

ECPS5003: The Brain, Biology and Cognition

Lecture 2 Neurodevelopment

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Axon Growth and Synapse Formation

- We begin as a zygote (single cell)
 - This cell divides, then those divisions divide, etc.
- Some cells turn to muscle, some to neurons, etc.
- All cells make their way to appropriate sites and align to form a structure.
- Cells then establish relations with other cells.
- Five phases of neurodevelopment:
 1. Induction of neural plate,
 2. Neural proliferation,
 3. Migration and aggregation,
 4. Axon growth and synapse formation,
 5. Neuron death and synapse rearrangement.



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Axon Growth and Synapse Formation

- Once cells are in appropriate locations/aligned, axons and dendrites begin to grow from them.
- They grow toward specific targets relevant to what they need to do through a growth cone:
 - A fingerlike cytoplasmic extensions that extend and retracts to find the correct route.
- Work of Sperry (1940s) on optic nerves of frogs led to:
 - **Chemoaffinity hypothesis:**
 - Suggests each postsynaptic surface releases specific chemical that attracts a growing neuron



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Axon Growth and Synapse Formation



- But it fails to explain why axons follow same circuitous route to reach target in every member of a species rather than growing directly to it.
- Revised hypothesis suggests growth cones may be influenced by other chemicals along the way.
 - Other signals come from adjacent cones.
- The first growth cones to travel along a route are pioneer growth cones.
 - They follow the correct route by interacting with guidance molecules.
- Then other growth cones follow the route.

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Synapse Formation



- Once axons reach relevant site, they must establish a pattern of appropriate synapses.
 - Coordination of two neurons is required
- Formation of new synapses (synaptogenesis) also requires presence of glial cells:
 - Because developing neurons require a high degree of cholesterol which is supplied by the astrocytes.
 - Also thought to play a role in processing, transferring, and storing information supplied by neurons.

Current research is examining the exchange of chemical signals between pre and postsynaptic neurons.



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Neuron Death and Synapse Rearrangement



- Any synapses that do not function appropriately tend to be eliminated, which is fine because.....
 - ~50% more neurons than are needed are produced.
- Cell death can be passive (**necrosis**) and active (**apoptosis – genetic programming inside neuron triggers it to die**)
- Apoptosis is safer than necrosis – because it does not promote inflammation

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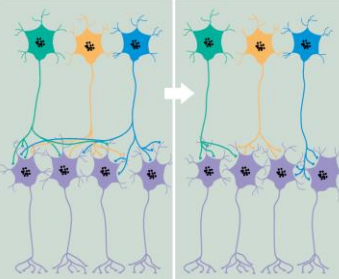
Neuron death and Life-Preserving Chemicals

- Some neurons die due to fulfilling their function
- Some die due to failure to compete for chemicals provided by targets:
 - The more targets, the fewer cell deaths
 - Destroying some cells increases survival rate of remaining cells
 - Increasing number of innervating axons decreases the proportion that survives
- One type of chemical is called **Neurotrophins**
 - promote growth and survival of neurons, guide axons, stimulate synaptogenesis.
 - It has a Nerve growth factor (NGF)

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Life-Preserving Chemicals

- Neurons failing to establish correct connections are likely to die.
- Space left after apoptosis is filled by sprouting axon terminals of surviving neurons
- Ultimately leads to increased selectivity of transmission



A diffuse pattern of synaptic contact is characteristic of early stages of development.

A more focused pattern of synaptic contact is present after synapse rearrangement.

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Postnatal Cerebral Development in Human Infants

Human brain develops slower than other species.

What happens to our brain after we are born.

Postnatal growth is a consequence of:

- Synaptogenesis
- Myelination – sensory areas and then motor areas. Myelination of prefrontal cortex continues into adolescence
- Increased dendritic branches

- Overproduction of synapses may underlie the greater plasticity of the young brain



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Development of the Prefrontal Cortex

- Goes through the longest period of development.
- Believed to underlie age-related changes in cognitive function.
- No single theory explains the function of this area.
- Prefrontal cortex plays a role in working memory, planning and carrying out sequences of actions, and inhibiting inappropriate responses, rules for social behavior.

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Effects of Experience on the Early Development, Maintenance, and Reorganisation of Neural Circuits



- **Neurodevelopment occurs through interactions between neurons & environment:**
 - Environment = all structures/events inside and outside the organism that can affect the neuron.
- **Permissive experiences:** necessary for information in genetic programs to be manifested
- **Instructive experiences:** contribute to the direction of development
- **Effects of experience on development are time-dependent:**
 - **Critical period:** Has to happen within certain time
 - **Sensitive period:** Can effect outside certain time

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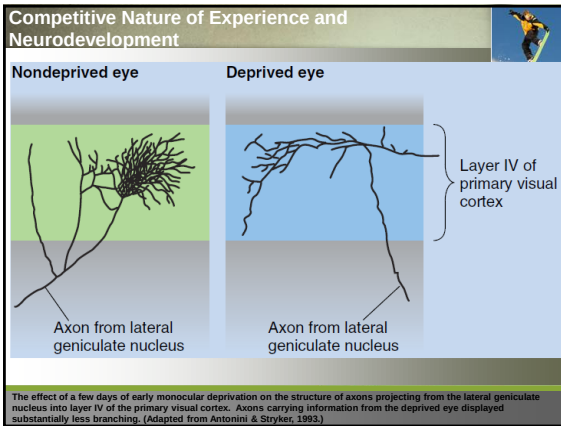
Early Studies of Experience & Neurodevelopment



- **Early visual deprivation**
 - Rats brought up in darkness were found to have fewer synapses and dendrites in primary visual cortex than normally reared rats, and as adults they had poor depth and pattern vision.
- **Enriched environment**
 - Rats brought up in complex group cages had:
 - Thicker cortexes
 - Greater dendritic development
 - More synapses per neuron



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Experience Fine-Tunes Neurodevelopment

- Research on experience & neurodevelopment might lead us to think that we should experience everything as soon as possible
- But these studies involve taking something away that would normally be part of our lives not adding anything to it.
- Also, neurons do spontaneously fire and interact with the environment before the nervous system finishes developing.
- These patterns of neural activity then fine-tune the rest of neural development.
- However, the mechanisms for how experience effects development is not fully understood but its thought that experience influences gene expression.



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Neuroplasticity in Adults

- The changing or adaptation of neurons
- Neurogenesis is seen in olfactory bulbs & hippocampuses of adult mammals'—adult neural stem cells created in the epedymal layer lining in ventricles and adjacent tissues.
- Adult neurogenesis seen in adult rats who lived in enriched environments (had toys, wheels to run on, & company of other rats).
 - They produced 60% more new hippocampal neurons than adult rats living in non enriched environments.
- Enriched environments and exercise can promote neurogenesis



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Effects of Experience on the Reorganization of the Adult Cortex

- **Tinnitus** (ringing in the ears) – produces major reorganization of primary auditory cortex
- Adult musicians who play instruments with left hand have an enlarged representation of the hand in the right somatosensory cortex
- Skill training leads to reorganization of motor cortex



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