Week 2 : Brain Origins and Evolution

- KW Chapter 2
- Sacks Chapter 3

Issues re: Evolution

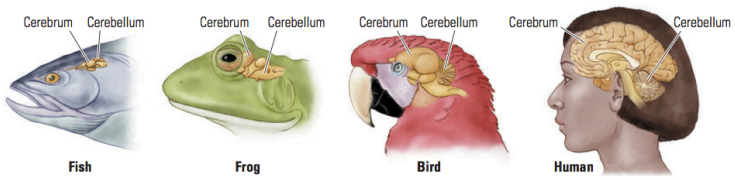
- Philosophical Issues
  - humans vs. animals - qualitative vs. quantitative difference?
- Scientific issues
  - conflicting & rare evidence
    - e.g. Neanderthals
- Religious issues
  - ancient texts
  - contrary teachings
  - literal vs. symbolic interpretation
    - "7 days" vs "4.5 billion years"
  - modern ideas

Catholic Church's "Evolution" on Evolution

- Catholic Church's position on scientific evolution has changed over time. E.g. July 2004:
- "According to the widely accepted scientific account, the universe erupted 15 billion years ago in an explosion called the 'Big Bang' […] In our own solar system and on earth (formed about 4.5 billion years ago), the conditions have been favorable to the emergence of life. While there is little consensus among scientists about how the origin of this first microscopic life is to be explained, there is general agreement among them that the first organism dwelt on this planet about 3.5–4 billion years ago. **Since it has been demonstrated that all living organisms on earth are genetically related, it is virtually certain that all living organisms have descended from this first organism**. […]"

Brain Evolution

- General increase in brain size & complexity across species

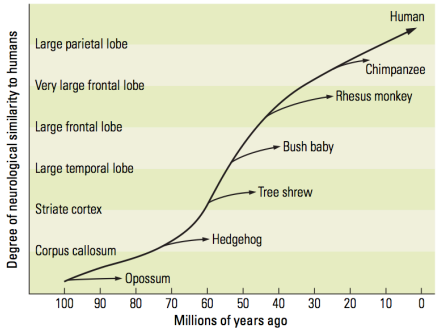


Why study animal brains?

- Understanding basic brain mechanisms
  - neurons, synapses, neural tracts & systems
  - genetic similarities are high
- Designing animal models
  - ethical issues with human research
- Evolutionary perspectives
  - similarities
  - differences in brain --> differences in behaviors?

Quasi-Evolutionary Sequence

- Hypothetical sequence mimicking the evolutionary sequence
- Living descendants of extinct animals are used
- Brain/Behavior relationships inferred
- Example - Shrew: striate cortex allows to see branches & insects, hedgehog can't



Evolution

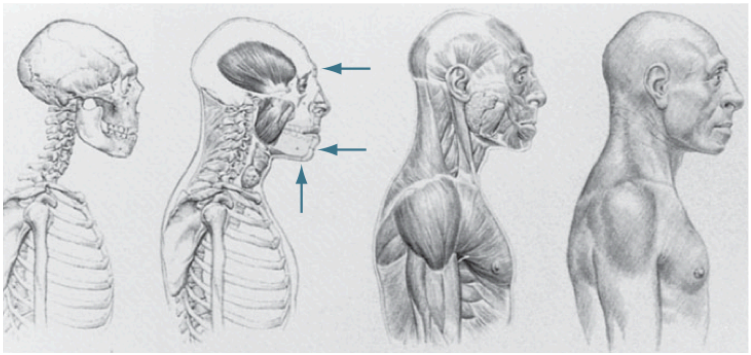
- Big Picture
  - Multicellular life ~ 650 MYA
  - Mammals ~ 150 MYA
  - Homo Sapiens ~ 250 KYA

Research Methods

- Archeological...
- Biochemical & Genetic...
- Behavioral...

Archeological Research

- Fossil ages
- Habitat & behavior
- Morphological reconstruction



Genetic & Biochemical

Genetics

- Human genome contains about 4 billion pairs of deoxyribonucleic acid (DNA)
- DNA is Transcribed into RNA
- RNA is Translated into Proteins
- Proteins
  - serve as structural components
  - function as enzymes to catalyze biochemical reactions
- Human DNA is grouped into 46 chromosomes
  - 23 pairs, one of each pair comes from each parent
  - 22 pairs in both males and females (autosomes)
  - 1 pair determines sex: either "XX" (females) or "XY" (males)

Genetics : Species Differences

organism	estimated size (base pairs)	# genes	gene size	# chromosomes
Homo sapiens (human)	3.2 billion	~25,000	1 gene per 100,000 bases	46
Mus musculus (mouse)	2.6 billion	~25,000	1 gene per 100,000 bases	40
Drosophila melanogaster (fruit fly)	137 million	13,000	1 gene per 9,000 bases	8
Arabidopsis thaliana (plant)	100 million	25,000	1 gene per 4000 bases	10
Caenorhabditis elegans (roundworm)	97 million	19,000	1 gene per 5000 bases	12
Saccharomyces cerevisiae (yeast)	12.1 million	6000	1 gene per 2000 bases	32
Escherichia coli (bacteria)	4.6 million	3200	1 gene per 1400 bases	1
H. influenzae (bacteria)	1.8 million	1700	1 gene per 1000 bases	1

Genetics : Dominant & Recessive Genes

- DNA in chromosomes further subdivided into Genes
- Often, a given Gene codes for (or controls) a single biological Trait
- Often, Genes are dominant or recessive
- Eye color:
  - B: Brown: dominant
  - b: Blue: recessive
- What eye color will a person have?
- Children?

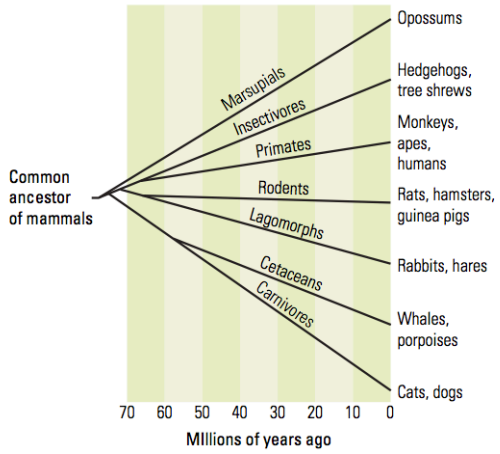
Genotype	Phenotype	Phenotype of Children
BB		
Bb		
bb		

Disorders with Simple (one gene) Inheritance

- Huntington's Disease (HD)
  - Degeneration of subcortical structures
  - Causes Motor dysfunction (chorea) & cognitive decline (progressive dementia)
  - Usually no symptoms till age 50
  - No effective treatment
  - Autosomal Dominant
- Phenylketonuria (PKU)
  - Inability to metabolize common amino acid (phenylalanine)
  - Toxic byproducts build up, causing progressive mental retardation
  - Diet that restricts PA can completely eliminate symptoms
  - Autosomal Recessive

Mammalian Evolution

- Common mammalian ancestor ~ 80 MYA

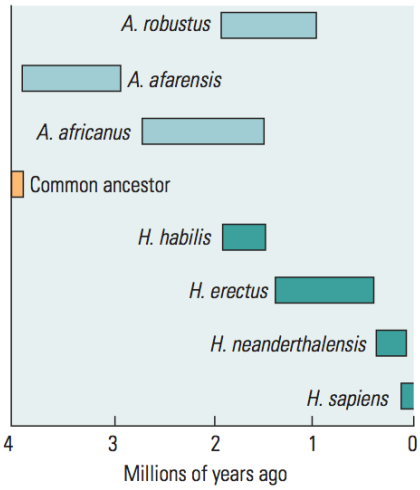


Primate Evolution

- Best research suggests *hominids* split from *apes* 5 to 8 million years ago
  - increased height
  - longer legs
  - bipedal (walk upright), ability to walk long distances
  - jaw/teeth changes : more varied diet
  - reduced sexual dimorphism
  - longer gestations
  - opposable thumbs / tool usage
  - brain size increased (300%)

Hominid Evolution

- Exact relationships unknown
- Fossil record incomplete



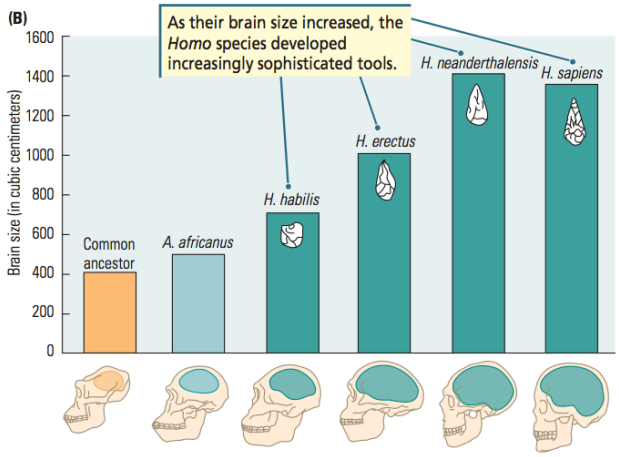
Homo Neanderthalensis

- Unclear relationship with modern Homo Sapiens
- Genetic difference : as little as 0.15% (same as wihin - H Sapiens). Vs. chipmanzees : 2%-4%
- Some consider subspecies : Homo Sapiens Neanderthalensis)
- Age: perhaps 600,000 years ago to 30,000 years ago?
- Based on bones from over 400 skeletons

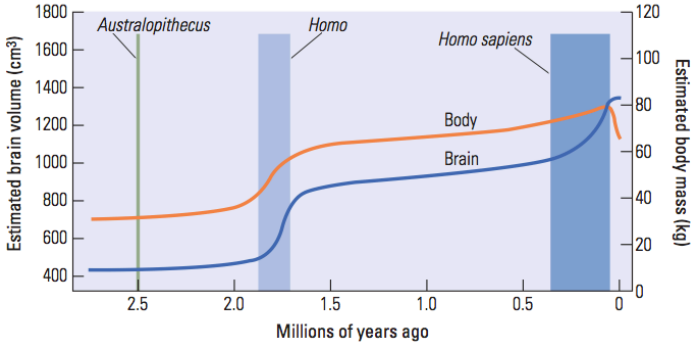
Homo

	H. Habilis *"handy"*	H. Erectus *"upright"*	H. Neanderthal-ensis *"new man"*	H. Sapiens *"wise"*
age	2 - 1.5 MYA	1.9 MYA - 0.5 MYA	0.5 MYA - ??? (20 KYA?)	0.25 MYA - present
tools	crude stone tools	better tools travel no cooking (?)	fire, cooking	iPhones
environment	africa scavenger?	worldwide	worldwide	worldwide
misc		bigger brain 600cc	biggest brain 1600cc	brain shrunk? 1400cc

Dramatic Brain Size Increase



Dramatic Brain Size Increase

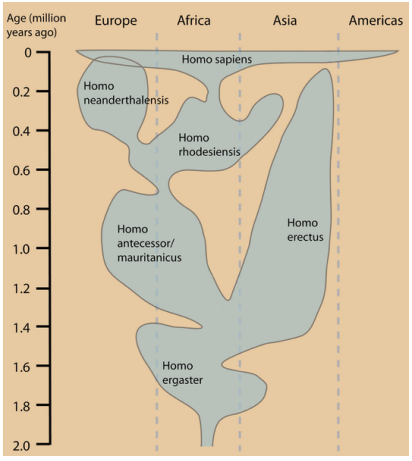


Big brains : Pros & Cons

- Pros:
  - smarter
  - survival advantage
- Cons:
  - metabolic expense
  - birth canal limitations
  - neotoney : slower development
  - culture & birth as adaptation

Homo Sapiens

- Homo Sapiens ~ 250,000 years ago?



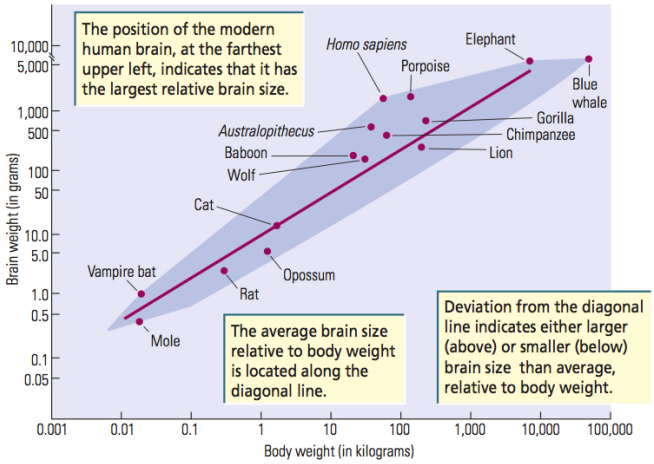
Encephalization Quotient (EQ)

- Roundworm C. Elegans
  - 302 of 959 cells are neurons = 30% of body
  - Actual size: .

- Blue whale
  - 15kg brain, but only 0.01%

- How to reconcile?
- EQ
  - ratio of actual brain size to "expected" brain size
  - Cat : "average" mammal : 1.0

Brain weight vs. Body weight



Encephalization Quotient (EQ)

Species	Brain Volume (ml)	EQ
Rat	2	0.4
Cat	**25**	**1**
Rhesus monkey	106	2.1
Chimpanzee	440	2.5
Human	1350	7.3

Cortical Changes

- Cortex grew faster than other brain areas
- Neoteny : adults retain juvenile features
  - small face
  - large brain to body ratio
  - big toe unrotated
  - development is slower
  - ::: gives cortex more time to grow and mature?

- Adult humans are more similar to baby chimps than to adult chimps

Cortical Organization

- Human brains : areas are functionally and anatomically separate
- larger number of “modules”

- Visual cortical areas
  - squirrel : 4
  - cat : 12
  - humans : 30 or more

Cortical Structure

- Human brains are more specialized
- Development is slower
  - requires more parenting
- New skills/abilities can replace older ones, making room
  - e.g. color vision & depth perception reduce need for sense of smell

Neanderthal DNA

A girl goes nose-to-nose with a Neanderthal statue in Germany. Ancient DNA research is increasingly revealing the genetic links between modern humans and our extinct ancestors, including Neanderthals and the mysterious Denisovans.

Credit: Neanderthal Museum (Mettmann, Germany)

View full size image

At least one-fifth of the Neanderthal genome may lurk within modern humans, influencing the skin, hair and diseases people have today, researchers say.

Although modern humans are the only surviving human lineage, othe groups of early humans used to live on Earth. The closest extinct relatives of modern humans were the Neanderthals, who lived in Europe and Asia until they went extinct about 40,000 years ago. The ancestors of modern humans diverged from those of Neanderthals between 550,000 and 765,000 years ago.

Recent findings revealed that Neanderthals interbred with ancestors o modern humans when modern humans began spreading out of Africa perhaps about 40,000 to 80,000 years ago, although some research suggests the migration began earlier. About 1.5 to 2.1 percent of the DNA of anyone outside Africa is Neanderthal in origin.

Brain Size vs. Intelligence

- Interspecies:
  - strong correlation
- Intraspecies:
  - weak correlation
- Controversy:
  - *The Mismeasure of Man* (Gold, 1981)
  - Faulty research, racist & nationalistic biases
    - Germans : "Germans have largest brains"
    - French : "French have largest brains"

Intelligence Tests

- IQ tests favor left hemisphere behaviors
- How many forms of Intelligence are there?
  - One? Spearman's *g*
  - Two? Verbal IQ, Nonverbal IQ?
  - Eight? Gardener's multiple intelligences

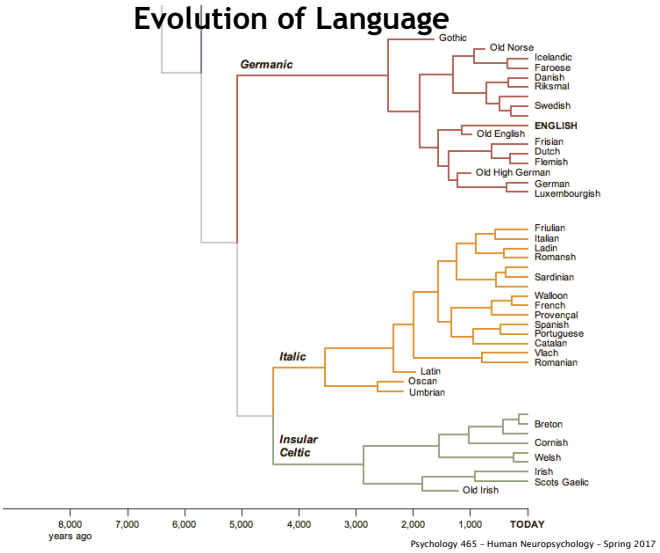
Gardner's 8 Intelligences

- logical-mathematical (*)
- verbal-linguistic (*)
- spatial (*)
- musical
- bodily-kinesthetic
- naturalist
- interpersonal
- intrapersonal

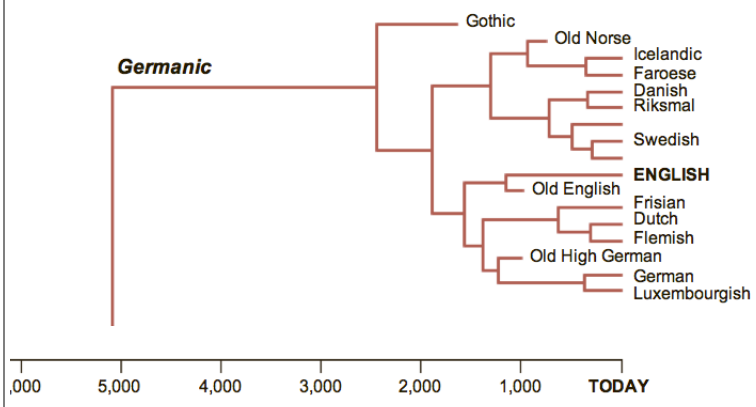
Evolution of Culture

- 25,000 years ago: First art
- 9000 years ago : agriculture, animal husbandry
- 5000 years ago : written language

Evolution of Language



Evolution of Language



Sacks "A man of letters"

- Sacks (2010), *The Mind's Eye*, p. 53-81
- Howard Engel
  - Canadian author of *Benny Cooperman* detective novels
- Symptoms
  - Newspaper looked to be in foreign language
  - verbal confusion (forgot name, address, relationship to son)
  - visual field blind spot
  - object agnosia
- Diagnosis
  - Prank?
  - Stroke
  - left hemisphere, occipital lobe injury
  - could still write

Sacks "A man of letters"

- Stroke in 2000
- Recovery was very slow
- Still alexic
  - Takes a month to read what he could read in 2 hours
- Yet,
  - managed to publish another book "Memory Book" in 2005
  - Plot concerns Detective waking up in bed, alexic, with amnesia.

Alexia sine Agraphia

- Alexia *without* Agraphia
- Ability to read : gone
- Ability to write : normal
- Can read one's own writing? No

- Broca's area:
  - motor images of words (how to say a word)
- Wernicke's area:
  - auditory images of words (how to understand a word)

- Inferior temporal gyrus
  - Similar brain area for written words?
  - probably a disconnection syndrome similar to Conduction aphasia

Evolution of Language : Wallace vs. Darwin

- Sacks (2010), *The Mind's Eye*, p. 71
- Background:
  - human written language ~ 5000 years ago
  - human evolution ~ 250,000 years ago
  - enough time for evolution of speech, but not for biological evolution to enable for written language
- Wallace:
  - evidence of "divine gift"
- Darwin:
  - "I hope you have not murdered too completely your own and my child"
- Modern theory:
  - "Exaptation" - redeployment / recombination of existing visual/verbal skills

Language Exaptation - Argument

- Brain can not come pre-loaded with object recognition
  - must be learned
  - (facial recognition: may be an exception)
  - Thus, brain has "object learning & categorization system"
- All written languages share geometrical similarities...with items seen in natural world
  - Written language re-uses brain's visual object recognition system

Review : 3 Language Impairments

- Broca's Aphasia - Expressive Aphasia
  - motor images of words (how to say a word)
- Wernicke's Aphasia - Receptive Aphasia
  - auditory images of words (how to understand a word)
  - "fluent" aphasia - speech output affected too
- Alexia without agraphia
  - visual word-form area (converting word images to word meaning)