Nature Versus Nurture

Neurons, The Brain and Nervous System
Today’s Topics

- The Concept of Nature Versus Nurture
- Overview of Function of the Nervous System
- Anatomy of a Neuron
- Stages of the development of the brain
- Developmental Milestones
What is Nature Versus Nurture?

- What determines our physical characteristics?
  - **Heredity?**
    - Nature: the code is in your genes and the code is a recipe for proteins
  - **Environment?**
    - Nurture; how do we interact with our environment and the interaction is extensive over ecological space and over billions of years of evolutionary time
Antony Gormley: Quantum Cloud
VIII
SFMOMA

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## Nature, Nurture or possibly both?

<table>
<thead>
<tr>
<th>Nature (genetic)</th>
<th>Nurture (environment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye color (Blue, Brown, etc..)</td>
<td>Eye color (Blue, Brown, etc..)</td>
</tr>
<tr>
<td>Menopause</td>
<td>Hormone replacement therapy</td>
</tr>
<tr>
<td>Production of Vitamins D</td>
<td>Vitamin D pills</td>
</tr>
<tr>
<td>Allergies</td>
<td>Allergies</td>
</tr>
<tr>
<td>Disease (Diabetes, heart disease, cancer)</td>
<td>Disease (Diabetes, heart disease, cancer)</td>
</tr>
<tr>
<td>We as a species have lost much of our body hair</td>
<td>We as a species lost much of our body hair</td>
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<tr>
<td>Pigmentation or skin color</td>
<td>Pigmentation or skin color</td>
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</tbody>
</table>
Function of the Nervous System

- Helps Maintain Homeostasis - regulates its internal environment to maintain a stable, constant condition
  - Responds to internal environment
    - Maintaining adequate oxygen supply to tissues
  - Responds to external environment
    - Changes in oxygen levels with altitude

- Survival and Reproductive Success of the Organism
How Do Nerve Cells Communicate to Each Other?

- Chemically
- Electricity
Nature and Nurture in the Nervous System

- The neuron and its synapses are important in nature and nurture

1. http://chemistry.caltech.edu/~fucose/Neural%20Connections.htm
What is a Neuron?

- A neuron is an electrically excitable cell that processes and transmits information by electrical and chemical signaling.

- Chemical signaling occurs via synapses, which are specialized connections with other cells.

- Neurons connect to each other to form networks.

- Neurons are the core components of the nervous system which includes the brain, spinal cord, and peripheral ganglia.

Anatomy of the Neuron

- **Dendrites**
  - Receive Information

- **Cell Body**
  - Contains Nucleus and Genetic Information

- **Axon**
  - Transmits information
Anatomy of the Neuron

- Synapse
  - Site of communication between neurons
  - Site of neurotransmitter (NTX) release
    (chemicals which transmit signals from neuron to neuron or another cell)

- Pre-synaptic Terminal
  - Contains synaptic vesicles (with NTX)
Chemical synapses are specialized junctions through which neurons signal to each other:

- allow neurons to form circuits within the central nervous system,
- crucial to the biological computations that underlie perception and thought,
- allow the nervous system to connect to and control other systems of the body.

From Wikipedia: Chemical synapse
http://en.wikipedia.org/wiki/Presynaptic

Diagram showing the components of a neuron:
- Cell body
- Genetic info & nucleus
- Receptors
- Dendrites
- Transmitters surrounded by Myelin (outer coat)
- Axon
- Electrical Impulses
- Neurotransmitter Molecules
- Site of communication between cells
- Synapse
A Sensory Pathway

- Example: Hearing

These are the sensory cells of the inner ear responsible for the ability to hear sound!
The top portion of the cells respond to sound waves!

They look like hairs, huh? So they’re called hair cells!
These are hair cells in cross-section!

Arrows point to synapses!
Synapses are functional connections between sensory cells and neurons and from neuron to neuron.

Information includes pitch and amplitude and pattern.
Axons form cables from sensory structures into the CNS
Anatomy of the Neuron

- Myelin - a dielectric (electrically insulating) material that forms a layer, around the axon of a neuron. It is essential for the proper functioning of the nervous system.
  - Speeds conduction of action potentials (Nerve Impulses)

- Pre-synaptic Terminal
  - Contains synaptic vesicles (with NTX)
Axons are electrically shielded by myelin and so transmit signals faster (=120m/sec)
Anatomy of the Neuron

- Post-synaptic Neuron
  - Contains receptors for NTX
  - **Neurotransmitters** are chemicals which transmit signals from a neuron to a target cell across a synapse.
The Ultrastructure of Synapses
The frequency response of a single auditory neuron!

Responds strongly to sounds around 300Hz. Middle C on the keyboard is 260Hz.
Nerve cells in the cortex

80 µm

Glia

Cell bodies of neurons
Review of the synapse

1. Axon
2. Synaptic vesicle containing neurotransmitter
3. Voltage-gated Ca\(^{2+}\) channel
4. Ligand-gated ion channels

Presynaptic cell

Postsynaptic cell

Ca\(^{2+}\)

Voltage-gated Ca\(^{2+}\) channel

Ligand-gated ion channels

K\(^+\)

Na\(^+\)
Nature and Nurture in the Nervous System

- What are the developmental milestones in the nervous system?
- You start from a single cell with genetic information from your mother and father. Then what happens?
- That cell undergoes successive divisions guided by the proteins code for by this genetic information.
- And as cells divide they are influenced by the environment around them.
- This results in differentiation of cells, into specific tissues such as muscle and nerve and the formation of organ systems such as the nervous system.
Patterns of structure

- Some genes also control the movement of cells as the organism grows and develops.
- As this occurs, the organization of the organism becomes apparent.
- This includes such readily visible things such as placement of the head, tail and appendages.
- Also included is the organization of cardiovascular, musculoskeletal and nervous systems.
Fetal Development

- First trimester (first 3 months)
  - Synapses begin to form

- Second trimester (second three months)
  - The fetus can move

- Third trimester (third three months)
  - Sensory pathways form
Newborn to 3 Months

- Visual and other systems start to mature
First Two Years

- 100 billion nerve cells form
- Myelination begins (remember that this is the insulation surrounding neuronal axons).
- Once this happens, signals and processing of information occurs much more quickly!
First Two Years

- The following systems begin to develop
  - Motor
  - Language
  - Emotional
  - Memory
  - Sense of self
Two to Twelve Years

- Synapses are sculpted or strengthened by experience
- This means that the structure and therefore the function of synapses change
Teen Years

- Last big maturation of the brain—a second growth and sculpting spurt-impacted in part by the activities one engages in (use it or loose it)
- Brain still developing (mainly the pre frontal cortex)
- Reasoning, Planning and Judgment abilities still not fully realized
- Emotional systems still maturing
- Attention systems still maturing
- Myelination continues
Diseases which manifest during the teen years – 20s

- Schizophrenia
- Depression
- Addiction
Early Twenties

- Memory systems start to decline
- Prefrontal cortex continues to mature
- New synapses in language and perception centers
- Myelination continues
- Synapse remodeling continues!
Up to Thirty-two Years

- Myelination continues
Throughout your life!

- Synaptic REMODELING as you interact with your environment
- This includes strengthening these connections as you might expect
  - Remember that as you interact with others you change the structure of their nervous system and they change yours!
- This also includes, yes..... removing and weakening synapses
The Aging Brain

- Small loss of cells
- Some loss of synapses
- Physical activity positively impacts the ability of the brain to remember information
- Evidence suggests that if an aging person remains active; doing so will decrease the rate of mental decline and possibly prevent it altogether
- Plasticity present through life
Diseases of the Aging Brain

- Parkinson’s disease
- Alzheimer’s disease
- Both can be treated at this point but neither cured with current technology
Topics Covered Today

- The Concept of Nature versus Nurture
- Nature and Nurture in the Nervous System
- Developmental Milestones of the Brain
Dendrite
Soma
Axon
Nucleus
Node of Ranvier
Axon terminal
Schwann cell
Myelin sheath