DOT POINT

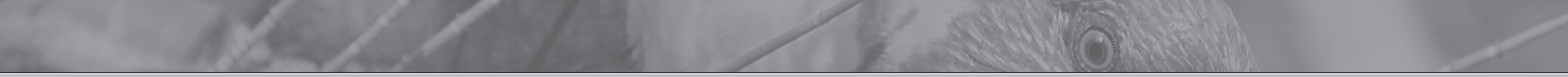
VCE BIOLOGY UNITS 3 AND 4

• Kerri Humphreys •

Science Press

Unit 3 How Do Cells Maintain Life?

Science Press
ISBN 978-0-85583-8522



Unit 4 How Does Life Change and Respond To Challenges?

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Unit 3

How Do Cells Maintain Life?

In this unit you will:

- Explore the relationship between nucleic acids and proteins as key molecules in cellular processes.
- Analyse the structure and function of nucleic acids as information molecules, gene structure and expression in prokaryotic and eukaryotic cells and proteins.
- Examine the biological consequences of manipulating the DNA molecule and applying technologies.
- Learn about the structure, regulation and rate of biochemical pathways, with reference to photosynthesis and cellular respiration.
- Understand how the application of biotechnologies to biochemical pathways could lead to improvements in agricultural practices.
- Apply your knowledge of cellular processes by investigating a selected case study, data analysis and/or bioethical issue.

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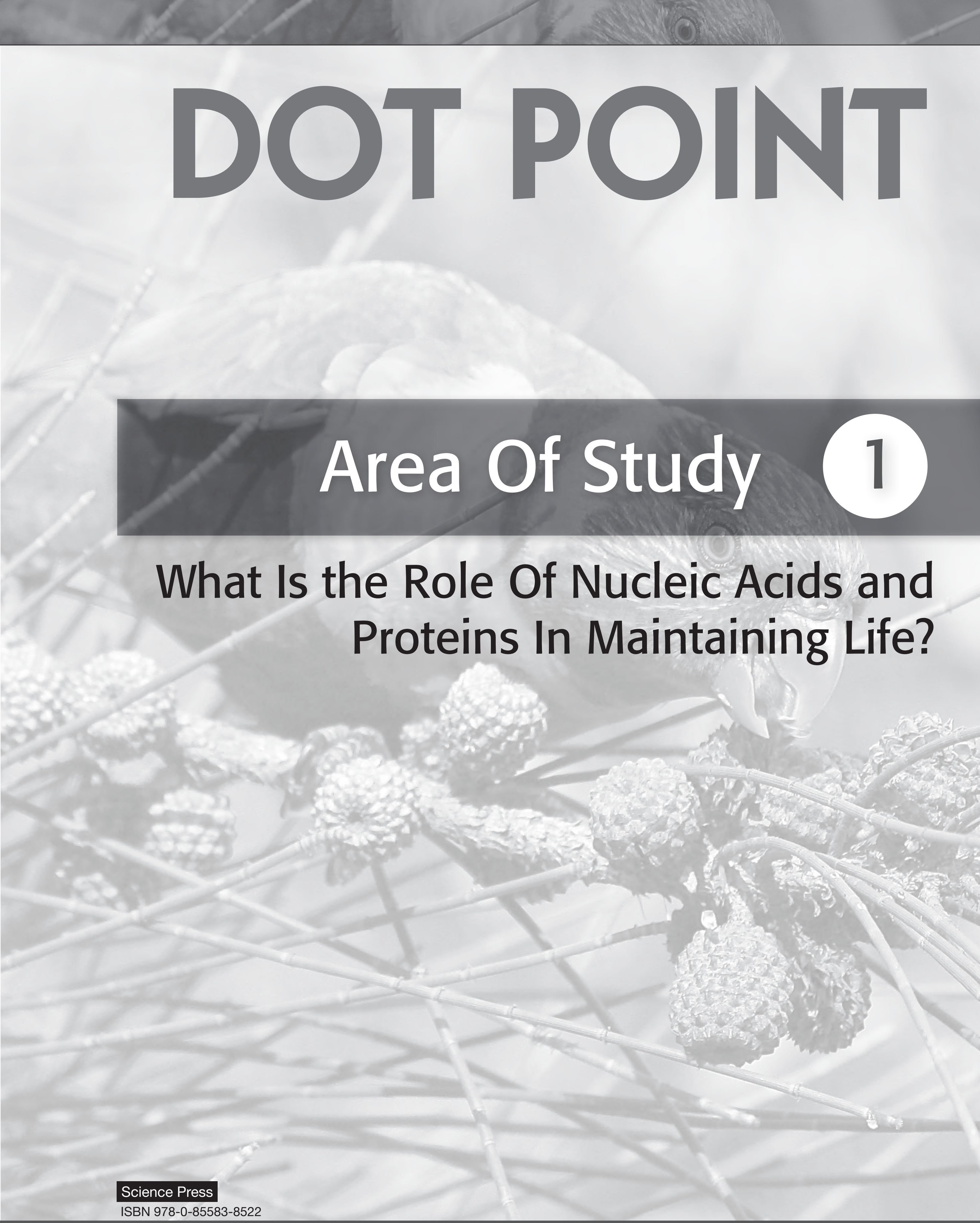

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Area Of Study 1

What Is the Role Of Nucleic Acids and Proteins In Maintaining Life?

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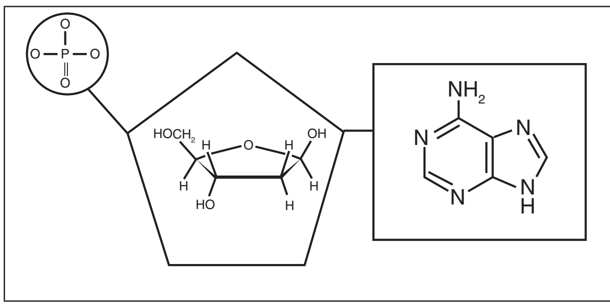
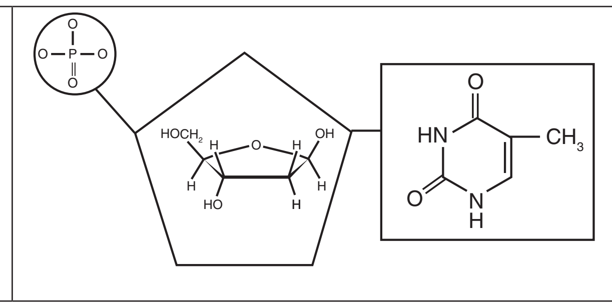
1.1 The relationship between nucleic acids and proteins.

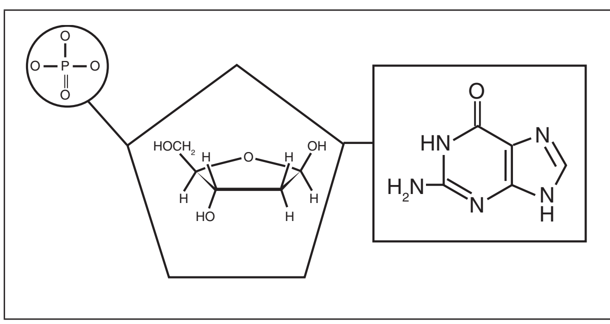
1.1.1 Nucleic acids as information molecules that encode instructions for the synthesis of proteins; the structure of DNA, the three main forms of RNA (mRNA, rRNA and tRNA) and a comparison of their respective nucleotides.

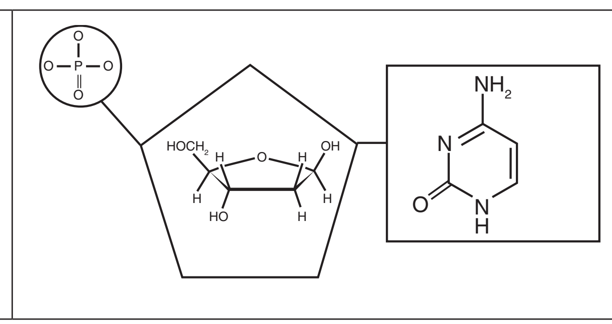
1.1.1.1 Outline the structure of DNA.

1.1.1.2 Complete the table by labelling each of the components of the four nucleotide bases of DNA.









1.1.1.3 Describe the bonding found in DNA.

1.1.1.4 What is formed by the hydrolysis of a nucleotide?

1.1.1.5 In 1953, James Watson and Francis Crick suggested the double helix structure of DNA. Outline how Watson and Crick were able to work out a three-dimensional model of DNA.

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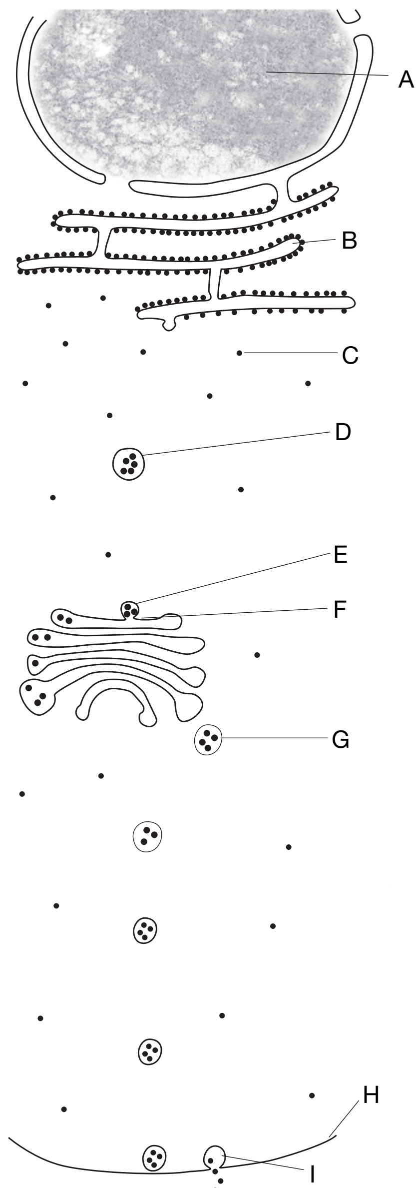
1.1.7 **The role of endoplasmic reticulum, Golgi apparatus and associated vesicles in the export of proteins from a cell via the protein secretory pathway.**

1.1.7.1 Complete the table and label the diagram to show the sequence of events in the production of a protein product to its secretion and export from the cell.

Diagram	What happens at:
	Ribosomes
	Endoplasmic reticulum
	Golgi apparatus
	Plasma membrane

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1.2 DNA manipulation techniques and applications.

1.2.1 The use of enzymes to manipulate DNA, including polymerase to synthesise DNA, ligase to join DNA and endonucleases to cut DNA.

1.2.1.1 Define an endonuclease.

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1.2.1.2 What is a restriction endonuclease?

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1.2.1.3 The diagram shows two ways restriction enzymes can cut DNA. Outline what is happening in each case.

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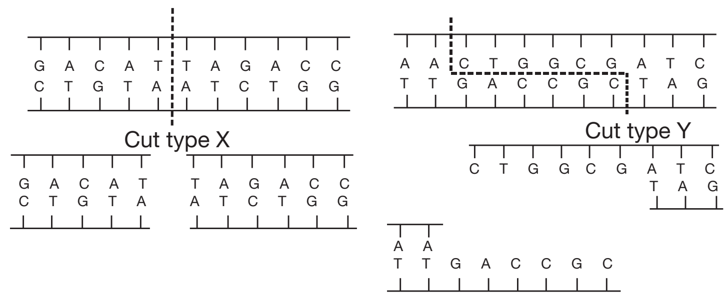

1.2.1.4 What is DNA ligase and define DNA ligation.

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1.2.1.5 Explain why DNA ligase is useful in DNA manipulation.

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1.2.1.6 Explain why DNA ligase from thermophilic bacteria is used in laboratory research.

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1.2.1.7 Explain why DNA ligation in DNA manipulation requires each of the following.

(a) Two or more DNA fragments with either blunt or compatible sticky ends.

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(b) A buffer containing ATP.

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(c) T4 DNA ligase.

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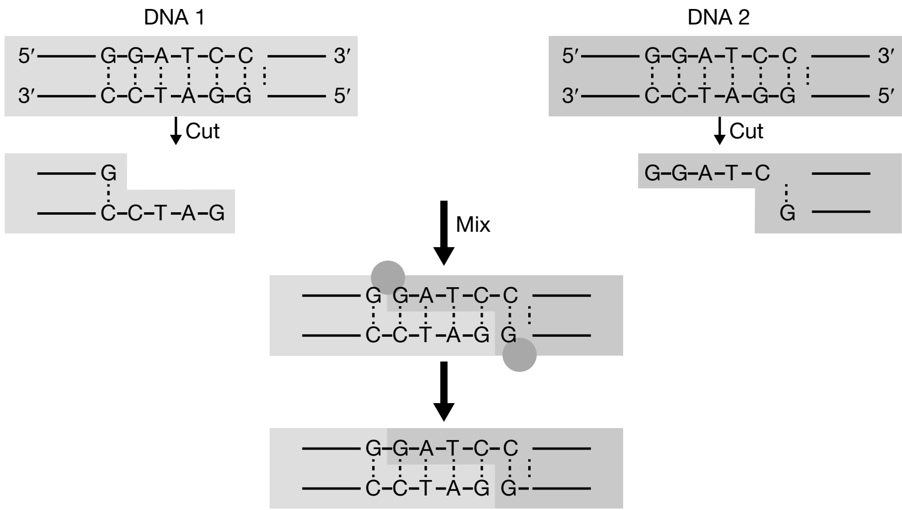
1.2.1.8 Annotate the diagram to indicate what is happening.

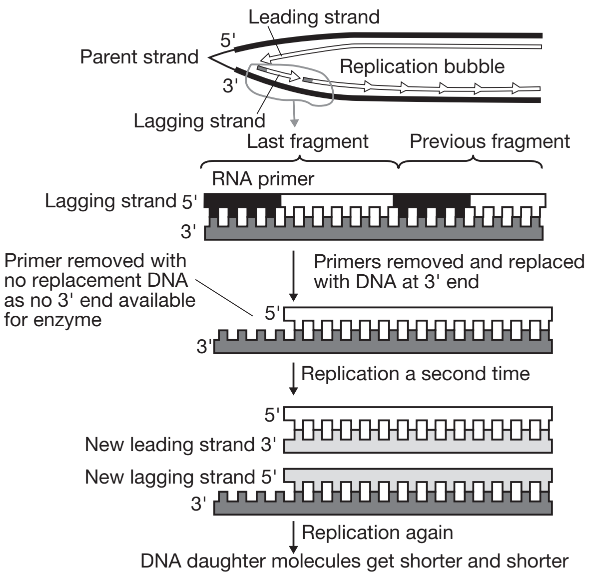


1.2.1.9 Outline how DNA polymerases work.

1.2.1.10 Explain why the action of DNA polymerase results in DNA replication having a leading strand and a lagging strand.

1.2.1.11 Explain why the action of DNA polymerase means there needs to be a primer in DNA replication.

1.2.1.12 Outline the problem that is shown in the diagram of several cycles of DNA replication.



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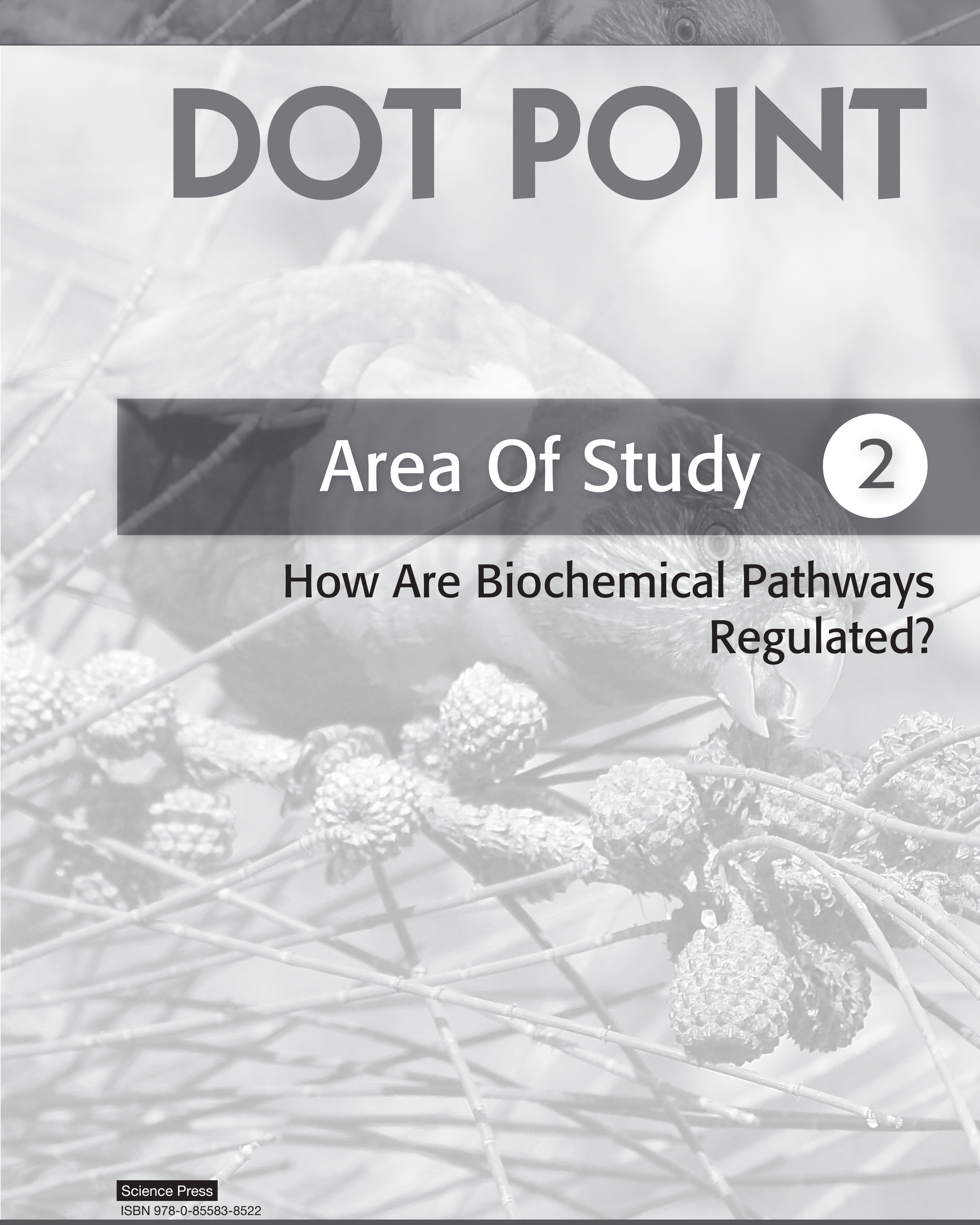

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Area Of Study 2

How Are Biochemical Pathways Regulated?

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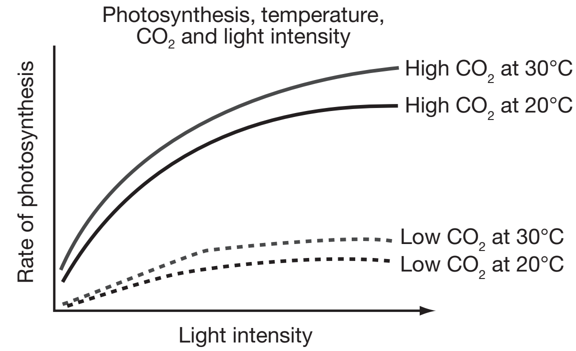
2.2.3.10 The graph shows the rate of photosynthesis at two different concentrations of CO_2, at 20°C and 30°C, for differing light intensities.

Refer to the graph to explain how the levels of carbon dioxide concentration, light intensity and temperature interact to determine the rate of photosynthesis.



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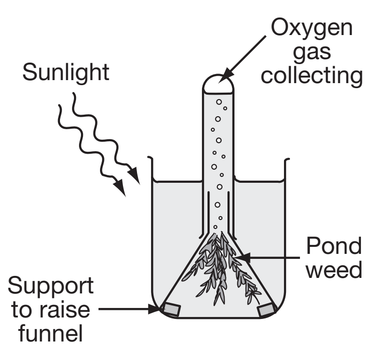
2.2.3.11 Complete the table by explaining each of the three ways of measuring the rate of photosynthesis.

<table>
<tr><th colspan="3">Measuring the rate of photosynthesis</th></tr>
<tr><th>Production of oxygen</th><th>Uptake of CO_2</th><th>Increase in biomass</th></tr>
<tr>
<td>
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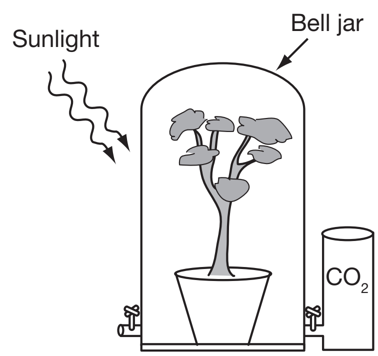
<td>
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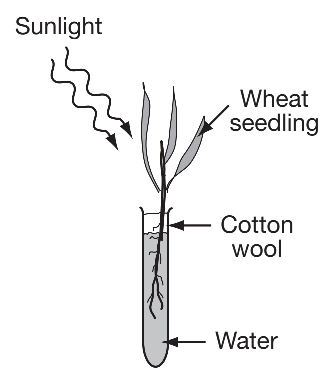
<td>
</td>
</tr>
<tr><td></td><td></td><td></td></tr>
</table>

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2.2.3.19 The diagram shows a row of firemen using a bucket of water to put out a fire.

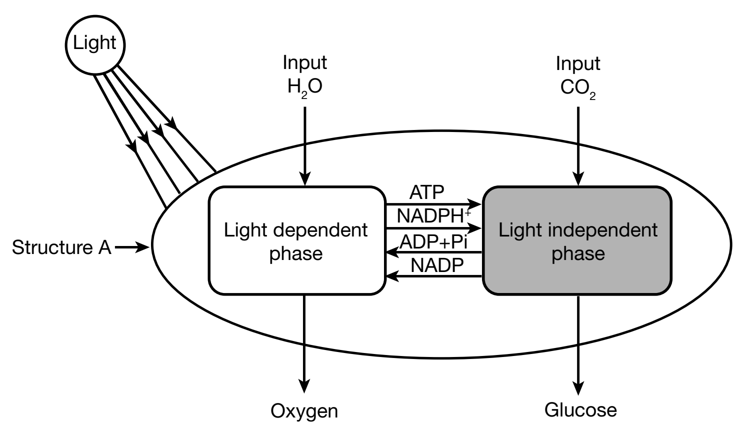
Explain how this diagram is an analogy to show a limiting factor in a reaction.

2.2.3.20 A senior biology student wished to carry out an experiment to determine the effect of varying light availability on photosynthesis.

(a) For such an experiment, identify the independent variable, the dependent variable and the factors the student would need to keep constant.

(b) For such an experiment, explain a possible limiting factor.

2.2.3.21 The diagram summarises photosynthesis.



(a) Identify structure A.

(b) From this diagram, which phase would cease first if the carbon dioxide supply was limited?

(c) In which phase is ATP formed?

(d) How is the ATP used in photosynthesis?

(e) Outline a suitable method for measuring the rate of photosynthesis.

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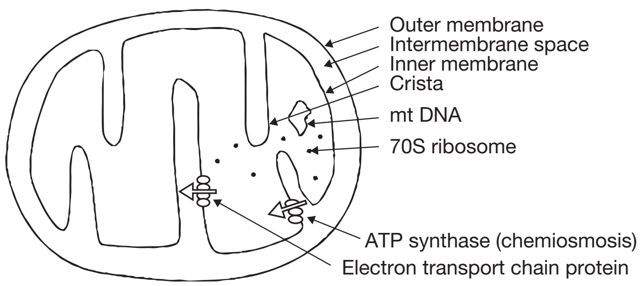
2.3.1.7 What happens to the hydrogen released during glycolysis?

2.3.1.8 Why is glycolysis a catabolic reaction?

2.3.1.9 Where is the location of glycolysis?

2.3.1.10 Define chemiosmosis.

2.3.1.11 The diagram shows a cross-section of a mitochondrion.



How are mitochondria involved in cellular respiration?

2.3.1.12 Use an example to explain why some cells have many more mitochondria than other cells.

2.3.1.13 Outline the evidence of the bacterial origins of mitochondria.

2.3.1.14 Define the Krebs cycle.

2.3.1.15 What is the electron transport chain?

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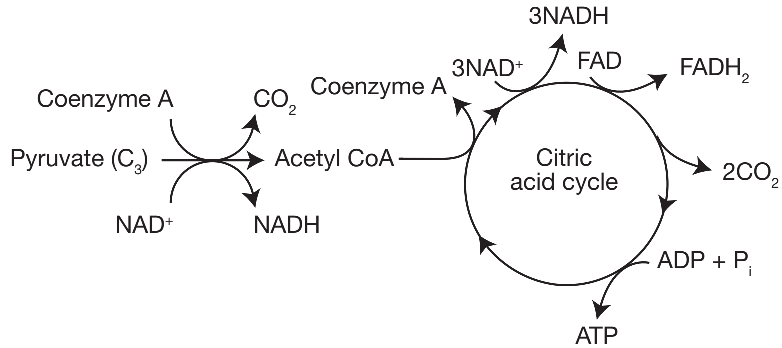
2.3.1.16 The first stage of respiration is glycolysis. The diagram shows what happens in the second stage of aerobic respiration after the formation of pyruvate.



From the diagram, what happens after glycolysis?

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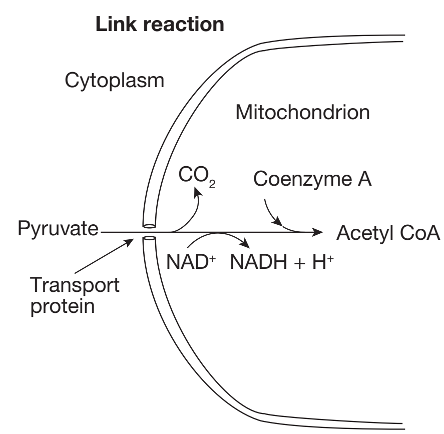
2.3.1.17 The diagram shows the link reaction. What is the link reaction?



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2.3.1.18 Explain how NAD^+ is involved in respiration.

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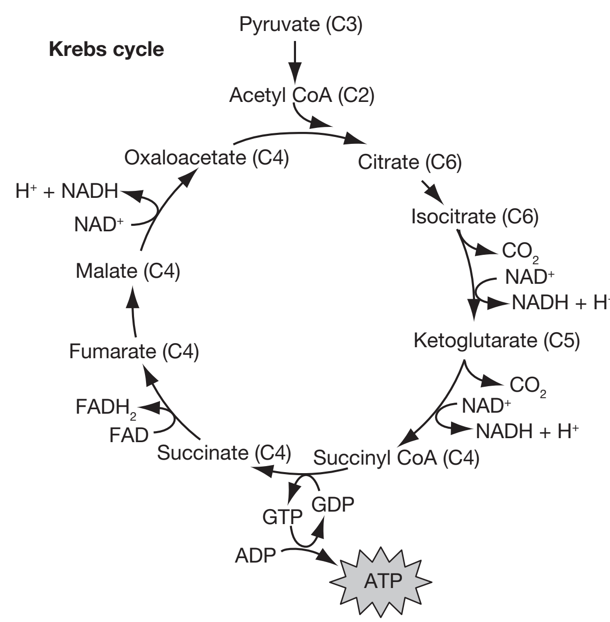
2.3.1.19 Complete the table to summarise the different aspects of the Krebs cycle.



Aspect	Description
Beginning of cycle	
Waste products of cycle	
Net energy gain	
C2 + C4 = C6 → C5 → C4 and cycles	

2.3.1.20 Outline how NADH and oxygen are involved with the electron transport chain.

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Unit 4

How Does Life Change and Respond To Challenges?

In this unit you will:

- Study the human immune system and the interactions between its components to provide immunity to a specific pathogen.
- Consider how the application of biological knowledge can be used to respond to bioethical challenges related to disease.
- Investigate the impact of various change events on a population's gene pool and the biological consequences of changes in allele frequencies.
- Examine the evidence for links between species and change in life forms over time using evidence from palaeontology, structural morphology, molecular homology and comparative genomics.
- Analyse evidence for structural trends in the human fossil record and recognise that interpretations can be contested, refined or replaced when challenged by new evidence.
- Apply your knowledge of how life changes and responds to challenges by investigating a selected case study, data analysis and/or bioethical issue.

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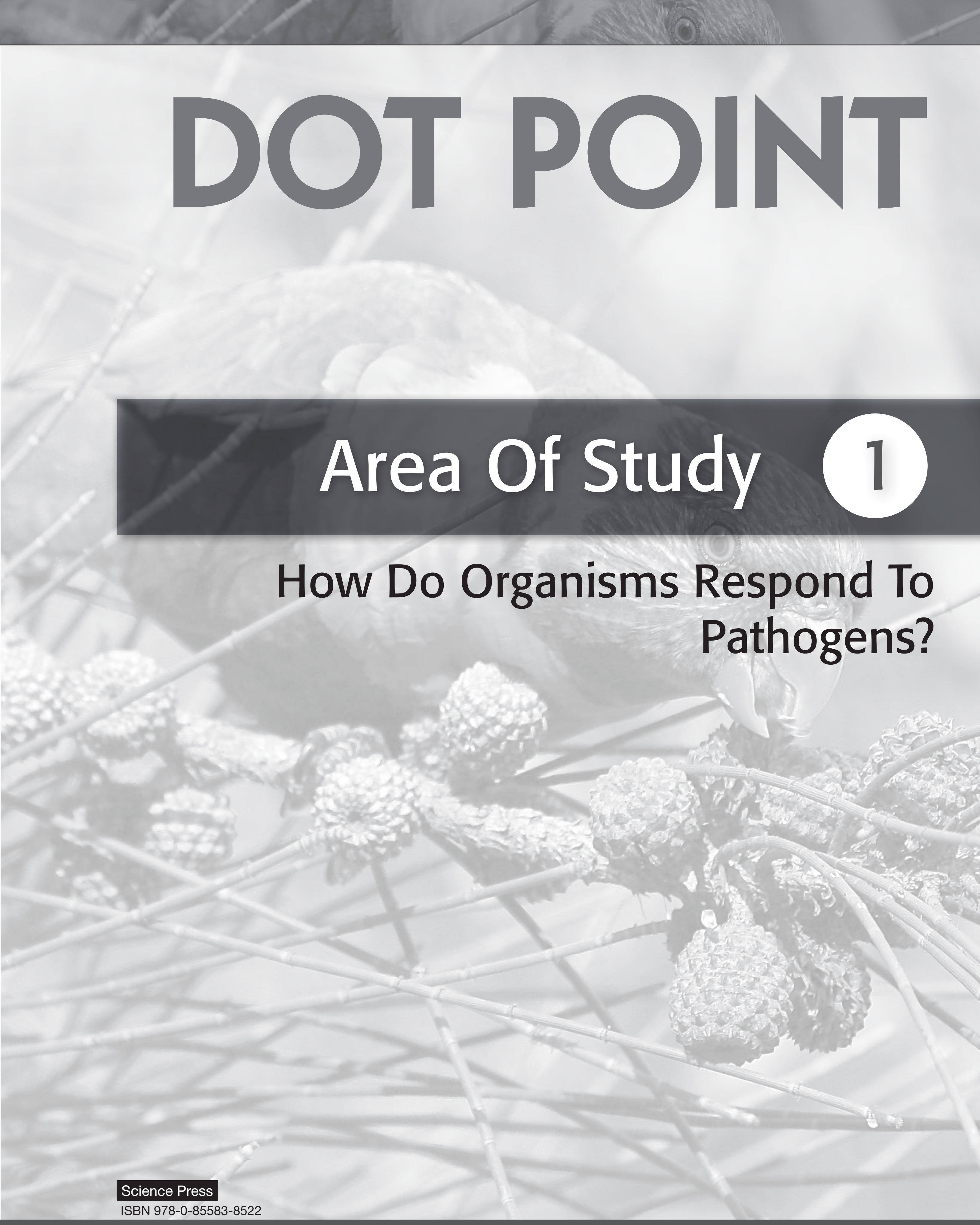

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Area Of Study 1

How Do Organisms Respond To Pathogens?

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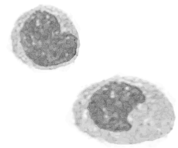
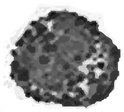
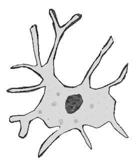
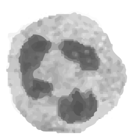
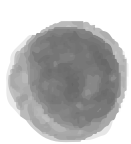
1.1.2.13 Complete the table to summarise the function of each of these cells.

Cell	Diagram	Function
Monocyte and macrophage		
Mast cell		
Dendritic cell		
Neutrophils		
Eosinophils		
Natural killer (NK) cells		
Lymphocyte		

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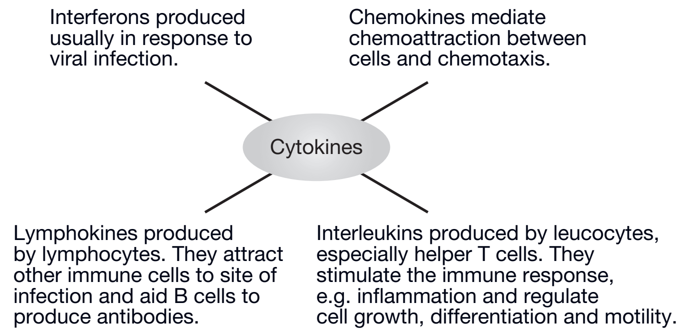
1.1.2.14 What is meant by the complement system being a cascade of steps?

1.1.2.15 Explain why pus often forms at sites of infection and the inflammatory response.

1.1.2.16

(a) What are cytokines?



(b) Explain why cytokines are an essential part of the inflammatory response.

1.1.2.17

(a) What are interferons?

(b) What is the function of interferons?

(c) In what situations are interferons most effective?

1.1.2.18 Describe how the cell death to seal off pathogens is a defence adaptation.

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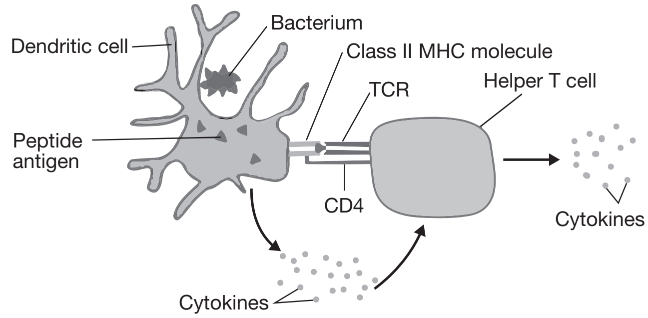
1.1.3.10 Use the diagram to explain the process of antigen presentation.



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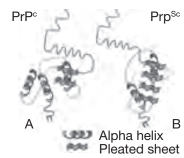
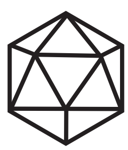
1.1.3.11 Complete the table to summarise the different types of pathogens.

Type of pathogen	Pathogen	Diagram of example	Description	Disease example
Non-cellular	Prion	 A – Normal prion B – Abnormal prion		
	Virus	 Papilloma virus		
Cellular	Bacteria	 Bacillus		
	Protozoan	 Flagellate		
	Fungi	 Yeast		
	Macro-parasites	 Tapeworm		

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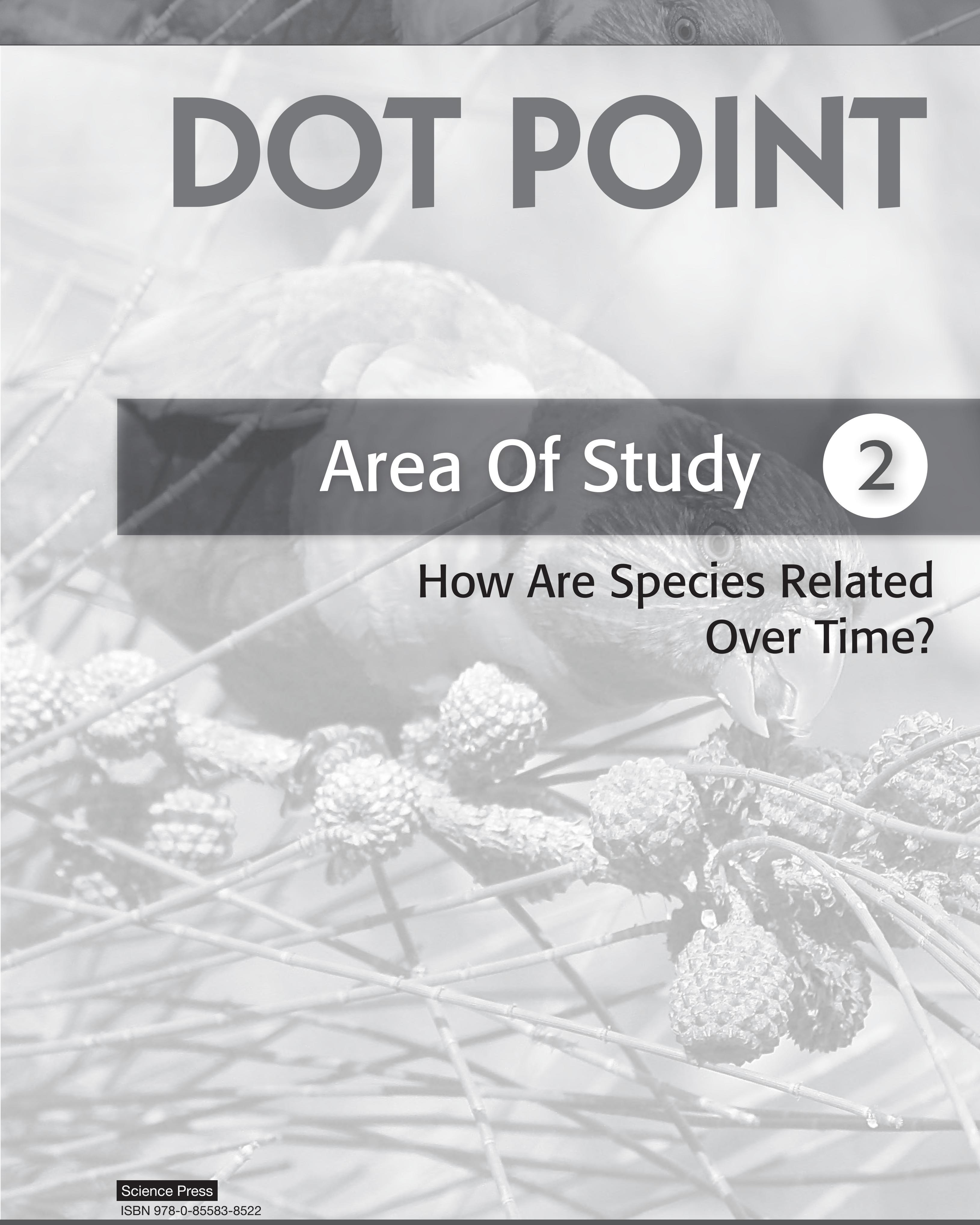

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Area Of Study 2

How Are Species Related Over Time?

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2.1.1.11 Outline the importance of mutation in gene pools.

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2.1.1.12 About 95% of DNA is non-coding. Suggest a reason why most point mutations have no genetic consequence and use an example to show how a point mutation and its subsequent change in the DNA sequence can have a dramatic effect on an individual.

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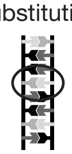
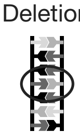
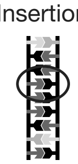
2.1.1.13 Complete the table to summarise different types of point mutations.

Original base pair codes 			
Substitution 	Deletion 	Insertion 	Inversion 

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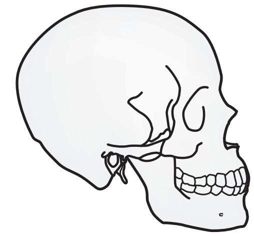
2.4.2.4 Complete the table to compare the structural, functional and cognitive differences between *H. erectus* and *H. sapiens*.

Change	Change	*Homo erectus*	*Homo sapiens*
Biological	Appearance		
	Forehead		
	Brain size		
	Brow ridge		
	Chin		
	Face		
Cultural	Tools		
	Lifestyle		

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Answers

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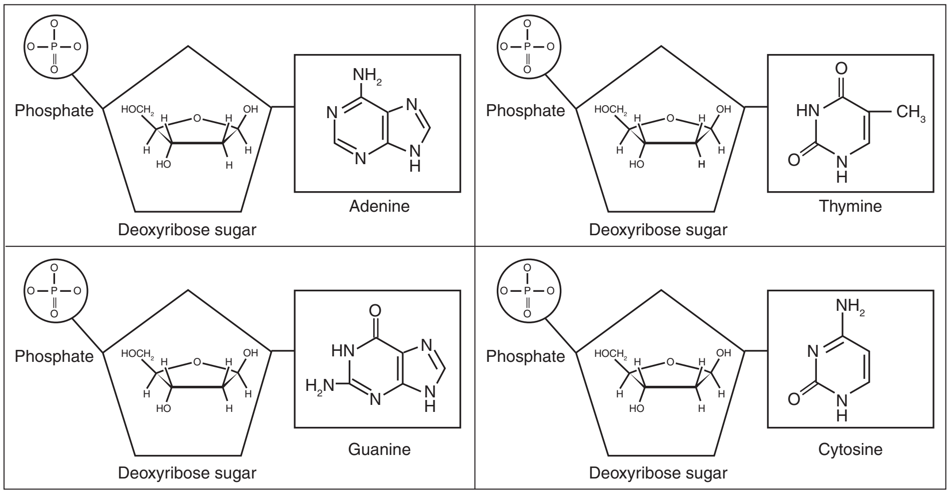
Unit 3 How Do Cells Maintain Life?

1.1.1.1 DNA is a double stranded helical nucleic acid molecule consisting of nucleotide monomers with a deoxyribose sugar and the nitrogenous bases adenine (A), thymine (T), cytosine (C) and guanine (G). DNA is a right handed spiral polymer with the backbone section consisting of a phosphate and pentose sugar and one of the four possible nitrogenous bases is attached to the deoxyribose sugar. The overall structure is a ladder that is twisted into a spiral to form a double helix.

1.1.1.2

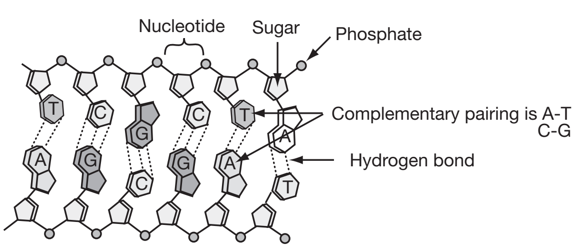


1.1.1.3 The base pairs on the rungs of the ladder are held together by hydrogen bonds and by van der Waals interactions between the stacked bases. The nucleotides are joined together by covalent bonds between the phosphate group of one nucleotide and the sugar of the next. These bonds are called phosphodiester linkages and occur between the –OH group on the 3' carbon of one nucleotide and the phosphate on the 5' carbon of the next.

1.1.1.4 Hydrolysis of a nucleotide form a pentose sugar, nitrogenous bases and phosphoric acid.

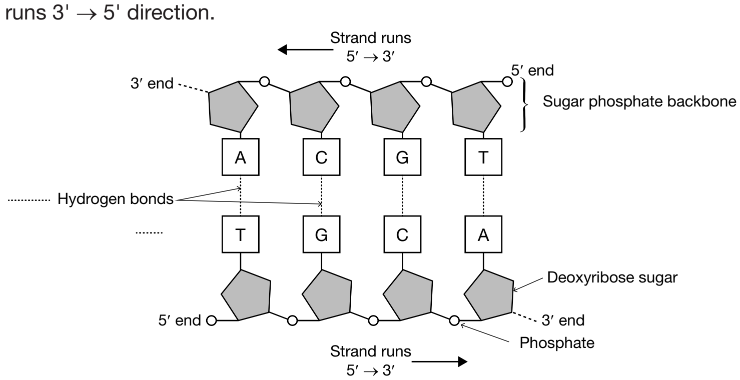
1.1.1.5 Watson and Crick based the double helix structure on X-ray diffraction photographs of DNA taken by Rosalind Franklin. Maurice Wilkins was Franklin's colleague and showed her X-ray photographs to Watson. From the photographs Watson and Crick constructed a ball and stick model that showed how the atoms and chemical bonding formed the DNA molecule.

1.1.1.6 Double strand of DNA – with double helix 'untwisted'



1.1.1.7 The two stands of DNA are called antiparallel as one sugar phosphate backbone runs 5' → 3' direction while the other strand runs 3' → 5' direction.

1.1.1.8



The diagram shows how the two strands of DNA are antiparallel – they run in opposite 5' → 3' directions. Each end of the double helix has an exposed 5' phosphate on one strand and an exposed 3' hydroxyl group on the other.

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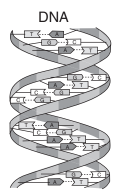
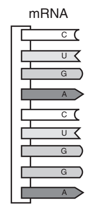
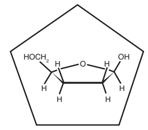
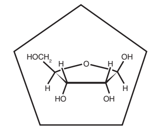
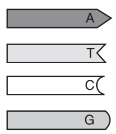
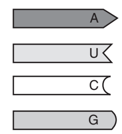
1.1.1.9 Dissociation of a DNA double helix means the helical strands of the DNA molecule separate to form two single chains of DNA. The heating breaks the hydrogen bonds between the complementary nitrogenous bases but not the strong sugar phosphate bonds that join the nucleotides together to form the backbone chain.

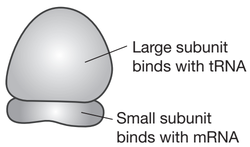
1.1.1.10

Feature	DNA		RNA	
	Diagram	Description	Diagram	Description
Shape		Double helix – two strands		Usually single strand
Sugar		Deoxyribose sugar		Ribose sugar
Bases		Adenine, thymine, cytosine guanine		Adenine, uracil, cytosine, guanine

1.1.1.11

Feature	mRNA	tRNA	rRNA
Definition	Messenger RNA is RNA that has been transcribed from DNA and specifies the amino acid sequence of a protein.	Transfer RNA are RNA molecules that bind to specific amino acids and aid the synthesis of the polypeptide at a ribosome with their anticodon binding to complementary mRNA codons.	Ribosomal RNA is the component of ribosomes found in the cytoplasm directing the translation of mRNA into proteins.
Formation	mRNA forms during gene expression when the enzyme RNA polymerase splits apart the two strands of DNA and joins together RNA nucleotides complementary to the DNA template strand.	Formation of tRNA is controlled by the DNA in the cell.	Formation of rRNA involves a series of steps transcribing rRNA genes.

1.1.1.12 Ribosome structure



1.1.1.13 The basic structure and function of ribosomes are the same in prokaryotes and eukaryotes with both subunits of ribosomes consisting of proteins and ribosomal RNA (rRNA). Ribosomes in prokaryotes exist as 70S (Svedberg units which measure size and density), in prokaryotes and 80S in eukaryotes. The 70S ribosome is a combination of the 50S subunit and 30S subunit with the 50S subunit having two rRNAs and the 30S subunit having one rRNA. In eukaryotes the 60S subunit has three rRNAs and the 40S subunit has one rRNA.

1.1.1.14 A polysome or polyribosome is a cluster of ribosomes, bound to one mRNA.

1.1.1.15 The nucleosome is the basic unit of eukayotic DNA consisting of a section of DNA wound around a protein core which contains eight histone proteins (two copies of each of four types of histone). It is held together by another histone protein. They protect the DNA from damage and allow long lengths of DNA to be packaged, e.g. to assist movement in mitosis and meiosis.

1.1.1.16 DNA supercoiling refers to the compaction of DNA with the DNA wrapping around itself. Chromatin normally has a compact structure with nucleosomes interacting, e.g. interactions between histone tails, linker DNA and between adjacent nucleosomes leads to DNA supercoiling. Supercoiling reduces the space needed for DNA and is required for DNA/RNA synthesis and regulating transcription. Transcription cannot occur in such a supercoiled region. If the histone tails are acetylated, the chromatin becomes less compact, there is a looser structure and transcription can begin. Thus nucleosomes with supercoiling regulate transcription and gene expression.

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2.1.2.11 (a) ATP (adenosine triphosphate) contains stored energy in high energy bonds and acts as a reservoir of potential energy. ATP releases energy when the terminal phosphate group is cut from the molecule in a hydrolysis reaction to form ADP (adenosine diphosphate). The free energy is approximately 30 to 33 kJ mol^{-1}. Hydrolysis of ADP to AMP (adenosine monophosphate) releases a similar amount of energy.

(b) The triphosphate tail of ATP is unstable as the three phosphate groups are negatively charged causing mutual repulsion.

(c) The cycling of ATP/ADP as loaded and unloaded forms of energy drives active transport, e.g. across plasma membranes and mechanical work, e.g. driving motor proteins that move vesicles along the cytoskeleton in cells.

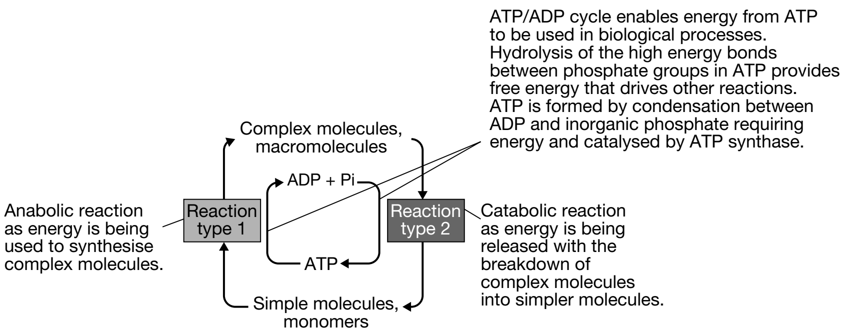
2.1.2.12 (a) NAD is a derivative of the vitamin niacin and is found in all living cells acting as an electron carrier. NAD^+ is an oxidising agent in redox reactions accepting electrons from other molecules to become reduced. NADH acts as a reducing agent in redox reactions donating electrons.

(b) NADP acts as an electron acceptor that stores energy in the form NADPH (reduced form) and cycles with $NADP^+$ (oxidised form), e.g. NADPH stores energised electrons produced during the light reactions of photosynthesis and is important in the biosynthesis of fats, e.g. cholesterol and biosynthesis of sugars.

2.1.2.13 The extra phosphate group on NADP, compared with NAD, means that although these two coenzymes are very similar they are able to interact with different sets of enzymes and participate in different chemical reactions. In cells the oxidised form NAD^+ is usually readily available to help oxidative reactions, e.g. glycolysis. While in cells the reduced form NADPH is usually the form available to help reductive reactions in biosynthesis. NADPH is mainly involved in anabolic reactions where it is a reducing agent and NADH is mostly in catabolic reactions where NAD^+ is an oxidising agent.

2.1.2.14 Anabolic reactions involve an input of energy for the synthesis of complex molecules from simpler molecules whereas catabolic reactions involve the release of energy by breaking down complex molecules to simpler molecules.

2.1.2.15



2.1.2.16

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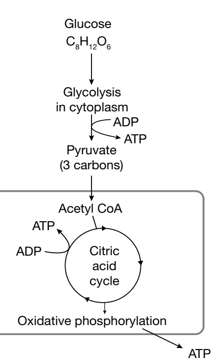
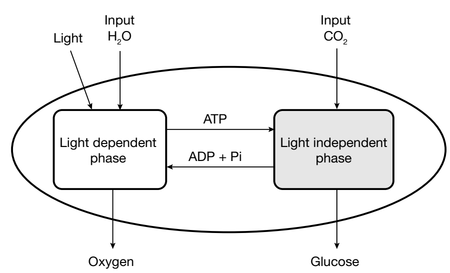
<tr><th>Coenzyme</th><th>Respiration</th><th>Photosynthesis</th></tr>
<tr><td>ATP/ADP</td><td>
</td><td>
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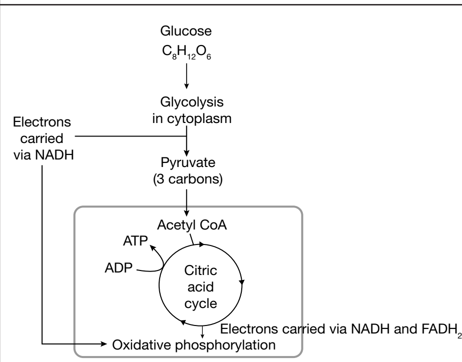
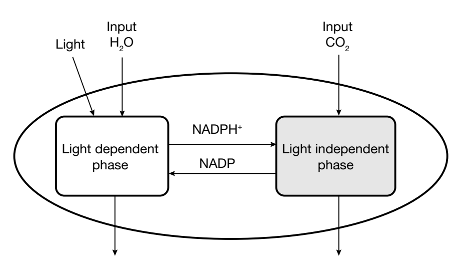
<tr><td>NAD/NADH
NADP/NADPH</td><td>
</td><td>
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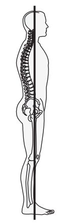
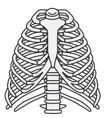
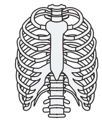
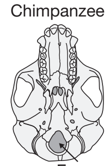
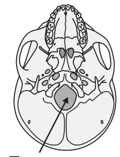
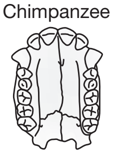
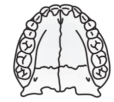
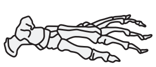
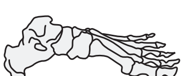
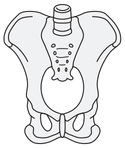
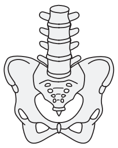
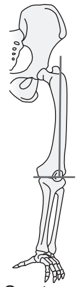
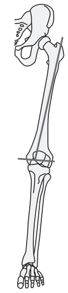
2.4.1.5

Feature	Ape		Human	
	Diagram	Description	Diagram	Description
Cranial capacity		Brain large.		Brain much larger with pronounced ‘forehead’ and larger cerebral cortex. Allows greater abstract thought and problem solving.
Shape of spine	 Chimpanzee	C shaped spine with forward centre of gravity.		S shaped spine with centre of gravity over hips assists bipedal locomotion.
Shape of rib cage		Apes have powerful neck muscles and a cone shaped rib cage.		The human head balances on the backbone giving humans a more barrel shaped rib cage.
Position of foramen magnum	Chimpanzee  Foramen magnum	At back of skull.	 Foramen magnum	Well forward for upright posture, sits vertically beneath the top of the skull.
Teeth and jaw	Chimpanzee 	U shaped tooth row with large canines, especially in males.		Bow shaped tooth row and canines small in both sexes. Teeth covered in thick enamel.
Feet	 Gorilla	Big toe is opposable to some degree.	 Human	Big toe is not opposable and is the last point of contact with the ground when walking, giving the human footprint distinctive features. Human foot has two arches (longitudinal and transverse) that help absorb shocks. Transverse arch is unique to humans.
Hip	 Great ape	Long narrow pelvis has hip joint with thigh bone angled at right angles to knee.	 Human	Short broad pelvis for muscle attachment for bipedal location, e.g. gluteus maximus to lift pelvis when opposite leg is off the ground. Short broad pelvis has hip with thigh bone angled outwards from knee.
Knee	 Great ape	Carrying angle (valgus angle) of knee is at right angles to thigh bone.	 Human	Angled out from the knee so that weight distribution remains closer to the central axis to give stability when walking.

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