

# **PSYCH 260/BBH 203**

Evolution of the brain

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# Prelude



# Prelude



# Announcements

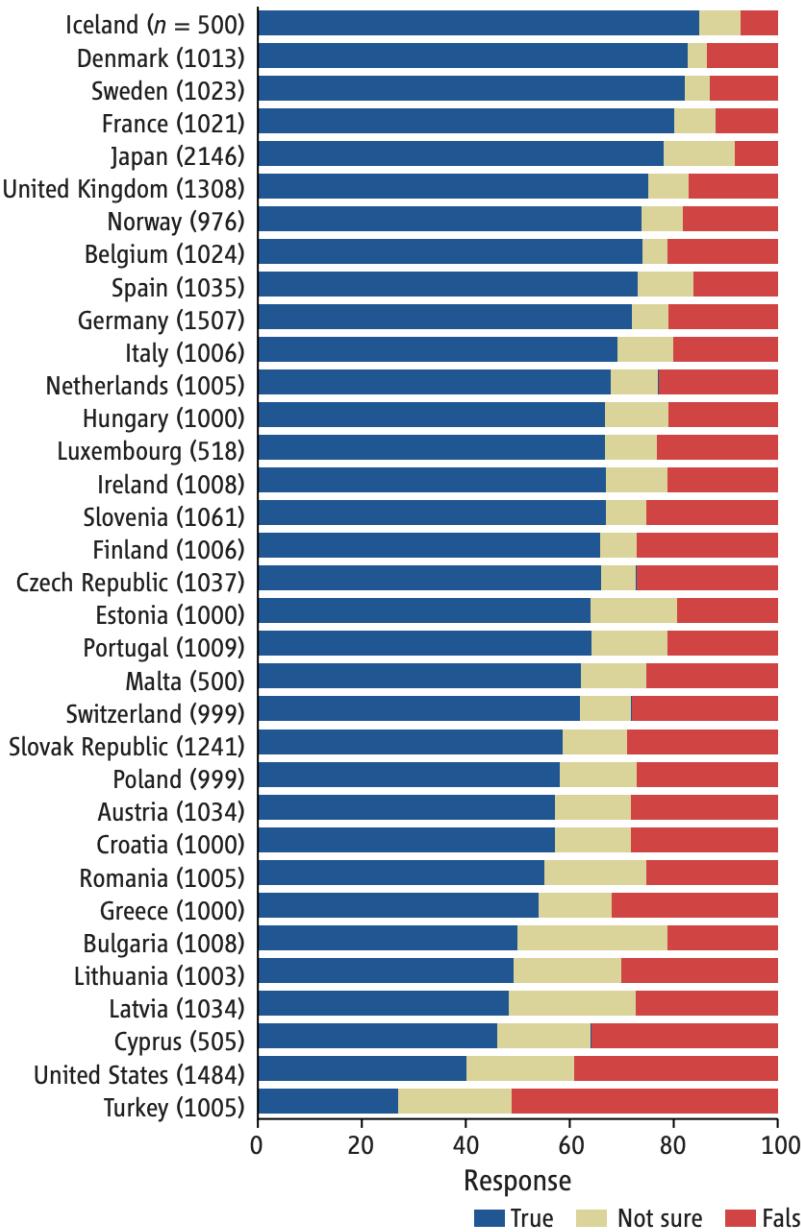
- Exam 2 next Tuesday (no class meeting)

# Today's Topics

- Evolution and U.S. public attitudes
- The evolution of the human brain

# Evolution and U.S. public attitudes

# Public acceptance of evolution



(Miller, Scott, & Okamoto, 2006)

# 2021 data



[[@Miller2021-lb]](<http://dx.doi.org/10.1177/09636625211035919>)  
[\(Miller et al., 2021\)](#)

*"A structural equation model indicates that increasing enrollment in baccalaureate-level programs, exposure to college-level science courses, a declining level of religious fundamentalism, and a rising level of civic scientific literacy are responsible for the increased level of public acceptance."*

(Miller et al., 2021)

# Principles of evolution

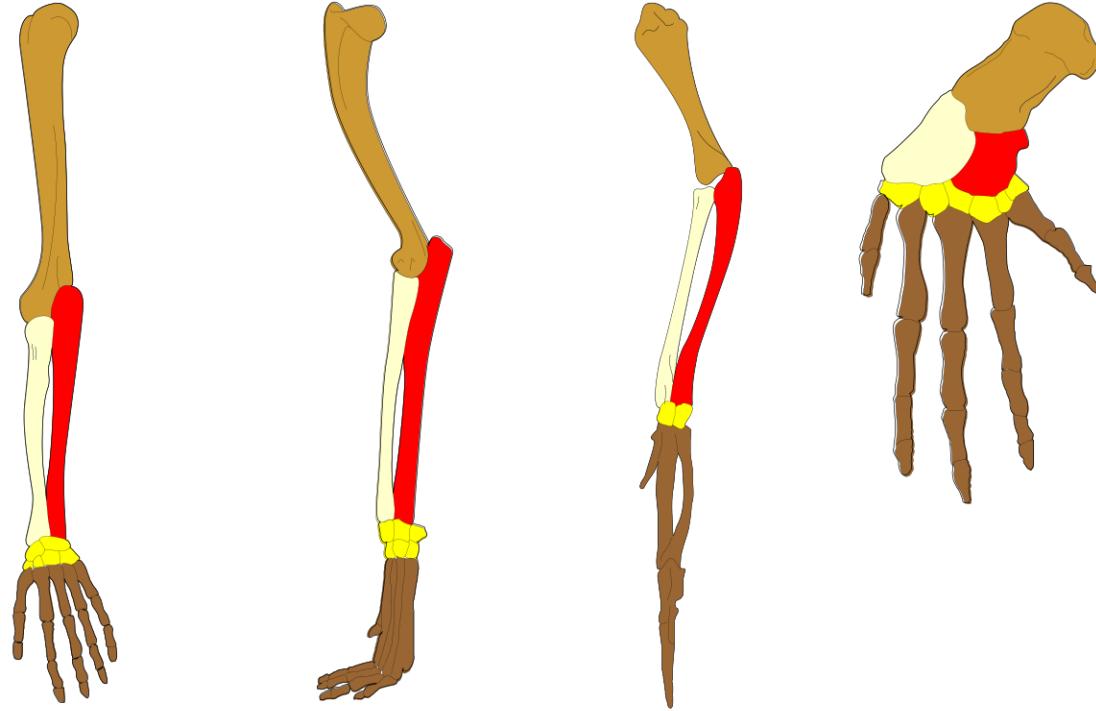
- Life forms existing in the Earth's past differed from those living today
- New generations of life forms inherit properties from their predecessors
- New life forms evolved as a result of *mutations, selection pressures, and geological events*
- Greater reproductive success (more offspring) for some, not others

# Evidence for evolution

- Fossil
  - Fossil dating (radiometric)
- Geological
  - Where fossils are found relative to one another (relative dating)
  - How long it takes to form layers

# Types of evidence

- Molecular
  - Similarities between vastly different species (e.g., in neurotransmitters, receptors, metabolic pathways, etc.)
- Genetic
  - Rates of mutation
  - Developmental patterns of gene expression
- Anatomical



Human

Dog

Bird

Whale

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By Волков Владислав Петрович - Own work, [CC BY-SA 4.0](#), [Link](#)

# *Nothing in Biology Makes Sense Except in the Light of Evolution*

*“Seen in the light of evolution, biology is, perhaps, intellectually the most satisfying and inspiring science. Without that light, it becomes a pile of sundry facts some of them interesting or curious, but making no meaningful picture as a whole.”*

(Dobzhansky, 1973)

# Why Gilmore thinks it's controversial (in the U.S.)

- Contradicts verbatim/non-metaphorical reading of some religious texts
- Makes humans seem less special
- Time scales involved beyond human experience
- Scientific method vs. other ways of knowing
- Found in nature ≠ good for human society

# Why Gilmore thinks it's controversial (in the U.S.)

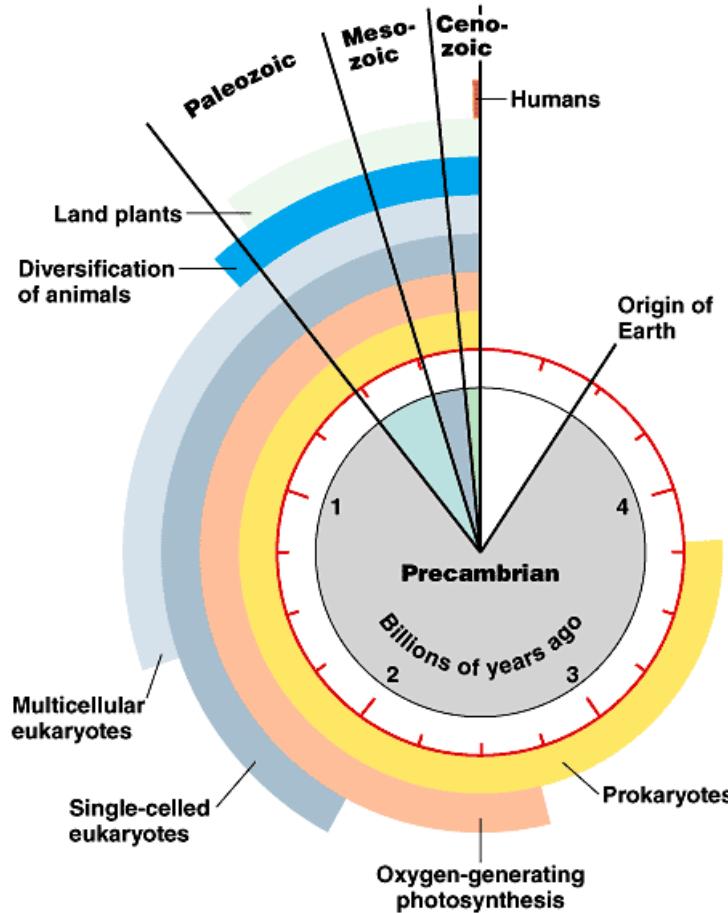
- Few negative consequences of 'disbelief'
- U.S. culture individualistic, skeptical of experts & expertise
- Lower levels of religious belief among U.S. scientists
- Politics

# Evolution of the human brain

# The dawn of time



# History of life on Earth



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# Cambrian Explosion



- Complex multicellular lifeforms emerged ~541 million years ago
- “Explosion” in geological terms: lasted ~13-25 million years

# What sparked the explosion? (Fox, 2016)

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- Behavior requires movement through space
- Behavior requires coordinating perception with action
- Behavior requires perception at a distance
- Behavior requires fast & specific communication systems
- Behavior requires **energy**

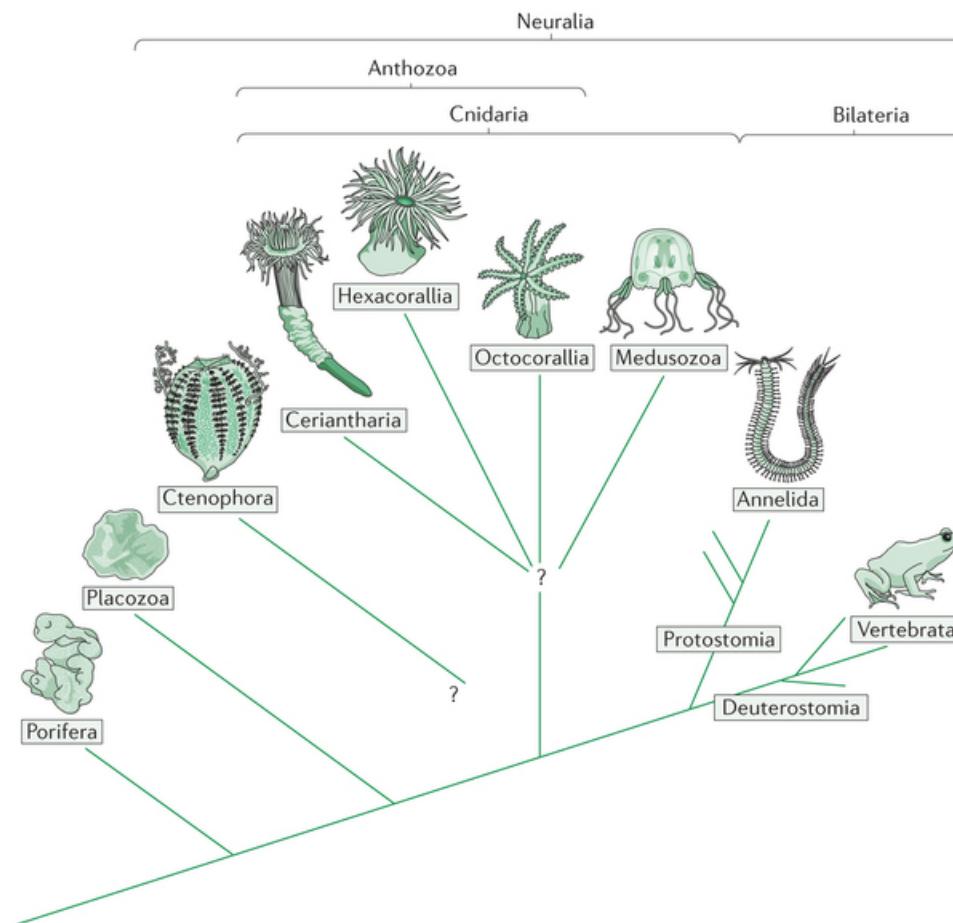
# Tree of life

<https://www.evogeneao.com/en/explore/tree-of-life-explorer>

# How nervous systems differ

- Body symmetry
  - radial
  - bilateral
- Segmentation
- Centralized vs. distributed function
- Cephalization: sense organs & nervous system concentrated in anterior
- Encasement in bone (vertebrates)

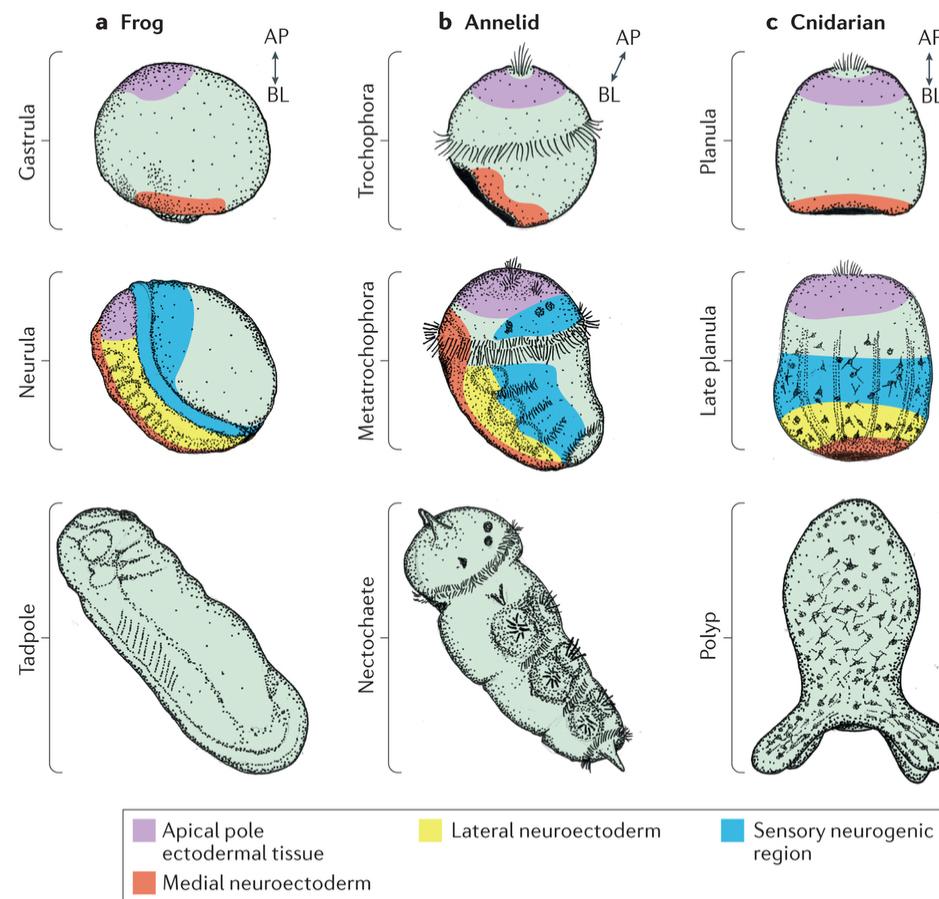
# (Arendt, Tosches, & Marlow, 2016)



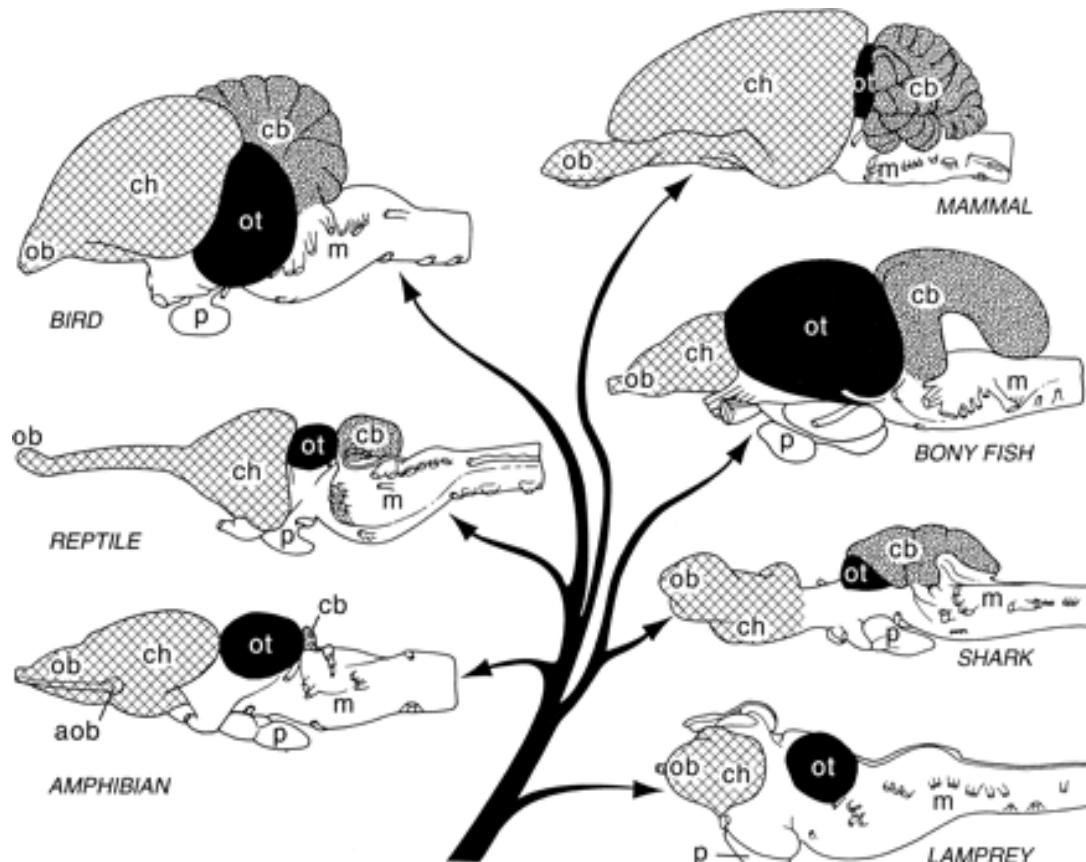
# Cellular/molecular mechanisms

- Similarities in patterns of early nervous system development
  - across vastly different species
  - with very distant (in time) common ancestors
  - limited number of ways to build nervous systems that successfully regulate behavior

# (Arendt et al., 2016)



# Comparing vertebrate brain structures

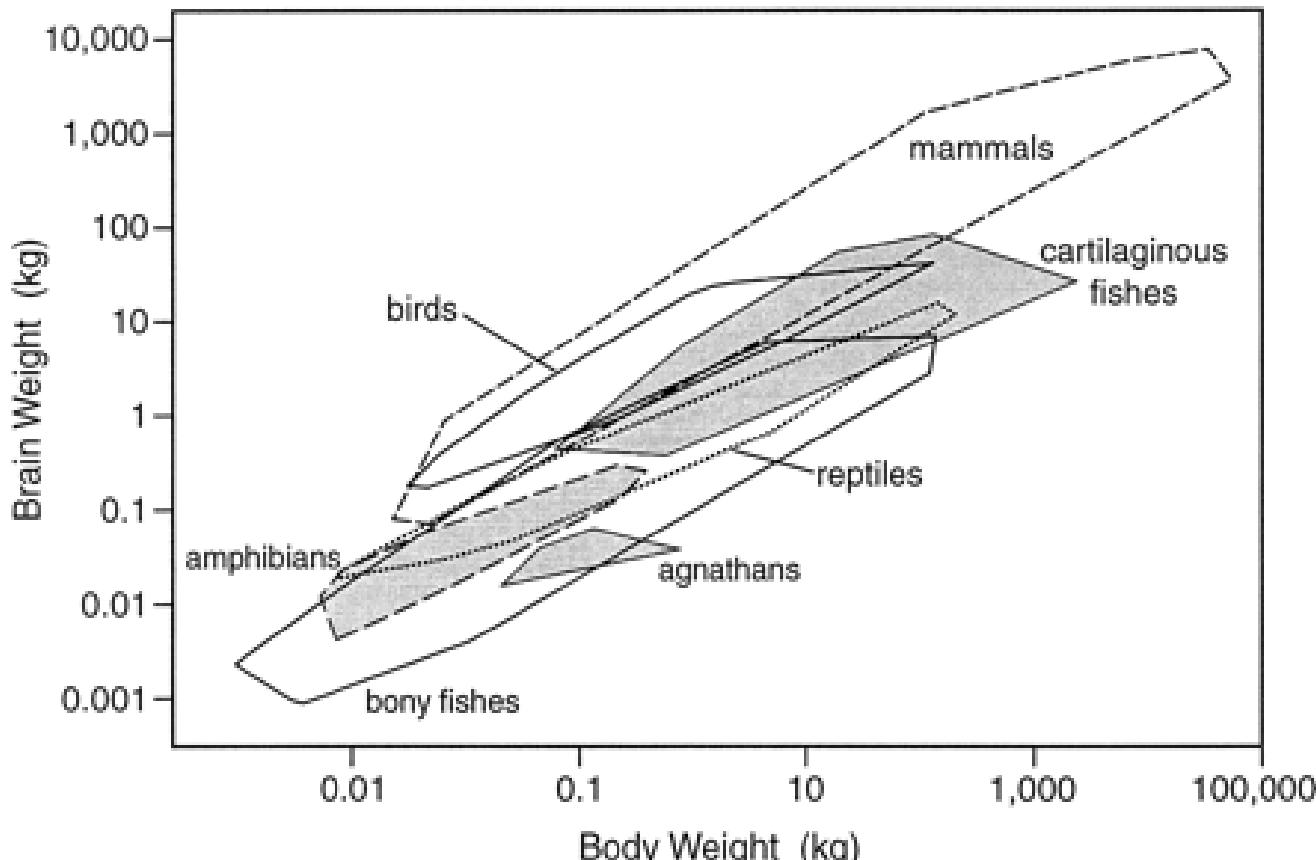


(Northcutt, 2002)

# Comparing brain structures

- Vertebrates have similar brain plans
- Species differ in relative size of parts

# Brain sizes differ by vertebrate groups

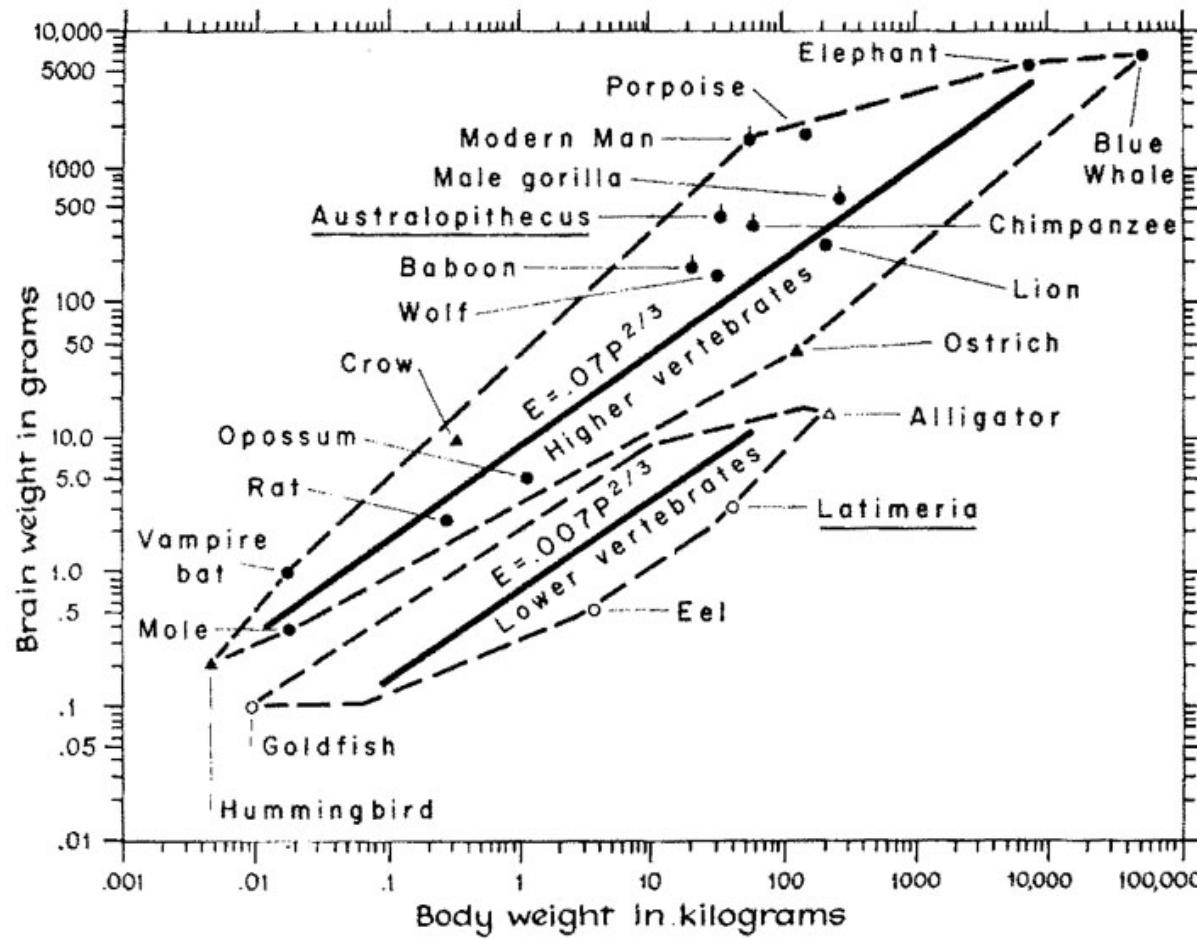


(Northcutt, 2002)

# But have similar “slopes”

- Brain sizes scale with body size

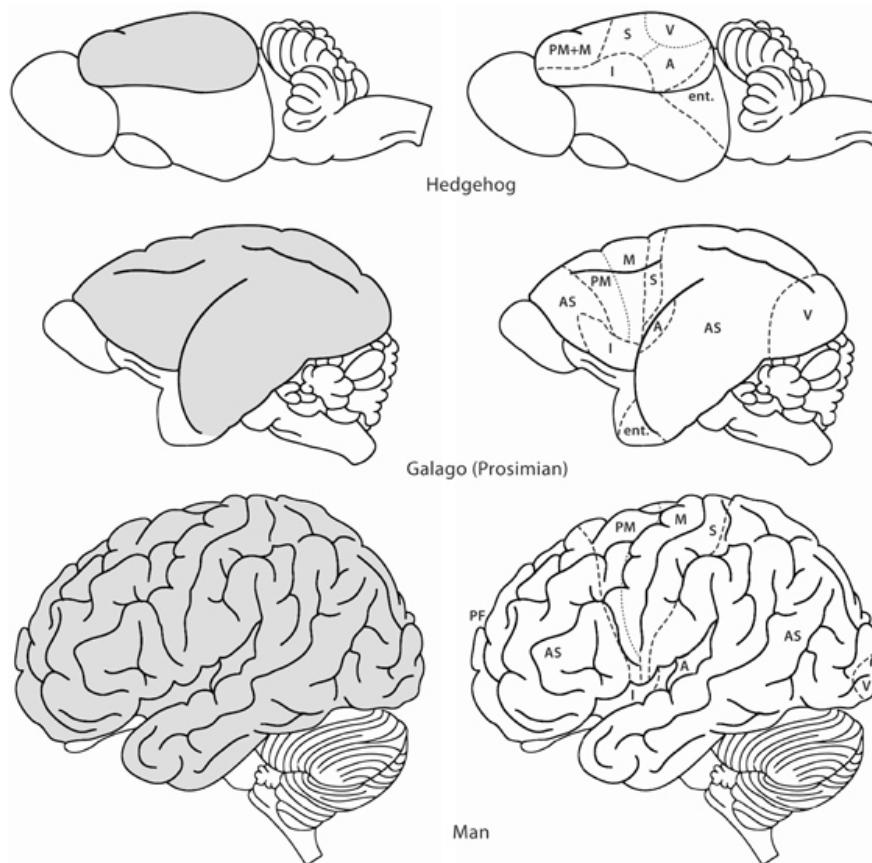
# Comparing brain sizes



# Brain sizes across vertebrate groups

- Brain size scales with body size (more or less)
- Mammals and birds have big brains
- Some animals have big brains for their bodies
  - Humans
  - Crows
  - Porpoises
- Bigger than expect brains (relative to average) = high 'encephalization factor'

# Cortical size within groups



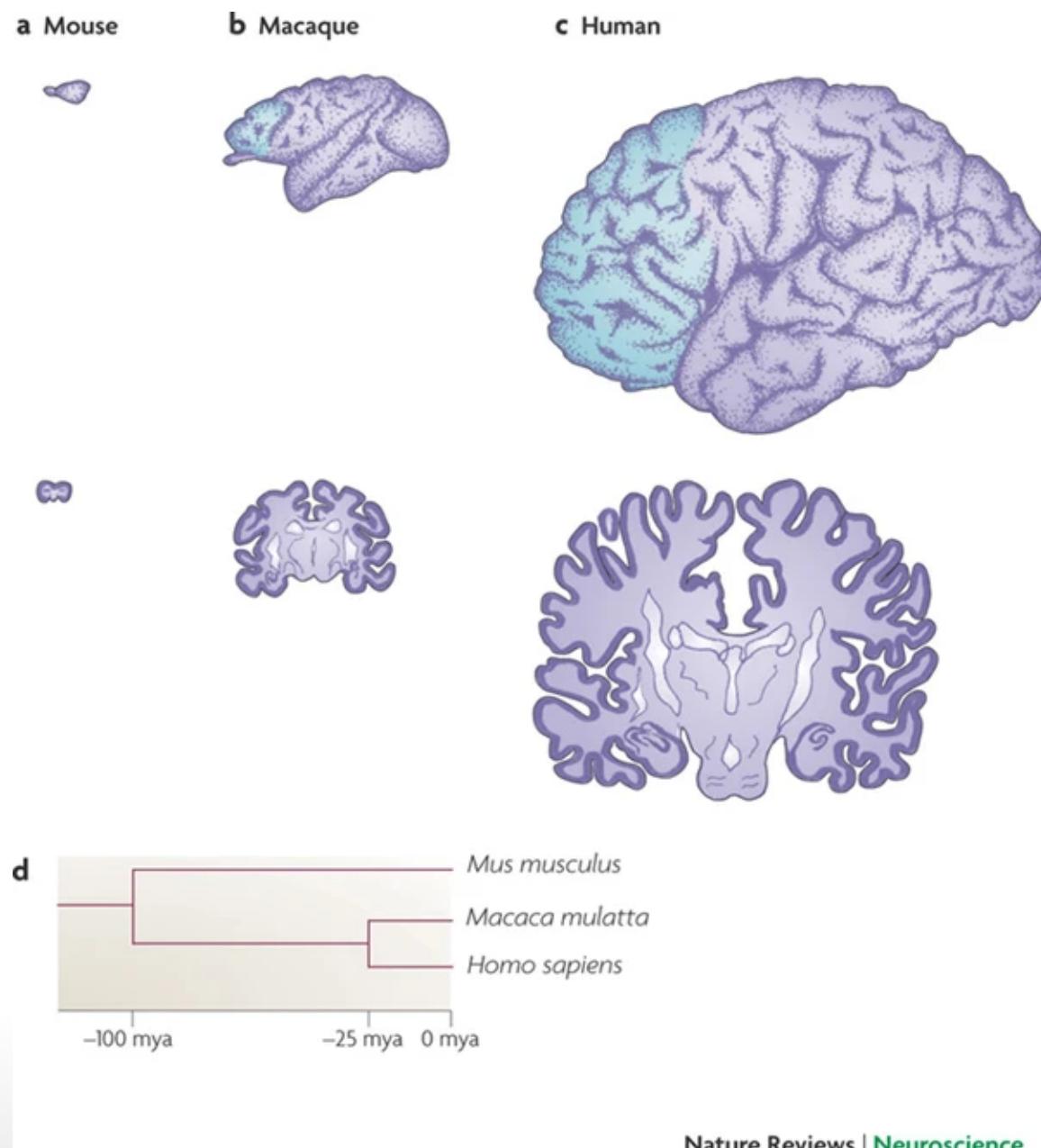
(Hofman, 2014)

# Evolutionary trends in cortical size

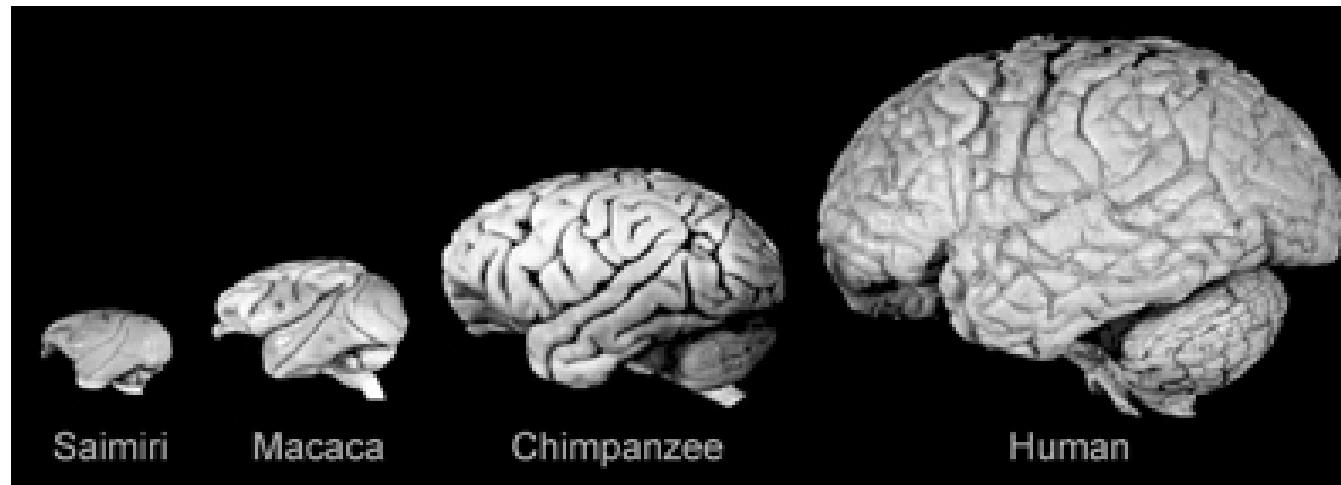
Structural measure	Non-human comparison	Human
Cortical gray matter %/tot brain vol	insectivores 25%	50%
Cortical gray + white	mice 40%	80%
Cerebellar mass	primates, mammals 10-15%	10-15%

- Cerebral cortex larger in humans

# Evolutionary trends in cortical size



# Evolutionary trends in primate brain size



# Evolutionary trends

- In primates, including humans
  - Smaller olfactory bulbs
  - Cerebellum comparable to other mammals
  - Large cerebral cortex

# Selection pressures

- Natural and sexual selection for
  - Traits that improve reproductive success
- Physical AND psychological traits
  - Hardware and software

# Samsung Galaxy S21+

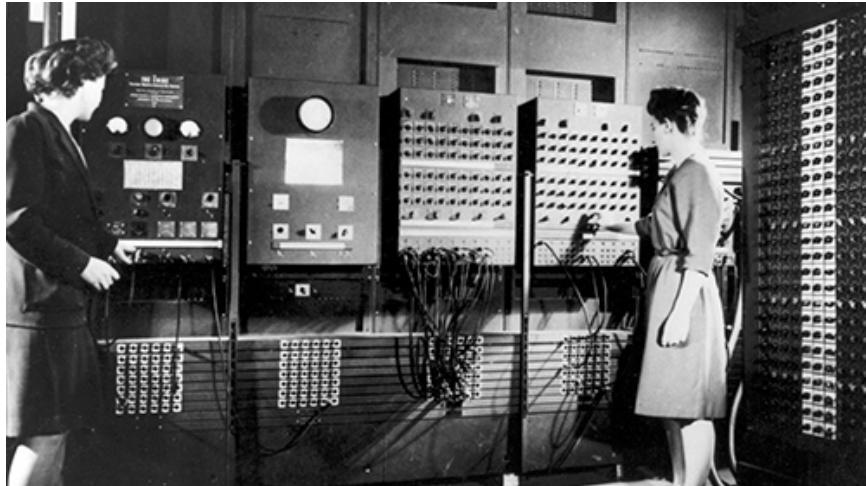
# Virtues of big phones/brains

- More storage
- More processing capacity
- Better sensors
- Better output
- More, better apps
- Do more, faster

# Costs of big brains

- Long time to build
- Lots of energy to nourish/maintain
- Long time to program/train/educate
- Head/neck must be strong enough to carry
- How to connect brain/body parts widely, but process info quickly

# Does size matter? Maybe not so much.



# A new view (Herculano-Houzel, 2016)

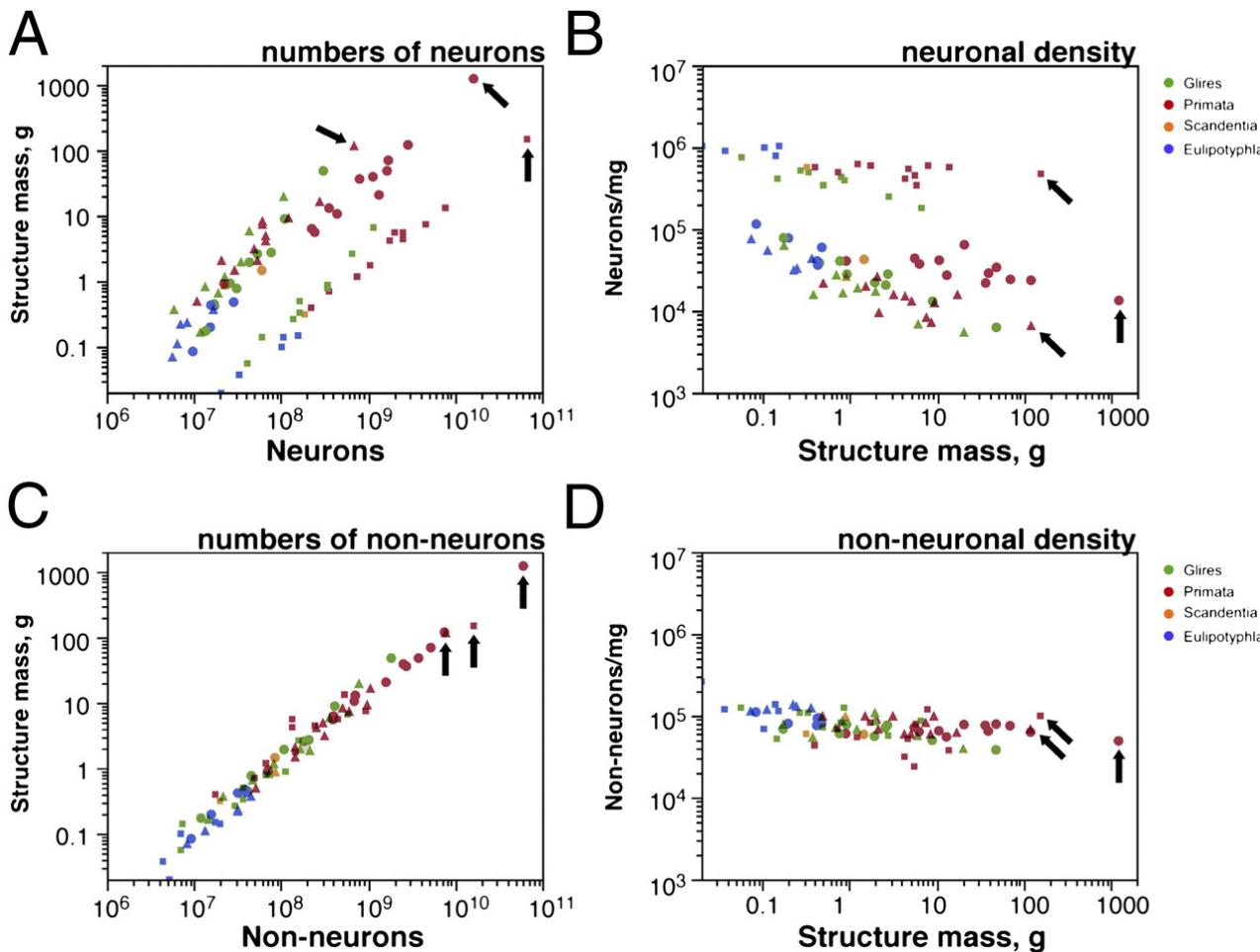
- Number of neurons in *cerebral cortex* makes humans “special”

Species	# cortical neurons	cortical mass (g)
Human	16 B	1233
Chimpanzee	6 B	286
Elephant	5.6 B	2800
Baboon	2.9 B	120.2

# A new view (Herculano-Houzel, 2016)

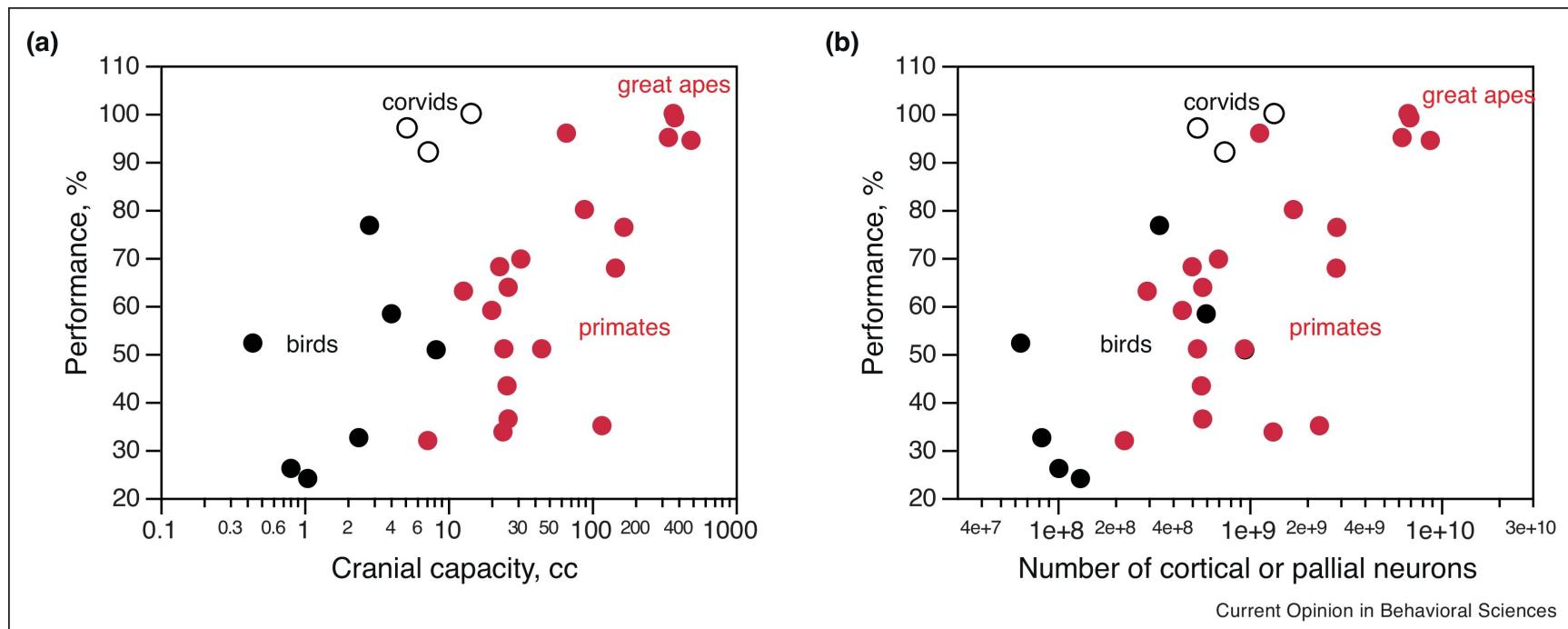
Species	# cortical neurons	cortical mass (g)
Giraffe	1.7 B	398.8
Rhesus	1.7 B	69.8
Pig	303 M	42.2
Rabbit	71 M	4.4

# But humans follow typical scaling rules



(Herculano-Houzel, 2012)

# # of cortical (or its equivalent) neurons predicts “cognition”?



(Herculano-Houzel, 2017)

# How did the human brain get this way?

- Builds upon mammalian/primate norms
- More efficient energy intake
  - calories/hr foraging vs.
  - cooking?
- Specialized pattern of development
  - Significant time post-natal/pre-reproductive (childhood)

# Take homes

- Life forms on Earth have evolved over *billions* of years
- Complex organisms with nervous systems emerged ~500-600 *million* years ago
- Centralized nervous systems have similarities in organization
- Human brains similar to closely related species, but have more neurons in cerebral cortex

# Next time

- Exam 2 on Canvas (start time 3:05 PM)

# References

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