BRAIN DEVELOPMENT

STRUCTURES OF THE BRAIN

DEVELOPMENTAL PROCESSES

THE IMPORTANCE OF EXPERIENCE

BRAIN DAMAGE AND RECOVERY
Brain Development

Virtually all human behavior is governed by the brain.

- Exceptions?

Remember: Experience that produces a change in behavior produces a change in the brain.
Increase in Brain Size

- 25% of adult weight by BIRTH
- 50% of adult weight by 6 months
- 75% of adult weight by 2 years
- 90% of adult weight by 4-6 years

<table>
<thead>
<tr>
<th>Age</th>
<th>Brain</th>
<th>Body</th>
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<tbody>
<tr>
<td>At Birth</td>
<td>25%</td>
<td></td>
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<tr>
<td>2 Years</td>
<td>75%</td>
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<tr>
<td>4 Years</td>
<td>90%</td>
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Overlapping stages of brain development

- Cell birth (neurogenesis)
- Cell migration
- Cell differentiation
- Cell growth and maturation
- Cell death
- Glial development and myelination
Neural Proliferation or neurogenesis

The early brain contains stem cells which divide to form more stem cells.

Eventually these cells differentiate to form neurons or glial cells.

- 1 billion neurons by 5 months gestation
- 100 billion by birth
- largely completed prenatally
Neural Migration

- neurons move from neural tube to form different parts of brain
- largely completed prenatally
- Occurs in waves - affected by alcohol and mercury
Cell Differentiation

- Stem cells divide to form precursor cells (neuroblasts or glioblasts) which differentiate to form specialized neurons or glia
CELL GROWTH AND MATURATION

- Neurons begin with simple dendritic trees, which become progressively more complex with age

**Synaptogenesis**: Neurons are connecting with different sections. It peaks at different times: (from first to last):

1. 
2. 
3.
During the period of synaptic rearrangement, neurons that do not project to a viable target undergo cell death!

- Hamburger (1950’s) limb removal in a developing chick leads to substantial cell death in motor neurons

- **Neurons require growth factors from their targets to survive**

**Use it or lose it!** - pruning may increase the efficiency of the brain
SYNAPTOGENESIS AND SYNAPTIC PRUNING

The graph illustrates the change in synaptic density across different cortical regions and ages. It shows two distinct curves:

- The blue line represents the Prefrontal Cortex, which shows an increase in synaptic density from Conception to approximately 2 years, followed by a decline during Adolescence and stabilization in the Adult phase.
- The red line represents the Visual Cortex, which shows a similar pattern but with a peak around 4 years and a decline during Adolescence.

The x-axis represents age, ranging from Conception to Adult, with key stages marked at Birth, 2 yrs., 4 yrs., 10 yrs., and Adolescence.

The y-axis measures synaptic density, with a scale from More dense to Less dense.
GLIAL DEVELOPMENT AND MYELINATION

Myelin - layer of fatty cells coat the neuron - insulation that improves speed and efficiency of transmission

- The birth of most glial cells begins after neurogenesis is complete
  - Glial cells have a number of important functions, including supplying oxygen and nutrients to neurons as well as removing dead neurons
GLIAL DEVELOPMENT AND MYELINATION

Myelin - layer of fatty cells coat the neuron - insulation that improves speed and efficiency of transmission

- Disorders affecting myelin have severe consequences
  - Multiple sclerosis: Immune system attacks myelin
  - Schizophrenia and bipolar disorder: Defects in gene that regulates myelin production
NEURONS

- Specialized cells that are the basic units of the brain’s information system
  - **Cell body**: Contains the basic biological material that keeps the neuron functioning
  - **Dendrites**: Receives input from other cells and conducts it toward the cell body
  - **Axon**: Conducts electrical signals to connections with other neurons
    - These connections are called **synapses**
Lobes are major areas of the cortex that are associated with different categories of behavior

- **Occipital lobe**: Primarily associated with processing visual information
- **Temporal lobe**: Involved in memory, visual recognition, and the processing of emotion and auditory information
- **Parietal lobe**: Governs spatial processing and integrates sensory input with information in memory
- **Frontal lobe**: Organizes behavior and is responsible for planning
MAPPING THE MIND

- Techniques used to map the mind and its workings in children:
  - **Neuropsychological Approach:** examining effects of brain damage on behavior
- EEG (electroencephalographic) recordings of electrical activity generated by active neurons

- ERPs (event-related potentials) record changes in the brain’s electrical activity in response to the presentation of a particular stimulus.
ERP RESPONSES

- These graphs show ERP waveforms in response to novel (red line) and familiar (yellow line) stimuli.
- The infants who later recalled how to assemble a toy (left panel) had clearly discriminated between the familiar and novel items on an earlier recognition test.
- The infants who did not recall the assembly sequence (right panel) had not discriminated between the components on the earlier test.
- fMRI (functional magnetic resonance imaging)

- Uses a powerful magnet to produce colorful images representing cerebral blood flow in different areas of the brain.

fMRI IMAGES: The figure shows fMRI images of the brains of a 9-year-old (panel A) and a 24-year-old (panel B) in a standard cognitive task that requires responding to some stimuli but inhibiting responding to others.
Some aspects of brain development are hard-wired - some cells know their place!

Sperry cut optic nerve and turned eye upside down
Experience plays a central role in determining which of the brain’s excess synapses will be pruned and which will be maintained.

Synapses that are frequently activated are preserved, a process described as “neural Darwinism.”
The normal wiring of the brain occurs in part as a result of the kinds of general experiences that every human who inhabits any reasonably normal environment will have.

- Is accompanied by **vulnerability**
  - If the expected experience is not available, as in the case of congenital cataracts, development will be impaired.
A key element in experience-expectant plasticity is timing.

There are a few sensitive periods when the human brain is particularly sensitive to particular kinds of external stimuli.
The process through which neural connections are created and reorganized throughout life as a function of an individual’s experience.
Timing and plasticity play important roles

- The worst time to suffer brain damage is when neurogenesis and neuron migration are occurring (during prenatal development and the first year after birth)
- The greatest plasticity is observed when synapse generation and pruning are occurring during early childhood
THE IMPORTANCE OF EXPERIENCE

- Experience-dependent processes
- Research on humans
  - Musicians demonstrate highly specific effects of experience on brain structure
  - Training program for dyslexic school produced increased left-brain activity

How would the cortical representations of their fingers be likely to differ for these two professional musicians?
At 6 years of age, children with congenital brain damage scored the same as normal children.

However, the children with brain damage failed to improve and fell progressively farther behind the normal children, so that by adolescence there were large differences between the two groups.
Hemispheric Differentiation

This is very controversial

Everything is performed by both hemispheres to some degree.

Right handed: 95% speech in left-hemisphere
Left handed: 70% speech in left-hemisphere

**Left brain**: right side of body

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**Right brain**: left side of body

•
Hemispheric Differentiation

Some research shows specialization complete by birth.

BUT other research shows compensation for hemispheric dysfunction in infants (i.e., still some plasticity).

- **Handedness** established by 2 years
- **Footedness** by 4-5 years

Often difficult to test because: lag motor skill at these ages.
THE BODY: PHYSICAL GROWTH AND DEVELOPMENT

GROWTH AND MATURATION
NUTRITIONAL BEHAVIOR
Physical Growth

Changes in Body Proportion and Shape

Body Proportions, Fetal Period Through Adulthood

2 months (fetal)  5 months (fetal)  Newborn  2 years  6 years  12 years  25 years
GROWTH CURVES

- Average height in inches
- Average height in centimeters
- Average weight in pounds
- Average weight in kilograms

Age:
- Boys
- Girls
• If growth continued at rates observed in spurts (e.g., first 6 months) 10-year-olds would weigh
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**Sex Differentiation**

• biggest changes in puberty

Why?
Physical Changes in Adolescence

Age (Male)
- Pubic hair appearing; penis enlarging
- Testes enlarging
- Underarm, facial hair appearing; voice deepening
- First ejaculation
- Penis adult size; mature pubic hair

Age (Female)
- Breast bud
- Pubic hair appearing
- Underarm hair appearing
- Mature pubic hair
- Mature breast
- First menstruation

Height Increase (in Inches)
- Growth spurt peak

Height Increase (in Centimeters)
Patterns of Growth

• Specific organs grow at different rates (e.g., head)

Directionality of Growth

Cephalocaudal (head-to-tail) trend:

Proximodistal (in-to-out) trend:
Determinants of Body Growth and Development

• **Genetic Factors**: Height and weight are affected by genes:
  
  But genes do not control growth directly:
  Instead, they regulate through neural and hormonal activity

• **Neural Control**: Brain includes a “growth center”
  
  Helps “catch up” and “lagging down” growth

• **Hormonal Influences**: Chemical trigger or inhibit growth
  
  Hormones in hypothalamus related to production of Human Growth Hormone (HGH)
  
  Low HGH leads to height of 4-4.5 feet
Nutrition and Health

Nutrition and exposure to disease are important determinants of growth

- Colombia: Protein supplements lead to 1 inch increase over control group

Marasmus: insufficient calories – weight loss, wrinkly skin, hollow appearance

Kwashiorkor: inadequate protein – apathy, stomach swelling, LT cognitive deficits
Model on Interactions effects of Malnutrition on Intellectual Development

- Malnutrition
- Illness
- Poverty

- Brain damage (sometimes reversible)
- Lethargy and withdrawal
- Minimal exploration of environment
- Lowered expectations of child from adults because child appears young
- Lack of educational and medical resources
- Delayed development of motor skills such as crawling and walking
- Delayed physical growth
- Delayed physical growth
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- Delayed physical growth

DELayed INTElllectual DEVELOPMENT
Breast-feeding is obviously important for feeding but it also provides antibodies against infectious agents.

- The majority of infants in the United States are not breast-fed
- Most of the world must rely on breast-feeding, as water is unsanitary and formula expensive.

- Infants are sensitive to the taste of mother’s milk, which is affected by what she eats.
- Infants like garlic and vanilla and dislike
Social-Emotional Consequences of Body Growth

Height
Lots of “good” things associated with height: Examples?
But, height not reliably correlated with self-esteem
• Can use HGH: Is it worth it?
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Weight
Overweight people seen as “good” and “bad”
BUT: obesity generally found to correlate with low self-esteem
How do children become obese?
• Genetic factors and environmental factors
OVERWEIGHT—A GROWING PROBLEM
• 80% of obese children become obese adults.
• Obese children generally have obese parents.
• Early excessive fat storage leads to overabundance of fat cells.
• Obese individuals are more responsive to external eating signals.
• Obese individuals eat faster and chew less.
• Mothers of obese children interpret all expressions as a need for food, and use food as a reward.
• Obese children are less active.
• Social consequences of obesity include:
  • Behavior problems
  • Depression
  • Lowered self-esteem
OTHER EATING DISORDERS

- Bulimia – binges followed by vomiting
  - 1%-5% population – 9/10 women
  - Common in teens – often low self-esteem
    - 50% overcome problem within 10 years

- Anorexia – starving oneself
  - 1% population – mostly adolescent women
  - Distorted body image
  - Cause unknown – typically well balanced, perfectionists
    - 5% die