

PSYCH 260/BBH 203

Evolution of the brain

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Prelude



Prelude



Announcements

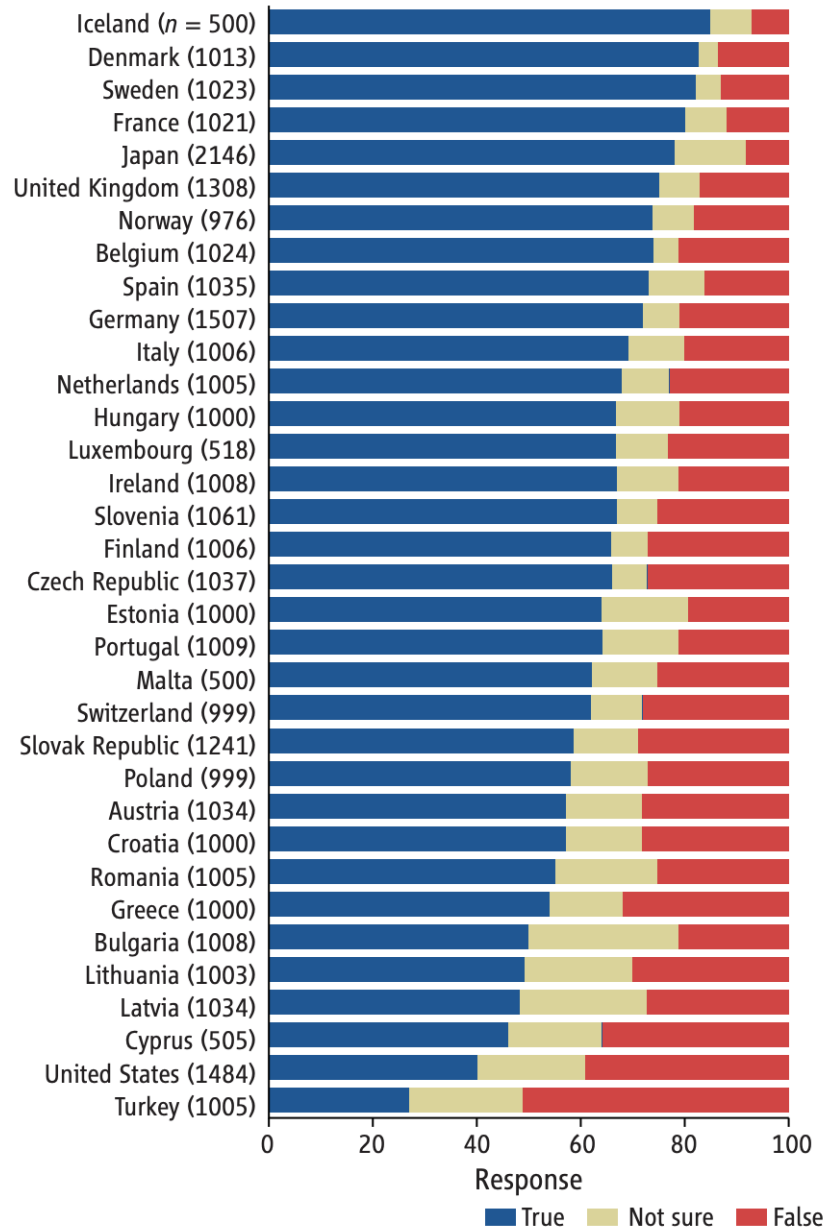
- Exam 2 next Tuesday (no class meeting)

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

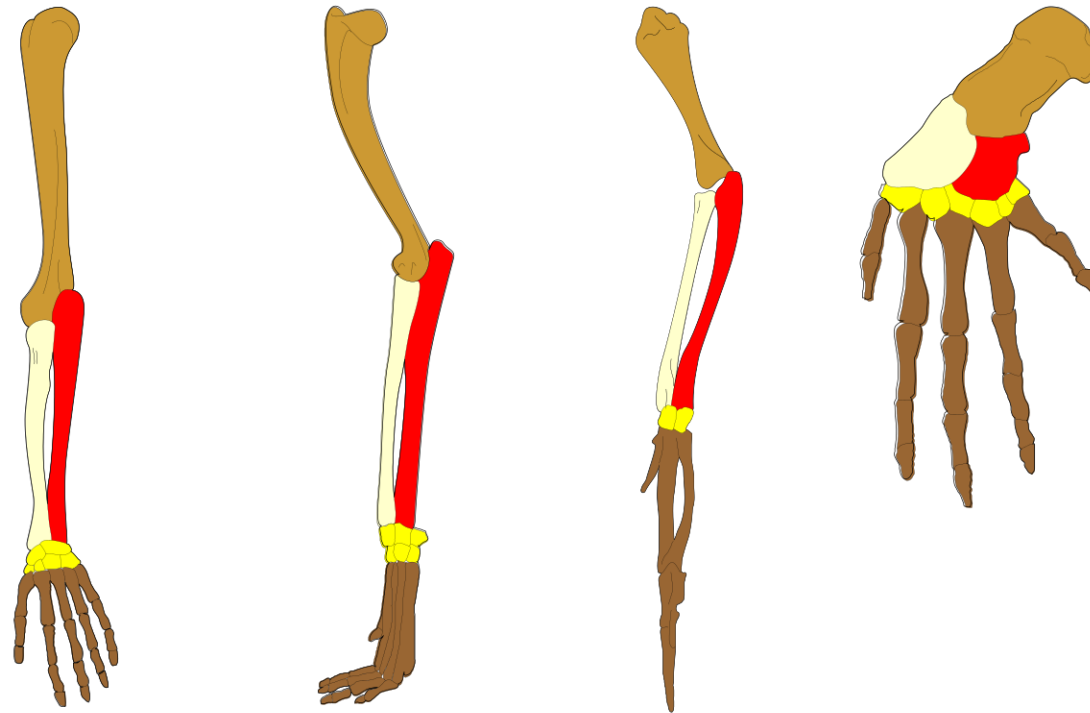
- Life forms existing in the Earth's past differed from those living today
- New generations of life forms inherit properties from their predecessors
- New life forms evolved as a result of *mutations*, *selection pressures*, and *geological events*
- Greater reproductive success (more offspring) for 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

Ву 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 \neq good for human society

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

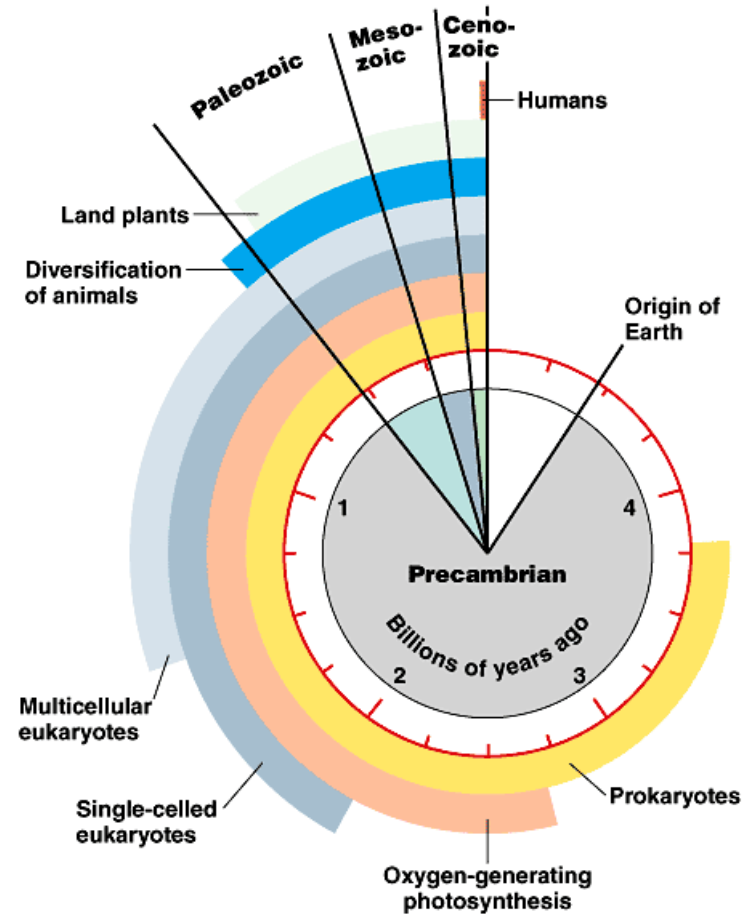
- Few negative consequences of 'disbelief'
- U.S. culture individualistic, skeptical of experts & expertise
- Lower levels of religious belief among U.S. scientists
- Politics

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? [\(Fox, 2016\)](#)

- 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**

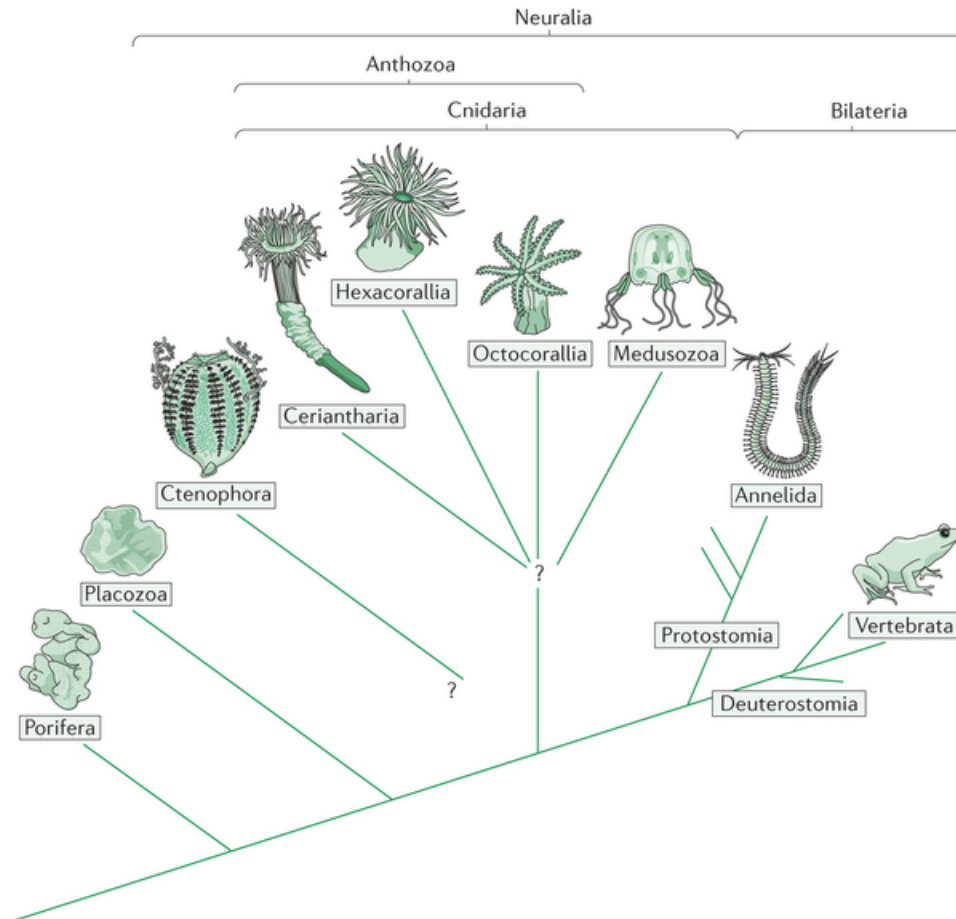
Tree of life

<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)

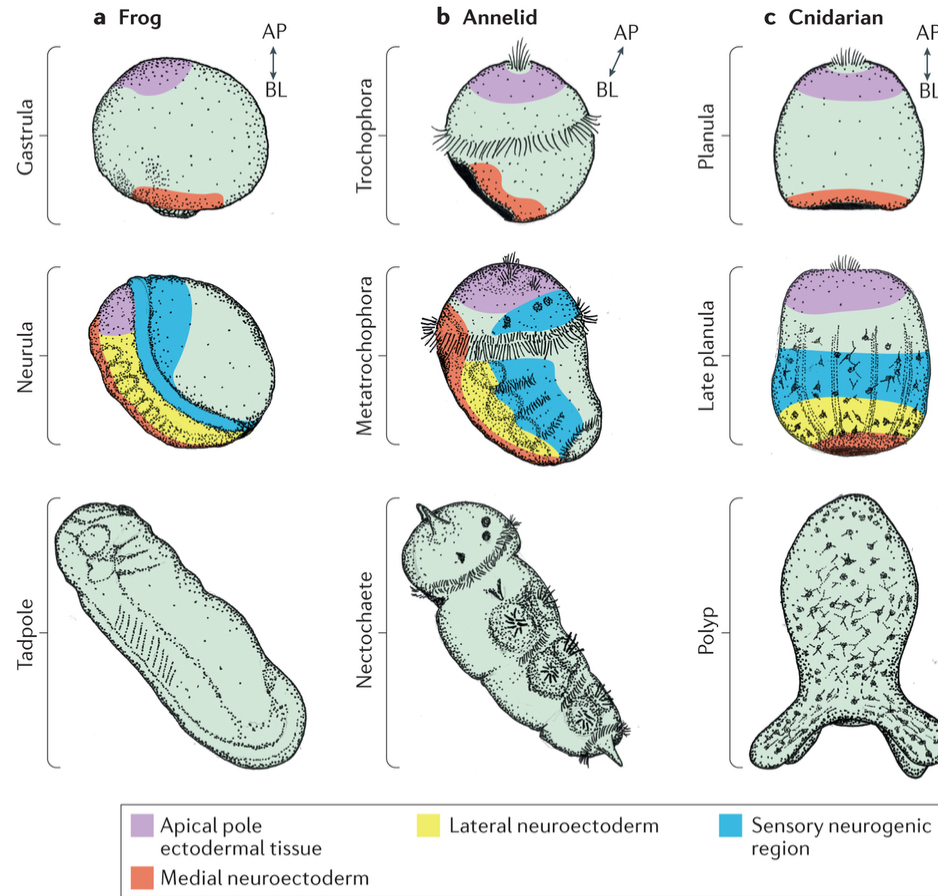
(Arendt, Tosches, & Marlow, 2016)



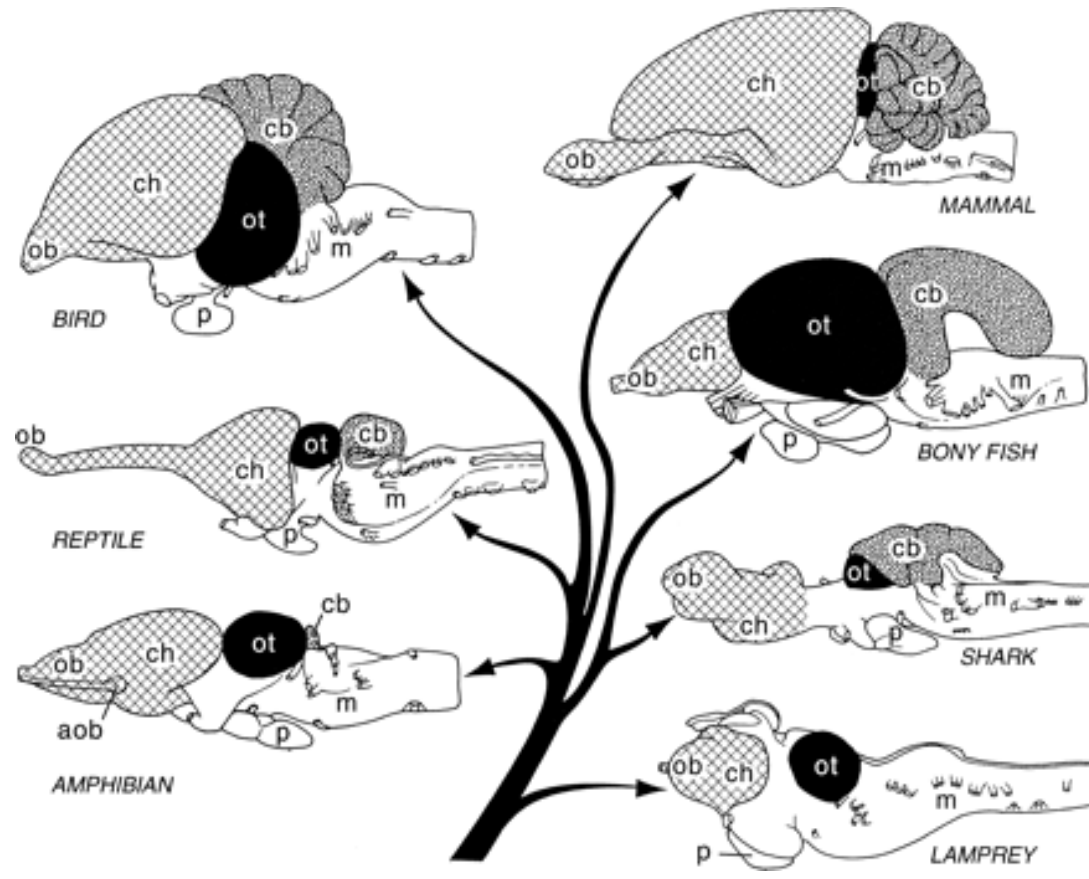
Cellular/molecular mechanisms

- 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

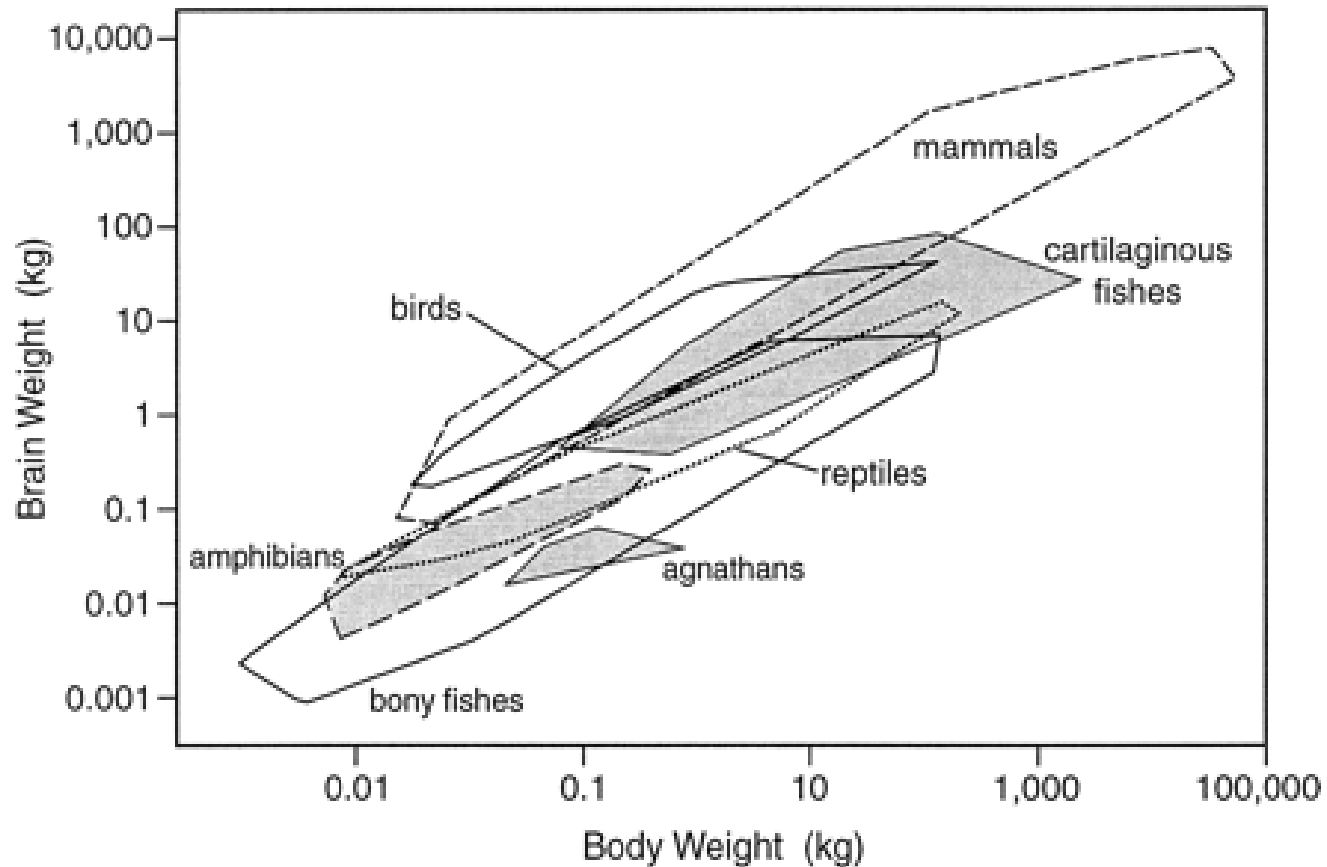


(Northcutt, 2002)

Comparing brain structures

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

Brain sizes differ by vertebrate groups

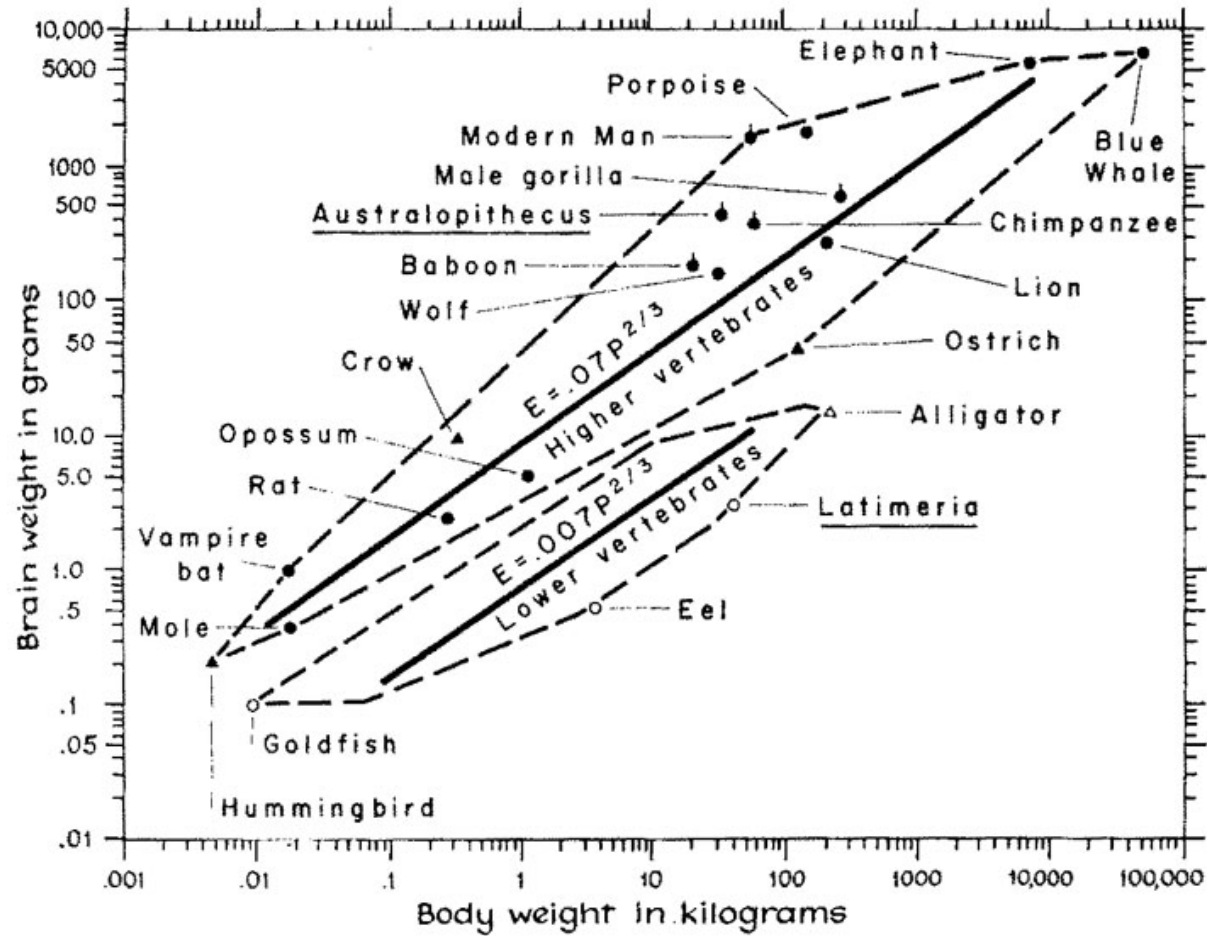


[\(Northcutt, 2002\)](#)

But have similar “slopes”

- Brain sizes scale with body size

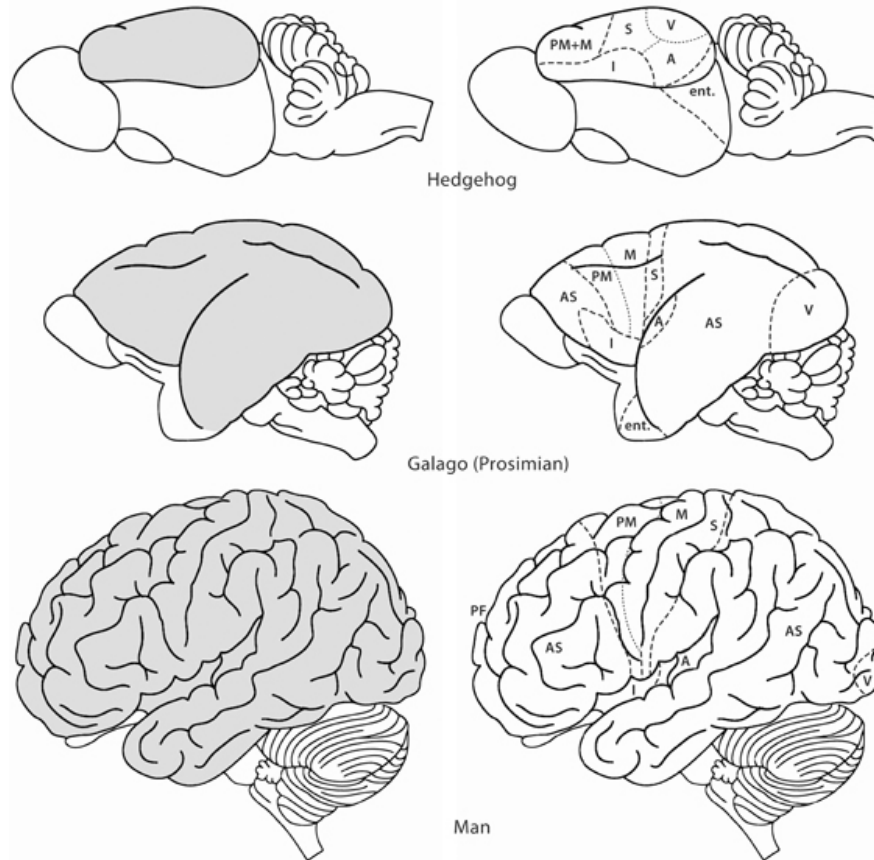
Comparing brain sizes



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



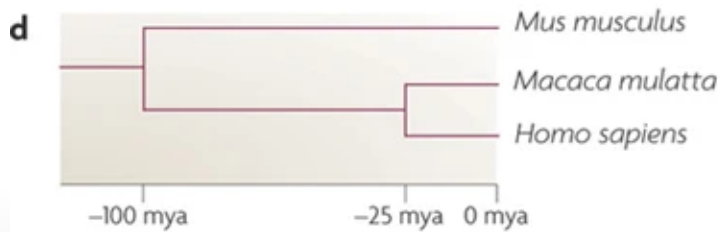
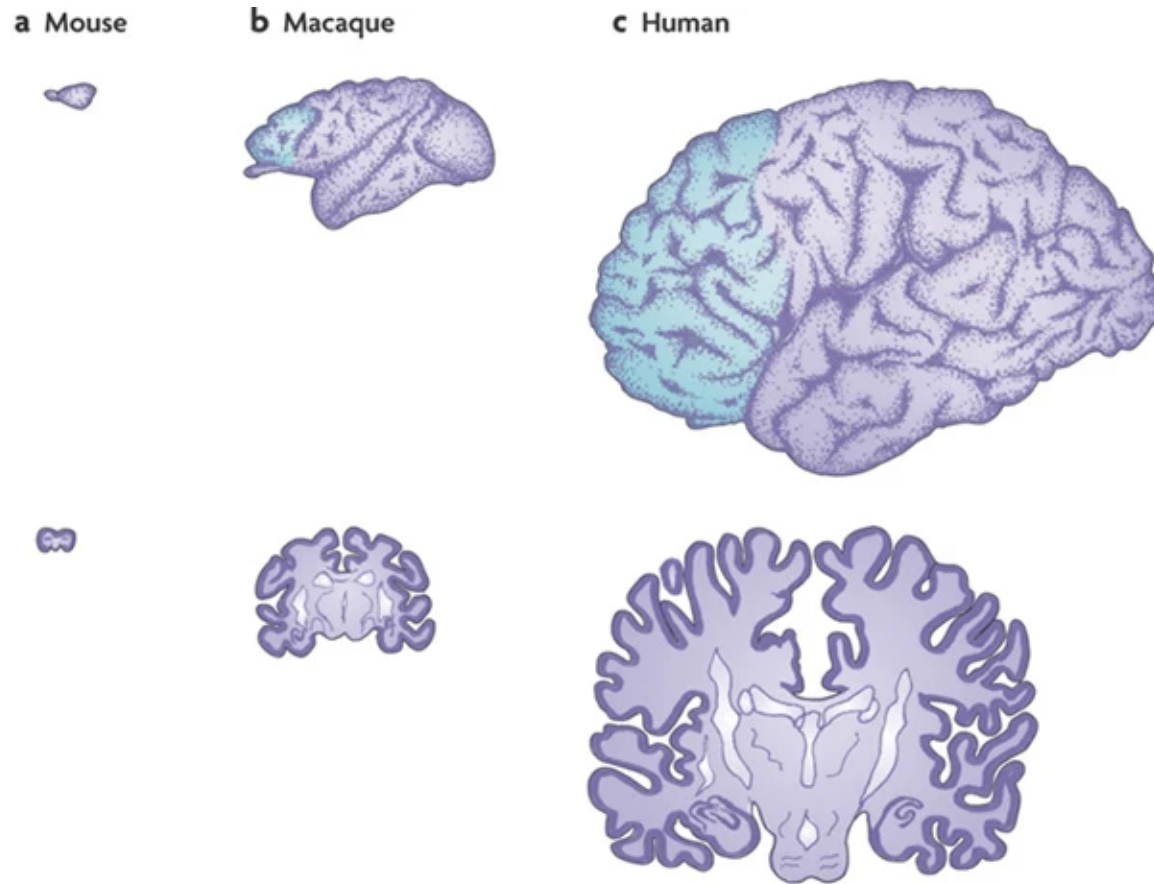
[\(Hofman, 2014\)](#)

Evolutionary trends in cortical size

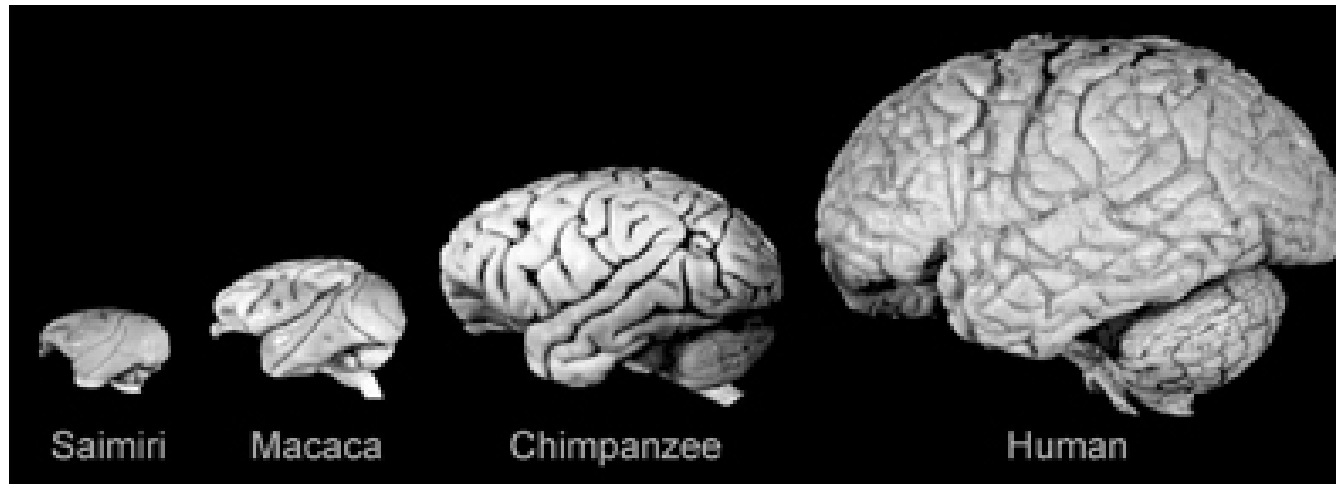
Structural measure	Non-human comparison	Human
Cortical gray matter %/tot brain vol	insectivores 25%	50%
Cortical gray + white	mice 40%	80%
Cerebellar mass	primates, mammals 10-15%	10-15%

- 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+

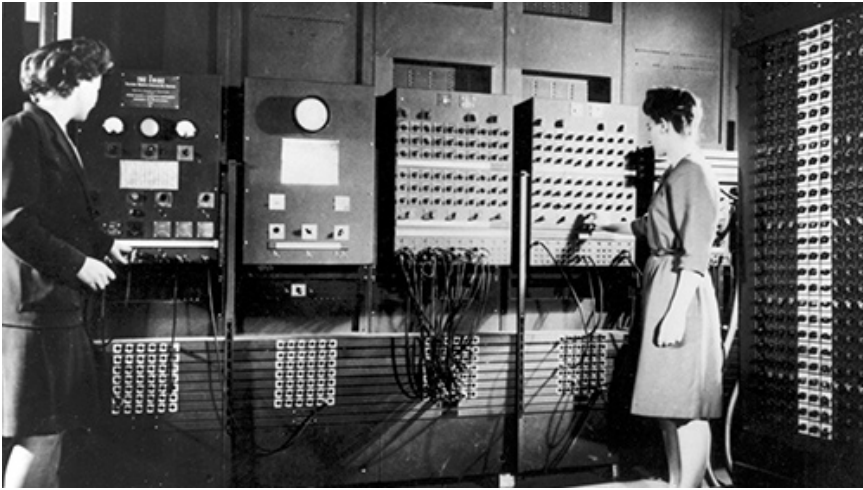
Virtues of big phones/brains

- 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)

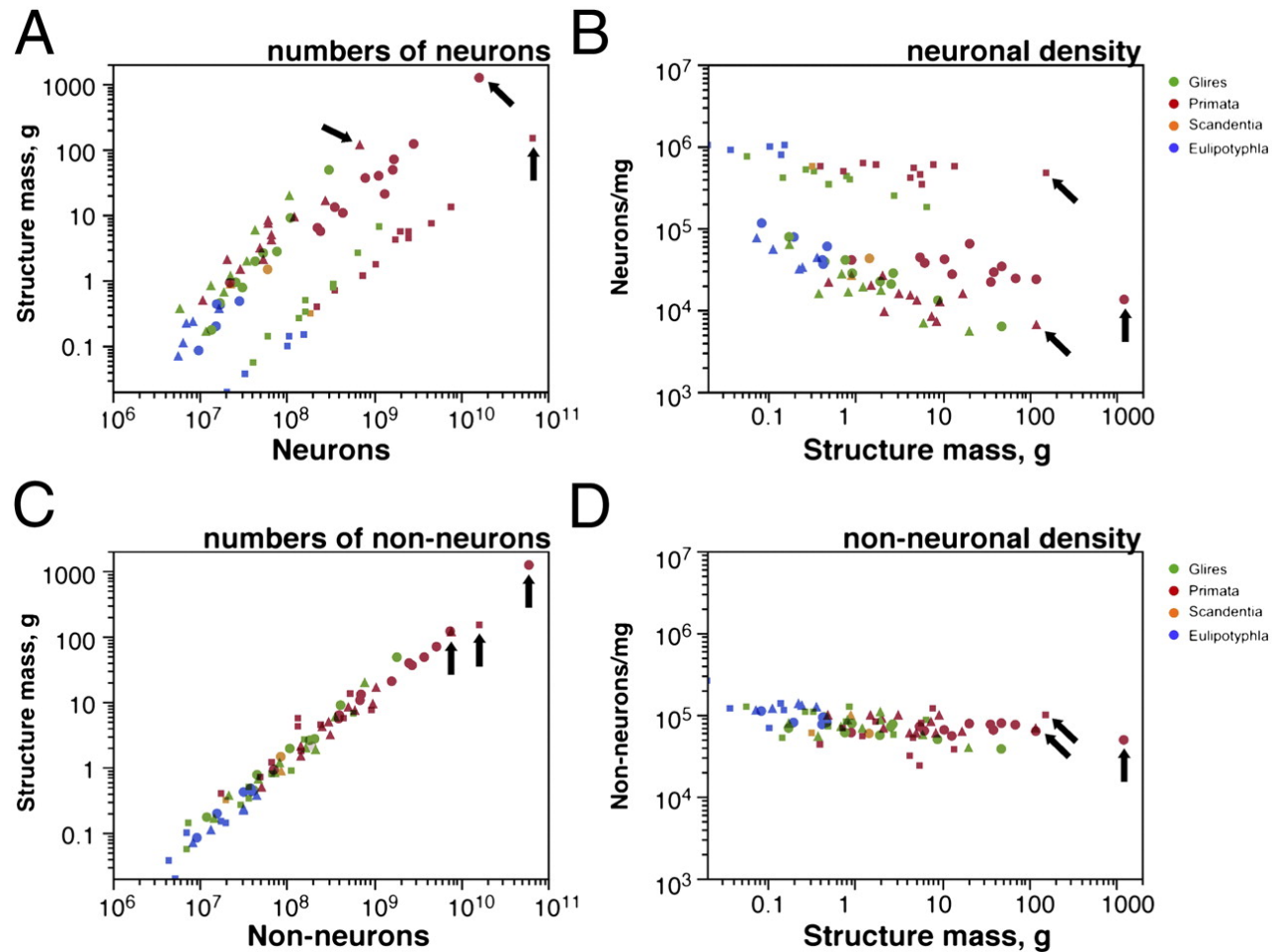
- Number of neurons in *cerebral cortex* makes humans “special”

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)

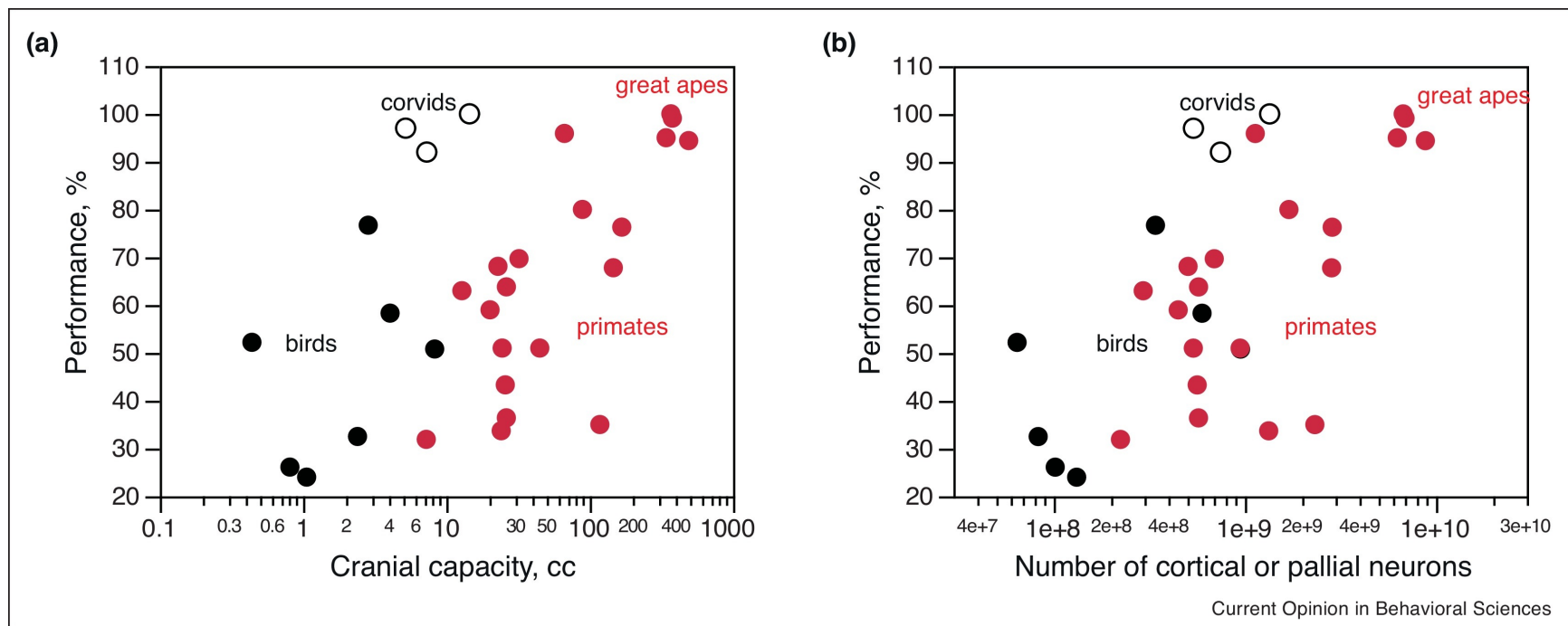
Species	# cortical neurons	cortical mass (g)
Giraffe	1.7 B	398.8
Rhesus	1.7 B	69.8
Pig	303 M	42.2
Rabbit	71 M	4.4

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)

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