Modification of neurons starts in the earliest stages of embryogenesis and continues to the final years of life. The parts of the brain specialize in different functions. Living organisms are able to detect changes in the environment.

A1. Neural Development

A1 A The neural tube of embryonic chordates is formed by infolding of **ectoderm** followed by elongation of the neural tube. (p 514)

**Neuralation:** development of a __dorsal nerve__ cord (or neural tube), during the beginning of gestation/embryonic development

An embryo has __3___ germ layers: ectoderm, mesoderm and endoderm

The __ectoderm__ forms a thickened area called the __neural plate__, this area folds into a tube in which the __spinal cord__ develops and __elongates__

**Neural plate**

**Ectoderm**

**Notochord**

**Neural crest**

**Neural tube**

**Peripheral nervous system**

**Central nervous system**

**Germ Layers**

- outer ectoderm
- middle mesoderm
- inner endoderm

**1st trimester review**

- month 1
- week 8-9
Skills

Annotation of a diagram of embryonic tissues in Xenopus used as an animal model during neurulation (p 515) Do the data based question on p 515

Annotate the diagrams with:

- Ectoderm, mesoderm and endoderm
- Development of the neural tube
- Wall of developing gut and gut cavity
- Notochord
- Developing dorsal fin

A1 B Neurons are initially produced by differentiation in the neural tube. (p514-515)

Neurons develop out of the ___ectoderm___ cells in early embryonic development, _____mitotic_ divisions (called _cell proliferation_), occur then _____differentiation_ occurs.

?neurogenesis
A1 C Immature neurons migrate to a final location. (p 516)

Once cells have ___DIFFERENTIATED___ into neurons they then __MIGRATE___ to different regions that will become “parts” of the __BRAIN___. (_______________________AMEBOID____ movement)

A1 D An axon grows from each immature neuron in response to chemical stimuli. (p 516)

Stage 1  Stage 2  Stage 3  Once neurons have __MIGRATED__ to different __REGIONAL__ positions, they extend out to form AXONS., CHEMICAL__stimuli determine neuron differentiation and the __DIRECTION___ of axon growth.

A1 E Some axons extend beyond the neural tube to reach other parts of the body. (p516)

Axons can grow very __LONG__________, the axon of a __MOTOR_neuron can go from the CNS (spinal cord) to your toe! (HL look back at reflex arc diagram!)

A1 F A developing neuron forms multiple synapses. (p517)

Once axons and __DENDRITES______ form, _______CONNECTIONS________ can be formed between neurons, these connections are called________SYNAPSES_________. (OVERLAP: remember? The presynaptic axon bulb contains specialized VESICLES__ filled with __NEUROTRANSMITTERS__, most neurons form ____MULTIPLE __ connections, especially in the brain. (draw below)
Option A — Neurobiology and behaviour

4. Modification of neurons starts in the earliest stages of embryo development and continues to the final years of life. The image shows changes occurring in mouse brain neurons at an early stage in life.

![Diagram of neuron development](source)

Days in culture: 0.25, 0.5, 1.5, 4, > 7

[Source: Republished with permission of Society of Neuroscience, from The establishment of polarity by hippocampal neurons in culture, CG Dotti, CA Sullivan and GA Banker, (4) 1998; permission conveyed through Copyright Clearance Center, Inc.]

(a) Outline how an immature neuron develops an axon.

(b) Explain neuroplasticity in terms of the developing neurons.

Section B

Option A — Neurobiology and behaviour

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
</tr>
</thead>
</table>
| 4. a     | a. neurons initially produce multiple dendrites/prolongations ✓  
          | b. an axon develops in response to chemical stimuli ✓ |
| 4. b     | a. neurons that are stimulated develop more dendrites than those not stimulated ✓  
          | b. more dendrites allow for more synapses ✓  
          | c. developing neurons form multiple/new synapses ✓  
          | d. synapses that are stimulated/used many times are fortified ✓  
          | e. neural pruning involves the loss of unused neurons/synapses ✓  
          | f. plasticity of the nervous system allows it to change with environment/experience/to reorganize following damage  
          | | OR  
          | some neurons can regenerate ✓ |
The images show the differences in glucose uptake between the brain of a person without Alzheimer’s disease (image I) and the brain of a patient with Alzheimer’s disease (image II). The key indicates the levels of glucose uptake.

![Image I](image1.jpg) ![Image II](image2.jpg)

Key:
- high
- low


Deduce the implications of reduced glucose uptake in the brain of a patient with Alzheimer’s disease.

| 5. | d | a. brain metabolism requires large energy inputs  

   **OR**  

   glucose is the only source of energy of the brain ✓  

   b. «less glucose» means there is less respiration/metabolic reactions ✓  

   c. less cognitive/functional/synaptic activity ✓  

   d. some cell death ✓ |
A1 G Synapses that are not used do not persist. (p 517)
A1 H Neural pruning involves the loss of unused neurons. (p 517)

Synapses form **EARLY AND THROUGHOUT** life.

If they ARE used repeatedly, **CHEMICAL MARKERS** are left that strengthen the **SYNAPSES**.

Pathways are enhanced by repeated **PRACTICE**.

If they are NOT used, they may **DISAPPEAR**, (this is called pruning).

Parts or **AXONS** of a neuron may be **PRUNED** or destroyed. (the number of neurons is constant, the number of connections is not).

Much of this happens during **CHILD DEVELOPMENT**.

*There is a massive overproduction of synapses (surplus) during brain development in early childhood, up to 50% can be lost. This neural pruning allows for the persistence of synaptic connections that are most important (and will help overall survival of an organism).

*Pruning is effected by environmental factors.

**A1 I The plasticity of the nervous system allows it to change with experience.** (p 517)

Neural **PLASTICITY** is the ability of the nervous system to **REWIRE** itself.

Connections **BETWEEN** neurons can be changed by the growth of axons and the establishment of new **SYNAPSES**. The nervous system is especially plastic from 0-6 years old.

Plasticity occurs throughout life, and allows for new memories and learning to occur, (?also if the brain is injured functions can be “reassigned”)


Spina bifida occurs if the _NEURAL TUBE________ does not completely___CLOSE IN THE EMBRYO_______ and a gap forms between __VERTEBRAE___

It can be ___MILD_____ with ___FEW_________symptoms OR ___SIGNIFICANTLY _________ affecting the ability to walk

Genetic AND environmental causes

*taking ___FOLIC ACID_____ during pregnancy can decreases occurrence

NOTE: as the neural tube develops ___EARLY____ in pregnancy, many women do not know they are pregnant and should be taking folic acid, some recommend ALL women of child bearing age be on folic acid.
Option A — Neurobiology and behaviour

4. The diagram shows one of the stages in neurulation.

![Diagram of neural plate and epidermis](https://en.wikipedia.org/wiki/Neural_tube#/media/File:Neural_crest.svg)

(a) Describe what happens next in neurulation.

(b) Explain the causes of spina bifida in vertebrates.

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<table>
<thead>
<tr>
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</table>
| 4. a     | a. neural plate moves/folds/bends inwards to form a groove ✓  
b. cells multiply/edges increase in height ✓  
c. borders/edges of neural plate join/form neural crest ✓  
d. neural tube forms/separates from rest (of ectoderm) ✓ |
| 4. b     | a. spine/spinal cord does not form properly  
OR  
incomplete closure of embryonic neural tube/ tissues around the neural tube do not fuse ✓  
b. lack of folic acid/folate (B9 vitamin) in pregnancy ✓  
c. genetic/family history ✓  
d. exposure to certain medication/environmental conditions during pregnancy ✓ |
5. Cells destined to become neurons differentiate in the neural tube. They grow and mature under the influence of chemical and other signals. The influence of insulin-like growth factor (IGF) was investigated in vitro using olfactory sensory neurons. The turning angle (direction) and extension of growth of these neurons were measured.

![Bar chart showing turning angle and neuron extension](image)

[Source: Reprinted from Neuron, 57, J A Scainick et al, Role of IGF Signaling in Olfactory Sensory Map Formation and Axon Guidance, 847. Copyright (2008), with permission from Elsevier]

(a) Evaluate the claim that IGF influences turning angle and neuron extension. [2]

(b) Outline the development of neurons from when they are first formed in the neural tube. [3]

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>5. a</td>
<td>a. turning angle of control is zero degrees whereas with IGF it is much larger ✓ b. neuron extension is greater with IGF than control ✓ c. non-overlapping error bars suggest a (significant) effect on turning angle OR overlapping error bars suggest a non-significant effect on neuron extension ✓</td>
</tr>
</tbody>
</table>

| 5. b     | a. an axon grows from each immature neuron (in response to chemical stimuli) ✓ b. each developing neuron forms several synapses (with other neurons) ✓ c. synapses that are not used degenerate ✓ d. neural pruning / loss of unused neurons ✓ e. neural connections can change / increase with experience ✓ f. neurons may migrate and complete development at their destination ✓ |
Events such as strokes may promote reorganization of brain function.

A stroke occurs when____BLOOD FLOW______to part of the BRAIN is disrupted (usually by a blood clot). That part of the brain that is deprived of blood (and therefore oxygen, means __c/R__ does not occur and no _ATP__ is made) will __DIE____

Severity of the stroke depends on __WHERE____the blood clot occurs, (can be instantly fatal or you may not even realize you had one).

Other parts of the brain, __NOT____effected by the stroke can take on __NEW _function (b/c of neural plasticity) , patients may have to re learn a task ex. ___SPEAK__________

NOS

Use models as representations of the real world—developmental neuroscience uses a variety of animal models. (1.10)

Neuroscience looks at how the ____HOW THE NERVOUS SYSTEM______ grows and develops

It can be difficult to gain __EXPERIMENTAL______ data b/c of ethical considerations.

We observe ___ANIMAL______ species and develop ___MODELS_____ from this ex XENOPUS frog at start of package!
A2. The Human Brain

A2 A The anterior part of the neural tube expands to form the brain. (p 519)

Identification of parts of the brain in a photograph, diagram or scan of the brain.

- Cerebral Hemispheres
- Cerebrum
- Hypothalamus
- Pituitary Gland
- Medulla Oblongata
- Cerebellum
Label the parts of the brain on the scan
A2 B Different parts of the brain have specific roles. (p 519)

a. Medulla oblongata:

Swallowing, ___BREATHING___ and ___HEART RATE___ are examples of activities coordinated by the medulla.

Breathing: ___RECEPTORS___ in the medulla monitor ___BLOOD pH___, as the concentration of ___carbon dioxide_________ increases, the ___blood pH drops (becomes more acidic as carbon dioxide reacts with water to form carbonic acid________, this leads to signal to increase inspiration (think back, which muscles??)

Heart Rate: receptors measure pH and ___blood pressure____________________ and regulate heart rate accordingly, by signaling the _____SA, sino atrial noded__________ (part of the heart!, where??)

b. Cerebellum:

Co-ordination, of ___involuntary___ muscle movements

___posture___ and ___balance____________

c. Hypothalamus: Controlling link between the central nervous system/brain and the _____endocrine_____ system (particularly the ___pituitary______). It regulates the _____anterior_ pituitary and ____makes the ___hormones (cool!) for the_______posterior_ pituitary.

Control center for ___HOMEOSTASIS__________, body temperature or ___thermo-__regulation, blood glucose levels, hunger and thirst.

d. Pituitary gland:

Posterior: releases hormones such as ___oxytocin (birth) and ADH –anti diuretic hormone that acts at the collecting duct of the nephron in the kidney__

Anterior: produces and secretes hormones such as ___FSH, ____ and ___________________LH__________ (think back to reproduction, what do these do? in male? In female?)

e. Cerebral hemispheres:
Large and **folded** to increase **surface area**
numerous **synaptic** connections
Memory, complex thought, emotions, problem solving etc....see next page

**Applications:** Visual cortex, Broca’s area and accumbens are areas of the brain with specialized functions

**A. Visual cortex:**

![Visual cortex image]

Part of the **cerebrum** (both halves) that processes information from the **photoreceptors** (rods/cones) of the eye this is where **colour** is **perceived**

**B. Broca’s area:**

![Broca's Area image]

Area of the **left cerebral** hemisphere that is associated with **speech production and language processing**

**LEFT SIDE ONLY**

**C. Nucleus accumbens:**

![Nucleus accumbens image]

Both cerebral hemispheres, this is the area of brain associated with **pleasure/reward** (the neurotransmitter **dopamine** is released here, remember cocaine addiction is associated with the **dopamine** response)
Use of the pupil reflex to evaluate brain damage:

The pupil controls the amount of light entering the eye and therefore hitting the retina.

It is acranial reflex action that is NOT under conscious control.

Doctors shine a bright light in both eyes of an unconscious patient. If there is no response, i.e., the pupil doesn’t constrict/get smaller, this can indicate brain damage or brain death (defined as the irreversible cessation of brain functions). In conjunction with other tests (blinking, eye rotation), brain death is determined.

NOTE: drugs can also affect this reflex.

*also both eyes are tested

SPECIFIC

Photoreceptor fires as light hits it, a message goes down the optic nerve to the brain, a message is sent (via Peripheral Nervous System) and causes pupil constriction.

In bright light the circular muscles of the iris contract and the pupil constricts or decreases in diameter.

In dim light the radial muscles of the iris contract and the pupil dilates or increases in diameter.
A2 C The autonomic nervous system controls involuntary processes in the body using centres located mainly in the brain stem (p 521).

Autonomic Nervous System controls (ANS) involuntary processes such as digestion it is controlled by the Medulla oblongata

**SUBDIVISIONS OF THE NERVOUS SYSTEM**

NERVOUS SYSTEM

CENTRAL NERVOUS SYSTEM (CNS)
(Brain and Spinal Cord)

PERIPHERAL NERVOUS SYSTEM (PNS)
(Nerves to and from CNS)

SOMATIC
(touch, hearing, etc; muscles that move body)

AUTONOMIC
(internal senses for gut, etc.; smooth muscles in gut etc.)

SYMPATHETIC
(Emergency)

PARASYMPATHETIC
("HOUSEKEEPING")

Sympathetic is “fight or flight” (S=stressful) and acts to increase heart rate /breathing rate and decrease blood flow to the gut and redirect to other areas needed to flee/fight

Parasympathetic /(P= Peaceful) acts to lower heart rate TO NORMAL, increase blood flow to the gut

**A2 D The cerebral cortex forms a larger proportion of the brain and is more highly developed in humans than other animals. (p 522)**

Only mammals have a cerebral cortex

Humans have the largest proportion of brain as the cerebral cortex

An increase in size/proportion of cerebral cortex indicates an increased ability to perform higher order/complex functions
A2 E The human cerebral cortex has become enlarged principally by an increase in total area with extensive folding to accommodate it within the cranium. (p 522)

An increase in ___folding______allows for more ____neurons___and synaptic connections in the cerebral cortex. Greater surface area is a result of the extensive folding.

Note: Mice and rats have a smoother cortex, dolphins have a more folded cortex. (think about DBQ!)

A2 F The cerebral hemispheres are responsible for higher order functions. (p523-524)

Higher order functions include: ___speech______, emotions, learning, memory, an awareness of one’s own existence, planning and reasoning!!

A2 G The ___LEFT___cerebral hemisphere receives sensory input from sensory receptors in the ___RIGHT__ side of the body and the right side of the visual field in both eyes and (vice versa for the right hemisphere). (p 524)

MORE ON THIS LATER... the learning outcome is stated with the specific information already, just rewrite the learning outcome
A2 H The left cerebral hemisphere controls muscle contraction in the right side of the body and vice versa for the right hemisphere. (p 524)

Motor cortex in the ___left_hemisphere controls the ___voluntary_muscle contractions on the _right__of the body (and vice versa)

Figure AB-8: Brain Hemispheres

Each hemisphere controls the opposite half of the body.
A2 I Brain metabolism requires large energy inputs. (p 525)

The brain accounts for ____only 2%____ of the body by mass, but requires _______20 %__ of the total body energy needs. (less in lower vertebrates! Why?)

The brain has many neurons and therefore it needs lots of __ATP/energy_____________ AND glucose to make ATP, relative to its size.

*This helps neurons fire or send signals.*
Use of animal experiments, autopsy, lesions and fMRI to identify the role of different brain parts.

**How did scientists determine which parts of the brain have which function?**

**a. autopsy:** examine a person after death and see what part of the brain is damaged and associate it with a “missing” function

**b. lesions:** a lesion is __damage____ to part of the brain due to a __stroke____, _______tumour__ or accident. If the location of the lesion is known, and a person with a brain legion has missing /abnormal brain function, it can be deduced what part of the brain controls that function

ex. Lower left side of brain has a tumour- a person has an inability to ___speak______, that part of the brain must associated with speech!

**Sometimes large areas of the brain are effected and it is difficult to pinpoint the exact location of individual tasks.**

**c. animal experiments:** (a) and (b) do not enable scientists to see every area, so experiments are done on animals. This involves inflicting __damage____ to a part of the brain and seeing the __resulting________ effects. (limits?...ethics?)

**d. fMRI (functional magnetic resonance imaging)**

This is a __non invasive_____ technique

It can be used on __healthy__ subjects (the above three all involve people/animals with brain injury or trauma and this can influence results)

Subject activates part of the brain by _completing________________ a task and there is a resulting _increase______in _____BLOOD FLOW_______to that part of the brain that is being used, (as heat flows to this area) this shows up on the image. COOL!!

*allows scientists to see complex responses that involve ___multiple________area of the brain, unlike the first three.*
As there is an increase in body mass the mass of the brain _increases______, it is a __________positive____ correlation, but not directly __proportional /linear_______ (NOT linear-note the _logarithmic scale___________)

Note humans are high above the line indicating the brain mass is higher relative to body weight, The African elephant has a larger body weight but the ratio of brain/body weight is NOT higher. This graph has showed up on two exams, read more in textbook.

NOS

Use models as representations of the real world—the sensory homunculus and motor homunculus are models of the relative space human body parts occupy on the somatosensory cortex and the motor cortex. ( 1.10).
Size of each ____BODY part____is shown in proportion to how much of the sensory and motor cortex of brain is associated with the body part.

What areas are large?
   For sensory the fingers and lips are large
   For motor hands are very large