Nerves, Hormones and Homeostasis

Stephen Taylor

Banding International School
Introduction to the nervous system:

http://www.youtube.com/watch?v=xRkPNwqm0mM

http://faculty.washington.edu/chudler/introb.html

CNS/ANS:
http://www.biologyreference.com/images/biol_03_img0336.jpg
The nervous system consists of the **central nervous system** and **peripheral nerves**.

**Nervous System**

- **Central Nervous System**
  - Brain
  - Spinal Cord

- **Peripheral Nervous System**
  - Autonomic NS
    - Homeostasis
    - Involuntary control
  - Somatic NS
    - Receives external stimuli
    - Voluntary control of muscle

- **Sympathetic**
  - "Fight or flight"

- **Parasympathetic**
  - "Rest and digest"

- **Enteric**
  - Controls digestive system

Brain: [http://faculty.washington.edu/chudler/gif/brainwig.gif](http://faculty.washington.edu/chudler/gif/brainwig.gif)

The nervous system is composed of **neurons**. These are cells that carry **rapid electrical impulses**.

A typical motor neuron:

![Motor Neuron Diagram]

- **Cell body**
  - Nucleus
  - Cytoplasm

- **Dendrites**
- **Axon**
- **Myelin sheath**
- **Nodes of Ranvier**
- **Impulse**
- **Motor end plates**
- **Muscle cells**

A **synapse** is the junction between two neurons.

http://www.infovisual.info/03/041_en.html


http://sdp.by.ru/spravka/neurosci/
The reflex arc

Nerve impulse conduction:
① receptor to CNS: sensory neurons
② within CNS: relay neurons
③ CNS to effectors: motor neurons

Animation:

http://medical-dictionary.thefreedictionary.com/ARC
Nerve impulses are conducted along the neuron

The nerve impulse is a result of a change in concentrations of sodium ($Na^+$) and potassium ($K^+$) ions across the membranes of the neuron.

These changes are called depolarisation and repolarisation.

**Resting potential** is the electrical potential across the plasma membrane of a cell that is not conducting an impulse.

**Action potential** is the reversal (depolarisation) and restoration (repolarisation) of the electrical potential across a plasma membrane as a nerve impulse passes along a neuron.
Resting Potential
is the electrical potential across the plasma membrane
of a cell that is not conducting an impulse.

Resting potential is maintained by
active transport (antiport):

Sodium ions pumped out

Potassium ions pumped in

Some potassium ions diffuse
back out, leaving the outside
more positive and the
inside more negative

Adapted from http://www.blackwellpublishing.com/matthews/actionp.html
Action Potential is the reversal (depolarisation) and restoration (repolarisation) of the electrical potential across a plasma membrane as a nerve impulse passes along a neuron.

1. Resting potential is maintained by active transport: $\text{Na}^+/\text{K}^+$ pump pumps $\text{Na}^+$ out and $\text{K}^+$ in.

2. Arrival of an Action Potential (AP) causes depolarisation of adjacent sections of the neuron.
   - This causes local $\text{Na}^+$ diffusion and a current.
   - If the current is enough to rise above the threshold, voltage-gated $\text{Na}^+$ channels open and $\text{Na}^+$ rushes in. Internal potential is reversed - it is more positive than the outside (depolarisation).

3. $\text{K}^+$ channels are opened and $\text{K}^+$ diffuses out. Internal charge is negative again (repolarisation)

4. Refractory period is when the channels rest between openings. This ensures one-way impulse flow.

Resting potential is then returned by active transport.

http://scienceblogs.com/clock/upload/2006/06/ActionPotential.jpg
http://www.blackwellpublishing.com/matthews/actionp.html
Action Potential Resources

Action potential:
The Na channels are voltage gated -
Adjacent depolarization causes them
to open - the Na⁺ ions flood into the
nerve making it positive (depolarization)

http://www.mrothery.co.uk/images/nerveimpulse.swf

Unmyelinated axon

Begin continuous conduction

http://www.blackwellpublishing.com/matthews/actionp.html

http://www.psych.ualberta.ca/~ITL/ap/ap.htm
Synaptic Transmission

What happens when a nerve meets another nerve? This.

At the dendritic end of the nerve cell, each dendrite collects the nerve impulse from the terminal end of a different nerve cell. The impulse needs to 'jump' across a small gap - the synapse - by synaptic transmission.

The electrical impulse is converted to a chemical neurotransmitter.

Work thorough the tutorial below:

How does synaptic transmission work?
Label this diagram of a synapse

Pre-synaptic neuron (terminal end)

E
F

NT

Ca^+

ATP

ADP + Pi

G

H

Na^+

Post-synaptic neuron (dendrite)

A

B

C

D

G

H

I

A
Summary of Synaptic Transmission

1. Nerve impulse reaches terminal end of pre-synaptic neuron.

2. Depolarisation causes voltage-gated calcium channels to open. Ca\(^{2+}\) rushes in.

3. Ca\(^{2+}\) causes synaptic vesicles to move to the membrane and fuse.

4. Neurotransmitters (NTs) that were stored in the synaptic vesicle now diffuse across the synaptic gap.

5. NTs bind with post-synaptic receptors. *NTs are specific to the receptor.*

6. Sodium channels open, causing Na\(^+\) to enter, leading to depolarisation of the post-synaptic neuron. *An action potential is initiated.*

7. Enzymes in the synaptic gap then break down the NT. The products of this break down are taken up by the pre-synaptic neuron by active transport (hence the large number of mitochondria).

The nerve impulse is then propagated along the post-synaptic neuron.
Draw and label a diagram of a motor-neuron, showing the direction of nerve impulse propagation. (3 marks)
Draw and label a diagram of a motor-neuron, showing the direction of nerve impulse propagation. (3 marks)

- A dendrite
- B nucleus
- C axon
- D myelin sheath
- E node of Ranvier
- F synaptic knob/terminal end plate

arrow in correct direction;
Award [1] for any two of the following structures clearly drawn and correctly labelled, up to [2 max].
nucleus;
cell body;
axon;
dendrites;
myelin sheath;
node of Ranvier;
synaptic knob; 3 max

Image: QuestionBank CDROM
Explain how a nerve impulse passes along a non-myelinated neuron.

(8 marks)
Explain how a nerve impulse passes along a non-myelinated neuron.

(8 marks)

**Action potential** activates **voltage-gated sodium-channels**; 
**sodium ions** (+) rush in to **axon**;  
Potential increases;  
If it increases beyond **threshold**, more sodium channels open;  
Axon **depolarises**, stimulating adjacent sections;  
Potassium channels open, **potassium** (+) rushes out;  
Potential is reduced (repolarisation);  
Refractory period ensures **one-way conduction** of action potential;  
**sodium-potassium pump** returns axon section to resting potential.

Narrate this animation with the correct answer to the question:

[Image: The resting potential: Na⁺ & K⁺ are actively pumped across the nerve membrane]

Answer from QuestionBank CD Rom

[Link: http://www.mrothery.co.uk/images/nerveimpulse.swf]
Explain the principles of synaptic transmission.

(8 marks)
nerve impulse (AP) travels to end of presynaptic neuron; triggers influx of Ca^{2+};
causes synaptic vesicles to fuse with membrane; release neurotransmitter molecules into synaptic cleft;
(neurotransmitter) crosses / diffuses across channel;
(neurotransmitter) binds to receptors on next / postsynaptic neuron;
causes ion channels to open on post-synaptic neuron;
e.g. Na^+ diffuses into postsynaptic neuron;
can inhibit/excite;
by hyperpolarizing/depolarizing;
neurotransmitter degraded;
Ca^{2+} pumped back into the synaptic cleft by active transport;
acetylcholine / GABA / dopamine / serotonin / other examples of neurotransmitter;    8 max

Answer from QuestionBank CDRom
Outline the use of four methods of membrane transport in nerves and synapses.

(8 marks)
Outline the use of four methods of membrane transport in nerves and synapses.

(8 marks)

**Active transport**
- sodium-potassium pump resets resting potential in the axon following nerve impulse
- re-uptake of neurotransmitters to the pre-synaptic neuron following synaptic transmission
- removal of Ca\(^{2+}\) from pre-synaptic neuron following synaptic transmission

**Simple diffusion**
- diffusion of NT across synaptic cleft
- diffusion of K\(^+\) ions out of axon in resting potential

**Facilitated diffusion**
- opening of voltage-gated Na\(^+\) and K\(^+\) channels in action potential
- opening of voltage-gated Ca\(^{2+}\) channels at pre-synaptic terminal
- Na\(^+\) channels activated at post-synaptic terminal to propagate AP

**Vesicle transport**
- influx of Ca\(^{2+}\) activates vesicles of neurotransmitters
- exocytosis of NT from pre-synaptic neuron to synaptic cleft
The Endocrine System
A stimulus is received and processed. **Hormones are secreted into the blood, via ducts.** They are carried to the **target tissue** - the place of action. **The action of the hormone changes conditions of the tissue.** This **change is monitored through feedback.** Most hormonal change results in **negative feedback.**
Hormones in IB Biology

What do they all do?

- insulin
- glucagon
- adrenaline
- testosterone
- FSH
- LH
- oestrogen
- progesterone
- HCG
- oxytocin
Hormones in IB Biology

**What do they all do?**

- **insulin**: converts glucose to glycogen
- **glucagon**: converts glycogen to glucose
- **adrenaline**: "Fight or flight" increases heart rate
- **testosterone**: sperm production, male body development
- **FSH**: stimulates oocyte development
- **LH**: develops endometrium
- **oestrogen**: stimulates ovulation (release of the egg)
- **progesterone**: maintains endometrium
- **HCG**: maintains high levels of oestrogen and progesterone in pregnancy
- **oxytocin**: causes contraction of the uterus during childbirth
Homeostasis: maintaining the internal environment of the body within safe limits

Water balance (osmoregulation)
around 90% of blood volume
dehydration with water loss
kidneys & hormones (excretion)

Blood glucose concentration
80mg dl\(^{-1}\) - 110mg dl\(^{-1}\)
pancreas & liver
insulin & glucagon

CO\(_2\) concentration
10-13 kPa
kidneys (excretion)
circulation (breathing & heart rate)

Blood pH
pH 7.35 - 7.45
buffering agents
kidneys (excretion)
circulation (breathing & heart rate)

Body temperature (thermoregulation)
36°C - 38°
Vasodilation and Sweating (hot)
or vasoconstriction and shivering (cold)


Yeah, yeah, I know...
Homeostasis works by monitoring levels of variables and making corrections by negative feedback mechanisms.

Too hot? Get cooler!

How do you know?
Stimulus - Receptor - Coordinator

Check again! Effector

Feedback loops:
Monitor

increase

OK!

too Low
too High
Thermoregulation  Human core body temperature needs to remain at around 37°C.

Hypothermia occurs when the body's core temperature drops too low for metabolic reactions to occur. Death below 32°C.

Hyperthermia (heat stroke) occurs when the body's core temperature gets too high and tissues are damaged. Above 40°C is deadly.

A lot of heat is generated in the liver and carried around the body in the blood. Heat is lost through the skin - the larger the SA:Vol ratio, the faster the rate of heat loss.

Too Cold  Arterioles constrict (vasoconstriction)  Sweat glands close  Hairs stand up, trap layer of air  Muscles spasm (shivering)  Blood warms

Too Hot  Arterioles dilate (vasodilation)  Sweat glands open  Hairs lie flat, no boundary layer  Blood cools
Find out more:
http://bcswfreeman.com/thelifewire/content/chp41/4101s.swf
The hypothalamus and pituitary link the nervous and endocrine systems:

Cold temperature changes are detected by cells in the skin and relayed through the hypothalamus. The hypothalamus relays the signal to the pituitary, which acts to release thyroid stimulating hormone (TSH). TSH is carried in the blood and acts upon the thyroid, causing the release of thyroid hormone. This is carried through the blood, acting on almost all cells, leading to increased heat production through metabolism.


How is this an example of negative feedback control?
The hypothalamus and pituitary link the nervous and endocrine systems:

Cold temperature changes are detected by cells in the skin and relayed through the hypothalamus. The hypothalamus relays the signal to the pituitary, which acts to release thyroid stimulating hormone (TSH). TSH is carried in the blood and acts upon the thyroid, causing the release of thyroid hormone. This is carried through the blood, acting on almost all cells, leading to increased heat production through metabolism.

- stimulus: cold
- sensory neurons: cold receptor cells
- relay: hypothalamus
- effector: pituitary
- hormone 1: TSH
- gland: pituitary
- target cells: thyroid gland
- effect: release thyroid hormone
- target cells: all cells
- effect: increase metabolism, get warmer

How is this an example of negative feedback control?
Blood Glucose is maintained through the actions of the pancreas and liver.

- High blood glucose:
  - Beta-cells secrete insulin.
  - Liver releases glucose into blood.
  - Insulin released by beta cells of pancreas.

- Low blood glucose:
  - Alpha-cells secrete glucagon.
  - Liver releases glucose from glycogen.
  - Glucagon released by alpha cells of pancreas.

Explain the control of blood glucose.
Explain the control of blood glucose.

Pancreatic cells monitor blood glucose;
Absorption of glucose from digestion in the intestine increases blood sugar/ fasting reduces blood sugar;
Glucoregulation is an example of **negative feedback**;
Uses **hormones** insulin and glucagon;

**If blood glucose is too high**

β-cells of pancreas produce **insulin**;
insulin stimulates uptake of glucose to cells, e.g. muscle;
insulin stimulates liver/ fat cells to **store glucose as glycogen**;
leading to decrease in blood glucose;

**If blood glucose is too low**

α-cells of pancreas produce **glucagon**;
glucagon stimulates liver to **break glycogen into glucose**;
leads to increased blood sugar;
Diabetes: reduced ability to control blood glucose through insulin

**Type I: Early Onset**

1. Glucose stimulates pancreas
2. Pancreas does not produce enough insulin
3. Not enough insulin to stimulate cells
4. Target cells remove too little glucose
   - Target cells (liver, fat, muscle)
   - High blood glucose
   - Insulin

**Type II: Adult Onset**

1. Glucose stimulates pancreas
2. Pancreas produces insulin
3. Insulin does not stimulate cells (too few receptors)
4. Target cells remove too little glucose
   - Target cells (liver, fat, muscle)
   - High blood glucose
   - Insulin

**Hereditary, weak relationship**
- Trigger needed, e.g. illness
- Beta cells destroyed
- Insulin production stops

**Hereditary, strong relationship**
- Related to obesity & poor diet
- Fewer insulin receptors in liver
- Less sensitivity to insulin
  (insulin does not work as well)

For more resources and animations visit:
http://sciencevideos.wordpress.com