

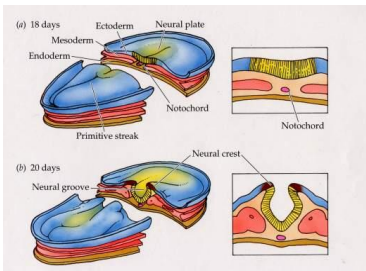
Nervous System Development

PSY 415
Dr. Schuetze

Question

- What are the basic patterns of synaptic and brain development in infancy?
 - How they are influenced by experience? What can go wrong in this pattern?

Nervous System Development in the Human Embryo

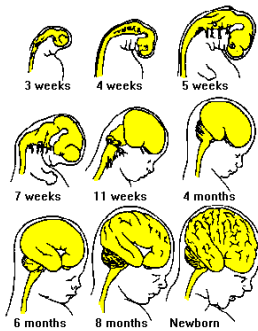


At 18 days after conception the embryo begins to implant in the uterine wall. It consists of 3 layers of cells: endoderm, mesoderm, and ectoderm. Thickening of the ectoderm leads to the development of the neural plate. The neural groove begins to develop at 20 days.

Brain Sculpting

- Embryonic brain development occurs rapidly
- Within the first month, the brain is emerging and the embryo is forming the separations of its parts – from the spinal cord to the brain, with the brain beginning to separate into forebrain, midbrain, and hindbrain

Prenatal Brain Development is primarily structural

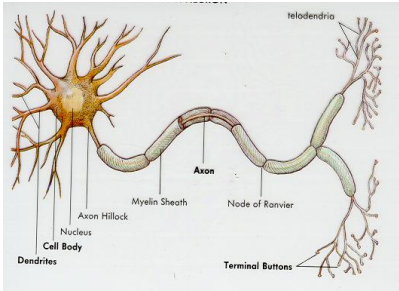


Before Birth



- Tremendous development occurs in utero. Nutrition, maternal emotions, etc. all affect brain development.
- There is no significant growth in the number of brain cells (neurons) following birth.
- What **does** grow after birth are the connections (synapses) between neurons.

Nervous System Development



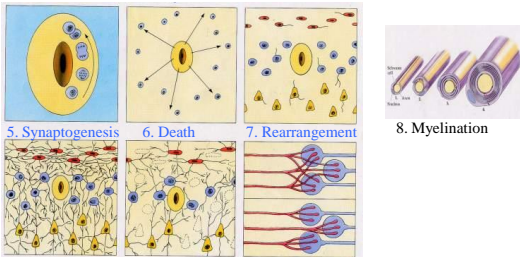
Eight Phases in Embryonic and Fetal Development at a Cellular Level

8 stages are sequential for a given neuron, but all are occurring simultaneously throughout fetal development

1. Mitosis/Proliferation
2. Migration
3. Differentiation
4. Aggregation
5. Synaptogenesis
6. Neuron Death
7. Synapse Rearrangement
8. Myelination

Eight Phases in Embryonic and Fetal Development at a Cellular Level

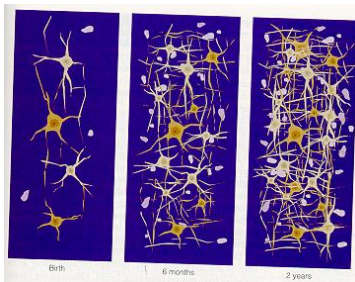
1. Mitosis
2. Migration
3. Aggregation and
4. Differentiation



Synaptogenesis

- Although most neurons are formed halfway through gestation there are virtually no synaptic connections – it is experience and interaction with the environment that forms the synaptic connections
- Most synaptogenesis occurs through the 2nd year of life
- 83% of dendritic growth (connections between synapses) occurs after birth

➤ After birth - development is refinement of neuronal connections, maturity of the neurons, and increasing complexity of dendrite interconnections.



Each cell can form up to 15,000 connections.

Use it or lose it – Natural Selection of Brain Wiring

- Neurons and synapses must get hooked together properly to develop specific skills and abilities in humans
- How the “right” connections are made is still being researched
- During infancy and early childhood the cerebral cortex overproduces synapses (2X as needed)

Use it or lose it – Natural Selection of Brain Wiring

- The overproduction leads to a competition for survival of the fittest synapses
- Experience shapes and solidifies these synapses

Synaptogenesis & Pruning

- In cortex, synapses begin to form after neuronal migration, 23 weeks prenatal
- However, most synapses form after birth
- Many form randomly (as axons and dendrites meet)
- Flourish, then selectively prune
- Up to 100,000 synapses pruned per second (Kolb, 1999)

Pruning

- During childhood, pruning causes a loss of up to 10% of volume of gray matter in the cortex (with 60% shrinkage in frontal lobes between 13 and 18 years of age). Weight of human brain is maintained, however, due to increased myelination (Huttenlocher, 1999)

2 Types of Synapse Development

- 1. Experience-expectant development
 - Overproduce synapses, prune with experience
 - “Experience leads to *less*”
 - Tied to critical/sensitive periods
 - Organizes brain to process information, behaviors *expected* for all humans
 - Sensory processes
 - Parental attachment
 - Eye-hand coordination
 - Language capacity

Greenough & Black, 1999

A lesson from Fragile-X syndrome

- A leading inherited form of MR: 1/2000 males
- A defective FMR1 gene suppresses production of proteins that stimulate pruning
- Excess synapses not pruned sufficiently
- “Noise” in the nueral system causes MR, ADD symptoms
- **LESS IS MORE! Pruning is important.**
 - » Greenough & Black, 1999; Nelson, de Haan, Thomas, 2006

2 Types of Synapse Development

- 2. Experience-dependent development
 - New synapses formed, maybe some pruning
 - “Experience leads to *more*”
 - Continues throughout life
 - Codes experiences/learning that is person-specific
 - -A particular language
 - Specific knowledge, memories, skills

» Greenough & Black, 1999

Lesson from Rat Experiments

Standard vs. More Complex (Enriched) cages

- **Infant Rats:**
 - Enrichment **REDUCED** synapse density
 - Facilitated pruning of excess synapses in experience-expectant development
 - Prune>Gain
- **Adult Rats**
 - Enrichment **INCREASED synapse density**
 - **Facilitated growth of new synapses in experience-dependent development**
 - **Gain>Prune**

Experience influences both pruning and growth of new synapses. Age dependent. (Kolb, Gibb, Dallison, 1999).

Pattern of Brain Development

- Neuron birth 6-20 weeks prenatally
- Neuron migration Peaks by 23 weeks prenatal
- Neuron differentiation
- Dendrites, axons grow
- Cell death
- Synaptogenesis Flourishes up to 2-3 yrs.
- Synaptic pruning Childhood, up to adol.



The Brain at Birth

ARE BABIES SMART?

- Immaturity at birth is an adaptive feature. This means that our brains develop in contact with the world and can adapt to different environments.
- Humans have the longest period of dependency of any species. For newborns the "world" means largely those who care for them.
- Early experiences create the architecture of the brain for the rest of one's life.



With every new experience, signals leap from one neuron to the next, forming new connections.

Use it or lose it – Natural Selection of Brain Wiring

- Exposure to enriched environments with extra sensory and social stimulation enhances the connectivity of the synapses, but children and adolescents can lose them up to 20 million per day when not used (stimulated)



- The PET scan above gives a fuzzy idea of the tremendous amount of activity taking place in a young child's brain.
- Activity Peaks at around age three.
- Both cognitive and emotional connections are formed during these early years.

Pruning Process

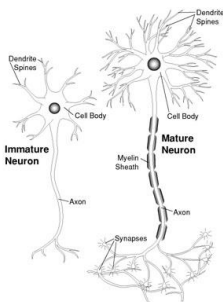
- Newborns start out with about 100 billions neurons and about 50 trillion synapses.
- By the time a child is three, the number of synapses has increased twenty-fold to 1,000 trillion.
- At about the time a child reaches puberty the “pruning” process kicks in, and streamlines the networks to about 500 trillion connections.
- This pruning isn’t a random process. **The synapses which have been used repeatedly tend to remain.** Those which haven’t been used often enough are eliminated.



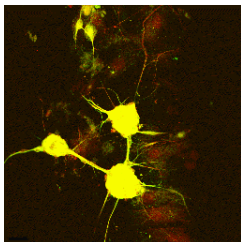
Brain development is truly a “use it or lose it” process.

Myelination

- In adults dendritic growth and synapse refinement are coated with myelin which serves as an electrical insulation
- When electrical impulses travel from neuron to neuron, some of their “strength” can be lost or “leaked” or can collide and interfere with other impulses
- Myelination speeds up the travel of the impulses and makes their travel more efficient
- Myelin is composed of 15 percent cholesterol with 20 percent protein which is why doctors recommend milk for babies.



Myelination



Myelin coating forms around neurons.
