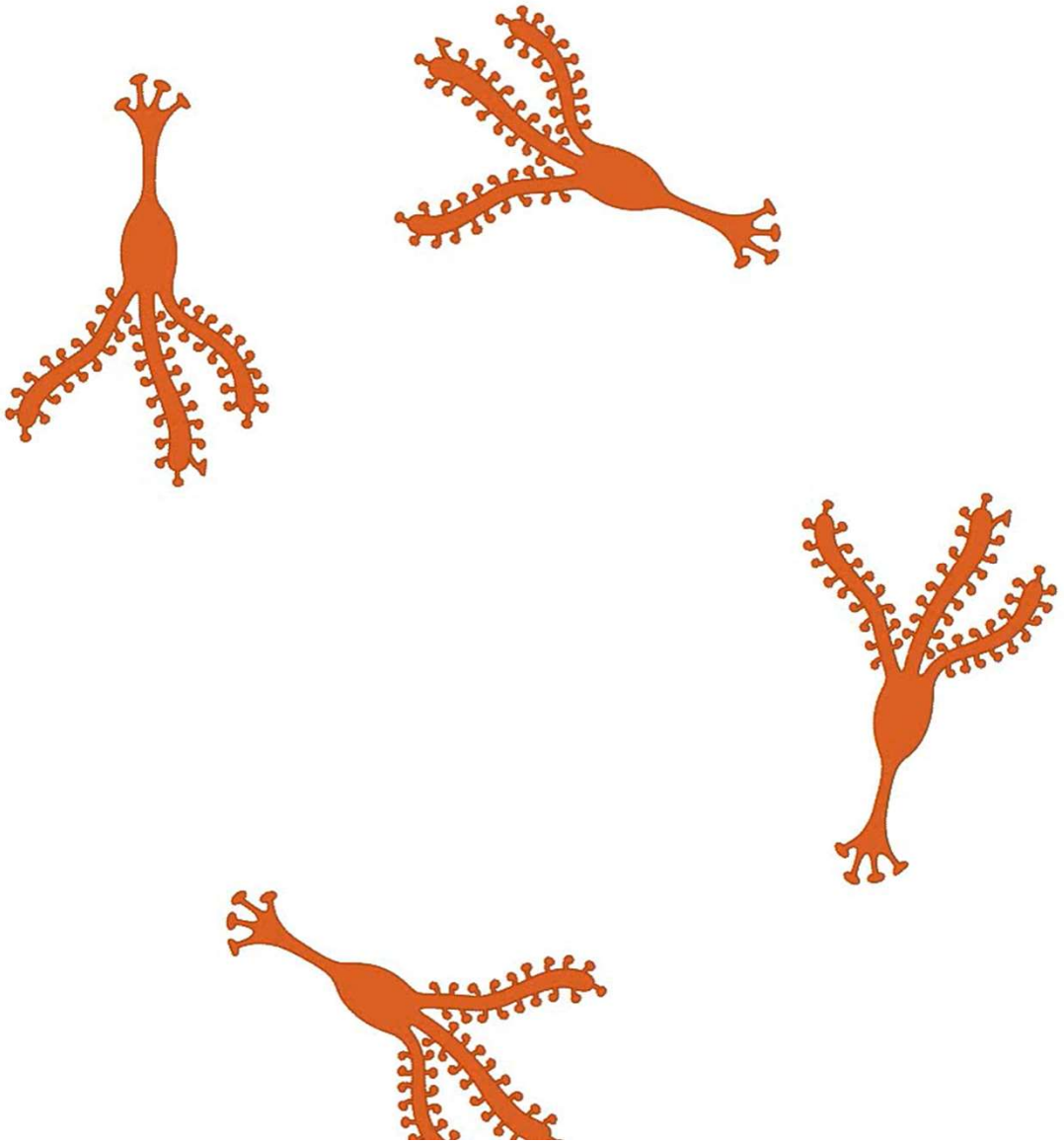
Working memory capacity

"Easy stuff"

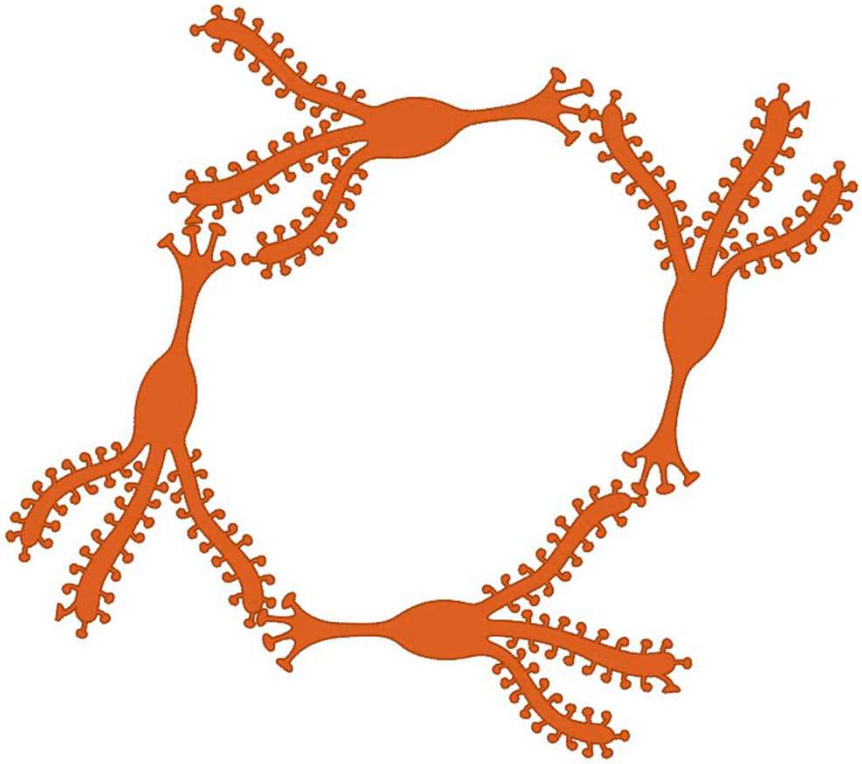
"Hard stuff"

Type of material being learned

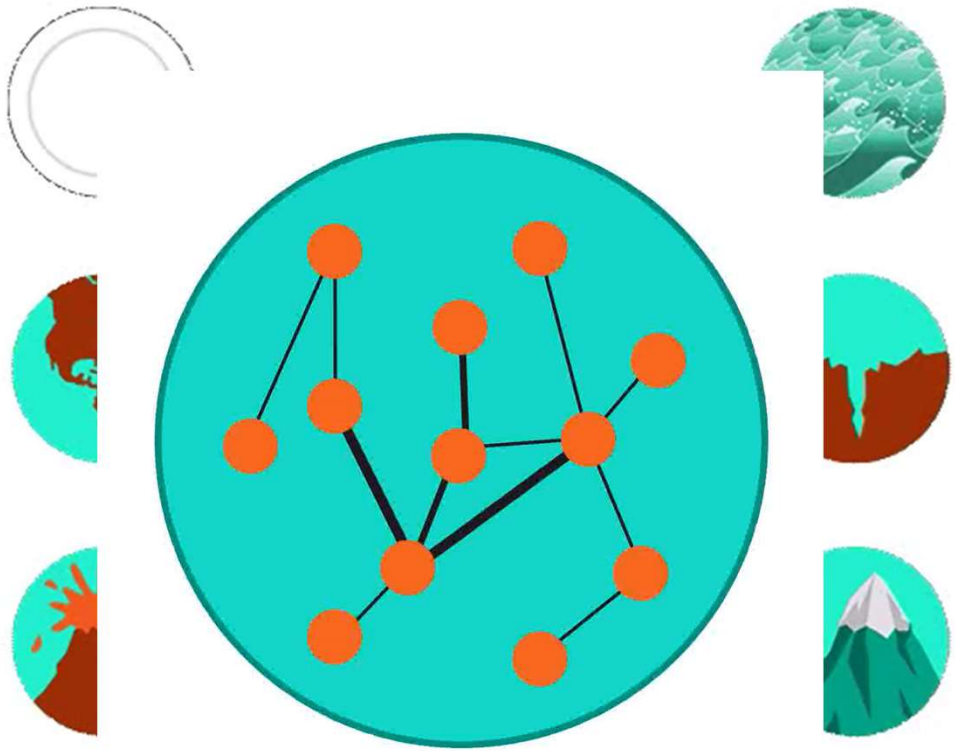
Neuron shorthand

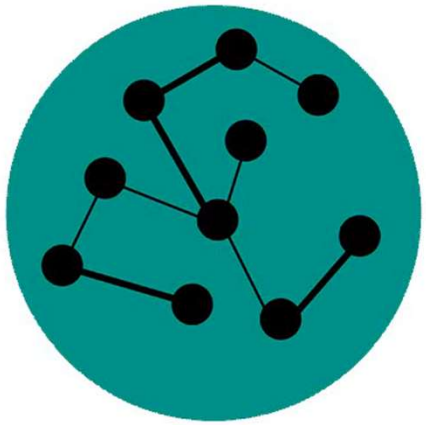


Neuron shorthand

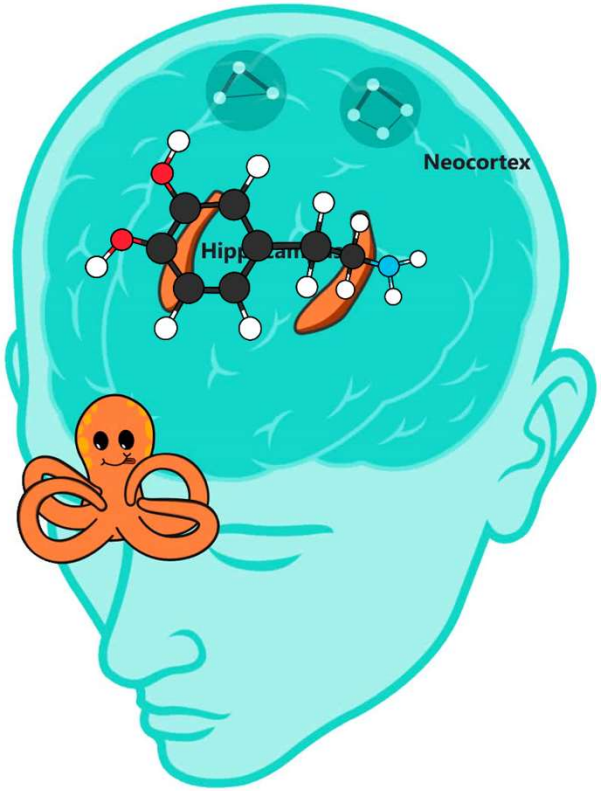


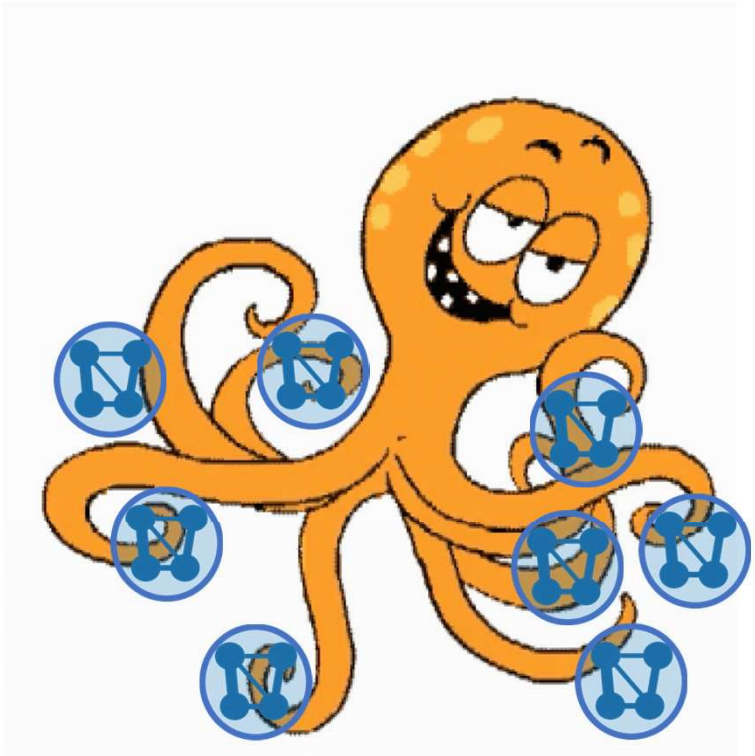
Consolidation

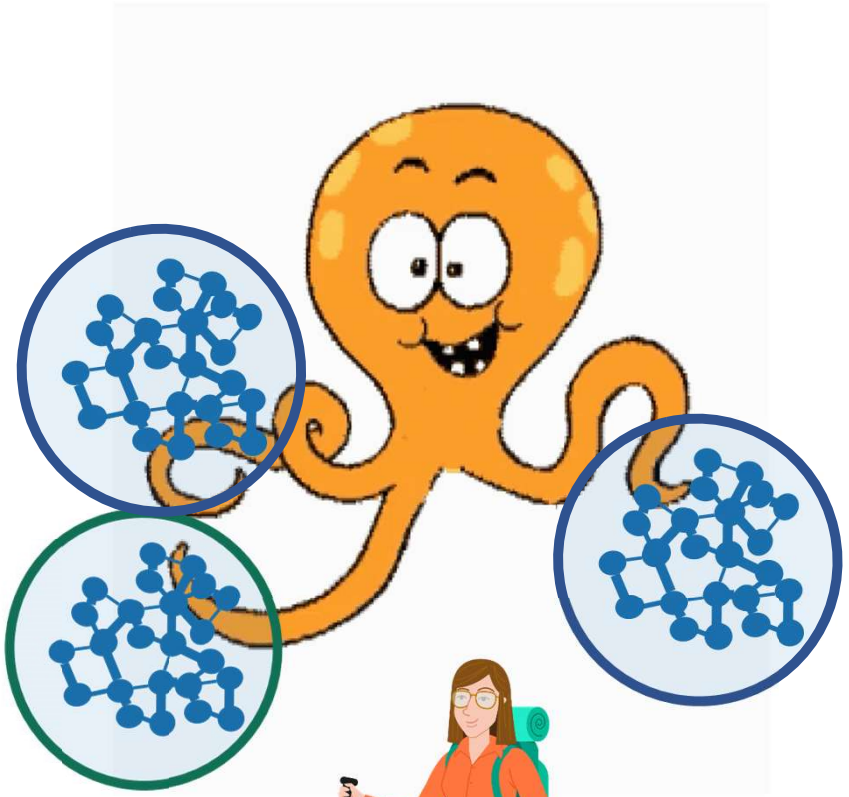


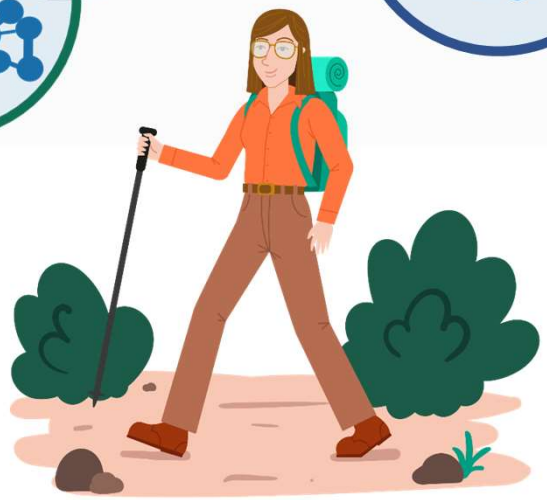


Consolidation

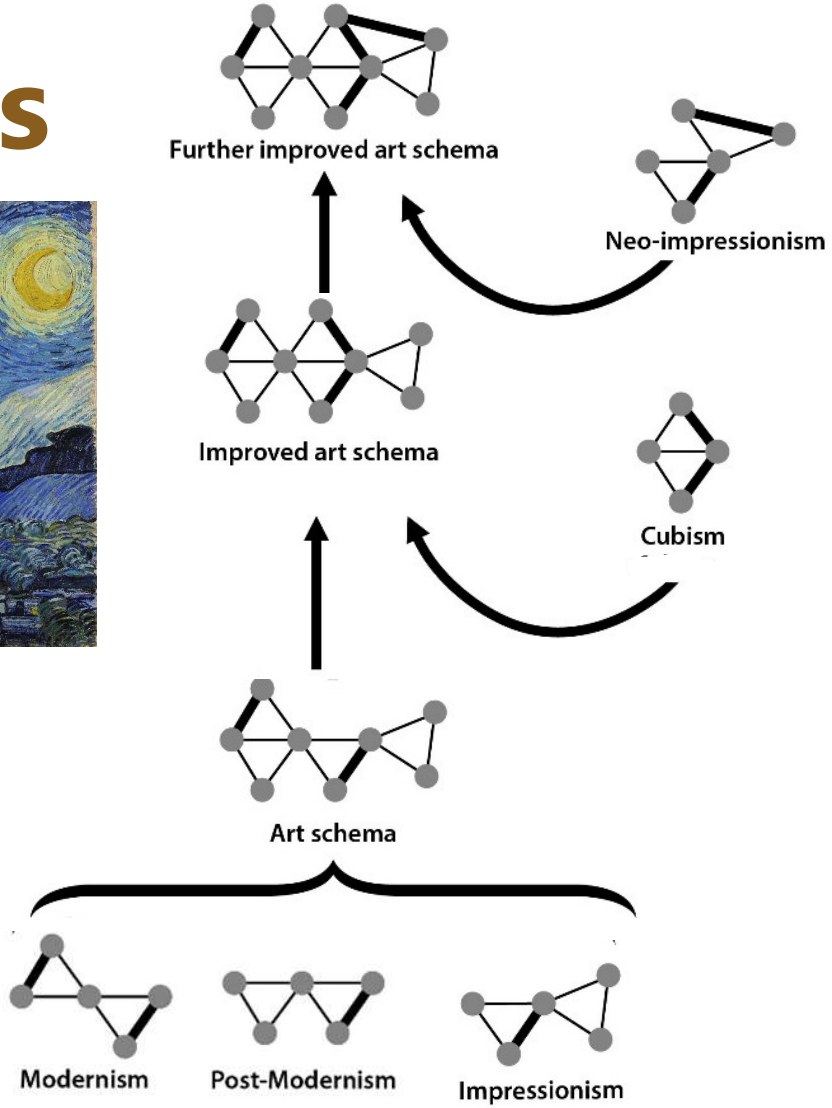


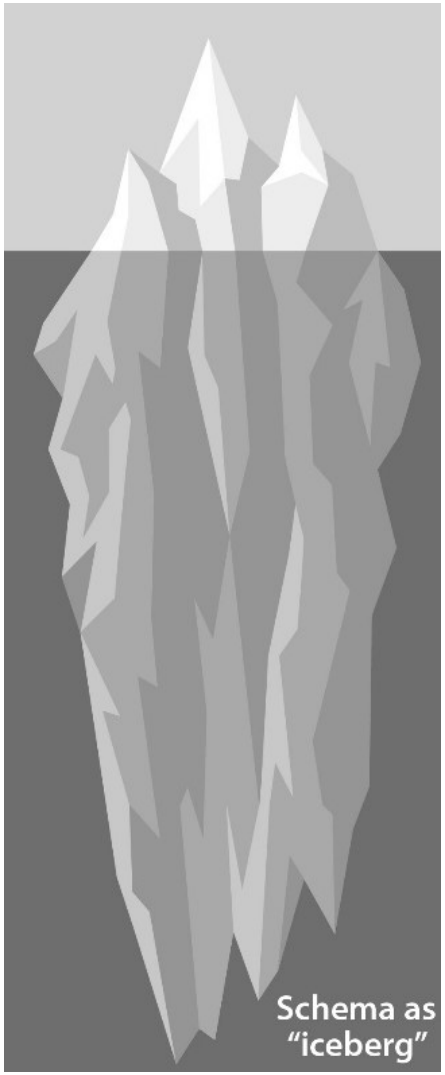






Schemas


Further improved art schema
Neo-impressionism
Improved art schema
Cubism
Art schema
Modernism
Post-Modernism
Impressionism


Schema as
"iceberg"

But you didn't give us time to practice all you taught!

Julius Yego

Participant input:
wmtest.supers.no

Admin/See graphs:
wmtestadmin.supers.no

Description of what I am to cover

- The whole presentation & active exercises should be 2 to 2.5 hours, and then an additional optional .5 hours questions.

- All people who have trained with them. They are trained as e-learning specialists. LMS administrators. People who have acted as mentors for the programs—have delivered support online by delivering seminars, etc—e-learning teaching. All are audit in one way or another. The Thai audit—vaccine rollouts, core-3d looking at public health in light of covid. They are teaching in audit scenario. Mainly in kind contributions. The organization gives time. It would help to have good stuff about online teaching—delivery tends to be synchronous. But they want good presentations—and documents and knowledge about the various audits. How to do a little video—provide some tips about how to make more interesting videos. One part of having good videos is the tool. Most important is to plan. Sometimes they put too much stuff in a slide. At the end of the video have free stuff. Ten minutes of tools—relate it to the earlier neuroscience. Prepare color coded poll questions & breakouts for presentation. This will be on Zoom.
-
- Talk about PowerPoint---prepare a video to show.
-
- Talk only a little about Camtasia--
- ----------

Learning How to Learn—and How to Teach—Based on Neuroscientific Insights

A. Instructors often have a feel for what they're supposed to be teaching in the classroom. But they often don't know why. This keynote will provide practical insights, using recent light microscopy imagery and neural animations, about how the brain learns. By seeing the restrictions of working memory, you'll gain a better idea of how to structure teaching to avoid student cognitive overload. And by understanding the changes that good teaching can make in students' brains, you'll gain a better idea of how to help students neurally encode information, concepts, and techniques and move information into long-term memory—the essence of learning. We will delve deeply into what is meant, from a neuroscientific perspective, by the term "active learning." We will also discuss why retrieval practice is invaluable in enhancing active learning; the effect size of different instructional interventions; evolutionary primary versus evolutionary secondary material and their relationship with student-centered versus direct instruction; and the role of learning individual facts in allowing the hippocampus (and students!) to develop a feel for overall patterns; and how to detect educational fads.

B. Learning Objectives:

1. Be able to describe the difference between working memory and long-term memory, and explain how this impacts your presentation of materials.
2. Explain from a neural perspective why procrastination occurs, and some of the best approaches we know from neuroscience about how to tackle it.
3. Explain why creating sets of neural links in long-term memory is so vital to the learning process.
4. Be able to explain the difference between biologically primary and biologically secondary materials, and explain how this impacts the teaching profession.
5. Describe from a neuroscientific perspective what is meant by the term "active learning," and explain how to best enhance active learning.

- 6. Explain why taking small breaks and using cooperative activities can be so helpful in placing information in long-term memory.
- 7. Be able to explain the use of focus and diffuse modes when gaining expertise with difficult new material.
- **C. Main overall objective**

- Be able to practically apply neuroscientific concepts from active learning in the classroom.