

CIE BIOLOGY 2

Cambridge International Examination

A Level Year 2 | **Student Workbook**

**CLASSROOM
GUIDE**



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FAQs ABOUT OUR CIE BIOLOGY 2 STUDENT WORKBOOK

BIOZONE
CIE BIOLOGY 2
Cambridge International Examination
A Level Year 2 | Student Workbook



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Meeting Key Competencies

We want today's biology students to be self-motivated, lifelong learners, to develop a sound grasp of biological knowledge, to plan and evaluate their work, and to think critically and independently. In developing CIE Biology 2, we have utilised the 5Es instructional model as a basis for developing materials to specifically address the CIE Biology syllabus. By successfully completing the activities, which make up the bulk of the student workbook, students can demonstrate competence in skills and knowledge. BIOZONE's workbooks and associated products provide a varied and interesting suite of resources which, if used effectively, can help your students achieve key competencies in all areas of biology.



BIOZONE encourages the development of an independent learner profile using the 5 Es model

The Five Es

- Engage:** make connections between past and present learning experiences.
- Explore:** become actively involved in the activity.
- Explain:** communicate the learning experience.
- Elaborate:** expand on the concepts learned.
- Evaluate:** assess understanding of the concepts.

ENGAGE: Highly visual activities	Use activities in class to engage a student when introducing a topic, or to consolidate student understanding and summarise the material covered by other methods. Using activities in class provides valuable opportunities for peer-to-peer learning.
ENGAGE: A connected plan of study	The check-box format of the contents pages and the chapter introductions provides a focus for planning achievement.
EXPLORE: Independent, self directed study	Activities are self-contained so students are encouraged to be independent learners and seek the answers to questions posed by the activity. Capable students can work quickly and independently through the material and can use the time for extension. Less able students can review or finish activities at home. Most activities are supported by web-based resources in the form of animations and video clips.
EXPLAIN: Communicating is the key to consolidation	All activities first engage the student with a key idea and a visually inviting delivery of content. Student engagement with this material leads them to the questions in which they must communicate their understanding of the content. Students are encouraged to use appropriate biological terms as referenced in the chapter introduction (key terms).
ELABORATE: Building up	Most introductory activities are supported by activities in which students apply their understanding of ideas to a new situation. These 'follow-on' activities often involve data analysis, and support science practices.
EVALUATE: Easy assessment	Encourage self assessment with chapter reviews (these can be graded if desired) or use specific activities to evaluate a student's skills and understanding or ideas.
WHAT ABOUT HOMEWORK?	Assign activities as homework to review a completed topic, explore a related concept, or introduce a topic prior to in-class practical work.



The Contents: A Planning Tool

The contents pages are not merely a list of the activities in the workbook. They serve as a planning tool for the programme of work to be completed. Students can identify the activities they are to complete and then tick them off when completed. The teacher can also see at a glance how quickly the student is progressing through the assigned material.

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Activity is marked: ☐ to be done; ☒ when completed

The teacher can see at a glance how this student is progressing through this unit of work. Any concerns with progress can be addressed early.

Students can mark the check boxes to indicate the activities they should complete. This helps them to quantify the work to be done and plan their work.

Control and coordination

<p><input checked="" type="checkbox"/> 48 Nervous System Regulation 61</p> <p><input checked="" type="checkbox"/> 49 Neurone Structure 62</p> <p><input checked="" type="checkbox"/> 50 The Basis of Sensory Reception 63</p> <p><input checked="" type="checkbox"/> 51 A Sensory Receptor 64</p> <p><input checked="" type="checkbox"/> 52 Reflexes 65</p> <p><input checked="" type="checkbox"/> 53 The Nerve Impulse 66</p> <p><input checked="" type="checkbox"/> 54 The Cholinergic Synapse 68</p> <p><input checked="" type="checkbox"/> 55 Integration at Synapses 69</p> <p><input checked="" type="checkbox"/> 56 Neuromuscular Junction 70</p> <p><input checked="" type="checkbox"/> 57 Skeletal Muscle Structure and Function 71</p> <p><input type="checkbox"/> 58 The Sliding Filament Theory 73</p> <p><input type="checkbox"/> 59 Hormones and the Control of the Menstrual Cycle 74</p> <p><input type="checkbox"/> 60 Control of Reproduction 76</p> <p><input type="checkbox"/> 61 Plant Responses 77</p>	<p><i>Learning Outcomes</i> 60</p>
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Introducing the CIE Biology 2 Content

Each chapter in CIE Biology 2 is prefaced with a one page introduction, providing students with an overview of the chapter content and organisation. Each of the numbered learning outcomes pertains to a point of key knowledge or a skill, and is matched to one or more activities. A list of key terms for the chapter is also included. The comprehensive, but accessible, list of learning outcomes encourages students to approach each topic confidently. Familiarity with the scientific terms used in each topic is implicit in this.

This identifies the part of the course to which this chapter applies.

Topic 12

Energy and respiration

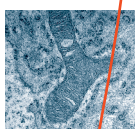
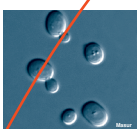
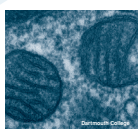
The list of **key terms** can be used to create a glossary for revision and encourages appropriate use of the correct terms when answering questions.

Key terms
acetyl coA
aerobic respiration
anaerobic metabolism
ATP
ATP synthase
cellular respiration
chemiosmosis
cristae
decarboxylation
dehydrogenation
electron transport chain
ethanol
FAD
fermentation
glycolysis
Krebs cycle
lactic acid
link reaction
matrix
mitochondrion
NAD
oxidative phosphorylation
pyruvate
respirometer
substrate level phosphorylation
triose phosphate

12.1 Energy

Learning outcomes

- ☒ 1 Explain reaction
- ☐ 2 Describe Explain
- ☐ 3 Outline the roles of the coenzymes NAD, FAD, and coenzyme A in respiration.
- ☐ 4 Explain how the synthesis of ATP is associated with electron transport in the membranes of mitochondria and chloroplasts.
- ☐ 5 Describe and explain the relative energy values of carbohydrates, lipids, and proteins as respiratory substrates. Describe how respiratory quotients (RQ) can be used to determine the respiratory substrate being utilised. Calculate and interpret RQ values for organisms in different conditions.
- ☐ 6 **PRAC** Use simple respirometers to determine the RQ of living organisms.



12.2 Respiration

Learning outcomes

- ☐ 7 Identify the four stages of aerobic respiration and their location.
- ☐ 8 Outline glycolysis and recognise it as the major anaerobic pathway in cells. State the net yield of ATP and NADH₂ from glycolysis.
- ☐ 9 Describe the link reaction to include decarboxylation of pyruvate, reduction of NAD, and formation of acetyl coenzyme A.
- ☐ 10 Outline the Krebs cycle including reference to the stepwise oxidation of intermediates and the importance of decarboxylation, dehydrogenation, reduction of NAD and FAD, and substrate level phosphorylation.
- ☐ 11 Explain oxidative phosphorylation in the electron transport chain to include the roles of electron carriers in the mitochondrial cristae and the role of oxygen as the terminal electron acceptor.
- ☐ 12 Describe the relationship between structure and function of the mitochondrion using diagrams and electron micrographs.
- ☐ 13 Describe chemiosmotic theory as an explanation for ATP generation in oxidative phosphorylation and photophosphorylation (in photosynthesis).
- ☐ 14 Compare aerobic and anaerobic pathways for ATP generation in eukaryotes to include alcoholic fermentation in yeast and lactic acid fermentation in mammalian muscle, including the concept of oxygen debt. Compare and explain the differences in ATP yield from aerobic respiration and from fermentation.
- ☐ **PRAC** Investigate factors affecting fermentation in yeast using a redox indicator.
- ☐ 16 Explain how rice is adapted to grow in anaerobic conditions with reference to its tolerance for ethanol and the presence of aerenchyma tissue.
- ☐ 17 **PRAC** Use a simple respirometer to investigate the effect of temperature on the respiration rate of germinating seeds or small invertebrates.

Activity number

1
2
3
4
5
6
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The activities in the workbook with the activities pertaining to these key knowledge outcomes

For students:

Key knowledge and skills are drawn from the study design. They are purposefully brief, with enough information to provide a framework, but not so much that students are overwhelmed.

Activities that cover practical skills are identified.

Introduce the concept with a grounding activity

Follow with an activity expanding on that concept

1 The Role of ATP in Cells

Key Idea ATP transports chemical energy within the cell for use in various metabolic processes. All organisms require energy to be able to perform the metabolic processes required for them to function and reproduce. This energy is provided by cellular respiration, a set of metabolic reactions that ultimately convert a set of metabolic reactions that ultimately convert

Adenosine triphosphate (ATP)
The ATP molecule consists of three components: a purine base (adenine), a five-carbon sugar (ribose), and three phosphate groups which attach to the 5' carbon of the purine sugar. The structure of ATP is described below.

The bonds between the phosphate groups contain electrons in a high energy state which store a large amount of energy. The energy is released during ATP hydrolysis. Typically, hydrolysis is coupled to another cellular reaction to which the energy is transferred. The end products of the reaction are adenosine diphosphate (ADP) and an inorganic phosphate (P_i).

Note that energy is released during the formation of bonds during the hydrolysis reaction, not the breaking of bonds between the phosphate (which requires energy input).

The mitochondrion
Cellular respiration and ATP production occur in mitochondria. A mitochondrion is bounded by a double membrane. The inner and outer membranes are separated by an intermembrane space, compartmentalising the regions where the different reactions of cellular respiration take place. The folded inner membranes provide a large surface area for reactions.

Phospholipids are the main components of the mitochondrial membrane. ATP synthase is a protein embedded in the inner mitochondrial membrane. It is responsible for the synthesis of ATP from ADP and P_i during oxidative phosphorylation.

ATP is required when bacteria divide by binary fission (left). The energy released from the breakdown of ATP is used to power the synthesis of new DNA, replication and to synthesise components of the peptidoglycan cell wall.

Maintaining body temperature requires energy. To maintain body heat, muscular activity (exercise) is essential. Contracting muscles require energy. For example, swimming is an energy requiring process involving contracting muscles and the release of energy from glucose in the muscle.

1 Why do organisms need to respire?

2 (a) Describe the general role of mitochondria in cell respiration.

(b) Explain the importance of compartmentalisation in the mitochondrion.

3 Explain why thermoregulation is associated with energy expenditure.

KNOW **1** **2** **3** **7**

2 ATP and Energy

Key Idea ATP is the universal energy carrier in cells. Energy is stored in the chemical bonds between the phosphate groups. The molecule ATP (adenosine triphosphate) is the universal energy carrier for the cell. ATP can release its energy quickly by hydrolysis of the terminal phosphate. This reaction is catalysed by the enzyme ATPase. Once ATP has released its energy, it becomes ADP (adenosine diphosphate), a low energy molecule that can be recharged by adding a phosphate. The energy to do this is supplied by the controlled breakdown of respiratory substrates in cellular respiration.

How does ATP provide energy?
ATP releases its energy during hydrolysis. Water is split and added to the terminal phosphate group resulting in ADP and P_i. For every mole of ATP hydrolysed, 30.5 kJ of energy is released. Note that energy is released during the formation of chemical bonds, not from the breaking of chemical bonds.

Hydrolysis is the addition of water. ATP hydrolysis gives ADP + P_i (H₂O → H⁺ + OH⁻).

The enzyme **ATPase** is able to couple the hydrolysis of ATP directly to the formation of a phosphorylated intermediate (A-P).

A-P is more reactive than A. It is more able to react with B.

In many textbooks the reaction series above is simplified and the intermediates are left out.

ATP → **ADP + P_i**

ADP + P_i → **ATP**

1 (a) How does ATP supply energy to power metabolism?

(b) In what way is the ADP/ATP system like a rechargeable battery?

2 What is the immediate source of energy for reforming ATP from ADP?

3 Which enzyme catalyses the hydrolysis of ATP?

4 Explain why highly active cells (e.g. sperm cells) have large numbers of mitochondria.

KNOW **7** **3** **1** **2**



Finding Your Way Around

The content of the CIE Biology 2 is organised into 8 chapters, each one beginning with an introduction and concluding with a student's self-test of understanding and vocabulary. Inviting, concept-based activities make up the bulk of each chapter, with each activity focussing on the student developing an understanding of a concept, applying that understanding to another scenario, and/or developing an essential skill, such as graphing, data analysis, or biological drawing. An important feature of each activity is the key idea, which encapsulates the main focus of the content provided. Clear annotated diagrams and photographs are a major part of almost all activities and the student's understanding of the information is tested through a series of questions and/or data handling and interpretation tasks. The tabs for each activity identify the nature of the activity, and identify related material and external weblinks, which provide support for the activity.

2 ATP and Energy

Key Idea: ATP is the universal energy carrier in cells. Energy is stored in the covalent bonds between phosphate groups. The molecule ATP (adenosine triphosphate) is the universal energy carrier for the cell. ATP can release its energy quickly by hydrolysis of the terminal phosphate. This reaction is catalysed by the enzyme ATPase. Once ATP has released its energy, it becomes ADP (adenosine diphosphate), a low energy molecule that can be recharged by adding a phosphate. The energy to do this is supplied by the controlled breakdown of respiratory substrates in cellular respiration.

How does ATP provide energy?

ATP releases its energy during hydrolysis. Water is split and added to the terminal phosphate group, releasing inorganic phosphate (Pi) and energy. For every mole of ATP hydrolysed 30.7 kJ of energy is released. Note that energy is released during the formation of chemical bonds, not from the breaking of chemical bonds.

Hydrolysis is the addition of water. ATP hydrolysis gives $\text{ADP} + \text{P}_i$ (HPO_4^{2-}) + H^+ .

The reaction of $\text{A} + \text{B}$ is endergonic. It will not occur spontaneously.

The enzyme **ATPase** is able to couple the hydrolysis of ATP directly to the formation of a phosphorylated intermediate **A-Pi**.

ATP is reformed during the reactions of cellular respiration (i.e. glycolysis, Krebs cycle, and the electron transport chain).

ATPase

Adenosine

Inorganic phosphate

A-Pi reacts with B and Pi is released.

In many textbooks the reaction series above is simplified and the intermediates are left out:

$\text{A} + \text{B} \xrightarrow{\text{ATP}} \text{AB} + \text{ADP} + \text{P}_i$

Note! The phosphate bonds in ATP are often referred to as high energy bonds. This can be misleading. The bonds contain electrons in a high energy state (making the bonds themselves relatively weak). A small amount of energy is required to break the bonds, but when the intermediates recombine and form new chemical bonds a large amount of energy is released. The final product is less reactive than the original reactants.

1. (a) How does ATP supply energy to power metabolism? _____

(b) In what way is the ADP/ATP system like a rechargeable battery? _____

2. What is the immediate source of energy for reforming ATP from ADP? _____

3. Which enzyme catalyses the hydrolysis of ATP? _____

4. Explain why highly active cells (e.g. sperm cells) have large numbers of mitochondria: _____

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LINK 7 LINK 3 LINK 1 WEB 2 KNOW

2 ATP and Energy

Key Idea: ATP is the universal energy carrier in cells. Energy is stored in the covalent bonds between phosphate groups. The molecule ATP (adenosine triphosphate) is the universal energy carrier for the cell.

The **key idea** provides a focus for each activity. It summarises the focus of the activity and provides a clear take-home message for the student.

Annotated diagrams, sometimes including photo panels, explain the content of the page, providing the information necessary to complete the activity.

Understanding of content is tested through questions, data handling, analysis, prediction, or summary. Students are often required to apply their understanding to a new scenario or make connections to related content. Students must interact with the information on the page in order to complete the activity. It is this interaction that provides the valuable learning experience and reinforcement and explanation of the key idea.

Related content is identified through the tab system. This activity also has a **weblink** assigned to it (see below).

THE ACTIVITY CODING SYSTEM

Main focus of the activity is:

DATA = data handling and interpretation

KNOW = content you need to know

PRAC = a paper practical or a practical focus

REFER = reference - use this for information

REVISE = review the material in the section

SKILL = a specific skill to be demonstrated

TEST = test your understanding

EXT = Extension activity



Links

These blue tabs indicate activities that provide content which is related to or builds on the content on the page.

Weblinks

This grey tab indicates a weblink. Bookmark the weblinks page:

www.biozone.co.uk/weblink/CIE-2-9322

Access the external URL for the activity by clicking the link next to its number.



6 Practical Investigations

The basic techniques and skills required for practical work and mathematical skills are addressed throughout the workbook. Activities that support practical investigations are identified in the introduction of the relevant chapters.

Topic 13

Photosynthesis

Key terms

absorption spectrum
accessory pigment
action spectrum
ATP
ATP synthase
Calvin cycle
carotenoid
cellular respiration
chemiosmosis
chloroplast
chlorophyll
cyclic photophosphorylation
glycerate 3-phosphate (GP or GP)
grana
light dependent phase
light independent phase
NADP
Non-cyclic photophosphorylation
photolysis
photosynthesis
photosystem
ribulose biphosphate (RuBP)
RuBisCo
stroma
stroma lamellae
thin layer
thylakoid discs
triose phosphate

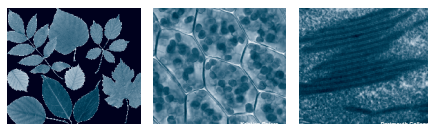
13.1 Photosynthesis as an energy transfer process

Learning outcomes

- Outline the events in the two stages of photosynthesis and their interdependence.
- Identify the sites of the two stages of photosynthesis.
- Explain the role of chlorophyll a and b and accessory pigments in light capture in the grana. Include reference to the photosystems (the protein complexes involved in the absorption of light and the transfer of energy and electrons).
- Interpret absorption and action spectra for chloroplast pigments.
- PRAC** Use chromatography to separate and identify chloroplast pigments. Investigate differences in chloroplast pigments in different plants.
- Describe the light dependent reactions, including the absorption of light by the photosystems, transfer of excited electrons between carriers in the thylakoid membranes, the generation of ATP and NADPH, and the photolysis of water.
- Compare and contrast cyclic and non-cyclic photophosphorylation.
- Describe the light independent reactions (Calvin cycle), including reference to the role of the enzyme RuBisCo: (1) the carboxylation of ribulose biphosphate (RuBP) to form glycerate 3-phosphate (GP), (2) reduction of GP to triose phosphate using NADPH and ATP, (3) the regeneration of RuBP using ATP.
- Describe the fate of the triose phosphate generated in the Calvin cycle.

Activity number

14 15
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13.2 Investigation of limiting factors

Learning outcomes

- Explain the term limiting factor in relation to photosynthesis.
- Explain the effects of changes in carbon dioxide concentration, light intensity, and temperature on the rate of photosynthesis.
- With reference to limiting factors, explain how controlled environments (e.g. glasshouses) can be used to increase crop yields.
- PRAC** Use a redox indicator and a suspension of chloroplasts to investigate the effect of light intensity or light wavelength on the rate of photosynthesis.
- PRAC** Investigate the effect of light intensity, CO₂ concentration, and temperature on the rate of photosynthesis in whole plants, e.g. Cabomba.

Activity number

22
22
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13.3 Adaptations for photosynthesis

Learning outcomes

- Describe the relationship between structure and function of the chloroplast using diagrams and electron micrographs.
- Explain how the anatomy and physiology of the leaves of C₃ plants are adapted for high photosynthetic rates at high temperatures. Include reference to the spatial separation of initial carbon fixation from the light dependent stage and the high optimum temperatures of the enzymes involved.

Activity number

15
27

26 Investigating Photosynthetic Rate

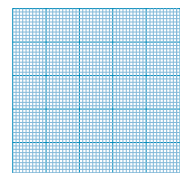
Key idea: Measuring the production of oxygen provides a simple means of measuring the rate of photosynthesis. The rate of photosynthesis can be investigated by measuring the substances involved in photosynthesis. These include:

The aim: To investigate the effect of light intensity on the rate of photosynthesis in an aquatic plant, *Cabomba aquatica*.

The method:

- 0.8-1.0 grams of *Cabomba* stem were weighed on a balance.
- The stem was cut and inserted to ensure a free flow of oxygen bubbles.
- The stem was placed into a beaker filled with a solution containing 0.2 mol l⁻¹ sodium hydrogen carbonate (to supply carbon dioxide). The solution was at approximately 20°C. A beaker was inverted over the *Cabomba* and a test tube filled with the sodium hydrogen carbonate solution was inverted on top of the test tube.
- The beaker was placed at distances (20, 25, 30, 35, 40, 45 cm) from a 60W light source and the light intensity measured with a lux meter at each interval. One beaker was not exposed to the light source (0 lux).
- Before recording data, the *Cabomba* stem was left to acclimatise to the new light level for 5 minutes. Because the volume of oxygen gas produced are very low, bubbles were counted for a period of three minutes at each distance.

Light intensity / (distance)	Bubbles counted / in three minutes	Bubbles per minute
0	0	
10 (45 cm)	0	
20 (40 cm)	9	
30 (35 cm)	10	
40 (30 cm)	16	
50 (25 cm)	33	
60 (20 cm)	35	



- Complete the table by calculating the rate of oxygen production (bubbles of oxygen gas per minute).
- Use the graph to evaluate the effect of light on photosynthetic rate.
- Although distance was used to vary light intensity, what would be a more accurate way of measuring the gas produced in the experiment?

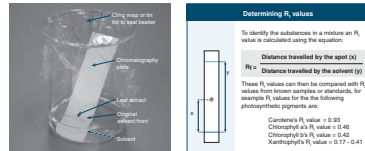
Students can use data provided to evaluate the effect of light on photosynthetic rate.

18 Separation of Pigments by Chromatography

Key idea: Photosynthetic pigments can be separated from a mixture using chromatography. Chromatography involves placing a mixture dissolved in a mobile phase (a solvent) through a stationary phase, which separates the molecules according to their specific characteristics (e.g. size or charge). In this layer chromatography, the stationary phase is a thin layer of adsorbent material (e.g. silica gel or cellulose) attached to a solid plate. A sample is placed near the bottom of the plate which is placed in an appropriate solvent (the mobile phase).

Separation of photosynthetic pigments

The four primary pigments of green plants can be easily separated and identified using thin layer chromatography. The pigments from the leaves are first extracted by crushing leaves, together with acetone, using a mortar and pestle. The extract is added to the chromatography plate, which is the stationary phase in this layer of coated silica. Acetone is used as the mobile phase (solvent). During thin layer chromatography, the pigments separate out according to differences in their relative solubilities. Two major classes of pigments are detected: the two greenish chlorophyll pigments and two yellow carotenoid pigments.



Determining R_f values

To identify the substances in a mixture an R_f value is calculated using the equation:

$$R_f = \frac{\text{Distance travelled by the spot (d)}}{\text{Distance travelled by the solvent (D)}}$$

These R_f values can then be compared with R_f values from known samples or standards. For example R_f values for the following photosynthetic pigments are:

Carotenoids R_f value = 0.85
Chlorophyll a R_f value = 0.46
Chlorophyll b R_f value = 0.42
Xanthophyll R_f value = 0.17 - 0.41

- Calculate the R_f values for the pigments A-D on the chromatography plate shown.

Students can complete the activity to understand the use of chromatography to separate photosynthetic pigments.

- For shade and a plant adapted for high levels of sunlight. Use your knowledge of plant photosynthetic pigments and the information on this page to predict the outcome of the two chromatography experiments in terms of the pigments that will appear on the chromatography paper and their relative darkness (indicating the amount of pigment).

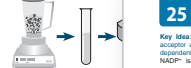
17 18

24 Experimental Evidence for Photosynthesis

Key idea: Hill's experiment using isolated chloroplasts and Calvin's 'lollipop' experiment provided important information on the processes of photosynthesis.

Robert Hill's experiment

The dye DCPIP (2,6-dichlorophenol-indophenol) is blue. It is reduced to 1⁺ ions (DCPIP⁺) when it accepts electrons. Hill used this dye to show that O₂ is produced during photosynthesis even when CO₂ is not present.



Calvin's lollipop experiment

Calvin and his colleagues placed the algae *Chlorella vulgaris* in a flask shaped like a lollipop.

Radioactive ¹⁴C labelled CO₂ was bubbled.

Radioactive ¹⁴C was tracked.

Background: Dehydrogenase enzymes play a role in the transport of electrons through the photosynthetic pathway of the light dependent reactions. This flow of electrons is the electron acceptor for the light dependent reaction.

Results:

Time / min	1	2	3	4	5
0	0.0	0.0	0.0	0.0	0.0
1	4.8	5.0	-	0.3	0.0
2	4.7	4.9	-	0.3	0.0
3	4.6	4.8	-	0.3	0.0
4	4.3	4.6	-	0.4	0.0
5	4.0	4.7	-	0.3	4.9
6	3.8	4.6	-	0.4	4.9
7	3.4	4.6	-	0.2	4.9
8	3.0	4.5	-	0.3	5.0
9	2.6	4.4	-	0.4	5.1
10	2.2	4.4	-	0.3	5.0
11	1.9	4.3	-	0.2	4.9
12	1.4	4.1	-	0.2	5.0
13	0.9	4.0	-	0.3	4.8
14	0.6	4.0	-	0.3	5.0
15	0.5	3.8	4.7	0.4	5.0

Students can use raw data to study the effect of light on enzyme activity.

Background: The chloroplasts were isolated from green leaves. The chloroplasts were then exposed to light. The rate of photosynthesis was measured by the rate at which oxygen was produced. The rate of oxygen production was measured by the rate at which the volume of gas produced was measured. The rate of oxygen production was measured by the rate at which the volume of gas produced was measured.

Results:

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12	1.4	4.1	-	0.2	5.0
13	0.9	4.0	-	0.3	4.8
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15	0.5	3.8	4.7	0.4	5.0

Making Use of Weblinks

1 The Role of ATP in Cells

Key Idea: ATP transports chemical energy within the cell for use in various metabolic processes. All organisms require energy to be able to perform the metabolic processes required for them to function and reproduce. This energy is provided by cellular respiration, a set of metabolic reactions that ultimately convert biochemical energy from 'food' into the nucleotide **adenosine triphosphate (ATP)**. ATP is considered to be a universal energy carrier, transferring chemical energy within the cell for use in metabolic processes such as biosynthesis, cell division, cell signaling, thermoregulation, cell motility, and active transport of substances across membranes.

Adenosine triphosphate (ATP)

The ATP molecule consists of three components: a purine base (**adenine**), a pentose sugar (**ribose**), and three **phosphate groups** which attach to the 5' carbon of the pentose sugar. The structure of ATP is described below.

The bonds between the phosphate groups contain electrons in a high energy state which store a large amount of energy. The energy is released during ATP hydrolysis. Typically, hydrolysis is coupled to another cellular reaction to which the energy is transferred. The end products of the reaction are adenosine diphosphate (ADP) and an inorganic phosphate (P_i).

Note that energy is released during the formation of bonds during the hydrolysis reaction, not the breaking of bonds between the phosphates (which requires energy input).

The mitochondrion

Cellular respiration and ATP production occur in mitochondria. A mitochondrion is bounded by a double membrane. The inner and outer membranes are separated by an intermembrane space, compartmentalising the regions where the different reactions of cellular respiration take place. The folded inner membrane provides a large surface area for reactions.

ATP synthase on the outer membrane surface. Phosphorylation between the inner and outer membranes. ATP synthase on the inner membrane (matrix). Soluble enzymes for the Krebs cycle and fatty acid degradation floating in the matrix.

1. Why do organisms need to respire? _____

2. (a) Describe the general role of mitochondria in cell respiration: _____

(b) Explain the importance of compartmentalisation in the mitochondrion: _____

3. Explain why thermoregulation is associated with energy expenditure: _____

1 2 3 7

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The tab system at the base of each activity identifies if there is a weblink available to support the activity's content. The weblinks are distinct from the general Biolinks area of BIOZONE's website. They are coded with the activity number and are only accessible through a specific url (below), so bookmark the address at the beginning of your teaching year and always have them on hand. The weblinks comprise short video clips or animations aimed specifically at the activity content. These are external sites from a wide range of reputable sources and are invaluable as support to explain content or view an animation of a process such as diffusion or active transport. It's easy and we've done the hard work for you. Just click and view.

GENERAL ANATOMY & PHYSIOLOGY

Active Transport

With active transport a molecule or ion combines with a carrier molecule. This combination alters the shape of the carrier molecule. Using ATP (Adenosine Triphosphate) energy, the carrier transports the molecule from an area of lower concentration to an area of higher concentration. Up to 40 percent of a cell's ATP may be used for this type of transport across the cell membrane.

Region of lower concentration

Region of higher concentration

Binding site

ATP

Protein carrier molecule

back next

Tags: active, atp, concentration, endocytosis, exocytosis, gradient, transport

Weblinks exist for most of the activities in the workbook, from cells to evolution.

www.biozone.co.uk/weblink/CIE-2-9322

This WEBLINKS page provides links to **external web sites** with supporting information for the activities. Almost exclusively, they are narrowly focussed animations and video clips relevant to the activity on which they are cited. They offer great support to aid student understanding of basic concepts, especially for visual learners.

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BIOZONE CIE BIOLOGY 2 WEBLINKS

Some of the activities in your BIOZONE workbook have references to specific websites, listed below under the relevant chapters. These websites (blue links) provide material, generally either animations or video clips, to help you visualize and understand the material presented on the relevant activity page.

Title	Weblinks
The Role of ATP in Cells	ATP in Metabolism
ATP and Energy	How ATP supplies energy
The Biochemistry of Respiration	Glycolysis
The Biochemistry of Respiration	Glycolysis
The Biochemistry of Respiration	The Citric Acid Cycle
The Biochemistry of Respiration	Oxidative Phosphorylation
Chemiosmosis	Electron Transport Chain Movie
Aerobic Pathways	Lactic Acid and Alcoholic Fermentation
Aerobic Pathways	Lactic Acid and Alcoholic Fermentation
Photosynthesis	Photosynthesis
Pigments and Light Absorption	Harvesting Light
Separation of Pigments by Chromatography	Thin Layer Chromatography of Pigments
Light Dependent Reactions	Photosynthesis Light Reactions
Light Dependent Reactions	Photosynthesis II

Chapter 1
Energy and respiration

Chapter 2
Photosynthesis

Chapter in the workbook

Activity in the workbook

Hyperlink to the external website page.



Bookmark weblinks by typing in the address: it is not accessible directly from BIOZONE's website
Corrections and clarifications to current editions are always posted on the weblinks page



Topic 12

Energy and respiration

Key terms

aerobic respiration
anaerobic respiration
ATP
cellular respiration
chemosynthesis
cristae
decarboxylation
electron transport
chain
ethanol
FAD
fermentation
glycolysis
Krebs cycle
lactic acid
the lactic acid
respiration
glycolysis
Krebs cycle
lactic acid
the lactic acid
respiration
glycolysis
Krebs cycle
lactic acid
the lactic acid
respiration

2.1 Energy

Learning objectives

- 1 Explain why organisms require energy, as illustrated by examples, e.g. anabolic reactions, movement, measurement, and regulation of body temperature.
- 2 Describe how ATP stores energy and is used in the universal energy currency.
- 3 Explain the roles of the coenzymes NAD⁺ and coenzyme A respectively.
- 4 Describe how the synthesis of ATP is associated with electron transport in the membranes of mitochondria and chloroplasts.
- 5 Explain and explain the relative energy yields of carbohydrates, lipids, and proteins in aerobic respiration. Describe how anaerobic respiration (ATP) can be used to determine the respiratory substrate being used. Calculate and interpret Q₁₀ values for organisms in aerobic and anaerobic respiration.

Practice Use the simple respirometers to determine the PD of living organisms.

Assess

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12.2 Respiration

Learning objectives

- 3 Identify the four stages of aerobic respiration and their locations.
- 4 Outline glycolysis and respiration as the main anaerobic pathway in cells. State the net yield of ATP and NADPH₂ from glycolysis.
- 5 Describe the link reactions to include decarboxylation, dehydrogenation, reduction of NAD⁺ and formation of acetyl coenzyme A.
- 6 Explain the Krebs cycle including reference to the oxidative decarboxylation of intermediates and the importance of decarboxylation, dehydrogenation, reduction of NAD⁺ and FAD, and substrate level phosphorylation.
- 7 Explain substrate phosphorylation in the electron transport chain to include the role of electron carriers in the mitochondrial membrane and the role of oxygen as the terminal electron acceptor.
- 8 Describe the relationship between structure and function of the mitochondrion using diagrams and electron micrographs.
- 9 Describe chemosynthesis: theory as an alternative for ATP generation in isolation using inorganic and photosynthetic pathways and photosynthesis.
- 10 Compare aerobic and anaerobic pathways for ATP generation in organisms to include alcoholic fermentation, lactic acid and acetic acid fermentation in organisms, including the concept of energy yield and compare and explain the differences in ATP yield from aerobic respiration and glycolysis.
- 11 Investigate factors affecting fermentation in yeast cells to select indicators to compare yeast to adapted to grow in anaerobic conditions and to determine the tolerance for ethanol and the presence of anaerobiosis.
- 12 **Practice** Use simple respirometers to determine the effect of temperature on the respiration rate of germinating seeds or small invertebrates.

Assess

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Activities are written and presented so that students progressively extend and deepen their understanding, using what they have learned in earlier activities to complete later related activities and to solve new problems.

12.1 Energy

Learning outcomes

- ☐ 1 Explain why organisms require energy, as illustrated by examples, e.g. anabolic reactions, active transport, movement, and regulation of body temperature.
- ☐ 2 Describe how ATP's structure enables it to act as the universal energy currency. Explain ATP generation by substrate-linked phosphorylation.
- ☐ 3 Outline the roles of the coenzymes NAD, FAD, and coenzyme A in respiration.
- ☐ 4 Explain how the synthesis of ATP is associated with electron transport in the membranes of mitochondria and chloroplasts.
- ☒ 5 Describe and explain the relative energy values of carbohydrates, lipids, and proteins as respiratory substrates. Describe how respiratory quotients (RQ) can be used to determine the respiratory substrate being utilised. Calculate and interpret RQ values for organisms in different conditions.
- ☐ 6 **PRAC** Use simple respirometers to determine the RQ of living organisms.

Activity number

1

2

6

6 7 19

4

5

Describe the general role of mitochondria in cell respiration: _____


Explain the importance of compartmentalisation in the mitochondrion: _____

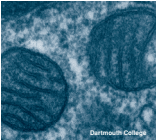
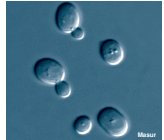
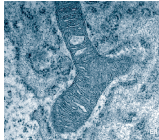
Explain why thermoregulation is associated with energy expenditure: _____

2

3

7



Batrachoseps attenuatus
Water

30 Homeostasis

Key idea: Homeostasis refers to the (relatively) constant physiological state of the body despite fluctuations in external conditions.

Organisms maintain a relatively constant physiological state, called **homeostasis**, despite changes that environmental change. Any change in the environment is detected by **receptors**, which then send signals to the **effector** to adjust their behaviour and physiology to maintain homeostasis. This requires the coordinated activity of the body's organ systems.

Homeostatic mechanisms prevent deviations from the steady state and keep the body's internal conditions within strict limits. Deviations from these limits can be harmful.

An example of homeostasis occurs when you exercise (right). Your body must keep your body temperature constant at about 37 °C despite the increased heat generated by activity. Similarly, you must regulate blood sugar levels and blood pH, water and electrolyte balance, and blood pressure. Your body's organ systems carry out these tasks.

To maintain homeostasis, the body must detect almost through receptors, process this sensory information, and respond to it appropriately via effectors. The responsibility for this is distributed to the receptor. These three components are illustrated below:

How homeostasis is maintained

The analogy of a thermostat on a heater is a good way to understand how homeostasis is maintained. A heater has sensors to respond to outside room temperature. It also has a control centre to monitor and process the data from the sensors. Depending on the room's situation, the control centre activates the heater (drawing only), switching it on or off when the room is too hot for heater settings or when it is too hot for the heater settings. This maintains a constant temperature.

31 Maintaining Homeostasis

Key idea: The body's organ systems work together to maintain homeostasis. Homeostasis relies on monitoring all the information received from the internal and external environment and controlling internal conditions, processes and physiological functions.

Regulating body gases

Oxygen demand increases with activity and metabolism (in athletes).

CO₂ production increases with activity and metabolism.

Ability to O₂ and CO₂ exchange is limited by blood transport in the lungs.

Muscle activity increases oxygen demand and produces CO₂.

Attach an air duct to the lungs to increase transport from large participants.

Attach an air duct to the lungs to increase transport from large participants.

Coping with pathogens

Lipid layer

Attached to cells with lipid layer

Microbes attach to the lipid layer

Attach an air duct to the lungs to increase transport from large participants.

All of us are under constant exposure. The body has mechanisms to maintain homeostasis. The body's organ systems are constantly monitoring all the information received from the internal and external environment and controlling internal conditions, processes and physiological functions.

Maintaining nutrient supply

Digestion of the food provides the building blocks for the body's metabolism. The water and electrolytes are absorbed and used for metabolism. The water and electrolytes are absorbed and used for metabolism.

Food and drink are absorbed and used for metabolism. The water and electrolytes are absorbed and used for metabolism.

Muscle and brain are the main sites of metabolism. The water and electrolytes are absorbed and used for metabolism.

Metabolism can be powered by the food and drink.

Food and drink must be taken in to maintain the body's energy balance. The digestive system breaks down soluble molecules and releases the nutrients. The nutrients are absorbed and used for metabolism. The water and electrolytes are absorbed and used for metabolism.

1. What is homeostasis?

2. What is the role of the following components in maintaining homeostasis:

(a) Receptor

(b) Control centre


(c) Effector

Engage, explore and explain

31 Maintaining Homeostasis

Key Idea: The body's organ systems work together to maintain homeostasis. Homeostasis relies on monitoring all the information received from the internal and external environment and controlling internal conditions, processes and physiological functions.

Students become actively involved in the learning activity by interacting with the material, answering the set tasks. Many activities are suitable

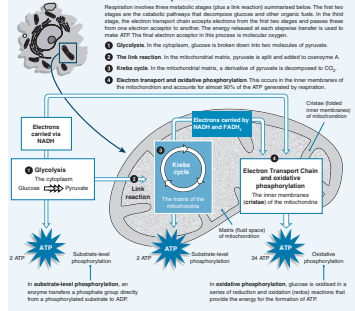
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3 ATP Production in Cells

Key Idea: Cellular respiration is the process by which the energy in glucose is transferred to ATP.

Cellular respiration can be aerobic (requiring oxygen) or anaerobic (does not require oxygen). Some plants and animals can generate ATP anaerobically for short periods.

Other organisms (aerobic bacteria) use only anaerobic respiration and live in oxygen-free environments. The overall process is summarized by the word equation: glucose + oxygen → carbon dioxide + water + ATP.



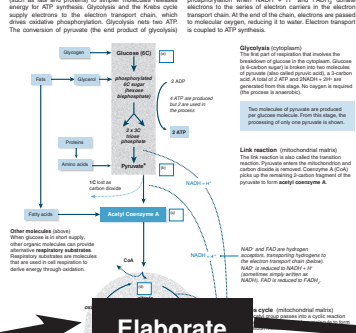
Explain

- Describe precisely in which part of the cell the following take place:
 - Glycolysis
 - The link reaction
 - Krebs cycle reactions
 - Electron transport chain
- How does ATP generation in glycolysis and the Krebs cycle relate to ATP generation via the electron transport chain?

7 The Biochemistry of Respiration

Key Idea: During cellular respiration, the energy in glucose is transferred to ATP in a series of enzyme-controlled steps.

The oxidation of glucose is a catabolic, energy-yielding pathway. The breakdown of glucose and other organic fuels (such as fats and proteins) to simpler molecules releases energy for ATP synthesis. Glycolysis and the Krebs cycle supply electrons to the electron transport chain, which drives oxidative phosphorylation. Glycolysis nets two ATP. The conversion of pyruvate (the end product of glycolysis) to acetyl-CoA feeds glycolysis to the Krebs cycle. One "turn" of the cycle releases carbon dioxide, forms one ATP and passes electrons to three NAD⁺ and one FAD. Most of the ATP generated in cellular respiration is produced by oxidative phosphorylation when NADH + H⁺ and FADH₂ donate electrons to the series of electron carriers in the electron transport chain. At the end of the chain, electrons are passed to molecular oxygen, reducing it to water. Electron transport is coupled to ATP synthesis.



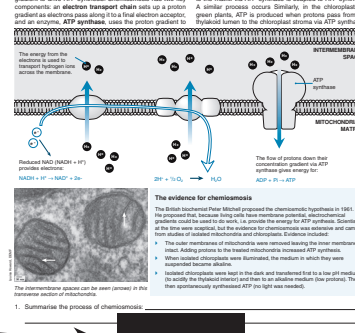
Elaborate

- Describe the process of cellular respiration, including the role of each stage.
- Explain how the electron transport chain is coupled to ATP synthesis.

8 Chemiosmosis

Key Idea: Chemiosmosis is the process in which electron transport is coupled to ATP synthesis.

Chemiosmosis occurs in the membranes of mitochondria, the chloroplasts of plants, and across the plasma membrane of bacteria. It involves establishing and using a proton gradient to drive ATP synthesis. Chemiosmosis has two key components: an electron transport chain and a proton gradient. The electron transport chain is a series of electron carriers that pass electrons from one molecule to another. The proton gradient is established by pumping protons from the matrix to the intermembrane space. The flow of protons back into the matrix through ATP synthase generates ATP. The overall reaction is: $\text{ADP} + \text{P}_i \rightarrow \text{ATP}$.



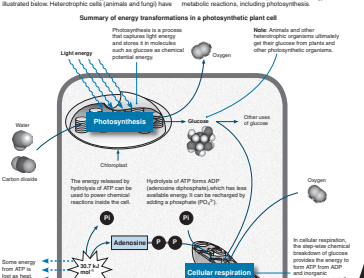
Evaluate

- Summarize the process of chemiosmosis.
- Why did the electron transport chain become alkaline when illuminated?
- Why did the suspension of isolated chloroplasts become alkaline when illuminated?
- (a) What was the purpose of transferring the chloroplasts first to an acid then to an alkaline medium?
- (b) Why did ATP synthesis occur spontaneously in these treated chloroplasts?

14 Energy in Cells

Key Idea: Photosynthesis uses energy from the sun to produce glucose. Glucose breakdown produces ATP, which is used by all cells to provide the energy for metabolism.

A summary of the flow of energy within a plant cell is illustrated below. Photosynthetic cells (plants and fungi) have metabolic reactions, including photosynthesis.



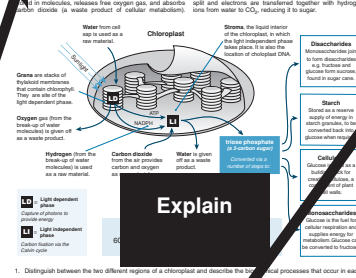
Engage the student with what is familiar to them

- What are the raw materials for photosynthesis?
- What are the raw materials for respiration?
- What is the immediate source of energy for reforming ATP from ADP?
- What is the ultimate source of energy for plants?
- What is the ultimate source of energy for animals?

15 Photosynthesis

Key Idea: Photosynthesis is the process by which light energy is used to convert CO_2 and water into glucose and oxygen.

Photosynthesis is a fundamental metabolic pathway that converts light energy into chemical energy. The process occurs in the chloroplasts of plants and in some bacteria. The overall reaction for photosynthesis is: $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$.



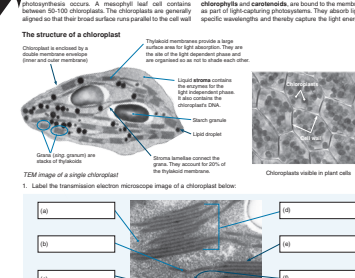
Explain

- Distinguish between the two different regions of a chloroplast and describe the biochemical processes that occur in each:
 - Light-dependent phase
 - Light-independent phase
- State the origin and fate of the following molecules involved in photosynthesis:
 - Carbon dioxide
 - Oxygen
 - Hydrogen
- Discuss the potential uses for the end products of photosynthesis.

16 Chloroplasts

Key Idea: Chloroplasts have a complex internal membrane structure that provides the sites for the light-dependent reactions of photosynthesis.

Chloroplasts are the specialized plastids in plant cells that carry out photosynthesis. They are bounded by a double membrane and contain a system of internal membranes called thylakoids. The thylakoids are arranged in stacks called grana. The overall reaction for photosynthesis is: $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$.



Explore: SEMs are used to identify structures.

- Label the transmission electron microscope image of a chloroplast below.
- Where is chlorophyll found in a chloroplast?
- Why is chlorophyll important for photosynthesis?
- Explain why plant leaves appear green.

This activity begins by engaging the student with something familiar (glucose is used in respiration) and introduces the concept of photosynthesis.

Students then explore the chloroplast and the sites of the light dependent and independent reactions.

Students apply their understanding to the identification of structures in the chloroplast.

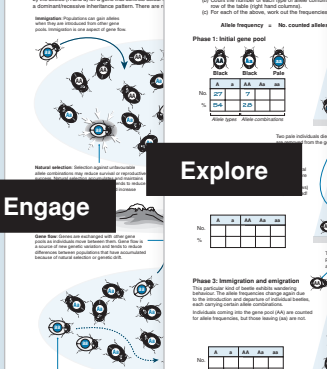
Groups of activities build knowledge and understanding by giving students the chance to learn and apply their knowledge in a series of linked activities.

- Engage:** visualise the concept of a gene pool
- Explore:** relate changes in allele frequencies to microevolutionary processes
- Elaborate:** calculate allele frequencies from provided data
- Evaluate:** apply understanding of the Hardy-Weinberg principle to the analysis of allele frequencies in a real population

110 Gene Pools and Evolution

Key Idea: The gene pool is the collection of all the genes in a population.

The gene pool is the collection of all the genes in a population. It is the genetic makeup of a population at a given time. The gene pool can change over time due to various factors, including natural selection, genetic drift, and gene flow.



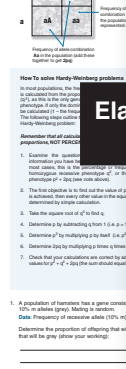
Engage

- What is a gene pool?
- What is an allele?
- What is allele frequency?

111 Changes in a Gene

Key Idea: Natural selection and migration can alter the gene pool.

Natural selection and migration can alter the gene pool. Natural selection is the process by which certain traits are favored over others, leading to changes in the frequency of those traits in a population. Migration is the movement of individuals from one population to another, which can introduce new alleles or change the frequency of existing ones.



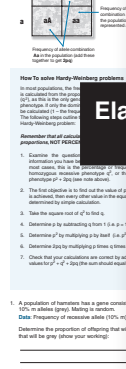
Explore

- What is natural selection?
- What is migration?
- How do these processes alter the gene pool?

112 Hardy-Weinberg

Key Idea: The Hardy-Weinberg equation is a mathematical model that predicts the frequency of alleles in a population.

The Hardy-Weinberg equation is a mathematical model that predicts the frequency of alleles in a population. It is based on the assumption that the population is in Hardy-Weinberg equilibrium, which means that the allele frequencies are constant over time.



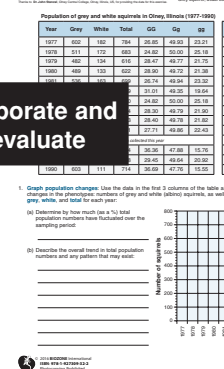
Elaborate and evaluate

- Calculate the allele frequencies for a given population.
- Use the Hardy-Weinberg equation to predict the frequency of alleles in the next generation.
- Compare the predicted frequencies to the actual frequencies.

113 Analysis of a Squirrel Gene Pool

Key Idea: Allele frequencies for real populations can be calculated using the Hardy-Weinberg equation.

Allele frequencies for real populations can be calculated using the Hardy-Weinberg equation. The equation is used to predict the frequency of alleles in a population, and it can be used to compare the predicted frequencies to the actual frequencies.



Evaluate

- Graph population change. Use the data in the first 3 columns of the table above to plot a line graph. This will show changes in the phenotype, numbers of gray and white (albino) squirrels, as well as changes in the total population. Plot gene, white, and black for each year.
- Describe the overall trend in total population numbers and any pattern that may exist.

10 LINKS - Making Connections

The **LINK** tabs help students to connect ideas between different topics in the CIE Biology syllabus. Connections may be made to activities that build on or develop an idea, utilise the same core principles in another biological context, or examine the evidence for a biological process. The connections help students to appreciate that the same core principles underlie many biological phenomena and there is evidence to support them. Understanding these core principles brings understanding to a wide range of contexts and situations, even if they are unfamiliar.

91 Gene Mutations

Key idea: Gene mutations are localised changes in the DNA sequence.

Most mutations are small, localised changes in the base sequence of a DNA molecule caused by a misreading or an error in the replication process. The change may be a single nucleotide (point mutation) or a change in a repeat (duplication or deletion).

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92 The Nature of Mutation

Key idea: A mutation is any change in the DNA sequence, from a single nucleotide to a whole chromosome.

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93 Beneficial Mutations

Key idea: Beneficial mutations increase the fitness of the organism.

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EXAMPLE 1

Gene Mutations

Understand what causes mutations, different types of mutation, and examples of harmful and beneficial mutations.

114 Mechanism of Natural Selection

Key idea: Natural selection is the mechanism by which organisms that are better adapted to their environment survive and reproduce.

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117 Types of Natural Selection

Key idea: Natural selection acts on phenotypes and can result in three types of selection: stabilising, directional, and disruptive.

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118 Directional Selection in Darwin's Finches

Key idea: The effect of directional selection on a population is to change the mean phenotype.

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Most mutations are small, localised changes in the base sequence of a DNA molecule caused by a misreading or an error in the replication process. The change may be a single nucleotide (point mutation) or a change in a repeat (duplication or deletion).

EXAMPLE 2

Natural selection

Explore the mechanism of natural selection and understand the characteristics of the three main types. An analysis of real population data involving directional selection follows.

147 Measuring Distribution and Abundance

Key idea: The distribution and abundance of organisms in an area can be measured using various techniques.

Most mutations are small, localised changes in the base sequence of a DNA molecule caused by a misreading or an error in the replication process. The change may be a single nucleotide (point mutation) or a change in a repeat (duplication or deletion).

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151 Quadrat Sampling

Key idea: Quadrat sampling is a technique used to estimate the distribution and abundance of organisms in an area.

Most mutations are small, localised changes in the base sequence of a DNA molecule caused by a misreading or an error in the replication process. The change may be a single nucleotide (point mutation) or a change in a repeat (duplication or deletion).

Most mutations are small, localised changes in the base sequence of a DNA molecule caused by a misreading or an error in the replication process. The change may be a single nucleotide (point mutation) or a change in a repeat (duplication or deletion).

153 Sampling a Rocky Shore Community

Key idea: Sampling a rocky shore community involves using various techniques to estimate the distribution and abundance of organisms.

Most mutations are small, localised changes in the base sequence of a DNA molecule caused by a misreading or an error in the replication process. The change may be a single nucleotide (point mutation) or a change in a repeat (duplication or deletion).

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EXAMPLE 3

Sampling

Understand the features of different types of sampling, and examine the use of quadrat sampling in more depth. Apply this understanding in a sampling simulation of rocky shore populations.



Achieving effective differential instruction in classes is a teaching challenge. Students naturally have mixed abilities, varying backgrounds in the subject, and different language skills. Used effectively, BIOZONE's workbooks and supporting products can make teaching a mixed ability class easier. Here, we offer three approaches for differential instruction.

MAKING A START



Regardless of which activity you might be attempting in class, a 5-10 minute introduction to the task by the teacher is useful orientation for all students. For collaborative work, the teacher can then divide the class into appropriate groups, each with a balance of able and less able students.

1

Efficient Differential Instruction

- Use **peer-to-peer learning** for more challenging activities where the level of content is more difficult and the questions require students to draw on several areas of their knowledge to synthesise an answer.
- Stronger peers can assist weaker students and both groups benefit from verbalising their thoughts and presenting them to a group. **ESL students** can ask their peers to explain unfamiliar terms (both scientific and English) and this benefits both parties. **Paper practicals** (e.g. *Modelling Meiosis*, *Sampling a Rocky Shore Community*) are another ideal vehicle for this kind of peer-to-peer learning.

73 Modelling Meiosis

Key Idea: We can simulate crossing over, gamete production, and the inheritance of alleles during meiosis using ice-block sticks to represent chromosomes.

This practical activity simulates the production of gametes (sperm and eggs) by meiosis and shows you how crossing over increases genetic variability. This is demonstrated by studying how two of your own alleles are inherited by the child produced at the completion of the activity. Completing this activity will help you to visualise and understand meiosis. It will take 25-45 minutes.

Background

Each of your somatic cells contain 46 chromosomes. You received 23 chromosomes from your mother (**maternal chromosomes**), and 23 chromosomes from your father (**paternal chromosomes**). Therefore, you have 23 homologous (same) pairs. For simplicity, the number of chromosomes studied in this exercise has been reduced to four (two homologous pairs). To study the effect of crossing over on genetic variability, you will look at the inheritance of two of your own traits: the ability to **tongue roll** and **handedness**.

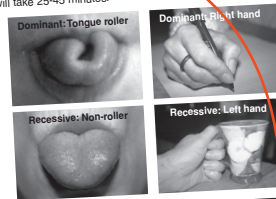
Chromosome #	Phenotype	Genotype
10	Tongue roller	TT, Tt
10	Non-tongue roller	tt
2	Right handed	RR, Rr
2	Left handed	rr

Record your phenotype and genotype for each trait in the table (right). **NOTE:** If you have a dominant trait, you will not know if you are heterozygous or homozygous for that trait, so you can choose either genotype for this activity.

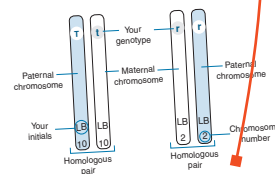
BEFORE YOU START THE SIMULATION: Partner up with a classmate. Your gametes will combine with theirs (fertilisation) at the end of the activity to produce a child. Decide who will be the female, and who will be the male. You will need to work with this person again at step 6.

- Collect four ice-block sticks. These represent four chromosomes. Colour two sticks blue or mark them with a P. These are the **maternal chromosomes**. The plain sticks are the **paternal chromosomes**. Write your initials on each of the four sticks. Label each chromosome with their chromosome number (right). Label four sticky dots with the alleles for each of your phenotypic traits. For example, if you are heterozygous for tongue rolling, the sticky dots will have the alleles T and t, and they will be placed on chromosome 10. If you are left handed, the alleles will be r and R and be placed on chromosome 2 (right).
- Randomly drop the chromosomes onto a table. This represents a cell in either the testes or ovaries. **Duplicate** your chromosomes (to simulate DNA replication) by adding four more identical ice-block sticks to the table (below). This represents **interphase**.

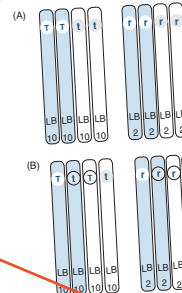
over increases genetic variability. This is demonstrated by studying how two of your own alleles are inherited by the child produced at the completion of the activity. Completing this activity will help you to visualise and understand meiosis. It will take 25-45 minutes.



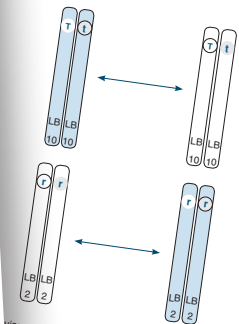
Trait	Phenotype	Genotype
Handedness		
Tongue rolling		



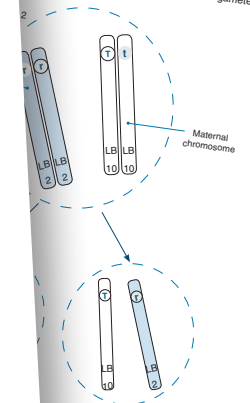
- Simulate **prophase I** by lining the duplicated chromosome pair with their homologous pair (below). For each chromosome number, you will have four sticks touching side-by-side (A). At this stage **crossing over** occurs. Simulate this by swapping sticky dots from adjoining homologs (B).



ment on the metaphase plate (as occurs in **metaphase I**). Simulate crossing over by swapping sticky dots from adjoining homologs (B).



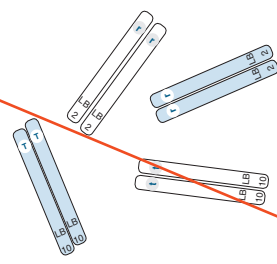
vious step, each intermediate cell will contain a mixture of maternal and paternal chromosomes. At the end of **metaphase II**, **anaphase II**, and **telophase II**, each intermediate cell will have produced two haploid gametes.



Finally select one sperm and one egg gamete. You have created a zygote. Record the genotype and phenotype of the child.

In Modelling Meiosis, students can collaborate in pairs to determine the outcome of a mating between two individuals with different traits. This tests and creates understanding by putting theory into practice.

Encourage students to consolidate and extend their knowledge by visiting the **weblinks** for the activity.



Interactive revision of tasks in class

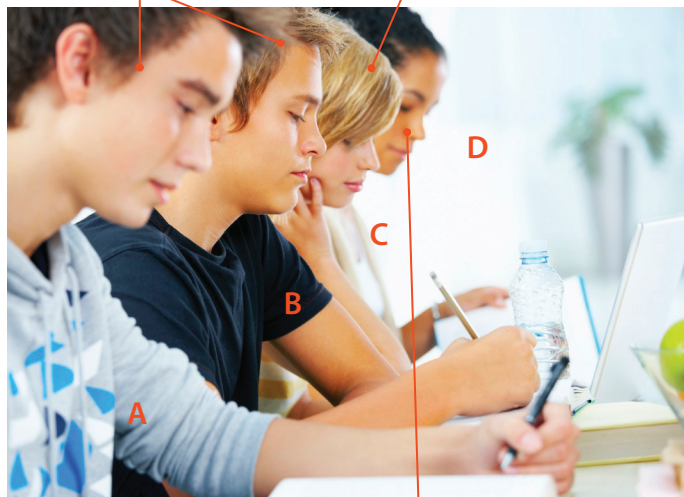
- Use the workbook PDFs with **HIDE/SHOW** answers on the **Teacher's Digital Edition** to review activities in class using a data projector or interactive whiteboard.
- Students benefit from the feedback in class, where questions can be addressed, and teachers benefit by having students self-mark their work and receive helpful feedback on their responses.
- This approach is particularly suited to activities with questions requiring a discussion, as students will be able to clarify some aspects of their responses. Stronger students can benefit by contributing to the explanatory feedback and class discussion.

3 Gaining Confidence

- The questions in BIOZONE's workbook activities have generally been written in a direct questioning style, e.g. "What are the differences between A and B", or "Why are A and B different?". This makes it easier for the students to understand what is required to answer the question.
- Questions are also arranged so that simpler questions (describe, what, identify, name) are generally asked first, followed by questions demanding an explanation (explain, how, why, account for). This allows students to gain confidence from answering the simpler questions first before attempting the questions that require more comprehensive answers.
- This arrangement also allows teachers to direct students appropriately so that some may attempt only the simpler questions themselves and work with peers to attempt the more challenging questions.

Students A and B will work through simpler questions themselves but may require assistance with the more challenging questions in this activity.

Student C is capable. She completes all of this activity including the more challenging questions.



Student D (above) is capable and completes the set work quickly. She can assist her peers and demonstrate her understanding in the relevant section of the review sheets.

112

Hardy-Weinberg Calculations

Key Message: The Hardy-Weinberg equation is a mathematical model used to calculate allele and genotype frequencies in populations. The Hardy-Weinberg equation provides a simple mathematical

model of genetic equilibrium in a gene pool, but its main application in population genetics is in calculating allele and genotype frequencies in populations, rather than as a means of studying changes and measuring their rates.

Punnett square

	A	a
A	AA	Aa
a	Aa	aa

Frequency of allele AA in the population is represented as p
 Frequency of allele aa in the population is represented as q
 Frequency of allele combination AA in the population and those together to equal p^2
 Frequency of allele combination Aa in the population and those together to equal $2pq$
 Frequency of allele combination aa in the population and those together to equal q^2

How to solve Hardy-Weinberg problems

1. **Identify the gene pool.** The gene pool of a population is calculated from the proportion of homozygous dominant and recessive alleles. The way to find the frequency of an allele is to divide the phenotype by the proportion of homozygous to a known, e.g. q^2 will be calculated ($1 - \text{the frequency of the dominant phenotype}$). The following steps outline the procedure for working out a Hardy-Weinberg problem.

Remember that all calculations must be carried out using population **PERCENTAGES**.

1. **Examine the question:** to determine what piece of information you have been given about the population, in this case the frequency of the dominant phenotype, the frequency of the homozygous recessive phenotype (q^2), or the dominant phenotype (p^2). 2% will be calculated ($1 - \text{the frequency of the dominant phenotype}$).

2. **The final objective is to find out the value of p or q .** It is to achieve, once other values in the equation can be determined by simplification.

3. **Take the square root of q^2 of q of p .**

4. **Determine p by subtracting from 1** ($p + q = 1$).

5. **Determine p^2 by multiplying from 1** ($p^2 + q^2 + 2pq = 1$).

6. **Determine $2pq$ by multiplying from 1** ($p^2 + q^2 + 2pq = 1$).

7. **Check that your calculations are correct** by adding up the values ($p^2 + q^2 + 2pq$ should equal approximately 1 or 100%).

1. A population of humans has a gene consisting of 80% alleles (B) and 20% in alleles (b). Mating in random.

Task: Frequency of homozygous allele (100%) and dominant (20%) alleles.

Solution: Determine the proportion of offspring that will be black and the proportion that will be grey (your working).

$$(p + q)^2 = p^2 + 2pq + q^2 = 1$$

Frequency of allele type

$p = \text{Frequency of allele B}$

$q = \text{Frequency of allele b}$

Frequency of allele combination

$p^2 = \text{Frequency of homozygous dominant (BB)}$

$2pq = \text{Frequency of heterozygous (Bb)}$

$q^2 = \text{Frequency of homozygous recessive (bb)}$

The Hardy-Weinberg equation is applied to a population with varying genetic structure and dominant and recessive alleles controlling a single trait. The frequency of all the dominant (A) and recessive alleles in a race is the same genetic complement, and each will be 1 in 100% of the alleles present in a population.

Worked example

Among white-skinned people in the USA, approximately 25% of the population are albino. The albinism is caused by the recessive phenotype of the gene for skin pigmentation. If the population is in Hardy-Weinberg equilibrium, what % of the population are heterozygous (carriers)?

Determine the frequency of: **Assure**

1. Homozygous recessive phenotype (q^2) 25% provided

2. The dominant allele (p) 50%

3. Homozygous dominant (p^2) 25%

4. Heterozygous dominant ($2pq$) 50%

Check: The frequency of the dominant phenotype (75%) matches

and: the frequency of the recessive phenotype are provided.

Work: Recalculate phenotype: $q^2 = 30\%$

$q = \sqrt{0.30}$

$q = 0.547$

$p = 1 - 0.547$

$p = 0.453$

$2pq = 2 \times 0.547 \times 0.453$

$2pq = 0.494$

Use p and q in the equation ($p^2 + q^2 + 2pq = 1$)

$p^2 + q^2 + 2pq = 0.205 + 0.494 + 0.453$

$p^2 + q^2 + 2pq = 1$

Heterozygous: $2pq = 0.494$

Recessive: $q^2 = 0.30$

Dominant allele: $p = 0.453$

Dominant phenotype: $p^2 = 0.205$

Homozygous dominant: $p^2 = 0.205$

140

- You are working with pea plants and found 50 plants out of 400 were dwarf.
 Data: Frequency of recessive phenotypes (50 out of 400 = 1/8)

(a) Calculate the frequency of the tall gene:

(b) Determine the number of heterozygous pea plants:

- You are working with pea plants and found 50 plants out of 400 were dwarf.
 Data: Frequency of recessive phenotypes (50 out of 400 = 1/8)

(a) Calculate the frequency of the tall gene:

(b) Determine the number of heterozygous pea plants:

- In humans, the ability to taste the chemical phenylthiocarbamide (PTC) is controlled as a simple dominant/recessive trait. Suppose you hand out test 360 out of 1000 college students could not taste for chemical.
 Data: Frequency of recessive phenotypes (360 out of 1000)

(a) State the frequency of the gene:

(b) Determine the number of heterozygotes:

- A type of albinism appears in 4% of the population. It is caused by a recessive gene.
 Data: Frequency of recessive phenotypes (4%)

(a) Calculate the percentage of the herd that are carriers of the gene:

(b) Determine the frequency of the dominant gene in this case:

- Assume you placed 50 pure bred black guinea pigs (dominant alleles) with pink genetic inheritance (recessive alleles) and allowed the population to attain genetic equilibrium (several generations have passed).
 Data: Frequency of recessive alleles (50%) and dominant alleles (50%).
 Determine the percentage (%) of the population that becomes albino:

- It is known that 4% of a large population exhibit the recessive trait of a characteristic controlled by two alleles (one is dominant over the other).
 Data: Frequency of recessive phenotypes (4%)
 Determine the following:

(a) The frequency of the recessive allele:

(b) The percentage that are heterozygous for this trait:

(c) The percentage that exhibit the dominant trait:

(d) The percentage that are homozygous for the dominant trait:

(e) The percentage that has one or more recessive alleles:

- Abnism is recessive to normal pigmentation in humans. The frequency of the albino allele was 10% in a population.
 Data: Frequency of recessive alleles (10% albino allele).

(a) Determine the frequency of the gene that you would expect to be albino:

14.2 Chapter Review

Summarize what you know about this topic under the headings and sub-headings provided. You can draw diagrams or word images, or write short notes to organize your thoughts. Use the images and links to help you and refer back to the introduction to check the genetic concepts.

Genetic pools

H107: How do gene pools change over time? What is the Hardy-Weinberg principle and how is it applied to the study of evolving populations.

Speciation

H107: How do speciation and allopatric and sympatric populations and explain the role of reproductive isolating mechanisms in the formation of species.

Natural selection

H107: Define natural selection and include examples of types of natural selection.

Selective breeding

H107: Explain the process of selective breeding. Why is it important to maintain genetic diversity?

REVISE

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76 Monohybrid Crosses

Diagram illustrating a monohybrid cross between a homozygous white rabbit (bb) and a homozygous black rabbit (BB). The gametes produced are b and B. The resulting F1 generation consists of heterozygous black rabbits (Bb).

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Natural selection

HINT: Define natural selection and include examples of types of natural selection.

▶ REVISE

Most students will have access to the internet. If they are having trouble understanding a subject or visualising a process, encourage them to visit the assigned **weblinks** where these are provided.

Focus on Literacy

Within all areas of science, scientific literacy is an important area of focus. With it, communication in the topic is more effective, more concise, and less cumbersome. BIOZONE's literacy and comprehension activities provide a vehicle for increasing the student's familiarity with the use of scientific terms in various contexts. Beginning with the list of KEY TERMS in the introduction to each chapter, students can create their own glossary of commonly used terms. They can learn to use these key terms appropriately by encountering them in context within the activities, and reinforce their understanding of the term by completing the literacy activities throughout the workbook. These take several forms:

Mix and match activities ask students to match each key term to its best definition. Finding the correct definition increases retention of the terms and their meanings.

Literacy activities use a range of question types to test vocabulary and understanding of basic principles. Questions include analysis or completion of flow charts, drawings or photographs, mix and match definitions, cloze questions and other vocab builders, and multiple choice.

Crosswords provide a non-threatening way to improve vocabulary.

143 KEY TERMS AND IDEAS: Did You Get?

1. Match each term to its definition, as identified by its preceding letter code.

allopatric speciation

allele frequency

founder effect

gene flow

gene pool

A The process by which heritable traits become more or less common in a population through differential survival and reproduction.

B An evolutionary event in which a significant proportion of the alleles in a population are lost.

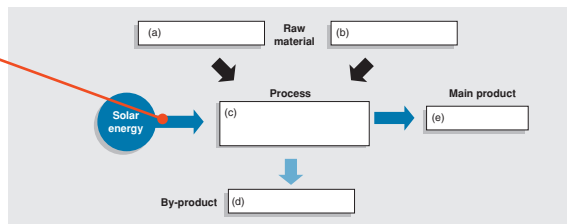
C The sum total of all genes of all breeding individuals in a population at any one time.

D The process by which particular phenotypes are favoured through human intervention.

E A type of intersexual selection. Typically the female selects the male she will mate

29 KEY TERMS AND IDEAS: Did You Get It?

1. Complete the schematic diagram of photosynthesis below:



2. (a) Write the process of photosynthesis as:

A word equation: _____

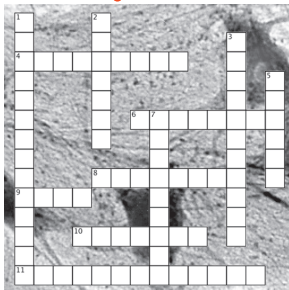
A chemical equation: _____

(b) Where does photosynthesis occur? _____

3. Test your vocabulary by matching each term to its correct definition, as identified by its preceding letter code.

69 KEY TERMS AND IDEAS: Did You Get?

1. Complete the crossword below:



Across

- A self propagating nerve impulse is called an action _____
- Extension of the nerve cell body specialised to receive stimuli.
- A specialised cell that detects stimuli and responds by producing a nerve impulse.
- Long extension of the nerve cell which transmits the nerve impulse to another cell.
- A cell specialised to transmit electrical impulses.
- An organ system comprising a network of specialised cells or neurones, which coordinates responses and transmits signals between different parts of the body.

Down

- A temporary change in membrane potential caused by influx of sodium ions.
- The gap between neighbouring neurones or between a neurone and an effector.
- These synapses release acetylcholine.
- This lipid-rich substance surrounds and insulates the axons of nerves in the peripheral nervous system.
- Motor nerves carry impulses from the central nervous system to these.

- (a) What is the name given to a plant growth response to directional light? _____
- (b) What is the name given to a plant growth response to gravity? _____
- (c) What is the name given to a plant response that is independent of stimulus direction? _____
- (d) What plant hormone is principally responsible for the phototropic effect? _____

3. (a) What responses are being shown by the orchid in the photo (right):

(b) What is the stimulus involved? _____



4. (a) Put these in order from largest to smallest: myofibril, muscle tissue, myofilaments, muscle fibre, fascicles.

(b) Identify the structure shown below: _____



(c) On the diagram above label the following: thin filament, thick filament, H zone.

5. Name the hormones involved regulating the menstrual cycle and ovulation: _____

6. What are the hormones used in combined oral contraceptive pill: _____

The biochemical process that uses light energy to convert carbon dioxide and water into glucose molecules and oxygen.

A 5-carbon molecule which acts as the primary CO₂ acceptor in photosynthesis.

Membrane-bound compartments in chloroplasts. They are the site of the light dependent reactions of photosynthesis.

The phase in photosynthesis where chemical energy is used for the synthesis of carbohydrate. Also called the light independent phase.

The liquid interior of the chloroplast where the light independent phase takes place.

The phase in photosynthesis when light energy is converted to chemical energy.

The term to describe the light absorption of a pigment vs the wavelength of light.

Plant pigments that absorb wavelengths of light that chlorophyll a does not absorb.

A profile of the effectiveness of different wavelengths of light in fuelling photosynthesis.

The green, membrane-bound pigment involved in the light dependent reactions of photosynthesis.

The stacks of thylakoids within the chloroplasts of plants.

chloroplast on the diagram below: granum, stroma, thylakoid disc, stroma lamellae



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TEST



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The Teacher's Digital Edition

15

The *Teacher's Digital Edition* is aimed primarily at extending the pedagogical tools at a teacher's disposal. Many of the features of this resource have been developed in response to requests from teachers themselves.



Digital copy of the Model Answers (non-printable). Suggested answers are provided to all activities. Some include explanatory detail.

A digital (PDF) version of the workbook (non-printable). Use the interactive buttons to HIDE or SHOW the answers.

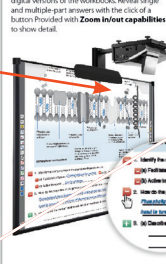
This Classroom Guide is provided as a printable PDF.

CIE BIOLOGY 2

Cambridge International Examination
A-Level Year 2

Teacher's Digital Edition

► Show and hide answers on-screen using the digital versions of the workbooks. Reveal single and multiple-part answers with the click of a button. Provided with Zoom in/out capabilities to show detail.



Model Answers

► The Model Answers booklet provides suggested answers for all activities in the workbook. Model Answers are also provided as 'showhide' in the PDF of the workbook.



Weblinks

► Many activity pages make reference to weblinks usually animations or short video clips that have particular relevance to the activity.



Access the *Weblinks* directly from this link for a range of animations and video clips to support the activities.

Presentation Media

► Sample from Evolution Presentation Media provide high quality colour PowerPoint/Keynote slides for your presentations. All slides are fully editable.



A **BONUS** sample from the Cell Biology and Biochemistry Presentation Media.

Classroom Guide

► A comprehensive guide to effective use of BIOZONE's CIE Biology 2 A-Level Year 2. It provides strategies for use with students of different abilities and for a variety of tasks, including assessment.



Spreadsheets and Statistics

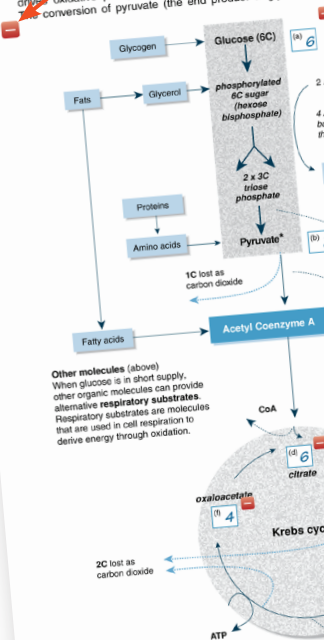
► Microsoft® Excel® Spreadsheets directly support the data handling and graphing activities in the workbook. Click here to view the ICT activities available.



Link to *Excel®* spreadsheets for all activities with a graphing or data analysis component.

Use the interactive buttons to reveal the answers as you work through the activity on-screen.

Key Idea: During cellular respiration, the energy stored in glucose is transferred to ATP in a series of enzyme-controlled steps. The oxidation of glucose is a catabolic, energy-yielding pathway. The breakdown of glucose and other organic fuels (such as fats and proteins) to simpler molecules releases energy for ATP synthesis. Glycolysis and the Krebs cycle supply electrons to the electron transport chain, which drives oxidative phosphorylation. Glycolysis nets two ATP; oxidative phosphorylation (the end product of glycolysis) nets 34 ATP.



The answer provided in the electronic answer is the minimum expected answer. Sometimes, further explanatory details is included in the Model Answers booklet.

1. In the longitudinal section of a mitochondrion (above), label the r...
2. Explain the purpose of the link reaction: *The purpose of the link reaction is to convert pyruvate into acetyl CoA, which then enters the Krebs cycle.*
3. On the diagram of cell respiration (previous page), state the num...
4. How many ATP molecules per molecule of glucose are generated? (a) Glycolysis: *2 ATPs* (b) Krebs cycle: *2 ATPs* (c) E...
5. Explain what happens to the carbon atoms lost during respirat...
6. Explain what happens during oxidative phosphorylation:

Many activities with data handling are supported by working spreadsheets, which include all data and comments on graphical analysis.



Using BIOZONE's Website

BIOZONE's web site should be the first stop for biologists. As well as providing all our product information (including shipping dates) and updates, www.biozone.co.uk provides quick access to the latest RSS newsfeeds and podcasts from around the world. You can also quickly link to the websites of publishers of references cited in the workbooks. Perhaps of greatest value to students and teachers is the BIOLINKS area of BIOZONE's website. The BIOLINKS pages are distinct from *WebLinks* (which are specific to each workbook edition) and provide a database of well organised hyperlinks pertaining to topics of interest in biology and environmental science. The database is updated regularly, so that outdated, not operational, or no longer relevant sites are removed and new sites are added as they appear.

Click on each topic to see a list of all related biology links. Each topic has relevant subtopics to make searching easier and each link has a brief description.

Click on the link to access the named site. The brief description tells you how the site may be of interest, as well as any country specific bias, if this is relevant.

BIOLINKS

- Anatomy and Physiology
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- Animal Biology
- Biochemistry
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- Biotechnology
- Cell Biology
- Conservation
- Ecology
- Earth Science
- Evolution
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General Sites for Cell Biology

BBC News: Cell discovery clues to body clock and beating jet lag

New discoveries into how the body clock works could provide clues to help combat jet lag, research suggests.

Kimball's Biology Pages

A comprehensive biology site created and maintained by John W. Kimball, a retired graduate of Harvard College where he taught immunology.

Molecular Biology Web Book

A free web book, covering such topics as Cells and viruses, protein structure, DNA and Cell division.

NIH: Using technology to study cellular and molecular biology

Using Technology to Study Cellular and Molecular Biology—developed with the the National Center for Research Resources (NCRR)—is a creative, inquiry-based instruction program designed to promote active learning and stimulate student interest in medical topics.

DNA Replication and Mutation

- DNA Replication by John Kyrk
- Karyotype Activities Genetic Science Learning Center
- DNA Repair Nature

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