E4 Neurotransmitters and Synapses

Stephen Taylor
Bandung International School
Synapses: How do neurons communicate with each other?

To what extent is our behaviour, especially with regard to addiction and drug use, pre-determined by our genes - and what can we do to make sensible and informed choices?

This animation is a good warm-up!

Types of Synapse:

Start this unit by reviewing the Nerves, Hormones and Homeostasis Core content:

Then check out the brilliant resources at Learn.Genetics: The New Science of Addiction centre:
http://learn.genetics.utah.edu/content/addiction/
Pre-synaptic neurons can either **excite** or **inhibit** post-synaptic transmissions. Remember that generation of an AP is 'all or nothing' condition.

This depends on which neurotransmitter (NT) is used - and which receptors they bind to.

**Excitatory:** NT stimulates an AP in the Post-Synaptic neuron

NT binding to the receptors opens sodium gates, causing sodium to flow in, **depolarising** the neuron.

Na⁺ in, neuron more positive, depolarisation occurs

NT e.g. Glutamate

Acetylcholine (ACh)

Norepinephrin (Norepi or NE),

Dopamine,

**Inhibitory:** NT prevents an AP in the Post-Synaptic neuron

NT binding to the receptors opens potassium gates, causing chloride to flow in, **hyperpolarising** the neuron.

Cl⁻ in, neuron more negative.

More difficult to depolarise, impulse inhibited.

NT e.g. GABA,

Dopamine,

http://txtwriter.com/Backgrounders/Drugaddiction/drugs1.html
What is GABA?

γ-Aminobutyric acid (gamma)

GABA is a NT that opens chloride (Cl⁻) ion channels on the post-synaptic membrane. Cl⁻ rushes in, hyperpolarising the post-synaptic neuron and reducing APs.

GABA is important in regulating nervous processes - a 'calming' or depressive effect (reducing activity).

It prevents neurons from overfiring, and can be used as a drug to help people with anxiety or stress-related disorders.

Alcohol mimics the effect of GABA, further increasing hyperpolarisation and therefore greatly reducing nerve activity.

http://kickyoutube.com/watch/?v=-pfG6yHAQ5U
Decision-making in the central nervous system (CNS)

Important points to remember:
- The axons of many neurons feed into the dendrite of the post-synaptic neuron
- Each axon contributes to the membrane potential of the post-synaptic neuron
- The effects of each input can be either excitatory or inhibitory
- The effect is summative, and is added up at the axon hillock

If the summative effect of the inputs reaches threshold, an AP is propagated

Spatial Summation: multiple inputs
Temporal Summation: multiple firing from one input

Animations from:
http://hsc.uwe.ac.uk/synapses_neuro/summation.htm
Psychoactive drugs affect the brain and personality by either increasing or decreasing postsynaptic transmission.

Use some of these great resources to learn more about how drugs affect your synapses, mood and behaviour - and about how they can be dangerous.
Psychoactive drugs affect the brain and personality by either increasing or decreasing postsynaptic transmission. They can act on the synapses in many ways:

**Inhibitory drugs**

- **Mimic inhibitory NTs**
  - Increase hyperpolarisation of post-synaptic neuron
  - Fewer action potentials
  - E.g. alcohol, mimics GABA effects, reducing propagation of APs

- **Block excitatory NTs**
  - Prevent propagation of action potentials
  - E.g. opiates (heroin) which block pain pathways by competitive inhibition with pain-related NTs

**Excitatory drugs**

- **Block re-uptake pumps for NTs**
  - NT remains in synapse
  - E.g. cocaine’s effect on dopamine

- **Mimic excitatory NTs**
  - Increase depolarisation of post-synaptic neuron
  - More action potentials
  - E.g. nicotine

- **Block inhibitory NTs**
  - Prevent inhibition of action potentials
  - E.g. caffeine competitively inhibits adenosine, an inhibitory NT

Some drugs can also increase amount of NTs released (nicotine), or stimulate NTs to be released without needing an AP to activate the vesicles (amphetamines and methamphetamines).

Many drugs act in more than one way, such as heroin. It inhibits pain pathways but also excites reward/pleasure pathways.
Excitatory drugs increase post-synaptic transmission

Effects of cocaine
- Normal:
  - dopamine acts as an excitatory NT
  - dopamine is re-uptaken at the pre-synaptic neuron pumps

- With Cocaine:
  - cocaine blocks receptors on reuptake pump
  - dopamine is not re-uptaken, so remains in the synaptic cleft
  - more dopamine is released
  - increased post-synaptic transmission

Effect on mood:
- dopamine is a 'pleasure' NT
- enhanced feelings of pleasure
- feelings last longer as dopamine is not recycled back to the pre-synaptic neuron

Effect on behaviour:
- feelings of euphoria
- increased energy and alertness
- highly addictive
- associated with depression (body reduces its own production of dopamine)

animations from: http://thebrain.mcgill.ca/flash/index_i.html
Inhibitory drugs decrease post-synaptic transmission

Effects of THC (cannabis)

**Normal:**
- Two pathways to consider
  - 1. pathway released dopamine, increasing feelings of pleasure
  - 2. GABA has an inhibitory effect on release of dopamine

**With THC:**
- THC inhibits GABA release
- By binding to cannabinoid receptors
- So GABA cannot inhibit dopamine
- Therefore more dopamine is released

**Effect on mood:**
- higher levels of dopamine stimulate reward centres
- increased feelings of pleasure

**Effect on behaviour:**
- intoxication (drunk feeling)
  - hunger
  - memory impairment


Animations from: [http://thebrain.mcgill.ca/flash/index_i.html](http://thebrain.mcgill.ca/flash/index_i.html)
Addiction is a chronic neurological disorder with genetic, psychosocial and environmental characteristics. It is characterised by changes in the brain resulting in a compulsive desire to use a drug.

Visit these excellent resources to find out more about the effects, impacts and possible causes of addiction:

http://learn.genetics.utah.edu/units/addiction/

Addiction research is fast-growing and interdisciplinary: genetics, biochemistry, neurobiology, sociology, epidemiology and more.

Do something useful with your IB Biology knowledge - become a scientist and make a difference!

Check out the mouse party to see how drugs affect the brain:

http://learn.genetics.utah.edu/content/addiction/drugs/mouse.html
Addiction

Reward centres in the brain play a key role in reinforcing behaviour that may lead to addiction.

The Reward Pathway Reinforces Behavior

The central job of the reward pathway is to make us feel good when we engage in behaviors that are necessary for our survival. These beneficial behaviors include eating, drinking and sex.

Dopamine is the neurotransmitter most prevalent in the reward pathways. It is also used in other pathways.

Drugs that stimulate the reward pathways generate a feeling of pleasure, which the user may seek to repeat by using the drug again.

High levels of dopamine cause a feeling of euphoria, and drugs that affect reward pathways are particularly addictive, including THC and cocaine.

Repeated use of drugs to repeat euphoric feelings reinforces the behaviour, leading to addiction.
Some people are genetically more pre-disposed to becoming addicted than others.

Family histories and pedigree charts can be used to estimate risk of some traits - including susceptibility to addiction.

The effect of genetics could be to produce a different allele of a receptor gene (such as is more common people with cocaine or alcohol addiction), or to carry modified versions of other genes linked to drug metabolism and reward pathways.

The children of addicts are more likely to become addicts themselves. Knowing this, people can take steps to reduce their likelihood of becoming addicted: avoid addictive substances and find peer groups that are supportive and non-destructive.

Finding genes that are more common in addicts, or using knockout mice to determine relationships between genes and addiction to some substances, has allowed researchers to develop more targeted approaches to treating addiction.
Addiction

Psychosocial factors are a heavy influence in addiction and addictive behaviour.

Peer Pressure
Strong peer influence increases chance of using drugs.

Timing
Adolescents are particularly susceptible to behaviours developing into addictions.

Availability
Even those with strong genetic susceptibility can't get addicted if they have no access to drugs.

Legality or Religion
Effectively enforced laws or strongly held beliefs can deter use of illegal drugs and thus addiction.

Community
Relaxed attitudes to drugs and guns can encourage a culture of addiction.

Family
Abusive and high-stress conditions can encourage use and abuse of addictive substances.

Mental Health
Depression, abuse and low self-esteem can lead to drug use and addiction.

Find out more here:
http://learn.genetics.utah.edu/content/addiction/factors/environment.html

http://en.wikipedia.org/wiki/Cocaine
Professor David Nutt is a neuropsychopharmacologist who specialises in drugs, their effects and brain conditions such as depression and anxiety.

He was employed as a government advisor in the UK for the Advisory Council for the Misuse of Drugs. He devised a scale of harm for drugs, based on dependence, physical and social harms caused by the drug. He was openly critical of the government's decision to upgrade cannabis to Class B from Class C, and was sacked from his position as a result.

The decision to sack Prof. Nutt sparked debate on the nature of Science and its relationship with politics.

Here are some questions to discuss:
1. How does the decision to sack the advisor in this case reflect on the government and on the advisor himself?
2. How does this case reflect on the nature of the relationship between scientific research and government policy-making?
3. Why are some clearly harmful drugs still legal (e.g. tobacco)?
4. If you were to form a drugs policy for a completely new country, which would you make illegal/ legal and why? Upon which evidence would you base your decision-making and why?
Now can you understand what they're rapping about?

Check my synaptic cleft:

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

Tell me about your addiction?
What is this 'precious' you must have?

For more IB Biology resources:
http://sciencevideos.wordpress.com