Nels Hoffman
Los Alamos Faith and Science Forum
19 June 2019

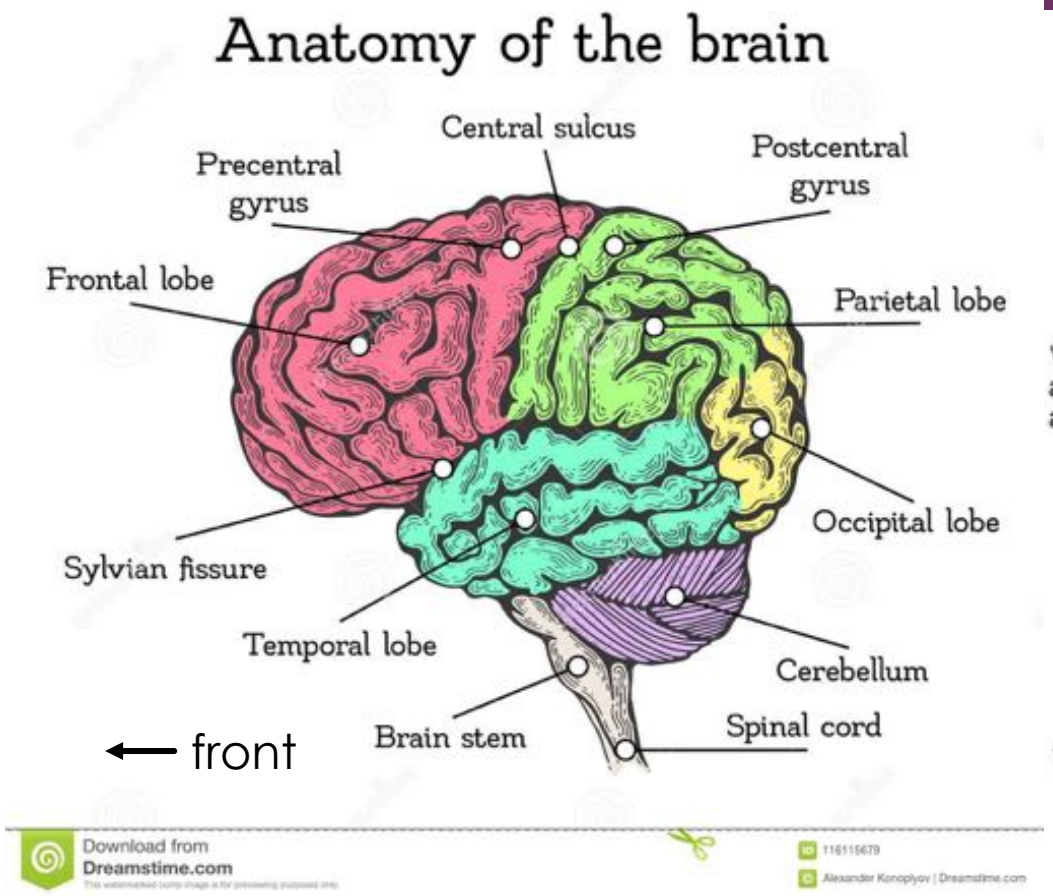
Neuroplasticity

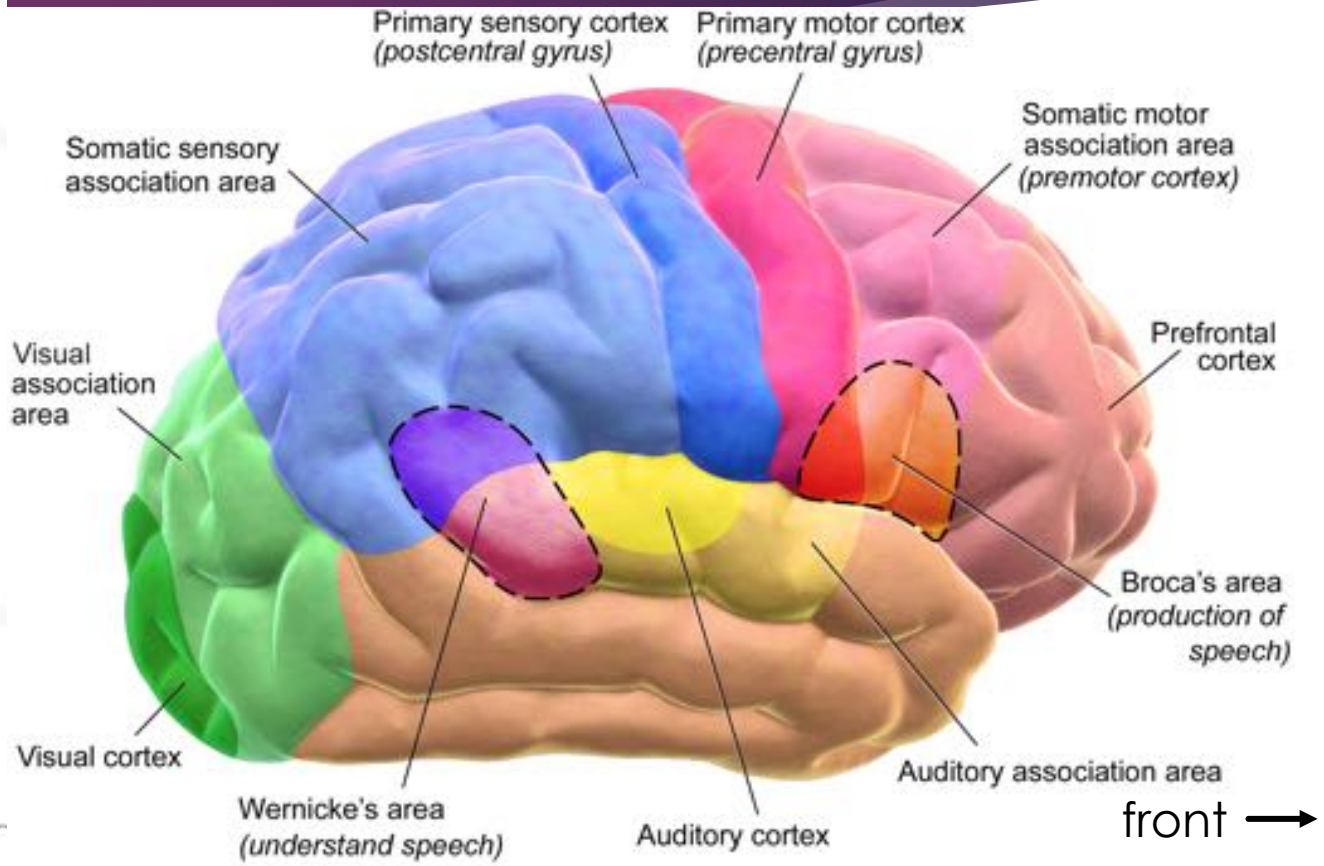
HOW THE MIND CHANGES THE BRAIN

Why is neuroplasticity interesting theologically?

- Top-down causality: "free will"
- Mind over matter – belief creates reality
- Importance of controlling our thoughts; mindfulness
- Knowledge is "written" in flesh
- Anecdotes – the power of a single story

Brain anatomy: structure and function





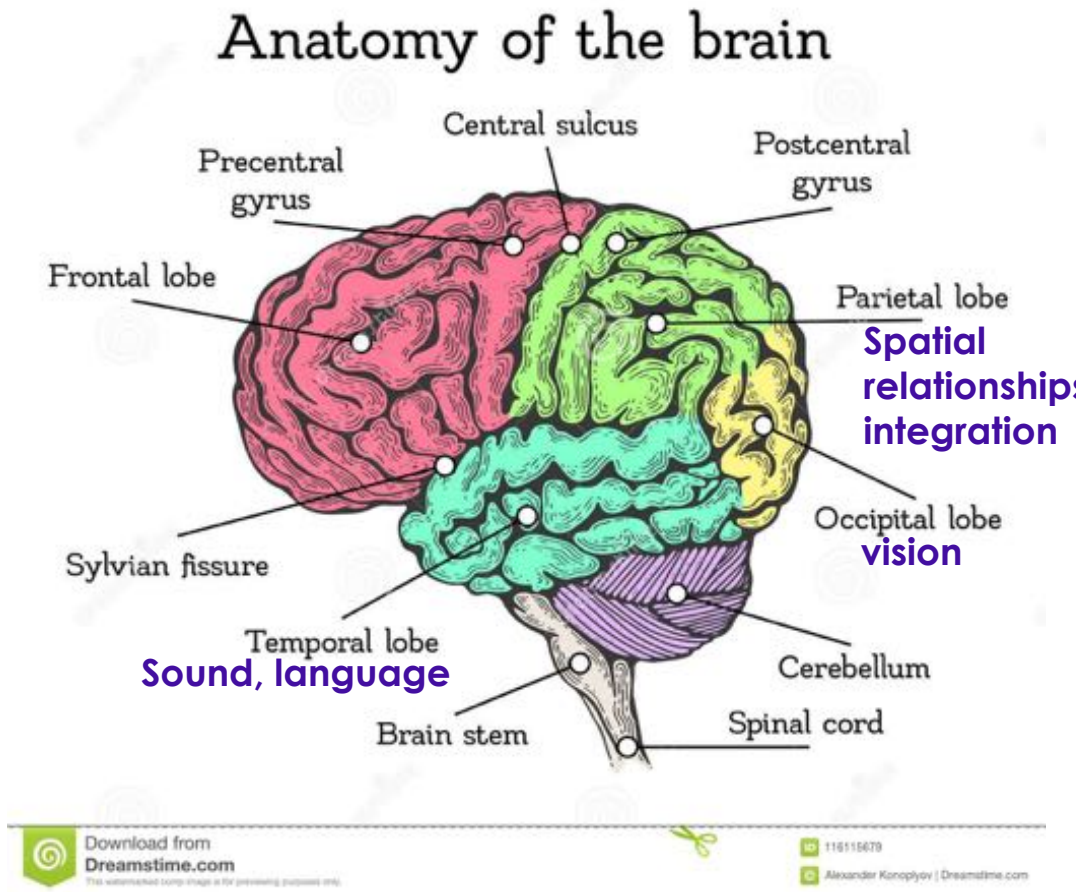
What is the mind?

- Mind
  - the software running on human (and perhaps animal) brains
  - a phenomenon of which psychology (including "cognitive science") is the science
    - Includes perception, attention, memory, conceptualization, communication, reasoning, learning, deciding, imagining,…
  - associated with *consciousness* (i.e., subjective experience) and *unconsciousness*

Justin L. Barrett, *Cognitive Science, Religion, and Theology: From Human Minds to Divine Minds* (West Conshohocken PA: Templeton Press, 2011)
Malcolm Jeeves and Warren S. Brown, *Neuroscience, Psychology, and Religion: Illusions, Delusions, and Realities about Human Nature* (West Conshohocken PA: Templeton Press, 2009)

Huge body of data shows that the adult brain changes continuously throughout life: *neuroplasticity*

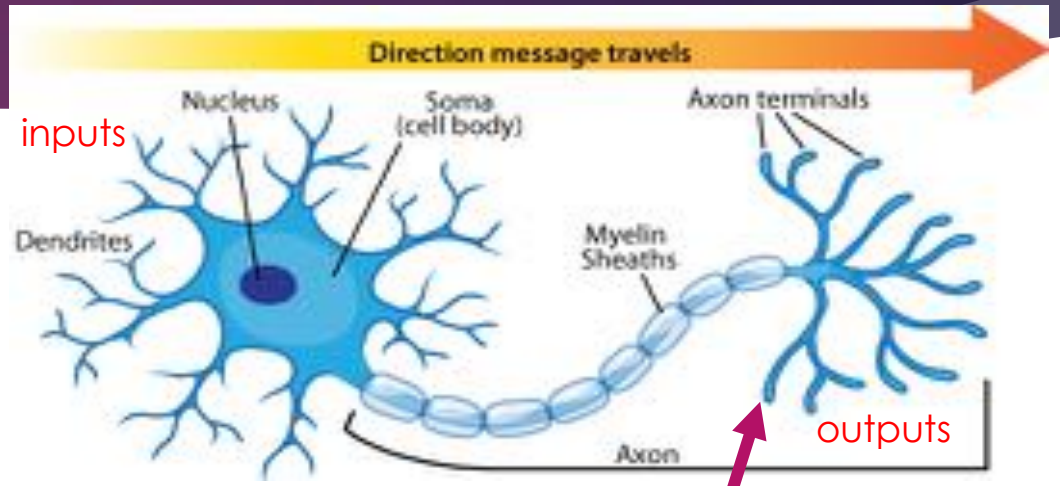
- Fifty years ago, the idea that the adult brain can change in any way was considered heretical
  - Definitive 1913 textbook declared that adult brain is unaffected by learning, experience, or training
  - Dogma of unchanging brain-as-machine persisted beyond mid-20th century
- By 1960s-1970s, new experiments showed clear evidence for neuroplasticity
- Adult brain changes in response to everything we do and every experience we have

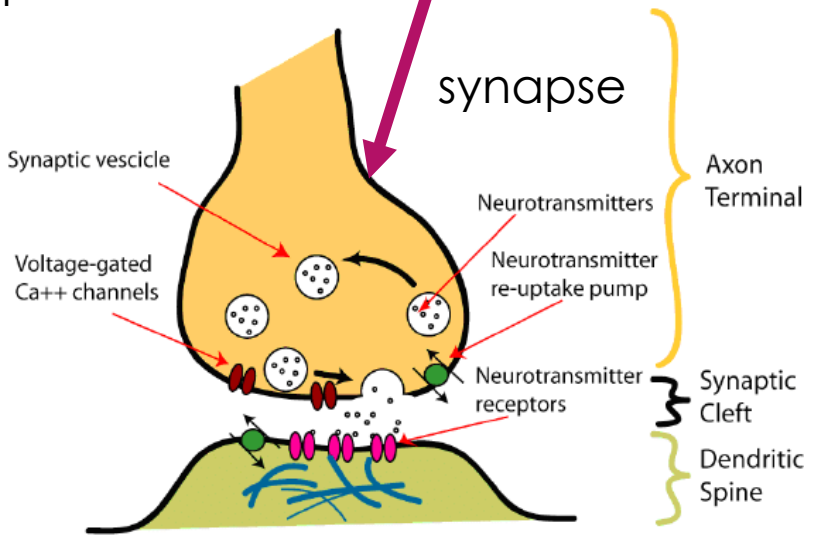


Moheb Costandi, *Neuroplasticity* (MIT Press, 2016), pp. 1-2

Two kinds of neuroplasticity

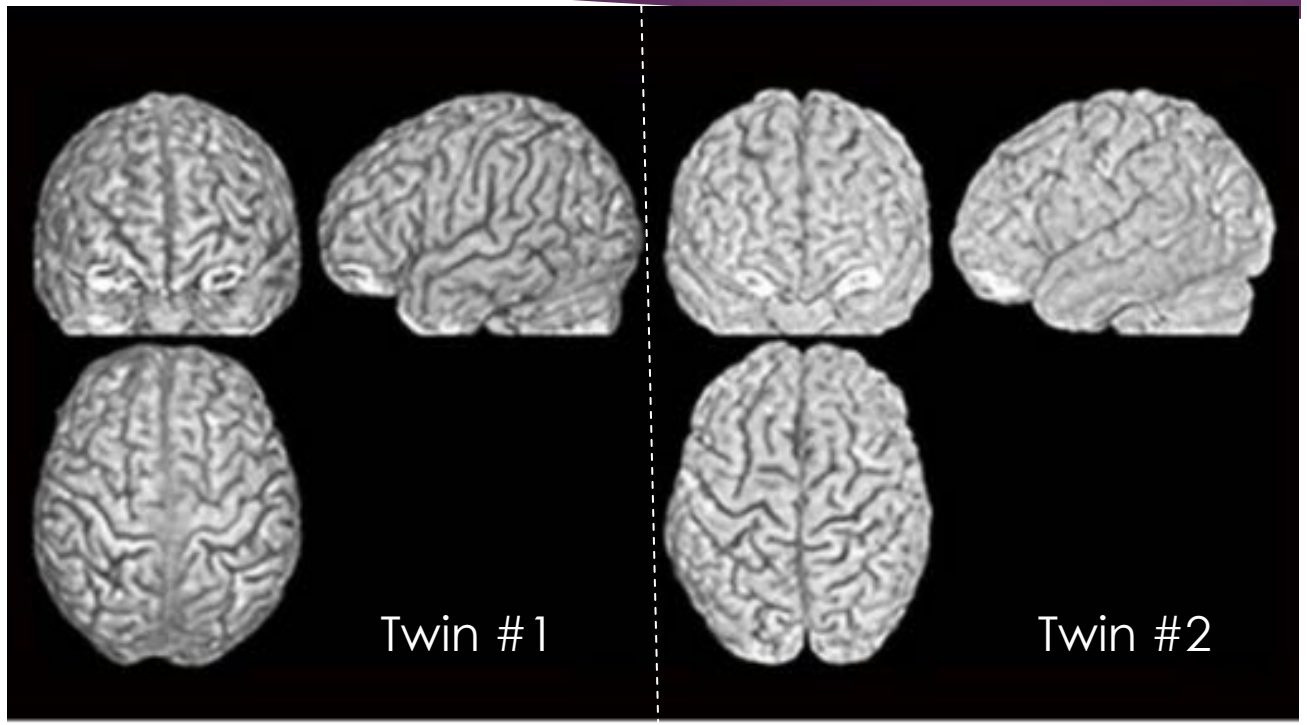
- Functional changes
  - …in frequency of nerve impulses
  - …in probability of releasing chemical signal
  - …in degree of synchronicity of cell populations
- Structural changes
  - …in volume of discrete brain regions
  - Formation of new neural pathways





Moheb Costandi, *Neuroplasticity* (MIT Press, 2016), p. 13

Every person has a unique brain anatomy



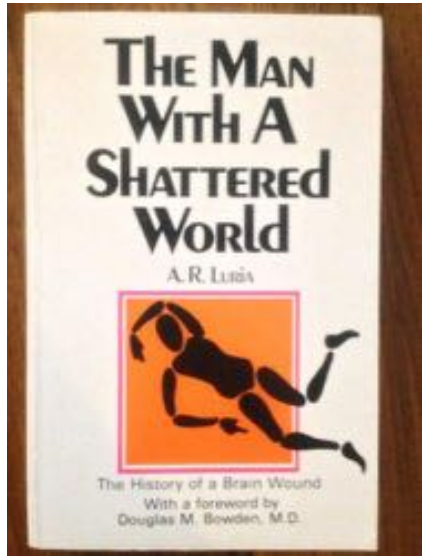
Three brain scans (from the front, side and above) of two different brains (pictured on the left and on the right) belonging to twins. The furrows and ridges are different in each person

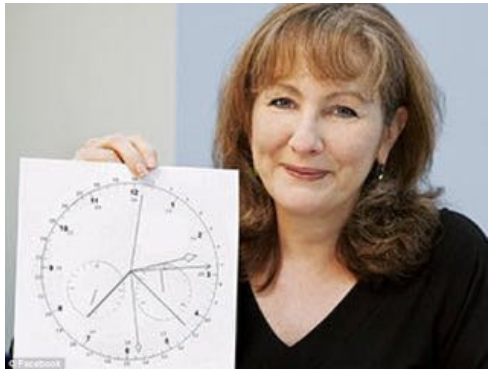
- Researchers at University of Zurich have shown that no two people have the same brain anatomy*
  - MRI scans were used to assess over 450 brain measurements for each of 191 participants
- Brains are as individual as fingerprints
  - UZ professor: "…over the course of years every person develops a completely individual brain anatomy"
  - "…Just 30 years ago we thought that the human brain had few or no individual characteristics. "

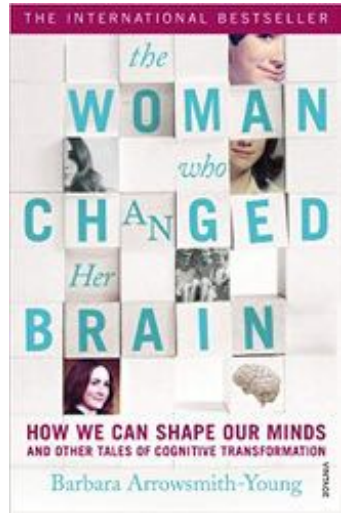
*Valizadeh et al., "Identification of individual subjects on the basis of their brain anatomical features ", Nature Scientific Reports | *(2018) 8:5611* | DOI:10.1038/s41598-018-23696-6
https://www.sciencedaily.com/releases/2018/07/180710104631.htm

A young woman who lived "in a fog"

- Barbara Arrowsmith Young, born in Toronto in 1951, was labeled "retarded"
  - Couldn't do spatial reasoning, had trouble with abstract concepts, humor
  - Understood nothing in real time, only after the fact
  - Had to read material over and over
  - Couldn't read a clock
  - Her excellent memory and tenacity helped her compensate, and she attended college
- Discovered the story of a Soviet soldier who lived with a bullet at the junction of temporal lobe, occipital lobe, parietal lobe
  - His symptoms were identical to hers!
- Discovered work by Mark Rosenzweig on neuroplasticity in rats
- Designed exercises to strengthen her brain
- Opened Arrowsmith School in 1980

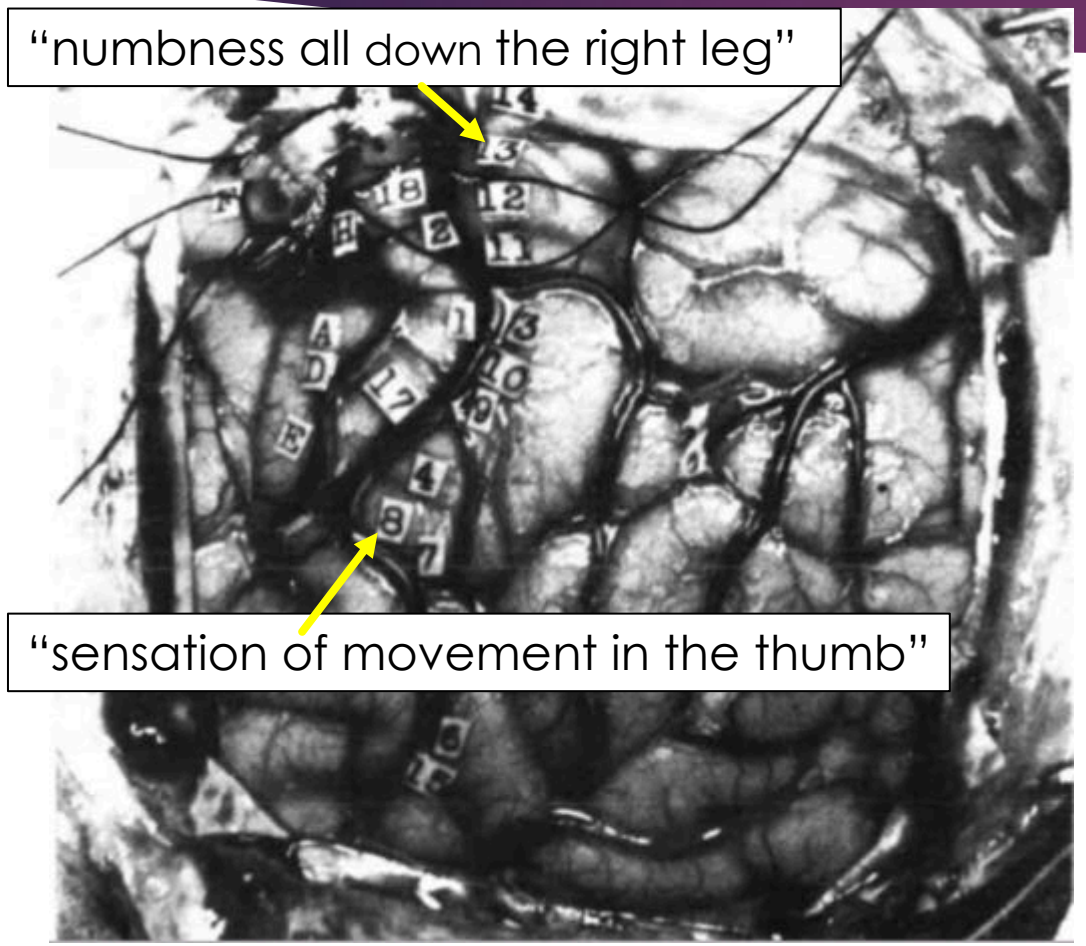






Norman Doidge, *The Brain That Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science* (Penguin Books, 2007)

The brain holds a map of the body

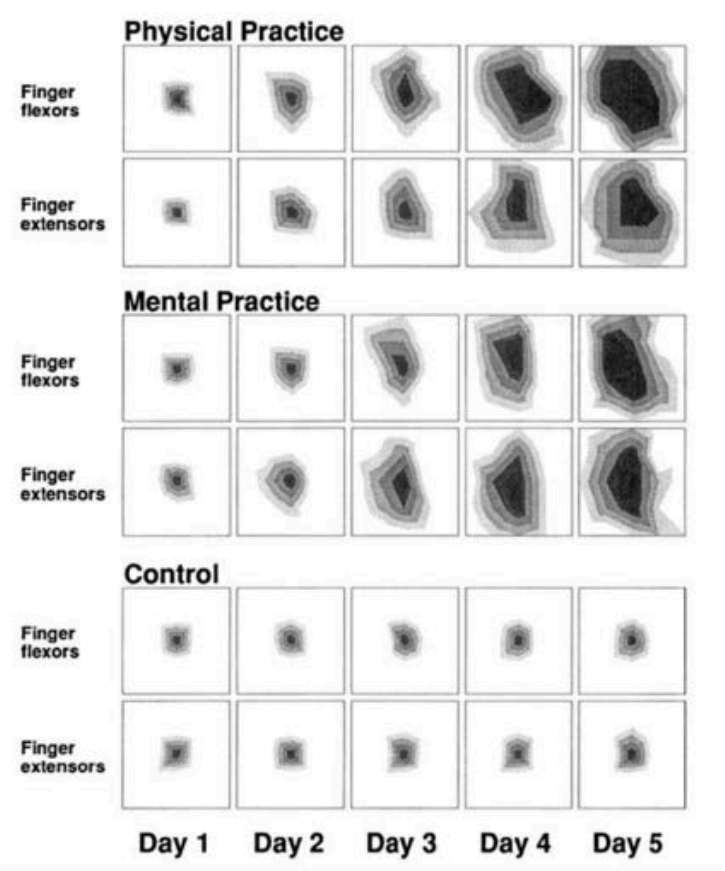


- Wilder Penfield (1891-1976) spent decades showing how the body is mapped onto the cerebral cortex
  - He needed to locate injured areas in brains of epilepsy patients before surgery
- Memories of sound, movement, and color were elicited by stimulation of the temporal lobes
- Today, non-invasive methods such as transcranial magnetic stimulation (TMS) are used

http://www.pbs.org/wgbh/aso/databank/entries/bhpenf.html

Merely thinking about playing the piano causes changes in the brain similar to actual piano practice

- Thinking changes physical reality – at least inside the brain
- Alvaro Pascual-Leone (Harvard Med School) taught two groups of people, who had never played piano, a sequence of notes on the piano*
  - One group practiced 2 hours per day on piano, for 5 days
  - Other group sat 2 hours per day in front of piano and *imagined* practicing, for 5 days
- Cortical motor maps of the two groups progressed at the same rate
- Skill levels of two groups were the same after first three days
- After five days, physical group was more skillful than mental group
- But after a single 2-hour physical session, mental group was as good as physical group



Cortical motor maps*

*A. Pascual-Leone *et al.*, "Modulation of Muscle Responses Evoked by Transcranial Magnetic Stimulation During the Acquisition of New Fine Motor Skills", J. Neurophysiology **74**, 1037 (1995)

Michelle Mack was born with half a brain

- Fairly normal basic language abilities
  - can construct a sentence and find words when she's talking
  - can understand instructions
- Graduated from high school
- Does data entry work from home
- Has trouble with
  - abstract concepts
  - some aspects of visual-spatial processing
- Can't always control her emotions
- Easily lost in new surroundings
- Her condition was not discovered until age 27

Her left hemisphere is missing, probably because of stroke *in utero*

https://www.disabilityscoop.com/2009/10/13/half-brain/5786/

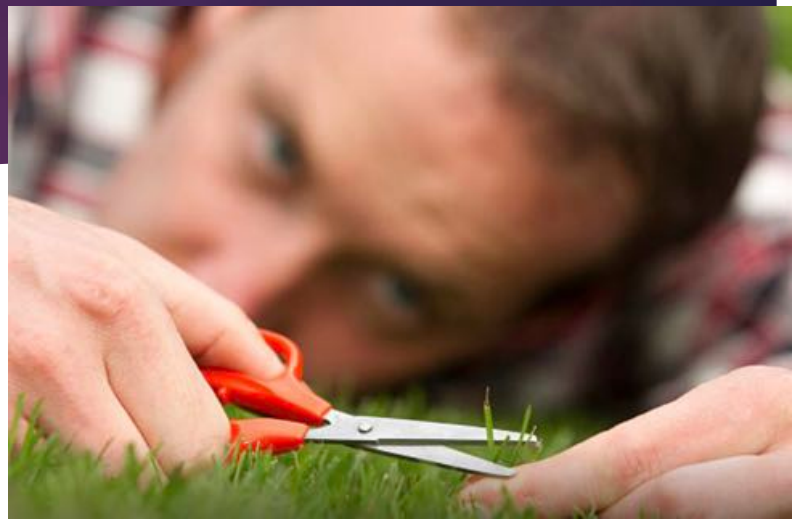
Removing half of your brain will not significantly impact who you are

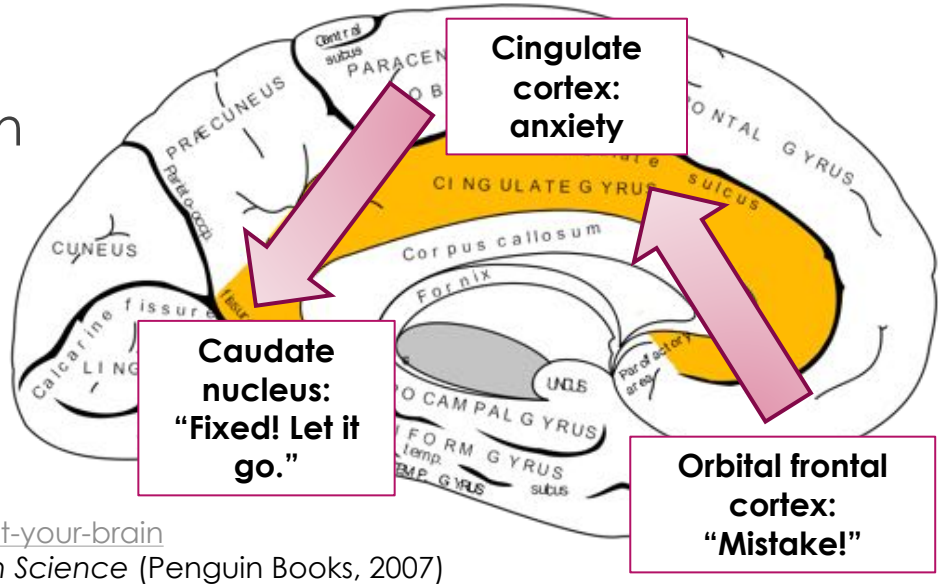
- *Hemispherectomy* is the surgical removal of one entire hemisphere of the brain
  - May be necessary for epilepsy patients who suffer dozens of seizures every day that resist all medication
  - Hundreds have been performed over past 90 years, usually on children
  - Very effective in stopping seizures
- Downside
  - vision and use of the hand opposite the missing hemisphere are lost
  - Speech problems if left side is removed, but even adults can regain speech
- Children that underwent hemispherectomies often improved academically once their seizures stopped
- Studies have found no significant long-term effects on memory, personality, and humor, and minimal changes in overall cognitive function

https://www.scientificamerican.com/article/strange-but-true-when-half-brain-better-than-whole/
http://www.northeastern.edu/storylab/sp16/2016/01/27/preliminary-research-living-without-brain-structures/
https://en.wikipedia.org/wiki/Hemispherectomy

Obsessive-compulsive disorder and neuroplasticity

- Symptoms: Locked into worry, unable to let go
  - Fear of: terminal illness, germs, asymmetry, disorder, harming others, blasphemy, battery acid,…
  - Compulsive act: cleaning, checking, correcting, ritualism, …
- Treatment
  - Most common: Exposure and response prevention
  - Jeffrey M. Schwartz (UCLA): "4 Steps"
    - Relabel, Reframe, Refocus, Revalue
    - Distinguishes between *form* and *content* of obsession
    - "You are not your brain"
    - It is not what you feel, it is what you do
    - Any time spent resisting is beneficial



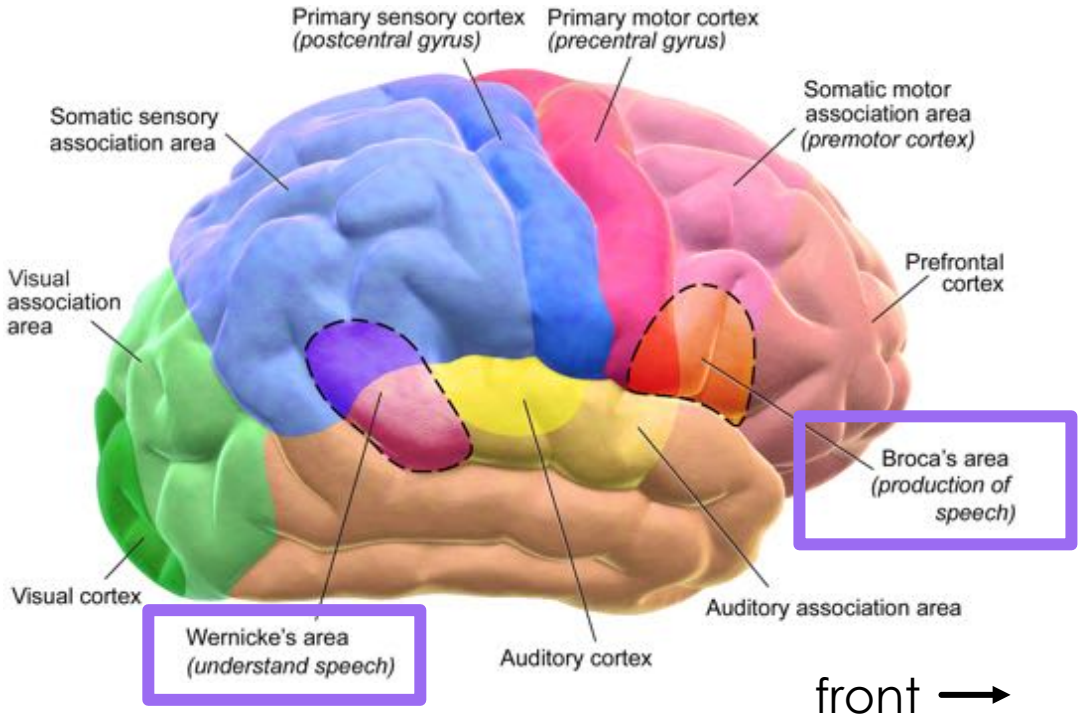


https://www.psychologytoday.com/us/blog/use-your-mind-change-your-brain/201106/you-are-not-your-brain

Norman Doidge, *The Brain That Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science* (Penguin Books, 2007)

Localizationism – Brain as Machine

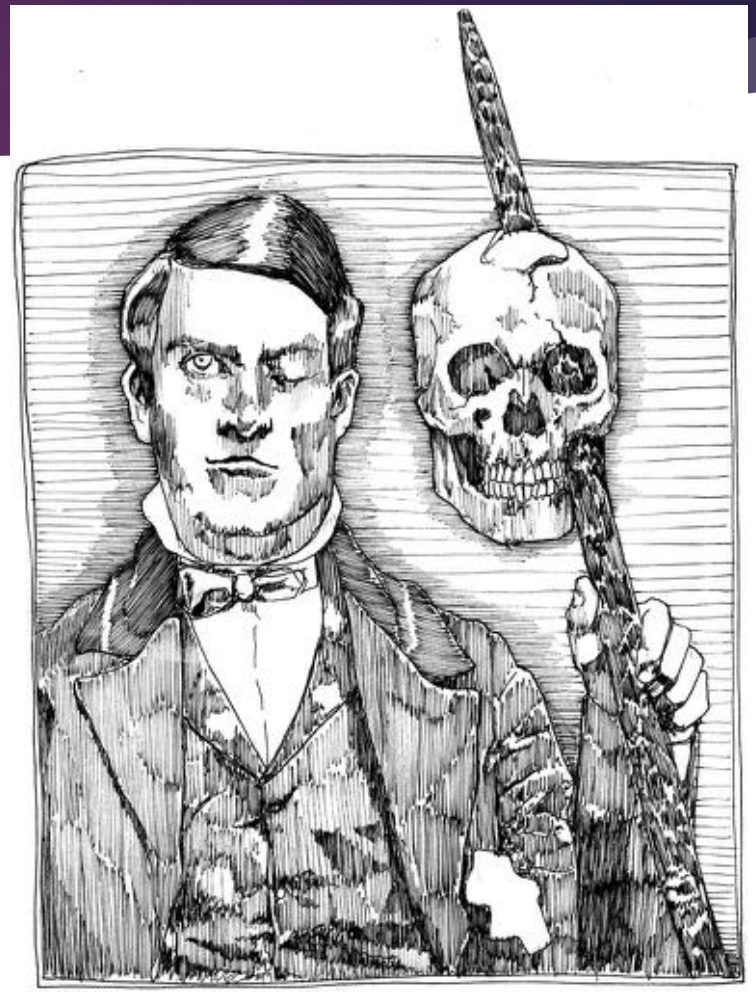
- *Localizationism*
  - Brain is like a complex machine
  - Brain has parts with specific functions hard-wired in specific pre-determined locations
  - If a part is damaged, the function is irrevocably lost
  - Was dominant viewpoint after work of Broca and Wernicke in 1860s-1870s
    - They identified specific brain regions associated with producing and understanding speech



But localizationism is inconsistent with evidence for neuroplasticity

Phineas Gage, localizationism, and neuroplasticity

- Railroad worker; accident with iron rod in 1848 destroyed much of his left frontal lobe
- His once even-tempered personality changed dramatically for a time
  - "He is fitful, irreverent… impatient of restraint or advice when it conflicts with his desires…capricious and vacillating"
  - Frontal lobe controls high level cognitive functions such as planning, initiating, organizing, personality
- His personality change was temporary
  - Gage was able to resume working and normal activity (as stagecoach driver in Chile) until his death
  - Died in 1860 as a result of a seizure



https://www.braininjurylawblog.com/phineas-gage-frontal-lobe-injuy.html
https://en.wikipedia.org/wiki/Phineas_Gage

When neuroplasticity is harmful: Pain and "phantom limbs"

- Many amputees experience their missing limb as still present
- Frequently amputees experience "phantom pain" in amputated limb
- Case of man whose hand was severed in auto accident
  - He experienced hand as still present
  - Phantom hand itched but couldn't be scratched
  - V. S. Ramachandran found that brain map of face had invaded brain map of amputated hand
  - Could scratch itch in phantom hand by scratching cheek

- Ramachandran showed phantom pain is caused by lack of feedback from severed limb
  - He designed mirror box to give illusion that phantom limb still exists
  - Several weeks of daily practice cured phantom pain and phantom limbs*

https://www.npr.org/2011/02/14/133026897/v-s-ramachandrans-tales-of-the-tell-tale-brain

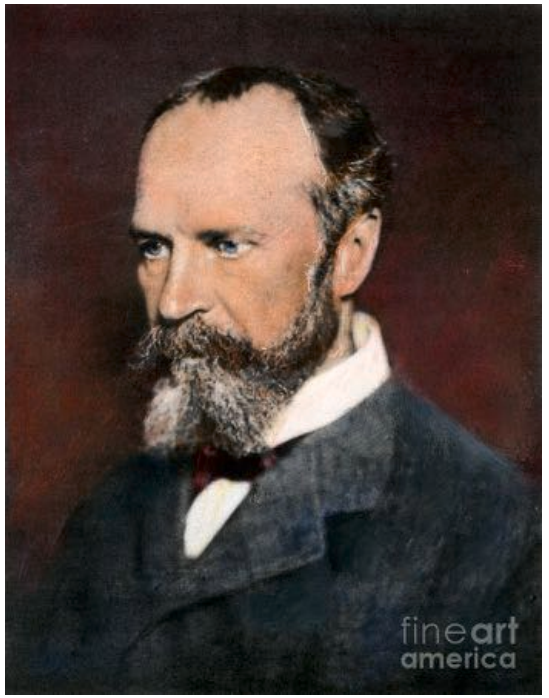
*V.S. Ramachandran and D. Rogers-Ramachandran, "Synaesthesia in phantom limbs induced with mirrors", Proc. R. Soc. London B **263**, 377 (1996)

When neuroplasticity is harmful: Addiction

- Addiction produces neuroplastic changes leading to:
  - Compulsive behavior despite negative consequences
  - Loss of control
  - Tolerance requiring ever higher levels of stimulation
  - Withdrawal symptoms if unavailable
- Breaking addiction requires "unlearning"
  - Feels like loss or even death
  - "For we know that our old self was crucified …"

William James (1842-1910) on neuroplasticity and habit

"Every smallest stroke of virtue or of vice leaves its never so little scar. The drunken Rip Van Winkle, in Jefferson's play, excuses himself for every fresh dereliction by saying, 'I won't count this time!' Well! he may not count it, and a kind Heaven may not count it; but it is being counted none the less. Down among his nerve-cells and fibres the molecules are counting it, registering and storing it up to be used against him when the next temptation comes." – William James, *The Principles of Psychology* (1890), Chapter IV, *Habit*



Religions teach the idea that knowledge is represented ("written") in flesh

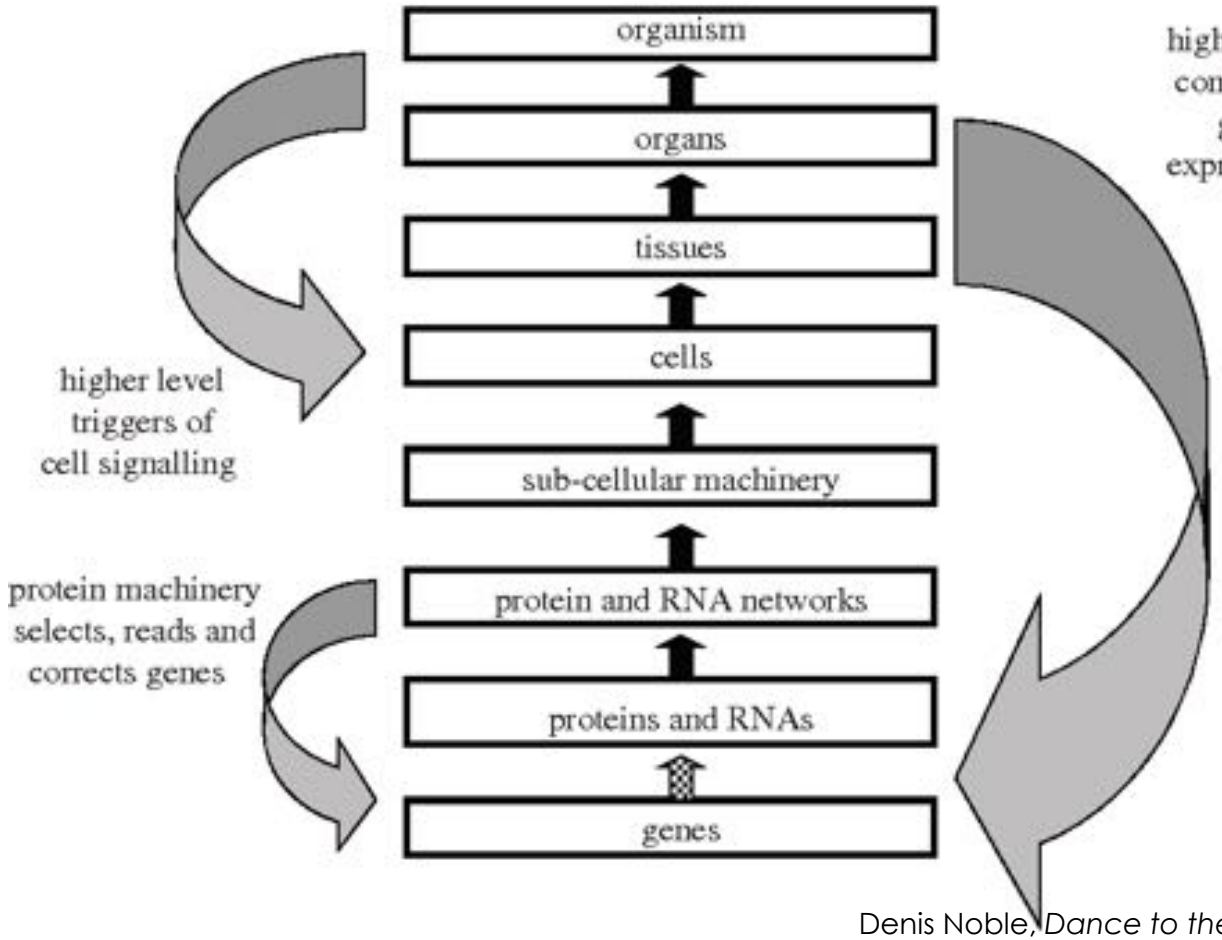
- "I will put my law in their minds and write it on their hearts. … No longer will they teach their neighbor, or say to one another, 'Know the LORD,' because they will all know me" (Jeremiah 31:33-34)
- "The Word (**λογος**) became flesh and made his dwelling among us" (John 1:14)

Why is neuroplasticity interesting theologically?

- Neuroplasticity shows we can be active agents, not only passive objects
  - It provides examples of top-down causality: "free will"
    - People can, on rare occasions, consciously decide to change their brains (i.e., the very organ that embodies decisions, instincts, habits, and addictions)
    - It may not be logically useful to say that the brain decided to change itself
    - Networks exhibit new causes at higher levels
  - This means God can act within and through us
    - E.g., God changes us, and then we act; causality flows downward
- Mind over matter – belief creates reality
  - Our thoughts alone can change neural tissue and its behavior
    - This might simply indicate that thoughts are physical processes
- It is important to control our thoughts; mindfulness
- Knowledge is written in flesh – for good or ill
- Driven by anecdotes – the power of a single story

Norman Doidge, *The Brain That Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science* (Penguin Books, 2007)

In biology, causality is both bottom-up and top-down



- You may have been taught that genes govern the organism
- But in reality, biological structures at larger scale often exert control over smaller scales
  - Barbara McClintock (1983 Nobel Prize in Physiology or Medicine): Cell is able to restructure the genome, perhaps in response to stress
    - Cell is the active agent, not the genes
    - Cells experience stress; genes do not
- Perhaps the conscious mind can likewise exert downward control of the organism

Denis Noble, *Dance to the Tune of Life: Biological Relativity* (Cambridge University Press, 2017), Fig. 3.6, p. 81

Mindfulness…and free will

- "…The thought is thinking itself. It comes uninvited. You will see that when there is a strong detachment from the thought process, thoughts don't last long. As soon as you are mindful of a thought, it disappears." – Joseph Goldstein, https://tricycle.org/trikedaily/joseph-goldstein-mindfulness-consciousness/

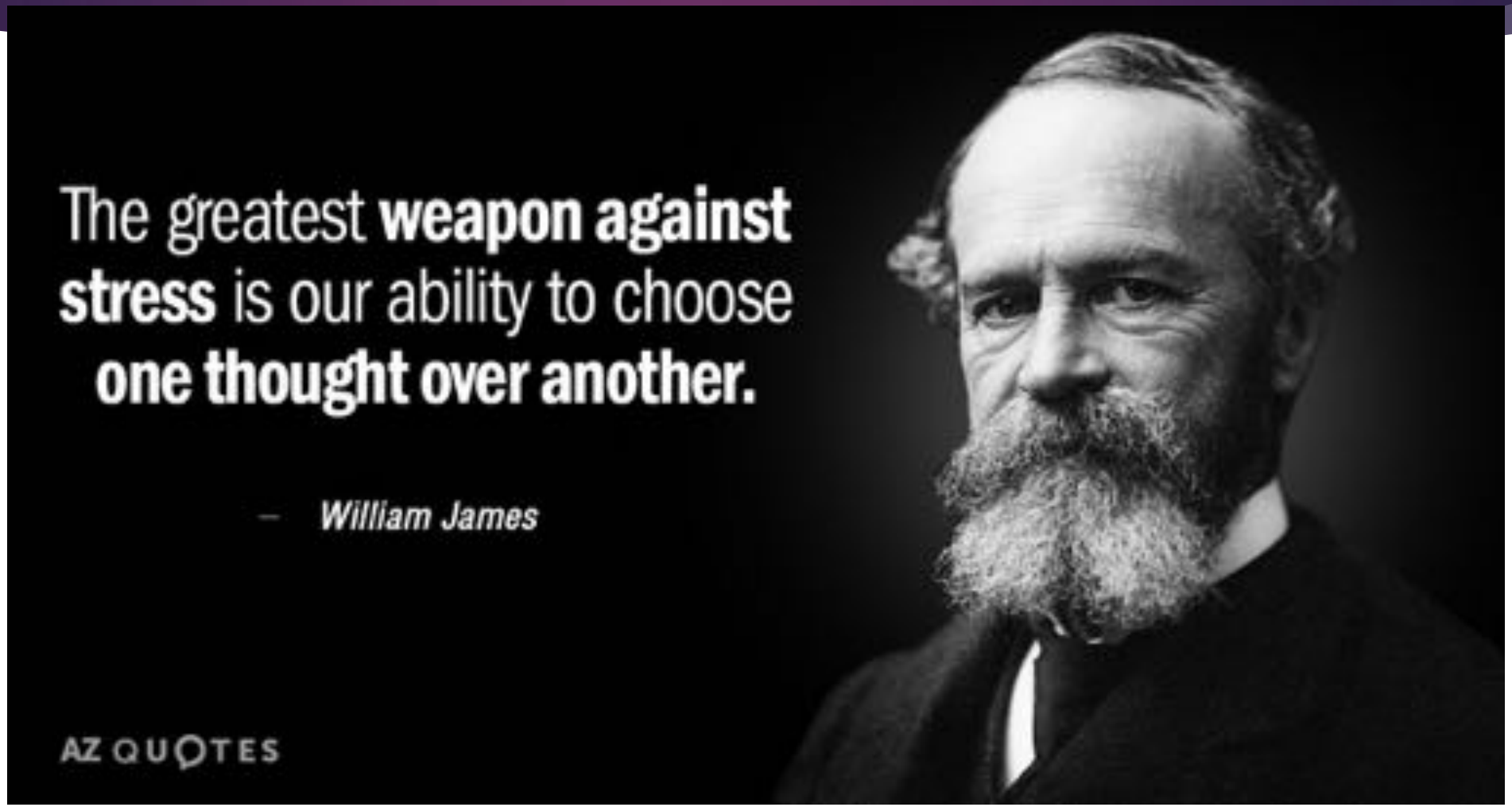
- "…the faculty of voluntarily bringing back a wandering attention, over and over again, is the very root of judgment, character, and will." -- William James, *The Principles of Psychology* (1890), Chapter XI, *Attention*

The content of our thoughts matters, because our subjective experience is all we ever know

- Miracle at Cana – changing water into wine
  - Was the molecular structure of water modified to become that of wine?
  - Or did the wedding celebrants have the *subjective experience* of drinking good wine?
    - "Everyone brings out the choice wine first and then the cheaper wine after the guests have had too much to drink; but you have saved the best till now."

The Marriage at Cana, Marten de Vos, c. 1596

William James on mindfulness



Questions

- Can we picture an injured brain as a stressed ecosystem, in which cognitive functions must compete for habitats, rather than as a damaged machine or computer?
- Are you more free in your thoughts than in your speech or actions? What are the limits on your thoughts, speech, and actions? Can and should you limit your own (or anyone else's) thoughts?
- Is the following Biblical admonition, about our thoughts, good advice or bad advice? If it is good advice, what are the obstacles to heeding it?:
  - "Finally, brothers and sisters, whatever is true, whatever is noble, whatever is right, whatever is pure, whatever is lovely, whatever is admirable – if anything is excellent or praiseworthy – think about such things."