

**Essential idea:** Neurons transmit the message, synapses modulate the message.

## 6.5 Neurons and synapses

### Nature of science:

Cooperation and collaboration between groups of scientists—biologists are contributing to research into memory and learning. (4.3)

### Understandings:

- Neurons transmit electrical impulses.
- The myelination of nerve fibres allows for saltatory conduction.
- Neurons pump sodium and potassium ions across their membranes to generate a resting potential.
- An action potential consists of depolarization and repolarization of the neuron.
- Nerve impulses are action potentials propagated along the axons of neurons.
- Propagation of nerve impulses is the result of local currents that cause each successive part of the axon to reach the threshold potential.
- Synapses are junctions between neurons and between neurons and receptor or effector cells.
- When presynaptic neurons are depolarized they release a neurotransmitter into the synapse.
- A nerve impulse is only initiated if the threshold potential is reached.

### Applications and skills:

- Application: Secretion and reabsorption of acetylcholine by neurons at synapses.
- Application: Blocking of synaptic transmission at cholinergic synapses in insects by binding of neonicotinoid pesticides to acetylcholine receptors.
- Skill: Analysis of oscilloscope traces showing resting potentials and action potentials.

### Guidance:

- The details of structure of different types of neuron are not needed.
- Only chemical synapses are required, not electrical, and they can simply be referred to as synapses.

### Utilization:

- An understanding of the workings of neurotransmitters and synapses has led to the development of numerous pharmaceuticals for the treatment of mental disorders.

Syllabus and cross-curricular links:

Biology

Topic 1.4 Membrane transport

Chemistry

Topic C6 Electrochemistry, rechargeable batteries and fuel cells

Psychology

Core: Biological level of analysis

### Aims:

- **Aim 8:** The social effects of the abuse of psychoactive drugs could be considered, as could the use of the neurotoxin *Botox* for cosmetic treatments.

**Essential idea:** Information stored as a code in DNA is copied onto mRNA.

7.2 Transcription and gene expression	
<p><b>Nature of science:</b></p> <p>Looking for patterns, trends and discrepancies—there is mounting evidence that the environment can trigger heritable changes in epigenetic factors. (3.1)</p>	
<p><b>Understandings:</b></p> <ul style="list-style-type: none"> <li>Transcription occurs in a 5' to 3' direction.</li> <li>Nucleosomes help to regulate transcription in eukaryotes.</li> <li>Eukaryotic cells modify mRNA after transcription.</li> <li>Splicing of mRNA increases the number of different proteins an organism can produce.</li> <li>Gene expression is regulated by proteins that bind to specific base sequences in DNA.</li> <li>The environment of a cell and of an organism has an impact on gene expression.</li> </ul> <p><b>Application and skills:</b></p> <ul style="list-style-type: none"> <li>Application: The promoter as an example of non-coding DNA with a function.</li> <li>Skill: Analysis of changes in the DNA methylation patterns.</li> </ul> <p><b>Guidance:</b></p> <ul style="list-style-type: none"> <li>RNA polymerase adds the 5' end of the free RNA nucleotide to the 3' end of the growing mRNA molecule.</li> </ul>	<p><b>Theory of knowledge:</b></p> <ul style="list-style-type: none"> <li>The nature versus nurture debate concerning the relative importance of an individual's innate qualities versus those acquired through experiences is still under discussion. Is it important for science to attempt to answer this question?</li> </ul> <p><b>Utilization:</b></p> <p>Syllabus and cross-curricular links: Biology Topic 2.7 DNA replication, transcription and translation</p>

**Essential idea:** Information transferred from DNA to mRNA is translated into an amino acid sequence.

### 7.3 Translation

#### Nature of science:

Developments in scientific research follow improvements in computing—the use of computers has enabled scientists to make advances in bioinformatics applications such as locating genes within genomes and identifying conserved sequences. (3.7)

#### Understandings:

- Initiation of translation involves assembly of the components that carry out the process.
- Synthesis of the polypeptide involves a repeated cycle of events.
- Disassembly of the components follows termination of translation.
- Free ribosomes synthesize proteins for use primarily within the cell.
- Bound ribosomes synthesize proteins primarily for secretion or for use in lysosomes.
- Translation can occur immediately after transcription in prokaryotes due to the absence of a nuclear membrane.
- The sequence and number of amino acids in the polypeptide is the primary structure.
- The secondary structure is the formation of alpha helices and beta pleated sheets stabilized by hydrogen bonding.
- The tertiary structure is the further folding of the polypeptide stabilized by interactions between R groups.
- The quaternary structure exists in proteins with more than one polypeptide chain.

#### Application and skills:

- Application: tRNA-activating enzymes illustrate enzyme–substrate specificity and the role of phosphorylation.
- Skill: Identification of polysomes in electron micrographs of prokaryotes and eukaryotes.

#### Utilization:

Syllabus and cross-curricular links:

Biology

Topic 2.7 DNA replication, transcription and translation

Option B: Biotechnology and bioinformatics

### 7.3 Translation

- Skill: The use of molecular visualization software to analyse the structure of eukaryotic ribosomes and a tRNA molecule.

**Guidance:**

- Names of the tRNA binding sites are expected as well as their roles.
- Examples of start and stop codons are not required.
- Polar and non-polar amino acids are relevant to the bonds formed between R groups.
- Quaternary structure may involve the binding of a prosthetic group to form a conjugated protein.

# Topic 8: Metabolism, cell respiration and photosynthesis

14 hours

**Essential idea:** Metabolic reactions are regulated in response to the cell's needs.

## 8.1 Metabolism

### Nature of science:

Developments in scientific research follow improvements in computing—developments in bioinformatics, such as the interrogation of databases, have facilitated research into metabolic pathways. (3.8)

### Understandings:

- Metabolic pathways consist of chains and cycles of enzyme-catalysed reactions.
- Enzymes lower the activation energy of the chemical reactions that they catalyse.
- Enzyme inhibitors can be competitive or non-competitive.
- Metabolic pathways can be controlled by end-product inhibition.

### Applications and skills:

- Application: End-product inhibition of the pathway that converts threonine to isoleucine.
- Application: Use of databases to identify potential new anti-malarial drugs.
- Skill: Calculating and plotting rates of reaction from raw experimental results.
- Skill: Distinguishing different types of inhibition from graphs at specified substrate concentration.

### Guidance:

- Enzyme inhibition should be studied using one specific example for competitive and non-competitive inhibition.

### Theory of knowledge:

- Many metabolic pathways have been described following a series of carefully controlled and repeated experiments. To what degree can looking at component parts give us knowledge of the whole?

### Utilization:

- Many enzyme inhibitors have been used in medicine. For example ethanol has been used to act as a competitive inhibitor for antifreeze poisoning.
- Fomepizole, which is an inhibitor of alcohol dehydrogenase, has also been used for antifreeze poisoning.

Syllabus and cross-curricular links:

Biology

Topic 2.7 DNA replication, transcription and translation

Chemistry

Topic 6.1 Collision theory and rates of reaction

### Aims:

- **Aim 6:** Experiments on enzyme inhibition can be performed.
- **Aim 7:** Computer simulations on enzyme action including metabolic inhibition are available.

**Essential idea:** Communication between neurons can be altered through the manipulation of the release and reception of chemical messengers.

A.5 Neuropharmacology	
<p><b>Nature of science:</b></p> <p>Assessing risks associated with scientific research—patient advocates will often press for the speeding up of drug approval processes, encouraging more tolerance of risk. (4.5)</p>	
<p><b>Understandings:</b></p> <ul style="list-style-type: none"> <li>Some neurotransmitters excite nerve impulses in postsynaptic neurons and others inhibit them.</li> <li>Nerve impulses are initiated or inhibited in post-synaptic neurons as a result of summation of all excitatory and inhibitory neurotransmitters received from presynaptic neurones.</li> <li>Many different slow-acting neurotransmitters modulate fast synaptic transmission in the brain.</li> <li>Memory and learning involve changes in neurones caused by slow-acting neurotransmitters.</li> <li>Psychoactive drugs affect the brain by either increasing or decreasing postsynaptic transmission.</li> <li>Anesthetics act by interfering with neural transmission between areas of sensory perception and the CNS.</li> <li>Stimulant drugs mimic the stimulation provided by the sympathetic nervous system.</li> <li>Addiction can be affected by genetic predisposition, social environment and dopamine secretion.</li> </ul> <p><b>Applications and skills:</b></p> <ul style="list-style-type: none"> <li>Application: Effects on the nervous system of two stimulants and two sedatives.</li> <li>Application: The effect of anesthetics on awareness.</li> </ul>	<p><b>International-mindedness:</b></p> <ul style="list-style-type: none"> <li>Attitudes to drugs and the use of drugs differ globally. There are many cultures that use drugs to enhance rituals or religious experiences.</li> </ul> <p><b>Utilization:</b></p> <ul style="list-style-type: none"> <li>Many psychoactive drugs have been used therapeutically to treat a range of mental illnesses and psychological disorders.</li> </ul> <p>Syllabus and cross-curricular links:  Chemistry  Option D Medicinal chemistry  Topic D1 Pharmaceutical products and drug action  Topic D3 Opiates  Psychology  Core: Biological level of analysis</p> <p><b>Aims:</b></p> <ul style="list-style-type: none"> <li><b>Aim 8:</b> The social consequences of psychoactive drugs could be considered, for the user, his or her family and the wider society.</li> </ul>

**A.5 Neuropharmacology**

- Application: Endorphins can act as painkillers.
- Skill: Evaluation of data showing the impact of MDMA (ecstasy) on serotonin and dopamine metabolism in the brain.

**Guidance:**

- Examples of stimulants are nicotine, cocaine or amphetamines.
- Examples of sedatives are benzodiazepines, alcohol or tetrahydrocannabinol (THC).

**Essential idea:** Bioinformatics is the use of computers to analyse sequence data in biological research.

B.5 Bioinformatics	
<p><b>Nature of science:</b></p> <p>Cooperation and collaboration between groups of scientists—databases on the internet allow scientists free access to information. (4.3)</p>	
<p><b>Understandings:</b></p> <ul style="list-style-type: none"> <li>Databases allow scientists easy access to information.</li> <li>The body of data stored in databases is increasing exponentially.</li> <li>BLAST searches can identify similar sequences in different organisms.</li> <li>Gene function can be studied using model organisms with similar sequences.</li> <li>Sequence alignment software allows comparison of sequences from different organisms.</li> <li>BLASTn allows nucleotide sequence alignment while BLASTp allows protein alignment.</li> <li>Databases can be searched to compare newly identified sequences with sequences of known function in other organisms.</li> <li>Multiple sequence alignment is used in the study of phylogenetics.</li> <li>EST is an expressed sequence tag that can be used to identify potential genes.</li> </ul> <p><b>Applications and skills:</b></p> <ul style="list-style-type: none"> <li>Application: Use of knockout technology in mice to determine gene function.</li> <li>Application: Discovery of genes by EST data mining.</li> <li>Skill: Explore chromosome 21 in databases (for example in Ensembl).</li> <li>Skill: Use of software to align two proteins.</li> <li>Skill: Use of software to construct simple cladograms and phylograms of related organisms using DNA sequences.</li> </ul>	<p><b>Theory of knowledge:</b></p> <ul style="list-style-type: none"> <li>Knowledge claims justified by reference to databases raise unique knowledge questions. How reliable are knowledge claims justified by reference to data sources developed for different purposes by different researchers using different methods?</li> </ul> <p><b>Aims:</b></p> <ul style="list-style-type: none"> <li><b>Aim 6:</b> Sequence alignment of related proteins such as hemoglobin and myoglobin could be investigated.</li> </ul>