Andy’s New Office Hours:
Tuesdays 3:30-5:30, McGill 3125B
Lecture Outline

1) Overview of Neural Development

2) Stages of Neural Development

3) The Nature vs. Nurture Issue

4) Modification of Development by Sensory Experience (Nurture)

5) Path-Finding by Axons (Nature)

6) Brain Evolution

7) Brain Size & Intelligence
Development of the Nervous System (NS)

“ONTOGENY recapitulates PHYLOGENY”

e.g., conservation of neural structures and neurotransmitter systems
“Pre-natal” vs. “Post-natal”

Pre-natal terms:

*Gestation*: period of time between conception and birth, i.e., pregnancy

*Embryonic*: early prenatal development

*Fetal*: late prenatal development
Human Nervous System begins to form at 2 weeks gestation

Neural Plate -> Neural Tube -> CNS (brain and spinal cord)

Eyes & optic nerve (cranial nerve #2)

Note: This lecture on BRAIN DEVELOPMENT (part of CNS), not on Spinal Cord (the other part of CNS) or PNS
At Birth = 350g, At 1 year = 1000g (adult = 1,200 to 1,400g)
Stages of Brain Development (mostly during gestation)

1) **Proliferation**: *Mitosis (division) of Neural Stem Cells* in *Ventricular Zone* of Neural Tube.

2) **Migration**: New cells migrate outwardly towards the cortical surface. (Along *radial glia*)

3) **Differentiation**: Cells differentiate into different neuronal types, and axons and dendrites formed.

4) **Synaptogenesis**: Synapses formed between neurons *especially during CRITICAL PERIODS* “neurons that fire together, wire together”

5) **Myelination**: Begins in the spinal cord, then the hindbrain, midbrain and forebrain.
HUMAN BRAIN DEVELOPMENT: Prenatal to 12 years

* but, reorganization of synapses occurs throughout life…. which is LEARNING

Visual Cortex

Percent of Adult Level

Gestation Birth 2 4 6 8 10 12
Age in Years

Neurons
Synapses
Metabolism
Myelin
Glia
Nature vs. Nurture Issue

NATURE ("innate") -> pre-programmed (genetic)  
    … *not* affected by experience

NURTURE -> shaped by environment and experience

*How does this map onto PRE- and POST-Natal Development?*

**PRE-NATAL development** ← NATURE
    … because it cannot be modified by sensory experience  ???

**POST-NATAL development** ← NATURE  
    → NURTURE  
    Janet Frick

Lower species (e.g., slugs): mostly nature

Higher Species (e.g., humans): nature & nurture

Functional Explanation (predictability of lifestyle, age to adulthood)
Brain Size: Nature or Nurture?

The MZ vs. DZ comparison provides evidence for Nature,
The MZ vs. DZ comparison provides evidence for Nature, …… but the non-perfect correlation in MZ data suggests that Nurture may ALSO influence. …*EPIGENETICS*
NURTURE: Examples of Modification by POST-NATAL Experience

1) Raise animals in “Vertical Lines” environment
   -critical periods and developmental plasticity

2) Humans raised in different environments

3) Auditory cortex in deaf people
   And...visual cortex in blind people
How do neurons know where to project to during development?

GROSS LEVEL:
Radial Glia

LOCAL (SPECIFIC) LEVEL:
How do neurons know where to go specifically?

Answer: “Chemical Markers” direct them

Roger Sperry, 1943:
Studied Visual Projections in Adult NEWTS

IMPORTANT: Sometimes can do brain experiments in adult animals to learn about development (you’ll see why on upcoming slides)! 
If cut Optic Nerve in some non-mammals (fish, amphibia, reptiles and birds) it regrows, forms new projections/connections, and animal can SEE again.

* Called "Superior Colliculus" in Mammals!

Oh no, don’t let these connections confuse you when we do Vision next lecture!

Difference between Amphibia and Mammals!
Local (Specific) Connections from Retina -> Optic Tectum

If cut Optic Nerve and rotate eye by 180 degrees, the “old-ventral” area of the Retina grows to the dorsal Optic Tectum.

WORLD IS NOW UPSIDE DOWN!
Sperry’s studies told us that there must be something “chemical” that directs projections from one part of the Retina to a specific part of the Optic Tectum

**Evidence for Chemical Markers** *(in vitro experiments)*

TOP$_{DV}$, high concentration in **Dorsal Retina**, low in **Ventral Retina** AND high in **Ventral Tectum**, low in **Dorsal Tectum** ….. forms a chemical *gradient*

There is a different chemical marker for anterior/posterior
Evolution of the Brain

Similarities across animals: Neurotransmitter types

Differences across animals: Dominance of functional areas

For example,
- Human and Non-Human Primates: large visual areas
- Dolphins and Bats: large auditory areas
- Raccoons: large “somatosensory” areas

As move up evolutionary tree.....
Greater task challenges:
- Need Bigger Brain
  (more invaginations to increase surface area)
- Need Relatively More Prefrontal Cortex
**Brain Size & Intelligence:** Is there a correlation?

Use **Brain-to-Body Mass Ratio** rather than overall **Brain Mass**.

- for your body size, how big is your brain?

Humans > Apes > Dolphins >>>>>>> Frogs

Complications:

1) *Should blubber count in body mass? Whales? Americans?*

2) *How to measure intelligence in animals?*

3) *How to measure intelligence in humans? What about men vs. women?*
Brain Size & Intelligence: Is there a correlation?

So humans have (one of) the highest brain-to-body ratio...

BUT WHY??

Because we are so SOCIAL!

Cooperative Breeding Hypothesis
Emerged ~2mya in *Homo erectus*
Preceded brain size doubling, prolonged childhoods, symbolic thought, language, metacognition...

Cooperative Breeding ➔ (Pro)sociality ➔ Neural Expansion
Thanks for your attention!