REAL-LIFE BIOLOGY

Cell Biology

Teacher guide

For the National 5 Biology workbook



C. Blewis

Blewis LEARNING

Using the workbooks

The National 5 Biology workbook for **Cell Biology** has six topics. Every topic has learning pages, a practical the learner plans and evaluates, a brain break and an exam-style check-up.

PRACTICALS

Learners plan each investigation (variables, prediction, kit, risk, method), take repeat readings, work out averages, draw graphs with their own scales, and write conclusions and evaluations.

PRACTICAL SAFETY

Every practical has a Stay safe table and a teacher note with hazards, adapted versions and common problems. The Stay safe tables and these notes are a starting point, not a complete risk assessment: the teacher or school must risk assess every practical for their own learners, room and kit before use, following their employer's policies and national guidance (in Scotland, SSERC). Always check learners' care plans and medical information. Activities with flames or microbes are teacher demonstrations, with example results provided.

NO LAB, NO KIT, OR A LEARNER ABSENT

Each practical includes example results so learners can still complete the results, graph, conclusion and evaluation.

EVIDENCE

The practicals develop the skills needed for the assignment and for questions on experimental work in the exam; the learn pages and check-ups build knowledge and problem solving. The skills tracker at the back of each workbook can be signed off as you go. Always check the latest course documents and your centre's arrangements.

Contents

Topic 1	Cell structure	**4**
Topic 2	Transport across cell membranes	**6**
Topic 3	DNA and the production of proteins	**9**
Topic 4	Proteins and enzymes	**11**
Topic 5	Genetic engineering	**13**
Topic 6	Respiration	**16**

TEACHER NOTES

Practical 1: Are the cells the same size in every layer of an onion?

Time	One 50-minute lesson in pairs. Five slides with three counts each takes about 30 minutes once learners can focus quickly.
Kit per group	Light microscope (× 10 objective, × 100 total magnification), slides and cover slips, forceps, dilute iodine solution with a dropper, a small knife and white tile, half an onion with the layers separated, paper towel. A transparent ruler to measure the field of view.
Prep	Separate the onion layers and number them from the outside. Measure the field of view at the chosen magnification in advance (often about 1.5 mm at × 100) or let learners measure it with a transparent ruler.
Expected results	Outer layer cells are usually longer than inner layer cells; typical lengths 150 to 300 µm. Counts vary across a slide, so three counts per layer matter.
Level	N5 plans the test, repeats counts, calculates the mean and cell length, draws a bar graph and evaluates.

Safety and inclusion

- Eye protection when using iodine; wipe up spills. Cut on a tile and away from fingers.
- Glass slides and cover slips: handle by the edges and report breakages. Never use a microscope mirror in direct sunlight.
- Learners who find fine handling hard can be the counter and recorder while a partner makes the slides, or use a microscope camera on a screen.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.

Common problems

- **Epidermis folded or too thick:** peel from the inside surface and lay it flat in the stain.
- **Air bubbles:** lower the cover slip at an angle with a mounted needle or pencil tip.
- **Units:** learners mix mm and µm; insist on converting the field of view to µm first.

No lab, no time, or a learner absent?

The sample results let learners complete the means, cell lengths, bar graph, conclusion and evaluation without the practical. A projected micrograph of onion epidermis can replace the microscopes.

Assessment link

Evidence of planning, recording, calculating a mean and a derived value, graphing and evaluating. Good practice for the assignment: compare with a published cell size and reference the source.

Answers: Topic 1

Topic 1: Cell structure (N5)

1 Inside animal and plant cells

1 Nucleus: contains genetic information (DNA) and controls the cell. Cell membrane: controls what enters and leaves the cell. Cytoplasm: where many chemical reactions happen. Mitochondrion: site of aerobic respiration. Ribosome: site of protein synthesis. Cell wall: supports the cell and stops it bursting. Chloroplast: site of photosynthesis. Vacuole: stores cell sap (water, sugars, salts) and keeps the cell firm.

2 Cell wall, (large) vacuole, chloroplasts.

3 The root is underground in the dark, so no light reaches it and it cannot photosynthesise. (It receives sugar made in the leaves.)

2 Fungal and bacterial cells

1 Nucleus: ✓ ✓ ✓ ×. Cell wall: × ✓ ✓ ✓. Mitochondria: ✓ ✓ ✓ ×. Chloroplasts: × ✓ × ×. Plasmids: × × × ✓ (columns animal, plant, fungus, bacterium). Accept ✓ or × for plasmids in yeast: some yeasts do have plasmids, but at N5 plasmids are linked to bacteria.

2 A fungal cell (e.g. yeast) or a plant cell that is not green (e.g. a root cell).

3 Bacterial DNA is not inside a nucleus (it is loose in the cytoplasm); bacteria also have plasmids (small rings of DNA).

3 Using a microscope

1 36 mm = 36 000 µm; real size = 36 000 ÷ 6000 = 6 µm.

2 Image = 50 × 400 = 20 000 µm = 20 mm.

3 2.0 mm = 2000 µm; 2000 ÷ 8 = 250 µm.

Practical 1: Are the cells the same size in every layer of an onion?

Variables: change the onion layer; measure the number of cells across the field of view (then calculate cell length); keep the same: magnification (field of view), the onion, the stain, where on the slide you count (across the middle).

Prediction, e.g. cells in the outer layers are longer, because the outer layers are older and their cells have grown more.

Equipment: microscope, slides and cover slips, forceps, iodine and dropper, knife (on a tile). Not needed: thermometer, stopwatch.

Hazards, e.g. knife (cut away from fingers on a tile); glass slides and cover slips (handle by the edges, report breakages); microscope lamp or mirror (never point a mirror at the Sun).

Method key points: peel a thin piece of epidermis from the inside of each layer with forceps; lay it flat in a drop of iodine and lower a cover slip; use the same magnification for every slide; count the cells in a line across the middle of the field in three places; mean count; cell length = field width ÷ mean count.

Sample results: layer 1 (outer): mean 5.3 cells, 281 µm; layer 2: mean 6.3 cells, 237 µm; layer 3: mean 7.3 cells, 205 µm; layer 4: mean 8.7 cells, 173 µm; layer 5 (inner): mean 10.3 cells, 145 µm.

Layer 3: mean = (7 + 8 + 7) ÷ 3 = 7.3 cells; length = 1500 ÷ 7.3 = about 205 µm.

Graph: bar graph, layer on the x-axis (in order from outer to inner), mean cell length (µm) on the y-axis, gaps between bars.

Conclusion: the cells get shorter (smaller) from the outer layer to the inner layer, from about 281 µm to 145 µm.

Evaluate: (a) cells are not all the same size, so counting in several places and taking a mean makes the estimate more reliable. (b) e.g. measure the field of view with a transparent ruler or graticule; count more cells by using a lower magnification; count only whole cells along a straight line.

Check-up

1 B (1). 2 A (1).

3 Loose in the cytoplasm (not in a nucleus) (1); plasmid(s) (1).

4 42 mm = 42 000 µm and real size = image size ÷ magnification (1); 42 000 ÷ 6000 = 7 µm (1).

5 Plant cell walls are made of cellulose; fungal cell walls are made of a different material (not cellulose) (1).

6 Leaf cells carry out a lot of photosynthesis, which happens in chloroplasts (1). Muscle cells need a lot of energy (ATP), which is released by aerobic respiration in mitochondria (1).

TEACHER NOTES

Practical 2: How does sugar concentration affect the mass of carrot?

Time	Two short sessions: 30 minutes to set up and 20 minutes the next day to reweigh. Groups of three, one concentration each per learner, or the whole range per group.
Kit per group	Large carrot, cork borer (about 8 mm), knife and tile, ruler, balance (0.01 g), six labelled boiling tubes in a rack, 25 cm^3 measuring cylinder, paper towel, sucrose solutions 0 to 1.0 mol/l.
Prep	Make 1.0 mol/l sucrose (342 g per litre) and dilute to make 0.2 to 0.8 mol/l. Label clearly. Potato, swede or beetroot work equally well.
Expected results	Gain of about 10 to 15% in water, a no-change point near 0.3 to 0.5 mol/l for carrot, and losses of 10 to 15% in 1.0 mol/l. Plasmolysis can be shown on a stained strip of red onion epidermis.
Level	N5 plans the test, uses means, calculates percentage change, draws a graph with negative values and uses it to estimate the no-change point.

Safety and inclusion

- Cut on a tile, pushing the borer and knife away from the hand; staff may cut cylinders for learners with fine-motor needs.
- Sugar solutions are low hazard; wipe spills to avoid slips. Do not eat the carrot.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.

Common problems

- **Inconsistent blotting:** roll each cylinder once on a paper towel.
- **Using change in mass, not percentage:** stress that the starting masses differ.
- **Graph axis:** learners forget negative values; show how to place zero part-way up the y-axis.

No lab, no time, or a learner absent?

The sample results let learners complete the calculations, graph, no-change estimate, conclusion and evaluation without the practical.

Assessment link

Evidence of planning, calculating derived values, graphing with negative values, interpolating and evaluating. Good practice for the assignment: compare with another group's results or published data and reference the source.

Answers: Topic 2

Topic 2: Transport across cell membranes (N5)

1 The membrane and diffusion

1 Phospholipids and proteins.

2 Oxygen is used up inside the cell, so its concentration inside stays lower than outside; oxygen moves down the concentration gradient from higher to lower concentration.

3 Starch molecules are too large to pass through the membrane; glucose molecules are small.

4 Carbon dioxide.

2 Osmosis

1 The salt makes a solution with a lower water concentration outside the cells, so water moves out of the cells by osmosis, from a higher to a lower water concentration, across the membrane.

2 They gain water by osmosis (higher water concentration outside), swell and burst, because they have no cell wall.

3 In water the celery cells take in water and become turgid. In strong sugar solution they lose water, the vacuole shrinks and the membrane pulls away from the wall: they are plasmolysed.

3 Active transport

1 Passive: high to low concentration (down the gradient); no energy; not always (many molecules diffuse straight through the phospholipids).
Active: low to high (against the gradient); yes, energy (ATP) from respiration; yes, membrane proteins.

2 Change = 2.16 − 2.40 = −0.24 g; −0.24 ÷ 2.40 × 100 = −10%, a 10% decrease.

3 Taking in nitrate needs active transport, which needs energy from aerobic respiration; without oxygen less energy (ATP) is released.

Practical 2: How does sugar concentration affect the mass of carrot?

Variables: change the sugar concentration; measure the mass before and after (calculate % change); keep the same: size and source of the carrot cylinders, volume of solution, time left, temperature, method of blotting.

Prediction, e.g. the carrot gains mass in water and weak solutions and loses mass in strong solutions, because water moves by osmosis from a higher to a lower water concentration.

Equipment: cork borer, knife, balance, boiling tubes, measuring cylinder, paper towel. Not needed: thermometer.

Hazards, e.g. broken glass from boiling tubes (use a rack, sweep up with a brush); spilt sugar solution making the floor slippery (wipe up straight away).

Method key points: cut cylinders with the same borer and trim to the same length; blot and weigh; place each in the same volume (e.g. 20 cm^3) of solution; leave for the same time (e.g. 24 hours); blot in the same way and reweigh; three cylinders per concentration and use the mean.

Sample results: 0.0 mol/l: +0.37 g, +11.9%; 0.2 mol/l: +0.18 g, +6.1%; 0.4 mol/l: +0.03 g, +1.0%; 0.6 mol/l: −0.15 g, −5.0%; 0.8 mol/l: −0.26 g, −9.0%; 1.0 mol/l: −0.40 g, −13.0%.

Graph: sugar concentration (mol/l) on x, % change on y with zero marked; a falling line of best fit crossing zero at about 0.43 mol/l (accept 0.4 to 0.5).

Use your graph: about 0.43 mol/l; at this concentration the water concentration of the solution is the same as inside the carrot cells, so there is no net movement of water.

Conclusion: as the sugar concentration increased, the percentage change in mass decreased, from a gain of about 12% in water to a loss of about 13% in 1.0 mol/l.

Evaluate: (a) the cylinders started with different masses, so percentage change allows a fair comparison. (b) Surface water adds to the mass; blotting the same way stops this from changing the results unfairly.

Check-up

1 C (1). 2 C (1).

3 It allows some molecules to pass through but not others (e.g. small but not large molecules) (1).

4 Change = 0.45 g ÷ 5.00 g (1); × 100 = 9% increase (1).

5 Both gain water by osmosis (1); the plant cell has a cell wall which stops it bursting / the animal cell has no cell wall (1).

6 Active transport (1); any two from: moves ions against the concentration gradient / from low to high concentration (1); needs energy (ATP) (1); needs membrane proteins (1).

TEACHER NOTES

Practical 3: Does more strawberry give more DNA?

Time	One 50-minute lesson in groups of three, each group doing the full range or one mass per group with class results pooled.
Kit per group	Fresh or defrosted strawberries, balance, sealable food bags (or mortar and pestle), extraction liquid (100 cm^3 water, 10 cm^3 washing-up liquid, 1.5 g table salt), funnel and filter paper, 10 cm^3 measuring cylinder, test tubes in a rack, ruler, glass rod.
Prep	Chill ethanol (or propan-2-ol) in a spark-free (laboratory) freezer, or in a stoppered bottle in an ice bath for at least an hour; never in a domestic freezer. Make the extraction liquid in advance.
Expected results	A white, stringy layer forms on top within a minute. Heights rise with mass and level off as the extraction liquid becomes limiting.
Level	N5 plans the test, repeats, calculates means, draws a line graph, describes a trend and evaluates the measurement method.

Safety and inclusion

- Ethanol is highly flammable: no naked flames in the room, the teacher dispenses it, and it is kept stoppered and away from heat. Eye protection for everyone.
- The extraction liquid is an eye irritant: wash hands afterwards. Nothing is eaten.
- Mashing in a sealed bag suits learners who prefer not to use glassware; a partner can measure.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.

Common problems

- **No DNA layer:** ethanol not cold enough, or poured too fast and mixed in. Tilt the tube and pour slowly down the side.
- **Different filtrate volumes:** measure 5 cm^3 every time.
- **Measuring:** read the top and bottom of the white layer at eye level.

No lab, no time, or a learner absent?

The sample results let learners complete the means, graph, conclusion and evaluation without the practical. A teacher demonstration of one extraction is enough to show what DNA looks like.

Assessment link

Evidence of planning, recording, calculating means, graphing, describing a trend and evaluating. Good practice for the assignment: compare with published data and reference the source.

Answers: Topic 3

Topic 3: DNA and the production of proteins (N5)

1 The structure of DNA

1 GCAATCGT

2 Adenine = thymine = 26%, so A + T = 52%; G + C = 100 − 52 = 48%; guanine = 48 ÷ 2 = 24%.

3 A double helix; the strands are held together by complementary base pairs (A with T, C with G).

2 Genes and the genetic code

1 A section of DNA that codes for a protein.

2 The sequence of bases in DNA (a gene) codes for the sequence of amino acids; this decides the shape and function of the protein made, and the proteins (e.g. enzymes) control the characteristics of the cell.

3 Their amino acids are in a different order (sequence), so they fold into different shapes.

4 Different genes are switched on (used) in different cells, so each cell makes only the proteins it needs.

3 From the nucleus to the ribosome

1 Top to bottom: 5, 1, 2, 4, 3 (copy made as mRNA, mRNA leaves the nucleus, reaches a ribosome, amino acids joined, chain folds into a protein).

2 DNA cannot leave the nucleus, but proteins are made at ribosomes in the cytoplasm; mRNA carries a copy of the code from the DNA to the ribosome.

3 Ribosome.

Practical 3: Does more strawberry give more DNA?

Variables: change the mass of strawberry; measure the height of the DNA layer; keep the same: same total volume (50 cm^3) of mash and extraction liquid, volume of filtrate, volume and temperature of ethanol, mashing time, ripeness of strawberries.

Prediction, e.g. more strawberry gives a taller DNA layer, because there are more cells and so more DNA.

Equipment: balance, bag or pestle for mashing, funnel and filter paper, test tubes, ruler. Not needed: microscope, thermometer.

Hazards, e.g. glass test tubes and funnels (use a rack, report breakages); detergent and salt mixture (avoid eyes, wash hands); slippery spills (wipe up).

Method key points: weigh each mass of strawberry, mash in a bag with salt and detergent extraction liquid for the same time and make each mash up to 50 cm^3 with extraction liquid, filter, measure 5 cm^3 of filtrate into a test tube, the teacher pours the same volume of ice-cold ethanol down the side, leave for the same time, measure the height of the white DNA layer with a ruler, repeat three times and take the mean.

Sample results (means): 5 g: 4.3 mm; 10 g: 8.3 mm; 15 g: 12.0 mm; 20 g: 15.3 mm; 25 g: 17.3 mm.

Graph: mass of strawberry (g) on x, mean height (mm) on y; a line that rises steeply then levels off.

Conclusion: as the mass of strawberry increased, the DNA layer got taller, but it levelled off at the highest masses.

Pattern: above 20 g the height increases only a little; e.g. the extraction liquid is not enough to break open all the extra cells, or the fixed volume of filtrate limits how much DNA can come out.

Evaluate: (a) to make it a fair test, since a larger volume would give more DNA regardless of the mass. (b) e.g. spool the DNA on a glass rod, dry it and weigh it, or measure the volume of the DNA layer in a narrow measuring cylinder.

Check-up

1 B (1). 2 C (1).

3 ACGTTA (1).

4 C = G = 34%, so G + C = 68% and A + T = 32% (1); adenine = 16% (1).

5 A copy of the gene's base sequence is made as mRNA in the nucleus (1); the mRNA carries the code out of the nucleus to a ribosome (1); at the ribosome amino acids are joined in the order set by the base sequence to make the protein (1).

6 The order of amino acids would change (1), so the enzyme would have a different shape / active site and the substrate would not fit (1).

TEACHER NOTES

Practical 4: What pH does amylase work best at?

Time	One 50-minute lesson in pairs. Each pair can do two or three pH values with class results pooled, or the full range if time allows.
Kit per group	Spotting tiles, dropping bottle of dilute iodine, 1% starch suspension, 1% bacterial α-amylase solution, pH buffer solutions 4 to 8, syringes (5 cm^3 and 1 cm^3), test tubes in a rack, stopwatch, glass rod or pipette for sampling.
Prep	Make starch fresh. Check the amylase concentration in advance so that the starch disappears in 1 to 3 minutes at pH 7; dilute if it is too fast.
Expected results	Fastest at about pH 6 to 7, slower either side. Times vary between runs; repeats and means matter.
Level	N5 plans the test, repeats, calculates mean and rate, draws a line graph, identifies an optimum and evaluates.

Safety and inclusion

- Use purchased amylase rather than saliva. Amylase powder can cause allergic sensitisation: the teacher makes up the solution, avoiding dust.
- Eye protection for iodine and buffers; wipe spills.
- Roles can be split: one learner times, one samples, one records. A printed colour chart helps learners judge the end point.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.

Common problems

- **End point unclear:** compare each drop with a control drop of iodine on its own.
- **Contaminated sampling rod:** rinse between samples.
- **Rate:** learners forget that a shorter time means a faster rate.

No lab, no time, or a learner absent?

The sample results let learners complete the means, rates, graph, conclusion and evaluation without the practical.

Assessment link

Evidence of planning, calculating means and rates, graphing, finding an optimum and evaluating. Good practice for the assignment: compare with a published optimum and reference the source.

Answers: Topic 4

Topic 4: Proteins and enzymes (N5)

1 Proteins and their jobs

1 Structural: builds cells and tissues, e.g. proteins in the cell membrane, collagen, keratin. Enzyme: speeds up reactions, e.g. amylase, catalase. Hormone: chemical messenger in the blood, e.g. insulin, glucagon. Antibody: made by white blood cells to defend against pathogens. Receptor: on a cell membrane, detects chemical signals, e.g. insulin receptor.

2 Their amino acids are in a different sequence, so they fold into different shapes, and the shape decides the job.

3 Insulin only affects cells with receptors of a complementary shape; without the receptor the cell cannot detect insulin.

2 How enzymes work

1 The active site of amylase is complementary to starch only; protein is a different shape and does not fit (amylase is specific).

2 Degradation: a large molecule (protein) is broken into smaller ones (amino acids).

3 Enzymes are unchanged at the end of the reaction, so each catalase molecule can be used again and again.

3 Temperature, pH and denaturing

1 The rate falls (to zero), because above the optimum the active site changes shape (the enzyme is denatured) and the substrate no longer fits.

2 pH 8 is far from pepsin's optimum (about pH 2), so pepsin is denatured: its active site changes shape and protein cannot fit.

3 Rate = 45 ÷ 2.5 = 18 cm^3 per minute.

Practical 4: What pH does amylase work best at?

Variables: change the pH (using buffers); measure the time for starch to disappear; keep the same: temperature, volume and concentration of starch and amylase, volume of buffer, how often iodine is tested.

Prediction, e.g. fastest near pH 7, because many amylases (such as salivary amylase) work best near neutral.

Equipment: spotting tile, iodine and dropper, syringes, test tubes, pH buffers, stopwatch. Not needed: microscope.

Hazards, e.g. glass test tubes (use a rack); buffer solutions in the eyes (eye protection); spills (wipe up).

Method key points: put a drop of iodine in each well of a spotting tile; mix the same volumes of starch and buffer, add amylase and start the clock; every 30 s put a drop of the mixture onto the iodine; record the time when the iodine stays orange-brown (no blue-black); repeat three times at each pH; work out the mean and the rate.

Sample results: pH 4: 420 s, rate 2.4; pH 5: 220 s, rate 4.5; pH 6: 110 s, rate 9.1; pH 7: 100 s, rate 10.0; pH 8: 170 s, rate 5.9.

Graph: pH on x, rate on y; a curve rising to a peak at about pH 7 and falling on each side.

Conclusion: amylase worked fastest at pH 7 (between about pH 6 and 7); the rate fell at lower and higher pH.

Explain: pH 4 is far from the optimum, so the active site changes shape (the enzyme starts to denature) and fewer starch molecules fit.

Evaluate: (a) test every 10 or 15 s, or use a colorimeter. (b) test more pH values close to the peak, e.g. pH 6.0, 6.5, 7.0, 7.5.

Check-up

1 C (1). 2 B (1).

3 The active site has a particular shape (1) which is complementary to only one substrate, so only that substrate fits (1).

4 36 ÷ 1.2 = 30 cm^3 per minute (1).

5 Enzymes are not living, so they cannot be killed (1); the heat denatured the enzyme: its active site changed shape so the substrate no longer fits (1).

6 Add amylase to starch in one tube and to another substance (e.g. protein or glucose) in a second tube (1); test for starch with iodine / for the product: starch is broken down but the other substance is not changed (1).

TEACHER NOTES

Practical 5: Does more food make yeast work faster?

Time	One 50-minute lesson in groups of three: 15 minutes to make the doughs, 40 minutes rising (use the time for the learning pages), 5 minutes to read.
Kit per group	Plain flour, fast-action dried yeast, sugar, warm water (about 35 °C), balance, five 100 cm^3 measuring cylinders, stirring rod or spatula, beaker, water bath at 35 °C, timer.
Prep	Set the water bath early. Pre-weigh 20 g portions of flour and 1 g portions of yeast to save time. A greased glass rod helps push the dough down.
Expected results	A small rise with no added sugar, rising to a much larger rise at 4 to 6 g; little extra above that.
Level	N5 plans the test, repeats, calculates means, draws a graph, explains a levelling-off and evaluates. Links GM production in fermenters to growth conditions.

Safety and inclusion

- Food materials in the lab are not eaten. Check for flour or yeast allergies; avoid raising dust.
- Water bath no hotter than 40 °C; place cylinders gently in a rack.
- Mixing dough suits learners who enjoy hands-on work; others can read volumes and record.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.

Common problems

- **Air pockets:** push the dough down firmly and read the start volume carefully.
- **Water too hot:** above about 45 °C the yeast is damaged and nothing rises.
- **Dough sticks to the side:** read the lowest level of the top surface.

No lab, no time, or a learner absent?

The sample results let learners complete the means, graph, conclusion and evaluation without the practical.

Assessment link

Evidence of planning, calculating means, graphing, explaining a trend and evaluating. Good practice for the assignment: research how fermenters are controlled and reference the sources.

Answers: Topic 5

Topic 5: Genetic engineering (N5)

1 What is genetic engineering?

1 They reproduce very quickly; their plasmids are easy to remove, change and put back (also: easy and cheap to grow).

2 Any two, e.g. large amounts can be made quickly; it is cheaper; it is exactly human insulin, so fewer reactions; no animals are needed.

3 The inserted gene's base sequence codes for the amino acids of human insulin, and the bacterium's ribosomes follow that code.

4 An organism that contains a gene (or genes) transferred from another organism.

2 The stages

1 Top to bottom: 5, 1, 4, 2, 6, 3 (identify the gene, extract the gene, extract a plasmid, cut the plasmid and insert the gene, insert the plasmid into a host, grow the bacteria).

2 To cut the gene out of the chromosome, to cut open the plasmid, and to seal (join) the gene into the plasmid.

3 So that the cut ends of the gene and the plasmid match and can be joined.

3 Growing GM microbes

1 80 ÷ 20 = 4 divisions; 2^4 = 16; 1000 × 16 = 16 000 bacteria.

2 The enzymes in the microbes work best at their optimum temperature; too hot and they would be denatured, too cold and growth would be slow.

3 Benefit, e.g. large amounts of pure medicine made quickly and cheaply without using animals. Concern, e.g. GM bacteria could escape into the environment / long-term effects unknown.

Practical 5: Does more food make yeast work faster?

Variables: change the mass of sugar; measure the rise in dough volume (cm^3) after a set time; keep the same: mass of flour and yeast, volume and temperature of water, temperature of the water bath, time, size of cylinder.

Prediction, e.g. more sugar gives a bigger rise, because yeast has more food to respire and releases more carbon dioxide.

Equipment: balance, measuring cylinders, water bath, stirring rod, timer. Not needed: microscope, iodine.

Hazards, e.g. hot water bath (set no higher than 40 °C); glass cylinders (place, do not drop, in the bath); slippery spills (wipe up).

Method key points: weigh the same flour and yeast for each dough, add the sugar, mix with the same volume of warm water; push the dough to the bottom of a 100 cm^3 measuring cylinder and read the start volume; stand all cylinders in the same water bath for 40 minutes; read the final volume; rise = final – start; three repeats and a mean.

Sample results (means): 0 g: 7 cm^3; 2 g: 14 cm^3; 4 g: 22 cm^3; 6 g: 26 cm^3; 8 g: 27 cm^3.

Graph: sugar (g) on x, mean rise (cm^3) on y; a line that rises then levels off.

Conclusion: as the mass of sugar increased, the dough rose more, up to about 6 g; above that the rise hardly increased.

Explain: carbon dioxide (from fermentation / respiration of the yeast); above 6 g something else limits the rate, e.g. the amount of yeast or the time allowed.

Evaluate: (a) to keep the temperature the same (and near the optimum for the yeast's enzymes) for every dough. (b) flour contains some sugar (starch broken down to sugar) that the yeast can use.

Check-up

1 B (1). 2 C (1).

3 The gene for human growth hormone is identified on a chromosome and cut out (extracted) using enzymes (1); a plasmid is extracted from a bacterium (1); the plasmid is cut open and the gene is inserted and sealed in with enzymes (1); the plasmid is inserted into a host bacterium, which multiplies and makes the hormone (1).

4 1.5 hours = 90 min, 90 ÷ 15 = 6 divisions (1); 2^6 = 64 bacteria (1).

5 e.g. GM organisms might escape and harm other organisms; long-term effects are not known; ethical objections to moving genes between species (1).

6 Sugar is food: the glucose is used in respiration to release energy (and as raw material) for growth (1); oxygen is needed for aerobic respiration, which releases the most energy (ATP) (1).

TEACHER NOTES

Practical 6: Does harder exercise make you breathe faster?

Time	One 50-minute lesson in pairs. Four exercise rates with rest between them takes about 30 minutes.
Kit per group	A low, stable step or gym bench, stopwatch, a metronome app to set the pace, trainers, space away from benches. Water for afterwards.
Prep	Check medical information and PE advice for learners with asthma, heart conditions or injuries. Agree a signal to stop. A respirometer demonstration with germinating seeds can be set up alongside. Soda lime or sodium hydroxide is corrosive: the teacher sets up the respirometer, eye protection is worn, and the organisms sit on a gauze above the absorber, never in contact with it.
Expected results	Resting breathing rate of about 12 to 20 breaths per minute, rising steadily with step rate. Individuals vary widely; pooled class data give the clearest pattern.
Level	N5 plans a fair test with a person as the subject, repeats, calculates means, graphs, explains using respiration and evaluates validity.

Safety and inclusion

- Taking part is voluntary. Any learner can be the timer or recorder instead; seated arm exercise is an alternative.
- Stop at once if anyone feels dizzy, breathless or unwell. Inhalers within reach for learners with asthma.
- No blood or other body fluids are sampled.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.

Common problems

- **Counting breaths:** learners change their breathing when watched. Count rises of the chest discreetly, or count for 30 s and double.
- **Not resting long enough:** wait until the breathing rate is back to the resting value.
- **Pace drifts:** use a metronome beat for each step rate.

No lab, no time, or a learner absent?

The sample results let learners complete the means, graph, conclusion and evaluation without the practical.

Assessment link

Evidence of planning, recording, calculating means, graphing, explaining and evaluating validity. Good practice for the assignment: compare with published typical values and reference the source.

Answers: Topic 6

Topic 6: Respiration (N5)

1 Energy and ATP

1 Muscle contraction: moving his legs (or breathing, the heart beating). Cell division: growing or repairing skin, healing a cut. Protein synthesis: making enzymes, hormones or new muscle protein. Nerve impulses: sending messages from the brain to the muscles.

2 Respiration happens as many steps, one after another, and each step is speeded up (catalysed) by a different enzyme.

3 Muscle contraction needs a lot of energy, so more glucose is respired to make more ATP.

4 ADP and inorganic phosphate (Pi).

2 Glycolysis and aerobic respiration

1 Glycolysis, in the cytoplasm.

2 Two.

3 Sperm need a lot of energy (ATP) to swim, and aerobic respiration in mitochondria releases a large yield of ATP.

4 The aerobic stage in the mitochondria uses oxygen to break pyruvate down to carbon dioxide and water; glycolysis (glucose to pyruvate) does not use oxygen.

3 Fermentation and measuring respiration

1 Oxygen: aerobic yes, fermentation no. Where: aerobic in the cytoplasm then mitochondria; fermentation in the cytoplasm. Products: aerobic carbon dioxide and water; fermentation lactate (animal) or ethanol and carbon dioxide (plant and yeast). ATP: aerobic large yield; fermentation small yield (2 ATP).

2 54 ÷ 12 = 4.5 mm per minute.

3 Fermentation releases only a small amount of ATP from each glucose, so less energy is available for contraction (and lactate builds up in the muscles).

Practical 6: Does harder exercise make you breathe faster?

Variables: change the step-up rate; measure breaths per minute straight after exercise; keep the same: person, step height, time exercising, time counting, rest time between tests.

Prediction, e.g. faster exercise gives a higher breathing rate, because the muscles need more oxygen for aerobic respiration and produce more carbon dioxide.

Equipment: step, stopwatch, partner, trainers (water for afterwards). Not needed: pulse monitor, which measures heart rate, not breathing rate.

Hazards, e.g. feeling dizzy or unwell (stop at once and sit down; nobody is made to take part); asthma (have an inhaler nearby; choose an easier task).

Method key points: count breaths for 1 minute at rest; step up and down in time to a beat (e.g. a metronome app) for 2 minutes at each rate; count breaths for 1 minute straight afterwards; rest until breathing returns to normal; three repeats and a mean.

Sample results (means): 0 step-ups per minute: 14.0 breaths per minute; 10 step-ups per minute: 18.3 breaths per minute; 20 step-ups per minute: 24.0 breaths per minute; 30 step-ups per minute: 30.0 breaths per minute.

Graph: step-ups per minute on x, breaths per minute on y; a straight line rising steadily.

Conclusion: as the rate of exercise increased, the breathing rate increased, from about 14 to 30 breaths per minute.

Explain: harder exercise needs more energy, so muscle cells carry out more aerobic respiration; this needs more oxygen and releases more carbon dioxide, so breathing speeds up.

Evaluate: (a) so each test starts from the same resting state, making it a fair test. (b) repeat with many different people (a larger sample) and take a mean.

Check-up

1 B (1). 2 C (1).

3 Glucose is broken down to two pyruvate in glycolysis, in the cytoplasm (1); with oxygen the pyruvate is broken down to carbon dioxide and water (1) in the mitochondria, releasing a large yield of ATP (1).

4 Any two from: muscle contraction, cell division, protein synthesis, transmission of nerve impulses (1 each).

5 42 ÷ 7 = 6 mm per minute (1).

6 Without oxygen the pyruvate cannot be broken down aerobically in the mitochondria (1); fermentation (to ethanol and carbon dioxide) gives only the 2 ATP from glycolysis, a small yield (1).

About the author

C. Blewis has taught for 17 years, including 10 years in Additional Support Needs (ASN) provision, teaching sciences, maths, PE and more.

In many schools, especially smaller and specialist settings, teachers are often asked to teach outside their own subject. These books are written for them, and for the young people they teach: clear, practical and ready to use from the first lesson.