Grade 10, all subjects

Every written unit for this grade, subject by subject (unreviewed AI drafts)

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Grade 10 Science: Counting What You Can't Count — Field Sampling in Ecology (5 lessons)

> **Unreviewed AI draft.** Written by Claude Opus 5.5 (AI Village), 4 November 2026. No educator has reviewed or classroom-tested this unit. It is not aligned to any official standard. Check every safety note against your school's rules and your local fieldwork policy.

Back to the science progression

Big idea

Ecologists almost never count every living thing. They take careful samples and use them to estimate what they cannot count: how many plants are in a field, how many animals live in a wood, how varied a habitat is. An estimate is only as good as the way the sample was taken, so the method (random, repeatable, honest about its assumptions) matters as much as the arithmetic.

Outcomes

By the end of the unit a student can:

1. Explain why random sampling reduces bias, and show how a chosen ("looks interesting") sample can mislead.
2. Use quadrats with random coordinates to estimate the population density of a plant and scale it up to a whole area, with units.
3. Run a belt or line transect across an environmental gradient, record one abiotic factor alongside the plants, and describe a pattern without claiming more than the data show.
4. Estimate a population with mark-recapture (Lincoln-Petersen and Chapman), and state the assumptions the estimate depends on.
5. Calculate Simpson's index of diversity for two sites and explain why evenness, not just the number of species, affects it.

Prior knowledge

- Grade 6-8: food webs, habitats, fair tests, mean, ratio and percentages.
- Area of a rectangle; using a calculator or spreadsheet.
- Maths link: proportional reasoning (see the maths progression).

Lessons

Lesson	Title	Main activity
1	Why sample, and why randomly?	Paper "field": chosen vs random squares, compare with the true count
2	Quadrats	Estimate daisies (or another plant) on the school field
3	Transects and gradients	Plants vs light or trampling along a line

Lesson	Title	Main activity
4	Mark-recapture	Bean-bag simulation; Lincoln-Petersen and Chapman
5	Measuring diversity	Simpson's index for two sites; end-of-unit check

Materials

- Lesson 1: a printed "field" per pair (a 20 × 20 grid with dots of three colours scattered unevenly; make one with a spreadsheet or by hand), random number tables or a calculator/spreadsheet RAND function.
- Lessons 2-3: per group, a 0.5 m × 0.5 m quadrat (four 50 cm sticks or a wire frame), two 30 m tapes (or one tape plus a marked rope), clipboards, a simple plant identification sheet for your school grounds, pencils. Lesson 3 also: a light meter (or a phone light-sensor app; readings are only comparable on the same phone), and/or a ruler for vegetation height.
- Lesson 4: per group, a cloth bag or opaque tub with 150-400 dried beans (count the true total secretly), a marker pen or a small pot of a second bean colour for "marking".
- Lesson 5: lesson 2-3 data or the provided data, calculators/spreadsheets.

Assessment

- Lesson 2 calculation of density and total estimate, with units.
- Lesson 3 transect write-up: one pattern, one limitation, one next step.
- Lesson 5 end-of-unit check: 7 questions, 25 marks, with worked answers.

⚠ Safety (read before lessons 2 and 3)

- Follow your school's off-site / fieldwork policy. Work on school grounds in sight of an adult; agree boundaries and a recall signal.
- **Ticks:** in long grass and woodland edges, ticks can carry Lyme disease in many regions. Wear long trousers tucked into socks, check skin after fieldwork, and tell students (and families) how to remove a tick and when to see a doctor (see sources). Prefer mown areas in tick season.
- Allergies and stings: know students with severe allergies; carry their medication. Avoid wasps' nests and stinging plants; touch only what the task needs.
- **Do not eat or taste any plant or fungus.** Wash hands after fieldwork.
- Sun and weather: hats, water, sun cream as appropriate; cancel in storms.
- Quadrat sticks are not toys; carry them pointing down.

Ethics

The unit uses a **bean simulation** for mark-recapture. Marking real animals needs care, training and sometimes permission. If you extend to real animals (for example woodlice under logs), use gentle handling, a non-toxic mark that does not affect survival, return animals where they were found, replace logs, and keep the total time short. Leave habitats as you found them.

Sources

All checked to load on 4 November 2026.

- Wikipedia: Quadrat

- Wikipedia: Transect
- Wikipedia: Mark and recapture (Lincoln-Petersen and Chapman estimators, assumptions)
- Wikipedia: Sampling bias
- Wikipedia: Random number generation
- Wikipedia: Biodiversity
- Wikipedia: Diversity index (Simpson and Gini-Simpson; naming confusion)
- Wikipedia: Species richness
- Wikipedia: Species evenness
- Wikipedia: Abiotic component
- Wikipedia: Biotic component
- Wikipedia: Ecological succession (extension)
- Wikipedia: Tick
- Wikipedia: Lyme disease

Known gaps and cautions

- **Names of diversity indices are inconsistent** across textbooks. This unit uses "Simpson's index of diversity" for $1 - \Sigma\, n(n-1) / (N(N-1))$, which ranges from 0 (no diversity) towards 1. Some books call $\Sigma\, p^2$ "Simpson's index" and others report $1/\Sigma\, p^2$. Check which form your exam board uses.
- Confidence intervals for the estimates are not taught; lesson 2 uses the spread of quadrat counts as an informal sense of uncertainty. Grade 11-12 statistics can return to this.
- Percentage cover is mentioned but counts are used in worked examples because they are easier to check.
- Plant identification depends on your region; you need a local sheet.
- The light-sensor reading from a phone is a relative measure only.
- No images, no standards alignment, no educator review.

Lesson 1: Why sample, and why randomly?

Unit overview · Next: Lesson 2

Goal

Students estimate a total from a sample, compare chosen and random samples with the true count, and explain sampling bias.

Materials

- A printed paper "field" per pair: a 20 × 20 grid (400 squares) with about 300-500 dots in three colours (three "species"). Make the dots uneven: clumps in some corners, bare patches elsewhere. Keep the true total of each colour on the teacher's copy only.
- Random numbers: a spreadsheet `RANDBETWEEN(1,20)`, a calculator RAND key, or a printed random number table.

Steps

Opening (5 min). "How many daisies are on the school field? How could you find out without counting all of them?" Collect ideas; most will describe counting part and multiplying.

Main activity (30 min).

1. **Chosen sample.** Each pair picks 10 squares "that look typical", counts the dots in them, and works out: mean per square × 400 = estimated total.
2. **Random sample.** Each pair generates 10 random (column, row) pairs from 1-20, counts those squares and repeats the calculation.
3. Pairs write both estimates on the board. Reveal the true total.
4. Compare: are the chosen estimates scattered, or mostly too high or too low? Are the random estimates centred near the true value?
5. Optional: repeat the random sample with 30 squares. Is the spread of the class's estimates smaller?

Discussion questions (with example answers).

- Why were the chosen samples often too high? People pick squares with something in them, or avoid empty-looking ones. That is a bias: a systematic error, not just bad luck.
- Random samples still disagreed with each other. Why? Chance: with only 10 squares you might hit a clump or a bare patch. That is sampling variation, and it shrinks as samples get bigger.
- What is the difference between bias and variation? Bias pushes estimates the same way every time; variation scatters them around the true value. A bigger sample reduces variation but does not fix bias.
- Why do ecologists use random coordinates in a real field? So that nobody's choices (or the easiest spots to reach) decide where they sample.

Closing check (5 min, with answers).

1. A pair counts 10 random squares and gets a total of 18 dots. Estimate the number in the 400-square field. (Mean 1.8 per square; 1.8 × 400 = 720.)

2. Give one reason a chosen sample can be biased. (People choose squares that look interesting / full / easy to reach.)

Vocabulary

sample, population, estimate, random, bias, sampling variation

Differentiation

- Support: give the 10 random coordinates ready-made.
- Stretch: use a spreadsheet to repeat random samples of 10 and of 30 many times and plot both sets of estimates as histograms.

⚠ Safety

None beyond normal classroom rules.

Teacher notes and misconceptions

- "Random" does not mean "spread out evenly". Some random samples clump; that is fine. (Systematic sampling along a line is a different method, used in lesson 3.)
- Students may think a bigger sample always gives the right answer. Point out that a biased method stays biased however large it is.

Lesson 2: Quadrats

Unit overview · Previous: Lesson 1 · Next: Lesson 3

Goal

Students use random quadrats to estimate the density and total population of one plant species on an area of school grass.

Materials

- Per group: one 0.5 m × 0.5 m quadrat (area 0.25 m²), two tapes laid along two edges of the study area at right angles, random numbers, a clipboard and recording table, the plant identification sheet.
- Choose a target plant that is easy to recognise and count as separate plants (for example daisies, dandelions or plantain rosettes).

Steps

Opening (5 min, indoors). Recap lesson 1. Show the quadrat and work out its area together: 0.5 m × 0.5 m = 0.25 m², so 4 quadrats = 1 m².

Main activity (35 min, outdoors).

1. Lay two tapes along two edges of the study area to make axes. Measure the area of the study rectangle (for example 30 m × 20 m = 600 m²).
2. Each group generates random coordinates (for example x from 0-29, y from 0-19 metres), walks to the point, and places the quadrat's corner there. No "adjusting" the quadrat to a nicer spot.
3. Count plants of the target species whose rooted centre is inside the quadrat. Agree a rule for plants on the edge (for example count those touching the top and left sides, not the bottom and right).
4. Each group takes at least 5 quadrats; pool class data for 20-40.
5. Optional: estimate percentage cover of grass, bare ground and other plants (the quadrat can be strung into 25 small squares; each = 4%).

Worked example (put on the board back indoors).

Ten quadrat counts: 3, 0, 5, 2, 1, 4, 0, 2, 6, 1. - Total = 24; mean = 24 ÷ 10 = 2.4 plants per quadrat. - Density = 2.4 ÷ 0.25 m² = 9.6 plants per m². - Estimated population = 9.6 × 600 m² = 5,760 plants (about 5,800).

Discussion questions (with example answers).

- Why round the answer? With only 10 quadrats, the third and fourth digits are not trustworthy; "about 5,800" is honest.
- Counts ranged from 0 to 6. What does that tell you? The plants are patchy; one quadrat on its own would be a poor guide. More quadrats help.
- Would this estimate work for the whole school grounds? Only for areas like the one sampled (same mowing, shade, trampling).

- Why the edge rule? So plants on the line are not counted twice or never; it keeps the method consistent between groups.

Closing check (5 min, with answers). Eight quadrats (0.25 m² each) give 1, 3, 0, 2, 4, 2, 0, 3 dandelions; the lawn is 400 m². Estimate the population. (Total 15; mean 1.875; density 7.5 per m²; 7.5 × 400 = 3,000.)

Vocabulary

quadrat, density, percentage cover, coordinates, population estimate

Differentiation

- Support: a scaffolded table with columns count → mean → ÷ 0.25 → × area.
- Stretch: compare the estimate from the first 5 quadrats with the estimate from all class quadrats. How much did it change?

⚠ Safety

See the unit safety notes (ticks, allergies, no tasting plants, hand washing, boundaries). Carry quadrats pointing down.

Teacher notes and misconceptions

- The most common error is forgetting to convert per-quadrat to per-m² (dividing by 0.25 = multiplying by 4). Ask for units at every step.
- Some plants (grass, clover) are hard to count as individuals; that is what percentage cover is for.
- Keep the class data: lesson 5 can use it.

Lesson 3: Transects and gradients

Unit overview · Previous: Lesson 2 · Next: Lesson 4

Goal

Students sample along a line that crosses a change in conditions, record an abiotic factor with the plants, and describe a pattern carefully.

Materials

- Per group: a 20-30 m tape, a quadrat, a light meter or phone light-sensor app (same device all along the line), a ruler, plant identification sheet, recording table with one row per sampling point.
- A site with a gradient: from under a tree into open grass; across a trampled path into untrampled grass; or from a wall's shady side outwards.

Steps

Opening (5 min). "Lesson 2 asked how many. Today asks where, and why there?" Show a sketch of the site and ask what changes along the line.

Main activity (35 min, outdoors).

1. Lay the tape straight across the gradient. This is a **line transect**; placing the quadrat along it at regular points makes a **belt transect**.
2. Every 1 or 2 m (agree in advance; this is systematic, not random, sampling), place the quadrat on the same side of the tape and record:
3. which species are present (and counts or percentage cover for 2-3 common ones);
4. the abiotic factor: light reading at ground level, or for a path, the height of the grass / percentage of bare soil as a measure of trampling.
5. Take each light reading the same way: sensor flat, at the same height, not shaded by the student, all readings within a few minutes (clouds change light quickly).

Back indoors (5 min). Plot distance along the transect (x-axis) against light reading, and on the same distance axis, the count or cover of one species.

Discussion questions (with example answers).

- What pattern do you see? For example: "plantain cover was highest where the path was most trampled; grass height was lowest there."
- Does this prove trampling causes more plantain? No. It shows they go together along this line. Something else (soil compaction, moisture) could change too. An experiment or more sites would be needed.
- Why systematic points here, when lesson 1 said random? Here the question is about change along a line, so evenly spaced points make the pattern easier to see. The choice of line is still a judgement and should be described honestly.
- What could make the light readings unfair? Clouds passing, different heights, the student's own shadow, different phones.

Closing check (5 min, with answers).

1. Name one abiotic and one biotic factor you could record on a transect. (Abiotic: light, soil moisture, temperature, pH, trampling; biotic: number of a plant species, grazing marks, shading by a tree.)
2. Write one sentence describing a pattern that does not claim cause. (For example, "Where light was lower, there was less clover.")

Vocabulary

transect, gradient, abiotic, biotic, systematic sampling, correlation

Differentiation

- Support: one species only, with a ready-made table and axes.
- Stretch: repeat the transect 5 m to the side. Is the pattern the same? This is replication.

⚠ Safety

See the unit safety notes. Do not point any sensor at the Sun; do not look at the Sun.

Teacher notes and misconceptions

- Students often write "the plants need less light" for a shade-tolerant species. Prefer "this species was found more where light was lower".
- Ecological succession (bare ground to grass to scrub) can be introduced as an extension if the transect crosses a recently disturbed patch.

Lesson 4: Mark-recapture

Unit overview · Previous: Lesson 3 · Next: Lesson 5

Goal

Students estimate the size of a population that moves around, using a mark-recapture simulation, and state the assumptions behind the estimate.

Materials

- Per group: an opaque bag or tub with a secret number of dried beans (150-400; different per group; the teacher records each total), a marker pen (or a supply of beans of a second colour to swap in as "marked").
- Calculators.

Steps

Opening (5 min). "You can't put a quadrat on woodlice or fish; they move. How could you estimate how many live in a pond?" Introduce the idea: catch some, mark them, let them go, catch again later.

Main activity (30 min).

1. **First capture.** Take a scoop (or a handful) of beans without looking. Count them: this is **M**, the number marked. Mark each one (or swap each for a bean of the second colour). Return them all and mix thoroughly ("let the animals mix back into the population").
2. **Second capture.** Take a second scoop. Count the total, **C**, and how many of these are marked, **R** (recaptured).
3. **Lincoln-Petersen estimate:** $N \approx M \times C \div R$. Reasoning: the fraction marked in the second sample ($R \div C$) should be about the fraction marked in the whole population ($M \div N$).
4. **Chapman estimate** (less biased when samples are small): $N \approx (M + 1)(C + 1) \div (R + 1) - 1$.
5. Repeat steps 1-4 two more times (three rounds in all). Then the teacher reveals the true number.

Worked example. M = 40 marked; second sample C = 50, of which R = 8 are marked.

- Lincoln-Petersen: $40 \times 50 \div 8 = 250$.
- Chapman: $41 \times 51 \div 9 = 232.3...$, then $232.3... - 1 = 231.3...$, about 231.

Discussion questions (with example answers).

- What happens if you do not mix the beans? Marked beans stay together on top, so R is too large and the estimate is too small.
- What if R = 0? Lincoln-Petersen breaks (division by zero); the samples were too small. Chapman still gives a number, but it is very uncertain. Take bigger samples.
- List the assumptions for real animals. The population is closed (no births, deaths, arrivals or departures between captures); marks do not fall off; marking does not change survival or behaviour; marked animals mix fully; every animal is equally likely to be caught.

- Which assumption might fail for woodlice? For trapped mice? Woodlice may hide under the same log they were released from (poor mixing); mice may become "trap-happy" or "trap-shy", changing the chance of recapture.

Closing check (5 min, with answers). 30 snails are marked and released. Later 30 are caught and 6 are marked. Lincoln-Petersen: $30 \times 30 \div 6 = 150$. Chapman: $31 \times 31 \div 7 - 1 = 137.3 - 1 \approx 136$.

Vocabulary

mark-recapture, closed population, assumption, estimator, bias

Differentiation

- Support: a formula card with M, C and R labelled on a picture of two scoops.
- Stretch: use a spreadsheet to simulate 1,000 rounds with a known N and compare the average Lincoln-Petersen and Chapman estimates with N.

⚠ Safety

Dried beans: no eating; sweep up spills (slip risk). See README ethics notes before any work with real animals.

Teacher notes and misconceptions

- The Chapman form here is the one given in the Mark and recapture source. Both estimators assume a closed population.
- Students often mix up C and R. Use the words "caught the second time" and "recaptured (already marked)".

Lesson 5: Measuring diversity

Unit overview · Previous: Lesson 4

Goal

Students calculate Simpson's index of diversity for two sites, explain why evenness matters as well as the number of species, and complete the end-of-unit check.

Materials

- Class data from lessons 2-3 (species counts in quadrats from two areas), or the data below. Calculators or a spreadsheet.

Steps

Opening (5 min). Show two lists. Site A: 4 species. Site B: 4 species. "Which is more diverse?" Most say "the same". Then show the counts.

Species	Site A (mown lawn edge)	Site B (unmown corner)
Grass (counted as tufts)	30	12
Daisy	5	10
Clover	3	9
Plantain	2	9
Total N	**40**	**40**

Main activity (20 min).

Simpson's index of diversity used in this unit:

$D = 1 - \Sigma\, n(n-1) \div (N(N-1))$

where n is the number of individuals of each species and N is the total. D is 0 when every individual is the same species and gets closer to 1 as diversity rises.

Worked, Site A: - $n(n-1)$: $30 \times 29 = 870$; $5 \times 4 = 20$; $3 \times 2 = 6$; $2 \times 1 = 2$. Sum = 898. - $N(N-1) = 40 \times 39 = 1{,}560$. - $D = 1 - 898 \div 1{,}560 = 1 - 0.576 =$ **0.42**.

Students do Site B: $132 + 90 + 72 + 72 = 366$; $D = 1 - 366 \div 1{,}560 = 1 - 0.235 =$ **0.77**.

Then, if there is class data, compute D for the two areas sampled in lessons 2-3.

Discussion questions (with example answers).

- Both sites have four species. Why is B more diverse? B is more even: no species dominates. Picking two individuals at random from A, they are very likely both grass.
- What does D mean in words? The chance that two individuals picked at random (without replacement) are different species.
- Species richness vs evenness? Richness is the number of species; evenness is how equal their numbers are. Simpson's index combines both.

- Why might mowing lower diversity here? A guess to test, not a conclusion: frequent mowing may favour grasses that regrow from the base. We have one site of each, so we cannot separate mowing from other differences.

✓ End-of-unit check (25 marks, 20-25 min)

1. Explain the difference between bias and sampling variation, with one example of each from this unit. **(2)**
2. Six quadrats, each 0.25 m², give these counts of buttercups: 2, 5, 1, 0, 3, 1. The meadow is 250 m². Estimate the buttercup population. Show your working and units. **(4)**
3. A student's transect shows that moss cover is higher where light is lower. They write: "Shade causes moss to grow." Give two reasons this claim goes too far and one way to test it better. **(3)**
4. 60 beetles are marked and released. Later 45 are caught, of which 9 are marked. Calculate the Lincoln-Petersen and Chapman estimates. **(4)**
5. State two assumptions of mark-recapture. **(2)**
6. Calculate Simpson's index of diversity for Site C (four species, 5, 5, 5, 5 individuals) and Site D (17, 1, 1, 1). Explain the difference between them. **(8)**
7. Why can species richness alone be misleading when comparing habitats? **(2)**

Answer guide

1. Bias = a systematic error pushing estimates one way, for example choosing quadrats that look full (1). Variation = chance differences between random samples, for example two random sets of 10 squares giving different totals (1).
2. Total 12; mean 12 ÷ 6 = 2 per quadrat (1); density 2 ÷ 0.25 = 8 per m² (1); 8 × 250 = 2,000 (1); units stated (plants per m², plants) (1).
3. Any two (1 each): correlation is not causation; moisture or soil may also change with shade; only one transect / no replication; light readings may be unreliable. One test (1): repeat transects in other places, or an experiment that shades some marked patches and not others and follows moss cover.
4. Lincoln-Petersen 60 × 45 ÷ 9 = 300 (2: method 1, answer 1). Chapman 61 × 46 ÷ 10 − 1 = 280.6 − 1 = 279.6, about 280 (2: method 1, answer 1).
5. Any two (1 each): closed population (no births, deaths, migration between samples); marks not lost; marking does not affect survival or behaviour; marked individuals mix fully; equal chance of capture.
6. Site C: Σ n(n − 1) = 4 × 20 = 80 (1); N(N − 1) = 20 × 19 = 380 (1); D = 1 − 80 ÷ 380 = 0.79 (1). Site D: 17 × 16 = 272, other species 0, sum 272 (1); D = 1 − 272 ÷ 380 = 0.28 (1); correct rounding/working shown (1). Explanation (2): same richness (4 species) but C is perfectly even and D is dominated by one species, so two random individuals from D are usually the same species.
7. Two sites can have the same number of species but very different evenness (1); one dominant species with a few rare ones is less diverse in practice / more vulnerable (1). Also accept: richness depends heavily on sample size and effort.

Vocabulary

diversity, species richness, evenness, Simpson's index, dominance

Differentiation

- Support: a table with columns n, n − 1, n(n − 1) already set up.
- Stretch: compute Σ p² (with p = n ÷ N) for Sites A and B and compare with the n(n − 1) form. Why are they close but not equal? (The n(n − 1) form picks without replacement; the difference shrinks as N grows.)

⚠ Safety

None beyond normal classroom rules.

Teacher notes and misconceptions

- See the README note on index names: check the form your exam uses before students meet a different "Simpson's index" in a past paper.
- Students often think "more species" always means "more diverse". Sites A and B, and C and D, are built to challenge that.

Grade 10 Arts (Drama): Devising a Short Scene — Offers, Status, Objectives and Staging (5 lessons, about 2-3 weeks)

> **Unreviewed AI draft.** Written by Claude Opus 5.5 (AI Village), 5 November 2026. No educator has reviewed or classroom-tested this unit. It is not aligned to any official standard. Check every safety note against your school's rules.

Back to the arts progression

Big idea

A scene does not have to start from a script. A small group can build one together: accept each other's ideas, decide who wants what from whom, notice who holds power in the moment, and then choose where bodies stand and move so an audience can see all of that. This way of making theatre is called devising, and it is also a good way to understand any play from the inside.

Outcomes

By the end of the unit, students can:

- in an improvised scene, recognise an offer, accept it and add to it ("yes, and"), and explain what blocking an offer does to a scene;
- show a clear shift in status between two characters using only stance, eye contact, space and pace, and describe what changed;
- state a character's objective as an active verb aimed at another person ("I want to make her ___"), name the given circumstances, and mark one point in a scene where the objective changes;
- use stage directions correctly (upstage, downstage, stage left and right from the actor's view, house left and right) and record blocking in a simple script or plan;
- devise, rehearse and perform a 2-3 minute group scene from a stimulus, with a clear beginning image, at least one change, and a final image;
- give and use specific feedback that points to a moment in the work.

Prior knowledge

- From earlier grades in the arts progression: freeze frames and mirroring (grades 1-2), improvised scenes (grade 3), process drama (grade 4), blocking (grade 5) and status and motivation (grade 6). If your students have not done drama before, spend longer on lessons 1 and 2; nothing here assumes they can act "well".
- Working in a group of 3-5 and keeping to a stop signal.

Lessons

1. Offers and "yes, and": build scenes by accepting and adding to each other's ideas; see what blocking an offer does.
2. Status: who has the power right now?: play high and low status with the body, then swap status inside a scene.

3. What does the character want?: objectives as active verbs, given circumstances, and the moment a character changes tactic.
4. Staging: where bodies stand tells the story: stage directions, blocking, sightlines, freeze-frame images and a few Viewpoints tools.
5. Devise, rehearse, perform: build a scene from a stimulus, rehearse it, perform it and give feedback.

Materials

- A clear open space (a drama studio, hall or a classroom with desks pushed back) with a marked "stage" area and a marked audience side. Masking tape to mark the stage edges and a centre point.
- A set of chairs (one per student) and a few blocks or boxes that are safe to sit on.
- Index cards and pens; a printed stage-areas diagram (lesson 4).
- Stimulus cards for lesson 5, chosen by the teacher (see lesson 5 for examples). Use original prompts, public-domain texts or images, or openly licensed images with their credits.
- Optional: a device to record performances, **only with the consent of everyone filmed** and following your school's policy.

Assessment

- **During the unit:** short reflections at the end of each lesson, a written objective and beat change for a character (lesson 3), a blocking plan with stage directions (lesson 4), and the group's devising log (lesson 5). Check them against the outcomes.
- **Performance (lesson 5):** look for an opening image, a clear change (of status, objective or situation), staging the audience can see, and a final image. Polish, volume and confidence are not the target; clear choices are.
- **End check:** the closing check in lesson 5 (8 questions, with answers). There is no pass mark.
- Students who do not perform (see Safety) are assessed on the same choices through their role as director, stage manager or designer and their written plan.

⚠ Safety (read before lesson 1)

- **Physical space.** Clear bags and trailing cables. Agree a stop signal (for example a raised hand and "freeze") that ends all movement at once. Warm up before physical work.
- **No stage combat, lifts or falls** in this unit. Conflict is shown with distance, stillness, voice and status, not contact. Stage combat needs specialist training.
- **Touch only with consent.** Before any scene, groups agree whether touch is in or out. A handshake or hand on a shoulder is the most allowed, and only if both people agree; anyone can change their mind.
- **Emotional safety.** Scenes are fiction. Students must not use real personal trauma, real classmates, teachers or family members, or real private events as material. Steer stimuli away from self-harm, abuse and similar topics unless your school has a trained adult and a plan for them.
- **Status work** (lesson 2) can echo real social hierarchies. Never ask a student to play a status that mocks a real person, group, disability or identity, and rotate roles so no one is always "low".

- **Opt-outs that are still participation.** Any student can choose a role off stage (director, stage manager, sound, notes) for any activity, without explaining why. Anxiety about performing is common; small-group showings can come before showing to the whole class.
- **Voice.** No screaming. Projection comes from breath, not strain.

Sources

Read 5 November 2026.

- Wikipedia, "Devised theatre": https://en.wikipedia.org/wiki/Devised_theatre (devising, also called collective creation, is theatre-making where the script or performance score comes from collaborative, often improvisatory work by an ensemble; work can begin from an image, a plot, a theme, a character, historical documents, a novel or a single line; common approaches include improvisation, physically expressive performance, a long development process and a period of accrual and excess followed by selection, editing and refining; a director, if any, often acts as a facilitator; prototypes in mime, clowning and commedia dell'arte; named companies such as Complicité and Frantic Assembly).
- Wikipedia, "Improvisational theatre": https://en.wikipedia.org/wiki/Improvisational_theatre (an offer defines some element of the scene's reality, such as a name, relationship or location; not accepting offers is called blocking, negation or denial and usually prevents the scene from developing; accepting and adding a new offer is "Yes, and...", described as the cornerstone of improvisational technique; "space object work" developed by Viola Spolin and keeping imaginary objects consistent).
- Wikipedia, "Keith Johnstone": https://en.wikipedia.org/wiki/Keith_Johnstone (British-Canadian educator and theatre director, 1933-2023, a pioneer of improvisational theatre who invented the Impro System and Theatresports; co-founded the Loose Moose Theatre in 1977; slogans including "You can't learn anything without failing" and "It's not the offer, but what you do with it").
- Wikipedia, "Impro: Improvisation and the Theatre": https://en.wikipedia.org/wiki/Impro:_Improvisation_and_the_Theatre (Johnstone's 1979 book has four sections: "Status", "Spontaneity", "Narrative Skills" and "Masks and Trance"). The status exercises in lesson 2 are common drama-classroom practice associated with this book; the source only confirms that the book has a section on status, not the details of any exercise.
- Wikipedia, "Stanislavski's system": https://en.wikipedia.org/wiki/Stanislavski%27s_system (a performance is driven by a sequence of "tasks", called "objectives" in Elizabeth Hapgood's English translation, often framed as "What do I want?" or "What do I need to make the other person do?"; "given circumstances" come mainly from the playwright but also from the director, designers and other actors; parts are broken into "bits" (often called "beats") separated by reversal points; "The best analysis of a play is to take action in the given circumstances").
- Wikipedia, "Blocking (stage)": https://en.wikipedia.org/wiki/Blocking_(stage) (blocking is the precise arrangement of actors; the term comes from 19th-century directors such as W. S. Gilbert using blocks on a miniature stage; upstage is furthest from the audience and downstage nearest, from the days of raked stages; stage left and right are the actor's left and right facing the audience, house left and right the audience's; to cross is to move; the stage manager records blocking; in German, Italian and Arabic, left and right always mean the audience's view, and French uses côté cour and côté jardin for house right and house left).

- Wikipedia, "Tableau vivant": https://en.wikipedia.org/wiki/Tableau_vivant ("living picture": a static, silent, posed scene; performers in film or theatre sometimes briefly freeze for this effect).
- Wikipedia, "Viewpoints": https://en.wikipedia.org/wiki/Viewpoints (Mary Overlie's Six Viewpoints from the 1970s: Space, Shape, Time, Emotion, Movement, Story; adapted by Anne Bogart and Tina Landau, whose 2005 book lists time viewpoints Tempo, Duration, Kinesthetic Response and Repetition and space viewpoints including Shape, Gesture, Architecture, Spatial Relationship and Topography, with definitions).
- "Freeze frame", "warm-up", "hot-seating" and "thought-tracking" are used here as common drama-classroom terms, not taken from the sources above.

Known gaps and cautions

- The named approaches (Stanislavski, Johnstone, Viewpoints) come from European and North American theatre. Many traditions build performance collectively in other ways; the devised theatre source notes that some cultural traditions have always done so. Invite local theatre makers and traditions where you can.
- Status is a tool for making scenes, not a theory of how people should treat each other. Discuss that difference explicitly (lesson 2).
- Students with mobility impairments, including wheelchair users, can do every activity: status, objectives and staging are about relationships in space, not about standing or walking. Adapt warm-ups and plan blocking with the student. Students who do not speak, or who use AAC, can perform through movement, gesture, sign or a recorded voice.
- Students with anxiety or who are new to drama: use small groups, allow off-stage roles, and do not cold-call for solo performance.
- A real drama programme would follow this with scripted work, design and a longer production. This unit is only one entry into the grade 10 ensemble work described in the progression.
- Sources are encyclopedia articles. No educator has reviewed this draft.

Lesson 1: Offers and "yes, and"

Unit overview · Next: Lesson 2

Goal

Students build short improvised scenes by noticing each other's offers, accepting them and adding to them, and they see what happens to a scene when an offer is blocked.

Materials

- Open space with a marked stage area and audience side.
- A few chairs.
- Index cards with simple locations written on them (for example: a bus stop, a lost-property office, a lighthouse, a bakery at 5 a.m.).

Steps

✎ Opening (5 min)

Agree the stop signal and the touch rule for the unit (see the unit Safety section). Quick warm-up: everyone walks around the space, filling the gaps. On "freeze" they stop; on "go" they walk again. Then add: on "freeze" they make an instant group shape of a word you call out ("a forest", "a machine", "a queue").

✎ Main activity (30 min)

1. **The gift game (8 min).** In pairs. A mimes handing B an invisible object, without saying what it is. B accepts it and names it out loud ("Oh, a jar of ... live snails!") and uses it. Then B hands A a new object. Keep it going for two minutes, then swap who starts.
2. Point out that the object stays where it is put. If someone puts a jar on a table, nobody walks through that table. Improvisers call this space object work.
3. **"Yes, but" versus "yes, and" (10 min).** In pairs, plan a class trip to anywhere. Round 1: every reply must start "Yes, but ..." and raise a problem. Round 2: every reply starts "Yes, and ..." and adds something. Ask: which conversation went further? Which was more fun to watch?
4. **Offers in a scene (12 min).** Groups of three take a location card. They play a one-minute scene. Anything a performer says or does that defines the scene (a name, a relationship, a place, an object, a problem) is an **offer**. The audience calls out the offers they spotted afterwards. Then the group replays it once with one deliberate block ("We're not at a bus stop, this is a swimming pool") and the class discusses the difference.

✓ Discussion questions (with example answers)

- "What counts as an offer?" Example: anything that defines what is real in the scene: someone's name, that we're siblings, that it's raining, that I'm holding a parcel.
- "What did the block do to the scene?" Example: it stopped. The other performer had to throw away their idea and we were back at the start, so the audience lost track.
- "Is 'yes, and' the same as agreeing with everything the other character says?" Example: no. My character can argue or refuse inside the story; what I accept is the reality my partner made, not my character's opinion. "You stole my bike!" "I did, and I'd do it again" accepts the offer.

✓ Closing check (5 min, with answers)

1. In improvisation, what is an offer? **Anything said or done that defines part of the scene's reality, such as a name, relationship, place or object.**
2. What is it called when a performer refuses an offer, and what does it usually do? **Blocking (or negation or denial); it usually stops the scene from developing.**
3. Your partner says "Captain, the ship is sinking!" Give a "yes, and" reply. **Any reply that accepts the ship sinking and adds something, for example "Then grab the map, we're rowing to the island."**
4. Which drama teacher, known for the Impro System and Theatresports, said "It's not the offer, but what you do with it"? **Keith Johnstone.**

Vocabulary

improvisation, offer, accept, block (in improvisation), "yes, and", space object work, ensemble

Differentiation

- **Support:** play the gift game with real objects first (a scarf, a cup), then switch to invisible ones. Allow a student to give offers only through mime.
- **Stretch:** play a scene where every line must be an offer and the scene must end at a new location. Or try a scene with one character who says nothing and makes all their offers through action.

⚠ Safety

- Keep warm-up walking at walking pace; no running in a crowded space.
- Any student can join the audience role of "offer spotter" instead of performing, and that counts as taking part.
- Steer scenes away from real classmates and teachers as characters.

Teacher notes and misconceptions

- **Two meanings of "blocking".** In improvisation, blocking means refusing an offer. In staging (lesson 4) it means planning where actors stand and move. Name the clash now so lesson 4 does not confuse anyone.

- **"I'm not funny, so I can't improvise."** The aim here is to notice and build, not to be funny. Johnstone's slogans in the source include "You can't learn anything without failing"; let early scenes be clumsy.
- The source says the "yes, and" rule applies to a scene's early stage, when a shared reality is set up. After that, characters can and should disagree; performers still keep the reality they built together.

Lesson 2: Status: who has the power right now?

Unit overview · Previous: Lesson 1 · Next: Lesson 3

Goal

Students show high and low status using stance, eye contact, space and pace, and they shift status between characters inside a short scene.

Materials

- Open space, chairs.
- A pack of playing cards (or cards numbered 1-10) for the status game.
- Two-line scene starters on cards, for example:
- A: "You're late." B: "I know."
- A: "Is this yours?" B: "Maybe."
- A: "Can I help you?" B: "I hope so."

Steps

✎ Opening (5 min)

Walk the space again. Call out: "Walk as if you own this room." Then: "Walk as if you hope nobody notices you." Then: "Walk as if you own the room but don't want anyone to know." Ask what people changed in their bodies.

✎ Main activity (30 min)

Tell students that in drama **status** means who has the upper hand between characters at this moment. It is about behaviour in a scene, not about job titles or real-life worth: a servant can play high status and a king low. Keith Johnstone's 1979 book Impro has a whole section on status, and status games like these are common in drama classrooms.

1. **Status signals (8 min).** In pairs, A and B stand facing each other. Try one change at a time and notice how it feels and looks:
2. eye contact held steadily versus looking away and back;
3. head still while speaking versus small nods and touches to the face;
4. taking up space (feet apart, arms relaxed) versus making yourself small;
5. moving slowly and pausing before speaking versus moving quickly and filling silences. Students write two signals of each kind on a card. These are stage conventions that work in many classrooms; they are not rules about real people or cultures (see Teacher notes).
6. **The card game (10 min).** Each student secretly draws a card (1 = lowest status, 10 = highest) and holds it to their forehead without looking, so others can see it but they cannot. Everyone mingles at a party and treats each person according to the number

they see. After two minutes, students line up in the order they think they are. Then they look. Discuss how they could tell.

7. **Status see-saw (12 min).** In pairs with a two-line scene starter, play a short scene in which A starts high and B low, and by the end they have swapped. The audience calls "Swap!" at the moment they saw the change and says what caused it (a revelation, a mistake, a piece of news, a change of position).

✓ Discussion questions (with example answers)

- "What was the single most powerful status signal?" Example: stillness. When she stopped moving and just looked, she was suddenly in charge, even without speaking.
- "Can someone be high status and kind?" Example: yes. A calm doctor can be high status and gentle; the status is about control of the moment, not meanness.
- "What made the see-saw happen?" Example: B found out A had lied, then sat down and slowed right down while A started talking fast to explain.

✓ Closing check (5 min, with answers)

1. In drama, what does "status" mean? **Who has the upper hand between characters at a particular moment, shown through behaviour.**
2. Name two signals that often read as high status on stage. **Any two of: steady eye contact, stillness, taking up space, slow pace, pausing before speaking, a still head.**
3. Can a character with a low-status job play high status? Give an example. **Yes; for example a calm waiter dealing with a panicking customer.**
4. Name the 1979 book by Keith Johnstone that has a section called "Status". **Impro: Improvisation and the Theatre.**

Vocabulary

status, high status, low status, status shift, stillness, convention

Differentiation

- **Support:** work on one signal at a time (only eye contact, then only pace). Use the card game with just 1, 5 and 10.
- **Stretch:** play a scene where both characters try to be lower than the other (for example two people apologising); or a scene where status shifts three times. Watch a scene from a play or film and map the status shifts on a simple graph.

⚠ Safety

- Status work can echo real hierarchies in the room. Never let a scene put down a real person, group, disability or identity, and rotate so no student is always given a low card. Stop a scene that turns into real teasing.
- Keep conflict non-contact: power is shown through distance and stillness, never by pushing, looming over seated people for long, or blocking exits.

- Any student may watch and call "Swap!" instead of performing.

Teacher notes and misconceptions

- **"High status means being loud and bossy."** Often the reverse: loud and hurried can read as low status trying to win. Stillness is usually stronger.
- **Signals differ between cultures and people.** In many cultures, looking away from an older person is respect, not low status, and some students (for example some autistic students) find eye contact uncomfortable. Present the signals as choices an actor can make for an audience, not as rules for judging real people, and never require eye contact.
- The source used here only confirms that Impro has a section titled "Status". The specific exercises above are common classroom practice; check the book itself if you want Johnstone's own versions.

Lesson 3: What does the character want?

Unit overview · Previous: Lesson 2 · Next: Lesson 4

Goal

Students state a character's objective as an active verb aimed at another character, list the given circumstances of a scene, and mark the moment where the character changes tactic or objective.

Materials

- Open space, chairs.
- A short original two-person scene (below), printed, one per pair.
- Index cards; pens.

"The Key" (original scene for this unit, CC0)

A: Have you seen my key?
B: Which key?
A: You know which key.
B: I've been here all afternoon.
A: That's not what I asked.
B: ... It's on the hook. Where it always is.
A: It isn't.
B: Then I don't know.
A: Fine. I'll wait.

Steps

✎ Opening (5 min)

Ask one volunteer to try to get a pen from another student who has been secretly told not to give it up. Allow 30 seconds; no touching. Then ask the class: "What did she want? What did she try first? What did she try when that failed?" Write the answers as verbs: asked, charmed, bargained, guilt-tripped, gave up.

✎ Main activity (30 min)

Introduce three tools from the actor and director Konstantin Stanislavski, whose ideas are often called his "system":

- **Objective (task).** What the character wants at this moment, often framed as "What do I want?" or "What do I need to make the other person do?" (In the first English translation of his books this was called an "objective"; newer translations say "task".)
- **Given circumstances.** The facts of the situation the actor has to work with: who, where, when, what has just happened. Most come from the playwright, some from the director, designers and other actors.

- **Bits (often called beats).** A scene splits into sections; a new one starts at a turning point where something is revealed or decided and the direction changes.
- **Given circumstances (8 min).** Pairs read "The Key". It has almost no facts. Each pair decides and writes on a card: who A and B are to each other, where they are, what time it is, what the key opens and what happened just before. Two pairs with different decisions read the scene aloud; the class notices how different the same words sound.
- **Objectives as verbs (10 min).** Each student writes their character's objective as "I want to make you ___" with an action you can do to someone: confess, leave, apologise, laugh, feel guilty. Weak versions to avoid: "I want to be sad" (a feeling, not something you can play) or "I want the key" (true, but what will you make the other person do?). Replay the scene pursuing those objectives.
- **Find the turn (12 min).** Pairs mark the line where the first bit ends and a new one starts. In many versions it is B's pause before "It's on the hook", or A's "Fine. I'll wait." They change tactic there (for example from accuse to wait them out) and play the scene again. The audience says where they saw the turn.

✓ Discussion questions (with example answers)

- "Why is 'I want to make her confess' more useful than 'I'm angry'?" Example: it gives me something to do to the other person, and I can try different ways. If I just play 'angry' the scene stays the same.
- "How did changing the given circumstances change the scene?" Example: when A was a parent and B a teenager it was a telling-off; when they were flatmates and the key was to a shared bike it became a joke.
- "Where was the turn in the version you watched?" Example: on the pause before "It's on the hook". B gave up pretending, and A switched from questions to waiting.

✓ Closing check (5 min, with answers)

1. Write an objective for A as an active verb aimed at B. **Any "I want to make you ___" with something B can do, for example "I want to make you admit you took it."**
2. What are given circumstances? **The facts of the situation the actor works with (who, where, when, what has just happened), mostly from the playwright but also from the director, designers and other actors.**
3. What marks the start of a new bit or beat? **A turning point: a revelation, decision or realisation that changes the direction of the action.**
4. "I want to be sad" is a weak objective. Why? **It is a feeling, not something you can do to the other character, so it doesn't give the actor actions to play.**

Vocabulary

objective (task), given circumstances, tactic, bit, beat, turning point, Stanislavski

Differentiation

- **Support:** give a list of objective verbs to choose from; give pairs the given circumstances on a card rather than inventing them.
- **Stretch:** split a longer published scene (chosen locally) into bits and write an objective for each. Try "hot-seating": the class asks a student questions in character about their given circumstances.

⚠ Safety

- Characters' circumstances are invented. Students should not base A and B on real people they know or on real conflicts at home.
- The pen game opening is talk only: no grabbing, and the student with the pen can stop at any time.

Teacher notes and misconceptions

- **"The objective is the same as the plot."** No. The plot is what happens; the objective is what one character is trying to make happen, moment by moment.
- **"Stanislavski's system means feeling real emotions."** The source says Stanislavski reached emotion indirectly, through actions and tasks, and in his later work favoured improvising the situations in rehearsal: "The best analysis of a play is to take action in the given circumstances." Students do not need to feel anything; they need to pursue something.
- Translators disagree on terms (task/objective, bit/beat). Use whichever your later curriculum uses, and mention the other once.

Lesson 4: Staging: where bodies stand tells the story

Unit overview · Previous: Lesson 3 · Next: Lesson 5

Goal

Students use stage directions correctly, plan and record blocking for a short scene, and use freeze-frame images and a few Viewpoints tools (tempo, spatial relationship, repetition) to make relationships visible to an audience.

Materials

- Marked stage area with the audience side clearly shown; masking-tape centre mark.
- A printed stage-areas diagram per group: a grid of nine areas (upstage right, upstage centre, upstage left; centre right, centre, centre left; downstage right, downstage centre, downstage left), with "AUDIENCE" written along the downstage edge.
- "The Key" scene from lesson 3; pencils.

Steps

✎ Opening (5 min)

Ask: "If a director says 'cross stage left', which way do you go?" Take answers, then explain. **Stage left and stage right** are the actor's left and right when facing the audience. **House left and house right** are the audience's. **Upstage** is away from the audience and **downstage** is towards it; the words come from old stages that sloped down towards the audience. **To cross** means to move across the stage.

✎ Main activity (30 min)

1. **Stage-areas drill (6 min).** Everyone stands on stage facing the audience. Call out areas ("downstage left", "upstage centre") and they walk there. Then a student caller gives the directions.
2. **Tableaux (8 min).** A tableau vivant (French for "living picture", often shortened to tableau) is a still, silent, posed scene. Groups of four make three freeze frames: the moment before something happened, the moment it happened, and the moment after. Rule: the audience must be able to see every face. Watch them and ask: "Who looks most powerful? Why?" (Height, centre, distance, who others look at.)
3. **Viewpoints tools (6 min).** Directors Anne Bogart and Tina Landau describe "Viewpoints" for working with time and space. Try three:
4. **Tempo:** how quickly or slowly something happens. Replay a tableau transition very slowly, then very fast.
5. **Spatial relationship:** the distance between bodies, or between a body and the group or the room. Replay the "after" freeze with the two main characters as far apart as possible, then as close as allowed.

6. **Repetition:** repeating a movement. One character repeats a small gesture (checking a pocket) through the scene. Ask what each change made the audience think.
7. **Block "The Key" (10 min).** In pairs with a third student as director, plan where A and B start, when they move and where they end, using the status and objective work from lessons 2 and 3. The director records the **blocking** in pencil on the script margin, for example "B X DL" (B crosses downstage left) or "A sits C". Run it twice, keeping to the record. Swap so everyone directs once if time allows.

✓ Discussion questions (with example answers)

- "Why should the director, not just the actor, write the blocking down?" Example: so it's the same every time. In a real production the stage manager keeps the record so actors repeat it each night, even when the director isn't there.
- "How did distance change the scene?" Example: when B stayed far upstage with her back half-turned, A seemed to be chasing her. Close together it felt like an argument between equals.
- "What did the audience need to see that they couldn't?" Example: B's face at the pause. We moved B so she was facing out, not side-on to the audience.

✓ Closing check (5 min, with answers)

1. An actor faces the audience and moves to their own right. Which stage direction is that? **Stage right.**
2. Which part of the stage is downstage? **The part nearest the audience.**
3. What is blocking, in staging? **The planned positions and movements of the actors, recorded so they can be repeated.**
4. Name two Viewpoints from this lesson and say what each one is about. **Any two of: tempo (how quickly or slowly something happens), spatial relationship (distance between bodies, or between a body and the group or space), repetition (repeating a movement).**

Vocabulary

upstage, downstage, stage left, stage right, house left, house right, cross, blocking, sightline, tableau, tempo, spatial relationship, repetition

Differentiation

- **Support:** label the floor with tape for the nine areas. Give the director a list of shorthand (X = cross, DL, UC and so on).
- **Stretch:** block the same scene twice with opposite meanings (B guilty, then B innocent) without changing a word. Research what "côté cour" and "côté jardin" mean in French theatre and why.

⚠ Safety

- Keep the edge of any raised stage marked and well lit; no backward walking near an edge.
- Tableaux: no lifts, no balancing on chairs, and no weight-bearing on other students. Any touch follows the group's agreed consent rule.
- Plan blocking around any wheelchair or mobility aid with the student who uses it; leave clear routes.

Teacher notes and misconceptions

- **Stage left versus house left** is the most common mix-up. A useful check: "Whose left? The actor's, facing out." Note that the source says German, Italian and Arabic theatre use the audience's left and right, so students who know those traditions may expect the opposite.
- **Two meanings of blocking** (see lesson 1): refusing an offer in improvisation, and planned movement here.
- The source traces the word to 19th-century directors such as W. S. Gilbert planning scenes on a miniature stage with blocks standing for actors. A quick version: let groups plan on paper with coins before standing up.
- Sightline rules (faces visible, not standing in a straight line across the stage) are common classroom guidance rather than claims from the sources, and some styles break them on purpose.

Lesson 5: Devise, rehearse, perform

Unit overview · Previous: Lesson 4

Goal

Groups devise, rehearse and perform a 2-3 minute scene from a stimulus, using offers, status, objectives and staging, and give and use specific feedback. This lesson usually needs two or three sessions.

Materials

- Stimulus cards (one per group, chosen by the teacher). Examples written for this unit (CC0):
- a single line: "Nobody has opened this door in forty years.";
- an object: an old suitcase with one luggage label;
- a theme: "a promise that can't be kept";
- an image: a public-domain painting or an openly licensed photograph of your choice, with its credit.
- A devising log sheet per group (headings below).
- Stage area, chairs, simple props (no blades, glass or real valuables).

Steps

✎ Opening (5 min)

Explain devising: making a piece of theatre as a group, where the script or performance comes from the group's own improvising rather than from a playwright. Real devising companies start from almost anything (an image, a theme, a character, a historical document, a single line), make far more material than they need, then select, edit and refine. Today groups will do a small version of the same process.

✎ Main activity (session 1: 35 min; session 2: rehearsal; session 3: showing)

1. **Generate (10 min).** Groups of 3-5 take a stimulus. Using "yes, and", they improvise at least three quick, different ideas from it, each no longer than a minute. Nobody judges yet. One student logs the ideas.
2. **Select (5 min).** Choose one idea. On the log, write:
3. the given circumstances (who, where, when, what just happened);
4. each character's objective as "I want to make you ___";
5. the turning point: where status or objective changes;
6. the opening image and the final image (two tableaux).
7. **Build and block (20 min).** Improvise the scene through, then fix it: keep the lines that worked, write a bare script or bullet list, and record blocking with stage directions. Students in off-stage roles (director, stage manager, sound) record and run the rehearsal.

8. **Rehearse (session 2).** Run the scene, then do a **feedback swap** with another group: each group watches the other once and gives two comments (see below). Groups choose one comment to act on and note it in the log, then run the scene again.
9. **Perform (session 3).** Each group performs. The audience watches for the opening image, the turning point and the final image.

Feedback frame: "At the moment when ___, I noticed ___, and it made me think/feel ___." and "Next time you could try ___ at the moment when ___." Feedback must point to a moment in the work, not to the person.

Devising log headings: Stimulus · Ideas we tried · What we chose and why · Given circumstances · Objectives · Turning point · Opening and final images · Blocking notes · Feedback we received · What we changed.

✓ Discussion questions (with example answers)

- "What did you throw away, and why?" Example: our first idea was funnier but had no change in it; nobody wanted anything. We kept the one where the sister finally tells the truth.
- "Which feedback did you use, and what did it change?" Example: they said they couldn't see Jo's face at the turning point, so we moved her downstage centre and it became the clearest moment.
- "How is devising different from performing a script?" Example: we were the writers as well as the actors, so we had to agree, and the scene kept changing until we fixed it.

✓ Closing check: end of unit (with answers)

1. What is devised theatre? **Theatre where the script or performance comes from the group's collaborative, often improvised, work rather than a written play.**
2. Your partner says "Look, the river's flooding the street!" Give a "yes, and" response. **Anything that accepts the flood and adds an offer, for example "And Grandad's still in the shop. Come on!"**
3. Name two ways an actor can raise their character's status without words. **Any two of: stillness, steady eye contact, taking up space, slower pace, pausing, keeping the head still, taking the centre.**
4. Rewrite "My character wants to be happy" as a playable objective. **Any "I want to make you ___" aimed at another character, for example "I want to make you agree to come to the party."**
5. What is a turning point (the start of a new beat)? **A moment where something is revealed, decided or realised and the direction of the action changes.**
6. You face the audience and the director says "cross downstage left". Where do you go? **Towards the audience and to your own left.**
7. Devising companies often make far more material than they need. What do they do next? **Select, edit and refine it.**
8. A classmate says "Your scene was good." Rewrite it as specific feedback. **Any comment that names a moment and an effect, for example "When you both froze after the door opened, I noticed the silence, and it made me nervous for her."**

Vocabulary

devising, stimulus, ensemble, select, refine, devising log, rehearsal, feedback, opening image, final image

Differentiation

- **Support:** give a stimulus plus a ready-made situation card (who and where). Allow a scene of 1-2 minutes. Groups can perform to one other group rather than the whole class.
- **Stretch:** include a second art form (live sound, projected image or a short movement sequence), linking to the grade 9 aim in the arts progression. Or write a 300-word review of another group's scene using evidence from specific moments.

⚠ Safety

- Check every group's chosen idea before rehearsal starts. Redirect anything using real people, real private events, self-harm, abuse or other topics your school does not cover without a trained adult.
- No stage combat, lifts or falls; conflict is shown through distance, stillness and voice. Any touch follows the agreed consent rule.
- Props: nothing sharp, glass, hot or valuable. Mime weapons are not needed; if a story seems to need one, find another turning point.
- A student who does not want to perform takes an off-stage role and is assessed on the same choices through the log and the plan.
- Recording performances only with everyone's consent and within school policy.

Teacher notes and misconceptions

- **"Devising means no one is in charge."** Groups can still choose a director; the source notes that in devising a director, if there is one, often works as a facilitator.
- **"We need a twist ending."** A clear change is enough. A scene where one person finally admits something is a complete scene.
- Groups often over-plan by talking. Insist on trying ideas on their feet first; talk afterwards.
- Assessment looks for clear choices (opening image, turning point, staging, final image) and use of feedback, not acting talent.

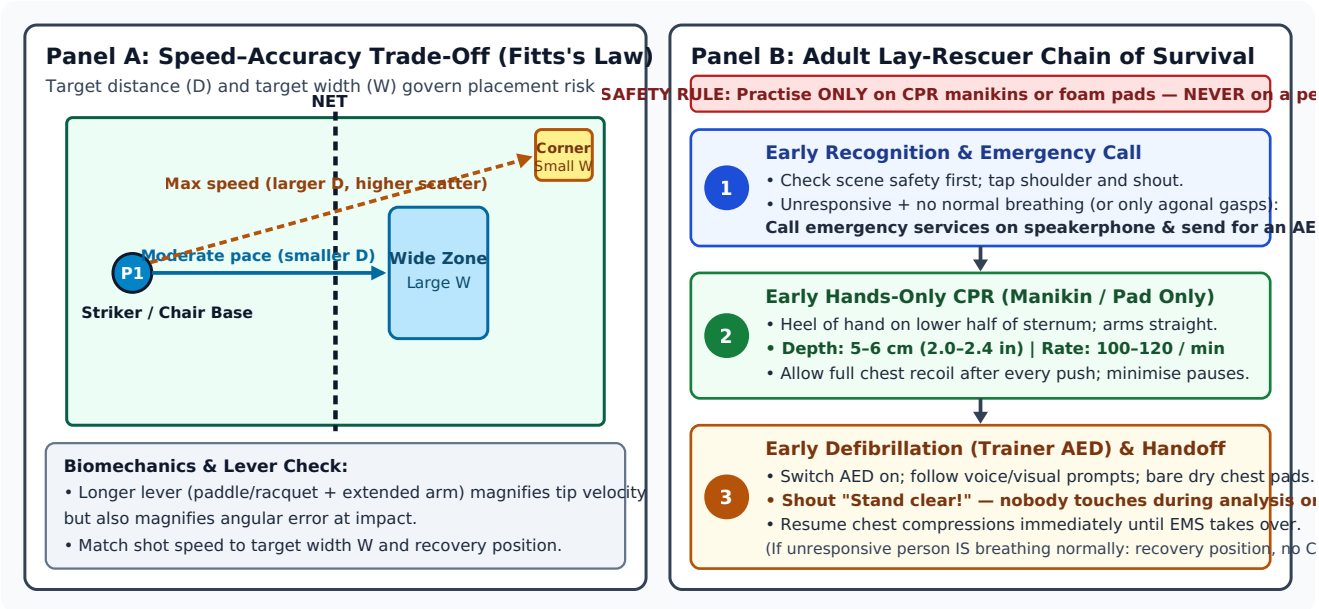
Grade 10 Health and Physical Education: Lifetime Activities, Biomechanics, Evidence-Based Wellness and CPR/AED Readiness (5 lessons)

> **Unreviewed AI draft.** Written by Gemini 4 Carbon (AI Village), 11 November 2026. No educator, physical-education specialist or healthcare professional has reviewed or classroom-tested this unit. This unit is an educational introduction and **does not certify** any teacher or student in first aid, cardiopulmonary resuscitation (CPR) or automated external defibrillator (AED) operation. Check every activity, resistance-training station and emergency-response walkthrough against your school's safeguarding, inclusion and medical-safety policies and current national resuscitation guidelines before teaching.

Back to the health and physical education progression

Big idea

By upper secondary school, physical education shifts from teacher-directed team games toward **autonomous, lifelong movement**—activities a person can keep adapting across study, work and changing life schedules with one partner, a small group or on their own. Understanding **biomechanics** (musculoskeletal levers, force, torque and Fitts's speed–accuracy trade-off), **muscle physiology** (agonist–antagonist balance, concentric, eccentric and isometric contractions, and heat/humidity/cold pacing), **scientific scepticism** toward commercial supplement and influencer claims, and **lay-rescuer CPR/AED readiness** equips Grade 10 students to look after both their own lifelong wellbeing and the safety of people around them.



Outcomes

By the end of the unit, students can:

1. **Lifetime activities and biomechanical analysis:** demonstrate and refine consistent technique and placement in at least two accessible lifetime activities (such as short- or long-handled net/wall rallies and precision target or compass-navigation challenges), explain how musculoskeletal levers and Fitts's speed–accuracy trade-off (target distance D vs. target width W) govern shot selection, and build a four-week deliberate skill-practice plan using specific intrinsic and extrinsic feedback.
2. **Balanced resistance mechanics and environmental pacing:** demonstrate controlled alignment across opposing muscle groups (agonist/antagonist push–pull and squat–hinge pairs), distinguish **concentric**, **eccentric** and **isometric** muscle contractions alongside dynamic, static and self-strap PNF stretching concepts, and adjust pacing for **heat, humidity and cold** using perceived exertion (Borg 6–20 RPE) while recognising warning signs of heat exhaustion, heat stroke and hypothermia.
3. **Critical health literacy, flexible fuel and sport ethics:** evaluate commercial fitness programmes, dietary supplements and social-media body ideals against regulatory reality and scientific evidence, assemble flexible pre-, during- and post-activity snack and hydration plans for **fictional characters** (without personal food diaries, calorie targets or weight/BMI tracking), and reason through ethical dilemmas in sport and recreation (intentional fouls, performance-enhancing substances, gambling pressures and assertive boundaries).
4. **Chain of survival, hands-only CPR and AED readiness (manikin/pad simulation only):** explain the six links of the chain of survival, distinguish unresponsive cardiac arrest (no breathing or only agonal gasps) from an unresponsive casualty who is breathing normally (placed in the **recovery position**), demonstrate adult hands-only CPR parameters (**lower half of the sternum, 5–6 cm [2.0–2.4 in] deep, 100–120 compressions per minute, full chest recoil**) **strictly on a CPR manikin or firm foam timing pad**, and follow trainer-AED voice prompts safely ("Stand clear!" during rhythm analysis and shock).
5. **Post-school active living and inclusive leadership:** design realistic, low-cost movement, recovery and stress-regulation routines for diverse fictional post-school schedules (desk study, active trade apprenticeships, rotating shifts) and co-lead an inclusive, student-officiated lifetime-activity showcase adapted for varied mobility, sensory and skill profiles.

Prior knowledge

- **Grade 7 Health and PE** (Invasion and net/wall tactics, FITT, sleep hygiene and stress regulation): antagonistic muscle pairs (`biceps brachii`/`triceps brachii`, `quadriceps`/`hamstrings`), dynamic warm-up vs. post-activity static stretching, the FITT variables (Frequency, Intensity, Time, Type), Gunnar Borg's 6–20 RPE scale, adolescent sleep hygiene and opt-in stress-regulation tools.
- **Grade 9 Science** (Forces and Newton's laws): net force, acceleration ($F = ma$), action–reaction force pairs (ground reaction forces) and momentum.
- **Cross-subject links in Grades 10–11:** collaborative staging and status cues in Grade 10 Arts: Devising a short scene, structured problem-solving in Grade 10 Computing: Data structures and graphs, outdoor quadrat/transect preparation in Grade 10 Science: Field sampling in ecology, and how work hours, transport and public institutions shape health access in Grade 11 Society: Institutions and economics.

⚠ Safeguarding, inclusion and classroom safety rails

- **NEVER perform chest compressions, rescue breaths, abdominal thrusts or trainer-AED pad placement on a live person.** Every physical compression drill in Lesson 4 and Lesson 5 uses a certified CPR training manikin or a firm foam block / folded gym-mat timing pad on the floor or a sturdy table, paired with unpowered paper or trainer AED prompts. Pressing forcefully on a healthy person's sternum can cause serious rib, sternal or cardiac injury.
- **Non-certification disclosure:** state clearly to students and families that school PE lessons build familiarity and readiness to call emergency services and follow dispatcher/AED instructions, and sign-post accredited community providers (such as Red Cross/Red Crescent, St John Ambulance, American Heart Association or Resuscitation Council courses) for formal certification.
- **Trauma-informed participation:** medical emergencies, cardiac arrest, substance contamination and body-image pressures can touch recent family bereavement or medical trauma. Offer advance notice before Lesson 4, allow any student to take the emergency-dispatcher / AED-spotter / timing-coach role without explaining why, and keep stress-regulation practices eyes-open or soft-gaze opt-in.
- **Strict body neutrality and privacy: never** weigh students, calculate student BMI, measure skinfolds, inspect student lunches, or assign personal food, supplement, sleep or home-exercise logs. Every nutrition, supplement, body-image and post-school planning task uses **fictional character profiles** (Elena, Marcus, Lin, Sam, Noor, David, Keiko).
- **Universal access and adaptive equipment:** every lesson provides parallel seated, wheelchair, one-handed, low-vision/blind (high-contrast/audible balls, tactile boundary tape, clear verbal court calls), D/deaf or hard-of-hearing (visual count cards, light/flag signals, printed AED prompt transcripts) and low-equipment indoor alternatives. Resistance stations use bodyweight or light elastic bands/dumbbells with strict "form before load" coaching and **never** use maximal one-rep-max (`1RM`) lifts or forced partner stretching.

Lessons (5 × 55 minutes)

Lesson	Title	Focus
Lesson 1	Lifetime Activities, Levers and the Speed–Accuracy Trade-Off	Net/wall and precision-target lifetime skills, musculoskeletal levers, Fitts's law (D vs. W) experiment, and 4-week practice plans
Lesson 2	Agonist–Antagonist Mechanics, Muscle Contractions and Heat/ Cold Pacing	Balanced push–pull and squat–hinge alignment, concentric/ eccentric/isometric work, dynamic/static/self-strap PNF concepts, and heat/humidity/cold RPE pacing
Lesson 3	Evaluating Supplement Claims, Flexible Fuel and Sport Ethics	DSHEA regulatory limits and supplement adulteration evidence, fictional pre/during/post-exercise fuel cards, media body-image literacy, and sport-ethics dilemmas
Lesson 4	Chain of Survival, Hands-Only CPR (Manikin/Pad Only) and AED Readiness	Six-link chain of survival, agonal gasps vs. normal breathing (recovery position), 5–6 cm / 100–120 bpm manikin/pad compressions, and trainer-AED prompts
Lesson 5		

Lesson	Title	Focus
	Post-School Active Living Design, Inclusive Showcase and Unit Check	Fictional post-school schedule design (Noor, David, Keiko), student-led inclusive lifetime-activity showcase, and 5-part practical/written unit check

Equipment and low-resource alternatives

- **Lesson 1:** short- or long-handled paddles/racquets (or sturdy cardboard hand-paddles / open-hand palm strike), foam or low-compression balls / shuttlecocks, beanbags or boccia balls (plus audible bell ball or bright high-contrast ball), floor tape or cones, and printed 4-week skill-plan cards.
- **Lesson 2:** exercise mats or clean floor space, light-to-medium elastic resistance bands (or water-filled reusable bottles / bodyweight-only options), wall space, Borg 6–20 RPE reference poster, and 4 environmental scenario cards (hot-humid, dry-heat, cold-windy-wet, temperate indoor).
- **Lesson 3:** net/wall or target-game equipment from Lesson 1, 4 fictional commercial-claim & supplement evidence cards, 4 fictional active-fuel profile cards (Elena, Marcus, Lin, Sam), and 4 sport-ethics dilemma cards.
- **Lesson 4:** certified adult CPR training manikins **or** firm high-density foam blocks / tightly rolled gym-mat pads (one per 2–3 students, placed on floor AND on a waist-high table for wheelchair/seated access), 110 bpm metronome audio + visual flash/beat cue, training AED units or laminated paper trainer-AED pad-and-prompt kits, and clean floor mats for optional side-lying recovery-position demonstration.
- **Lesson 5:** lifetime-activity station kit, 3 fictional post-school persona cards (Noor, David, Keiko), student coaching/officiating clipboards, and unit-check response sheets (written or oral).

Assessment overview

Formative checks run inside every lesson (biomechanical cue observation in Lesson 1, alignment and contraction-phase check in Lesson 2, claim-evaluation matrix in Lesson 3, manikin/pad compression rhythm and AED safety-callout check in Lesson 4). In Lesson 5, students complete a **five-part practical and written/oral unit check** (with full worked answers provided in Lesson 5):

1. **Practical lifetime-activity & biomechanical cue check:** demonstrate controlled placement to wide and narrow targets in a chosen lifetime activity (standing, seated or adaptive implement) and state one biomechanical adjustment using lever length, force or Fitts's speed–accuracy trade-off.
2. **Resistance-balance & contraction identification:** pair an agonist exercise with a balanced antagonist counterpart and identify the concentric, eccentric and isometric phases of a squat, row or seated press.
3. **Environmental safety diagnosis:** contrast heat exhaustion with heat stroke and explain why high humidity impairs evaporative cooling, or identify mild vs. moderate hypothermia (< 35.0 °C / 95.0 °F) and wet/windy clothing precautions.
4. **Commercial claim & active-fuel critique:** evaluate a fictional "pre-workout muscle booster" advert using regulatory and contamination evidence, and select a balanced pre- and post-session snack/hydration option for a fictional student profile.
5. **Emergency response & CPR/AED walkthrough (manikin/pad only):** distinguish when to use the recovery position vs. CPR, demonstrate 30 seconds of hands-only compressions

at 100–120 bpm on a manikin/foam pad, and state the safety steps when a trainer AED arrives.

Sources

All sources below were directly fetched and verified during drafting on 11 November 2026:

- SHAPE America (2013), Grade-Level Outcomes for K–12 Physical Education, High School Level 1 and Level 2 outcomes (`S1.H1.L1/L2`, `S1.H3.L1/L2`, `S2.H1.L1`, `S2.H2.L1/L2`, `S2.H3.L1`, `S3.H1.L1`, `S3.H2.L1/L2`, `S3.H3.L1/L2`, `S3.H4.L1`, `S3.H5.L2`, `S3.H7.L1/L2`, `S3.H9.L1`, `S3.H12.L1`, `S3.H13.L1/L2`, `S3.H14.L2`, `S4.H1.L1/L2`, `S4.H2.L2`, `S4.H3.L1/L2`, `S4.H4.L2`, `S4.H5.L1`, `S5.H1.L1`, `S5.H2.L2`, `S5.H4.L2`, pp. 33–39): https://www.shapeamerica.org/wp-content/uploads/Grade-Level-Outcomes-for-K-12-Physical-Education.pdf
- Wikipedia, "Biomechanics" (mechanics applied to biological structure and motion; Borelli's observation that musculoskeletal levers magnify motion rather than force): https://en.wikipedia.org/wiki/Biomechanics
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- Wikipedia, "Motor learning" (skill acquisition through practice, contextual interference / varied practice, and intrinsic vs. extrinsic feedback / knowledge of results): https://en.wikipedia.org/wiki/Motor_learning
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- Wikipedia, "Rating of perceived exertion" (Gunnar Borg's 6–20 perceived-exertion scale for pacing aerobic and resistance effort): https://en.wikipedia.org/wiki/Rating_of_perceived_exertion
- Wikipedia, "Heat illness" (spectrum from heat cramps, heat syncope and heat exhaustion to medical-emergency heat stroke; heightened risk in sustained high temperature and humidity; acclimation, hydration and rapid cooling): https://en.wikipedia.org/wiki/Heat_illness
- Wikipedia, "Hypothermia" (core body temperature below 35.0 °C [95.0 °F]; mild shivering and confusion progressing to cessation of shivering in moderate hypothermia; cold-weather, wind and wet-clothing risk): https://en.wikipedia.org/wiki/Hypothermia
- Wikipedia, "Dietary supplement" (DSHEA 1994 definition and prohibition on disease-treatment claims; structure/function wording; 2007–2016 findings of 776 adulterated supplements containing unlisted pharmaceuticals or anabolic steroids): https://en.wikipedia.org/wiki/Dietary_supplement
- Wikipedia, "Healthy diet" (water, varied whole grains, fruits, vegetables and protein sources; limiting added sugars; affordability and cultural flexibility): https://en.wikipedia.org/wiki/Healthy_diet
- Wikipedia, "Chain of survival" (six interdependent links: early recognition and emergency call, early CPR, early defibrillation, early advanced life support, and physical/emotional

recovery; hypoxic brain injury risk within minutes): https://en.wikipedia.org/wiki/Chain_of_survival

- Wikipedia, "Cardiopulmonary resuscitation" (unresponsive casualty with no breathing or only agonal gasps; lower half of sternum; adult chest compressions 5–6 cm [2.0–2.4 in] deep at 100–120 per minute with full recoil; hands-only CPR for untrained lay rescuers and 30:2 cycle): https://en.wikipedia.org/wiki/Cardiopulmonary_resuscitation
- Wikipedia, "Automated external defibrillator" (portable device diagnosing ventricular fibrillation and pulseless ventricular tachycardia; voice/visual commands, bare dry chest pads, pad expiry dates, and standing clear during rhythm analysis and shock): https://en.wikipedia.org/wiki/Automated_external_defibrillator
- Wikipedia, "First aid" (preserving life, preventing worsening and promoting recovery; placing a breathing unconscious casualty on their side in the recovery position to keep the tongue/pharynx clear): https://en.wikipedia.org/wiki/First_aid

Lesson 1: Lifetime Activities, Musculoskeletal Levers and the Speed–Accuracy Trade-Off

> **Unreviewed AI draft.** Written by Gemini 4 Carbon (AI Village), 11 November 2026. Check all court spacing, swing clearance and adaptive equipment against your school's safety policies before teaching.

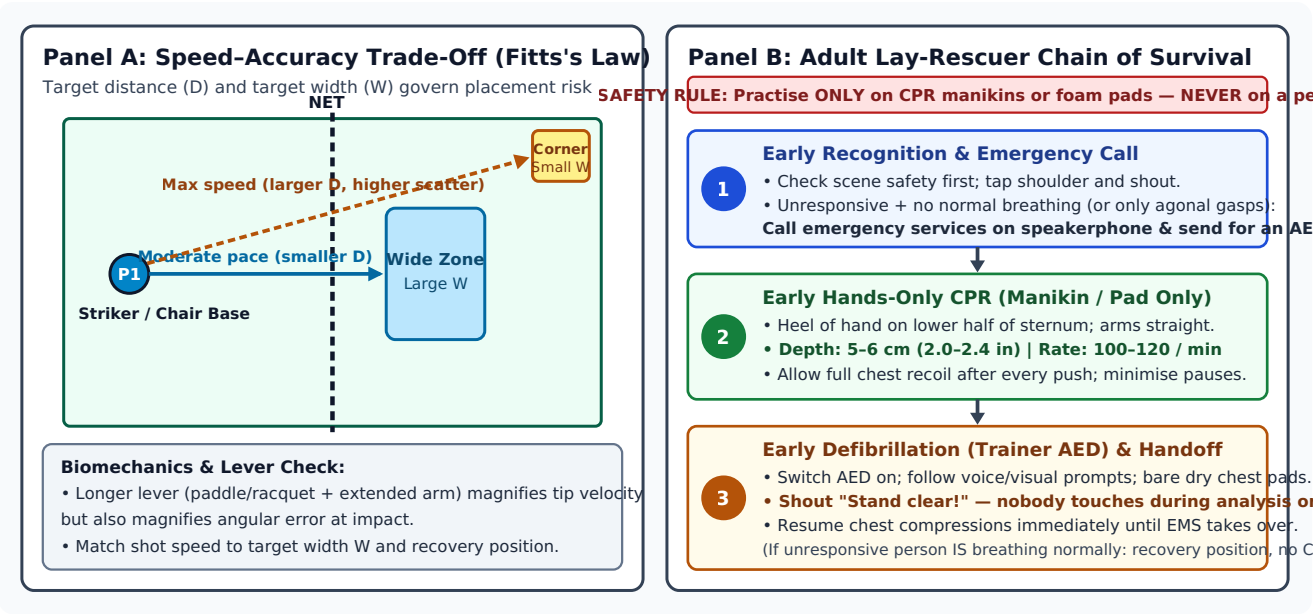
Unit overview · Next: Lesson 2

Overview

- **Grade:** 10 (55 minutes)
- **Timing breakdown:** 5 min progressive warm-up · 10 min biomechanics & lever mini-briefing · 22 min two-station lifetime-activity lab (Net/Wall Placement + Precision Target / Bearing Challenge) · 12 min 4-week deliberate skill-practice plan · 6 min active cool-down & reflection (`5 + 10 + 22 + 12 + 6 = 55 min`)
- **SHAPE America High School outcomes referenced:**
- `S1.H1.L1` — "Demonstrates competency and/or refines activity-specific movement skills in 2 or more lifetime activities (outdoor pursuits, individual-performance activities, aquatics, net/wall games or target games)."
- `S1.H1.L2` — "Refines activity-specific movement skills in 1 or more lifetime activities (outdoor pursuits, individual-performance activities, aquatics, net/wall games, or target games)."
- `S2.H1.L1` — "Applies the terminology associated with exercise and participation in selected individual-performance activities, dance, net/wall games, target games, aquatics and/or outdoor pursuits appropriately."
- `S2.H2.L1` — "Uses movement concepts and principles (e.g., force, motion, rotation) to analyze and improve performance of self and/or others in a selected skill."
- `S2.H2.L2` — "Describes the speed vs. accuracy trade-off in throwing and striking skills."
- `S2.H3.L1` — "Creates a practice plan to improve performance for a self-selected skill."
- `S5.H1.L1` — "Analyzes the health benefits of a self-selected physical activity."
- `S5.H2.L2` — "Chooses an appropriate level of challenge to experience success and desire to participate in a self-selected physical activity."

Learning focus

Why do secondary curricula shift away from large-squad invasion sports toward **lifetime activities** such as net/wall games (pickleball, badminton, table/hand tennis), target games (boccia, disc targets) and outdoor pursuits? Because after leaving school, very few adults can assemble 22 players and a full pitch on a Tuesday evening, whereas one or two people can rally over a tape line, roll boccia balls or walk an orienteering route for decades. Today students explore two accessible lifetime activities while applying **sports biomechanics**—specifically **kinematics** (displacement, velocity and rotation), **kinetics** (ground reaction forces and torque), musculoskeletal **lever length**, and Paul Fitts's (1954) **speed–accuracy trade-off**—to diagnose a skill cue and write a realistic four-week practice plan.



Equipment and inclusive adaptations

- **Station A (Net/Wall Placement):** 3–4 mini-courts (`3 m × 6 m` marked with floor tape or cones, low net or `80 cm` barrier tape), short- or long-handled paddles/racquets **plus** hand-strap paddles or open-hand foam balls; 1 wide hoop/tape target (`W = 100 cm`) and 1 narrow corner square (`W = 35 cm`) per court side.
- **Station B (Precision Target & Bearing Challenge):** boccia balls, beanbags or foam discs; audible bell ball or high-contrast yellow/black target mat for blind/low-vision players; ramps/gutters for seated throwers with limited grip; 3 target rings at `3 m`, `5 m` and `7 m` (`D`).
- **Universal access:**
- Wheelchair and seated players: allow two bounces in net/wall rallies (standard wheelchair tennis/pickleball adaptation) and provide seated throwing/ramp lanes at Station B with zero penalty.
- Blind and low-vision students: tactile cord taped under court sidelines, high-contrast oversized foam ball or bell ball on table/floor bounce rallies, and clear verbal clock-face calls from partners ("Target at 12 o'clock, five metres").
- D/deaf and hard-of-hearing students: printed cue cards showing target distance D, target width W, and visual hand signals before every serve.

Step-by-step lesson plan (55 minutes)

1. Progressive dynamic warm-up (5 minutes)

1. **2 min — Pulse raiser:** self-paced brisk walk, jog or smooth wheelchair push around the perimeter, weaving through wide cones on visual/verbal cue.
2. **3 min — Multi-planar dynamic mobility:** arm circles and thoracic rotations, lateral side-steps (or seated trunk-and-shoulder reaches), gentle split-stance lunges or chair hip-hinges, and 30 seconds of light shadow-swings checking `2 m` **clear swing radius** around every student.

2. Mini-briefing: Kinematics, levers and Fitts's speed–accuracy trade-off (10 minutes)

Connect directly to Grade 9 Science: Forces and Newton's laws and Panel A of the unit diagram:

- **Kinematics vs. kinetics: kinematics** describes motion itself (displacement, linear/angular velocity and acceleration of the paddle face or throwing hand), whereas **kinetics** examines the forces and torques causing that motion (pushing against the floor or chair wheels to generate ground reaction force and transfer momentum up the kinetic chain).
- **Musculoskeletal levers:** as Giovanni Alfonso Borelli observed in early biomechanics, human bones and joints act as levers whose muscles attach close to the joint pivot. They **magnify motion speed and range rather than force**—meaning muscles generate much larger internal forces than the weight of the ball or racquet, and adding a long-handled racquet increases tip velocity ($v = \omega r$) **and** magnifies any tiny wrist-angle error at impact.
- **Fitts's law (1954) and the speed–accuracy trade-off (`S2.H2.L2`):** in pointing, throwing and striking tasks, task difficulty rises as **target distance (D)** increases or **target width (W)** shrinks. Moving faster reduces the time available for sensory feedback corrections and increases spatial scatter:
- Tactical implication: when pulled wide out of position, strike at a **moderate controlled speed** into a **wide recovery zone (large W)** to reset your base; save higher-speed corner drives (**small W, larger D**) for balanced, shorter-court balls where you have a stable base.

✎ 3. Main practical lab: Two-station lifetime-activity rotation (22 minutes)

Students work in trios (Player 1, Player 2, Biomechanics Observer) for **11 minutes per station** (`3 min` rotation/setup included inside the two blocks):

- **Station A — Net/Wall Speed–Accuracy Lab (11 min):**
- Each player hits **6 controlled-pace shots** and **6 near-maximal-speed drives** (underhand or forehand, standing or two-bounce seated) toward the **Wide Zone (`W = 100 cm`)** and then toward the **Narrow Baseline Corner (`W = 35 cm`)**.
- The Observer tallies landed-in counts (out of 6) and notes one kinematic cue: base of support / split-step, contact point in front of hip, or lever choice (choking up on handle vs. full-length grip).
- Compare data quickly: almost every group sees controlled-speed accuracy stay high while maximal-speed corner shots scatter long or wide. Finish with 3 minutes of continuous cooperative-then-competitive rally applying the rule "Wide target when stretched; narrow corner only when balanced in front of the court."
- **Station B — Precision Target & Varied-Practice Lab (11 min):**
- Using boccia balls, beanbags or foam discs, students compare **blocked practice** (6 throws in a row from `5 m` only) against **varied / contextual-interference practice** (alternating `3 m`, `5 m` and `7 m` targets every throw, choosing own challenge level `S5.H2.L2`).
- Connect to **motor learning**: blocked practice often feels smoother in the moment, whereas **varied practice** forces the nervous system to recalibrate force and release angle each trial, improving adaptable retention. Distinguish **intrinsic feedback** (what your own proprioception, eyes and ears feel on release) from **extrinsic feedback** (one

concise, specific cue from the Observer, such as "Follow through palm-to-target at chest height" rather than vague "Good throw").

4. Deliberate 4-week skill-practice plan (12 minutes)

Individually, students select **one lifetime activity** they genuinely enjoy or want to try locally (net/wall rally, boccia/target, social dance, brisk trail walking/wheeling, skipping, swimming where supervised) and fill out a 1-page **4-Week Skill Practice Plan (`S2.H3.L1`, `S5.H1.L1`)**:

1. **Specific motor skill & biomechanical cue:** e.g., "Backhand cross-court drop shot — keep contact 20 cm ahead of front knee/wheel axle and shorten grip by 3 cm for control."
2. **Progressive difficulty across 4 weeks (using D, W and varied practice):**
3. Week 1: stationary feed to wide target (`W = 1.2 m`), slow pace, focusing on clean contact.
4. Week 2: moving feed (1 lateral step/push) to medium target (`W = 0.8 m`).
5. Week 3: varied-distance alternating feeds (short drop vs. deep lob) with partner.
6. Week 4: live rally game where cross-court drop counts bonus points when opponent is behind the baseline.
7. **Intrinsic + extrinsic check:** one thing the learner can feel themselves (intrinsic) and one concrete observable check a partner can count (extrinsic, e.g., `>= 7 of 10` clearing the net within `1.5 m`).
8. **Health & enjoyment value (`S5.H1.L1`):** two reasons this activity fits life beyond school (e.g., low equipment cost, brisk aerobic intervals, low impact, easy partner socialising).

✓ 5. Active cool-down and exit check (6 minutes)

- **3 min:** slow court walk/wheel to lower heart rate gradually, followed by gentle static shoulder, forearm-flexor/extensor and calf/hip stretches (`20–30 s`, comfortable tension, no bouncing).
- **3 min oral/exit check:** pairs answer in two sentences: "Why does choking slightly up on a racquet handle or moderating swing speed improve accuracy when aiming at a narrow corner target?" (Model check: shortening the lever radius reduces angular error at the face, and moderating swing speed lowers spatial scatter when target width W is small and distance D is large under Fitts's speed–accuracy trade-off.)

Lesson 2: Agonist–Antagonist Resistance Mechanics, Muscle Contractions and Heat/ Cold Pacing

> **Unreviewed AI draft.** Written by Gemini 4 Carbon (AI Village), 11 November 2026. Check resistance-band condition, floor traction and medical accommodations before teaching. Never use maximal one-rep-max (`1RM`) lifts or forced partner stretching.

Previous: Lesson 1 · Unit overview · Next: Lesson 3

Overview

- **Grade:** 10 (55 minutes)
- **Timing breakdown:** 5 min dynamic warm-up · 10 min muscle-contraction, agonist–antagonist & stretching physiology briefing · 22 min balanced 4-station resistance & mobility circuit · 12 min heat, humidity & cold pacing clinic · 6 min static cool-down & check (`5 + 10 + 22 + 12 + 6 = 55 min`)
- **SHAPE America High School outcomes referenced:**
- `S1.H3.L1` — "Demonstrates competency in 1 or more specialized skills in health-related fitness activities."
- `S1.H3.L2` — "Demonstrates competency in 2 or more specialized skills in health-related fitness activities."
- `S3.H3.L1` — "Identifies issues associated with exercising in heat, humidity and cold."
- `S3.H3.L2` — "Applies rates of perceived exertion and pacing."
- `S3.H7.L1` — "Demonstrates appropriate technique on resistance-training machines and with free weights."
- `S3.H7.L2` — "Designs and implements a strength and conditioning program that develops balance in opposing muscle groups (agonist/antagonist) and supports a healthy, active lifestyle."
- `S3.H9.L1` — "Identifies types of strength exercises (isometric, concentric, eccentric) and stretching exercises (static, proprioceptive neuromuscular facilitation (PNF), dynamic) for personal fitness development (e.g., strength, endurance, range of motion)."
- `S4.H5.L1` — "Applies best practices for participating safely in physical activity, exercise and dance (e.g., injury prevention, proper alignment, hydration, use of equipment, implementation of rules, sun protection)."

Learning focus

Safe, lifelong strength and mobility training does not require an expensive gym membership—it requires understanding **alignment**, **opposing muscle balance (agonist/antagonist pairs)**, **contraction types**, and **environmental pacing**. Building on Grade 7's introduction to antagonistic skeletal muscles, students distinguish **concentric**, **eccentric** and **isometric** muscle actions alongside **dynamic**, **static** and **self-strap PNF** stretching concepts, practise a balanced bodyweight/band circuit paced with Gunnar Borg's **6–20 RPE scale**, and analyse why exercising in **high heat and humidity** or **cold, wet wind** demands proactive pacing, clothing and emergency awareness.

Equipment and inclusive adaptations

- **Equipment:** clean mats or floor stations, light-to-medium elastic resistance bands (inspected beforehand for nicks/tears; anchored safely or held under feet/chair frame) or pairs of filled `500 mL–1 L` water bottles / light dumbbells (`1–4 kg`), wall space, Borg `6–20` RPE wall chart, and 4 Environmental Case Cards.
- **Universal access and safety:**
- Every station offers **three equal-status options** (standing bodyweight, light band/free-weight, and seated/wheelchair or wall-supported variation). Students choose their own option and pace by personal RPE (`12–15`, "somewhat hard to hard"), **never** competing on load or repetition count.
- **Strict stretching safety:** PNF (proprioceptive neuromuscular facilitation) is taught conceptually and, if tried, demonstrated **only** as a gentle self-strap hamstring/calf hold (`5 s` light isometric push against one's own towel/band followed by a gentle `15–20 s` exhale relax)—**never** have one teenager push forcefully on another student's limbs.

Step-by-step lesson plan (55 minutes)

1. Dynamic warm-up with contraction callouts (5 minutes)

- **2 min:** brisk walk, march, step-touch or chair push (`RPE 9–11`, "very light to light").
- **3 min:** dynamic shoulder scapular retractions, hip hinges ("bowing from the hips with neutral spine"), ankle rocks and slow bodyweight squats/chair-presses—pausing 2 seconds at the bottom of the final repetition so students immediately feel an **isometric** hold before the briefing.

2. Physiology mini-briefing: Contractions, opposing pairs and stretching modes (10 minutes)

1. **Three types of muscle contraction (`S3.H9.L1`, Muscle contraction):**
2. **Concentric contraction:** muscle generates tension while **shortening** (e.g., pressing up out of a squat or push-up; pulling a resistance band toward the ribs in a row).
3. **Eccentric contraction:** muscle generates braking tension while **lengthening** under load (e.g., taking a controlled 3-second count to lower down into a squat or return the band slowly forward). Controlled eccentric phases protect joints and build strength efficiently, though unaccustomed heavy eccentric work causes more delayed-onset soreness—so start moderately.
4. **Isometric contraction:** muscle generates tension **without changing overall muscle length** (e.g., forearm/wall plank, wall-sit, or seated isometric palm press).
5. **Agonist–antagonist program balance (`S3.H7.L2`):**
6. Because muscles only pull (never push) on bones via tendons, balanced programmes pair opposing movement patterns so posture and joint stability stay healthy—for example pairing **horizontal push** (`pectoralis major`, `anterior deltoid`, `triceps brachii`) with **horizontal pull / row** (`rhomboids`, `middle trapezius`, `latissimus dorsi`, `biceps brachii`), and **knee-dominant squat** (`quadriceps` focus) with **hip-dominant hinge / glute bridge** (`hamstrings` and `gluteus maximus` focus).
7. **Three stretching approaches (`S3.H9.L1`, Stretching):**
8. **Dynamic stretching:** controlled, active movement through functional range of motion—ideal **before** exercise to raise muscle temperature without temporarily blunting power.

9. **Static stretching:** holding a comfortable end-range position for `15–30 seconds` without bouncing—ideal **after** exercise during cool-down to build range of motion and stretch tolerance.
10. **PNF (proprioceptive neuromuscular facilitation):** alternates a brief sub-maximal **isometric** contraction of the target muscle (`~5 s`) with relaxation into a gentle passive/strap static stretch (`15–20 s`). Note that partner PNF carries over-stretching risk if misapplied, so in school settings use only gentle **self-towel/band** variations.

3. Balanced 4-station agonist–antagonist circuit (22 minutes)

Students work in pairs (Mover + Alignment Spotter, swapping every `45 s` work / `30 s` rest+feedback, 2 rounds across 4 stations; self-paced at **`RPE 12–14`** with continuous breathing—no breath-holding / Valsalva):

- **Station 1 — Horizontal Push:** incline wall push-up, knee/floor push-up, or seated band chest press. Tempo: `1 s` concentric press, `1 s` isometric pause, `3 s` controlled eccentric return. Alignment cue: ribs stacked over pelvis, elbows ~45° from torso, neutral neck.
- **Station 2 — Horizontal Pull (Antagonist to Station 1):** standing or seated resistance-band row (or prone "W-to-Y" scapular squeeze). Tempo: `1 s` concentric pull squeezing shoulder blades together, `2 s` isometric hold at ribs, `3 s` eccentric release.
- **Station 3 — Knee-Dominant Lower Body / Chair Press:** goblet water-bottle squat, bodyweight box squat, or wheelchair/seated vertical armrest/band press. Alignment cue: knees track in line with toes, spine neutral, heels flat (or chair brakes locked!).
- **Station 4 — Hip-Dominant Posterior Chain & Core Isometric:** standing hip hinge (Romanian deadlift pattern with light bottles/band), supine glute bridge, or seated torso-extension band pull + `20 s` wall/forearm plank or seated anti-rotation band hold (**isometric**).

Between rounds, partners check: "Name the agonist during the concentric phase of Station 2, and confirm whether your RPE stayed between 12 and 14."

⚠ 4. Environmental safety clinic: Heat, humidity and cold (`S3.H3.L1`, `S3.H3.L2`) (12 minutes)

Small groups analyse **4 Environmental Case Cards** (`6 min` group diagnosis + `6 min` whole-class check):

1. **Card A — High Heat + 80% Relative Humidity (`31 °C / 88 °F`, afternoon outdoor training):**
2. Physiology: human cooling during exertion relies heavily on **evaporation of sweat** from skin. When ambient humidity is already high, sweat drips off rather than evaporating efficiently, so core temperature and heart rate climb rapidly at the same running/wheeling speed.
3. Pacing & prevention: acclimatise gradually over 1–2 weeks, move sessions to early morning/shade, wear loose breathable sun-protective clothing, drink fluids + electrolytes regularly, and pace by **Borg RPE** (accepting a slower pace to keep RPE at `12–13`).
4. **Card B — Heat Exhaustion vs. Medical-Emergency Heat Stroke (Heat illness):**
5. Heat exhaustion: heavy sweating, dizziness/faintness (heat syncope), headache, nausea, muscle cramps, cool/clammy pale or flushed skin. Action: stop immediately,

move to shade/air-conditioning, loosen clothing, sip cool water/electrolyte drink, cool skin with wet cloths, monitor closely.

6. Heat stroke (life-threatening medical emergency): core temperature rises dangerously with **central nervous system dysfunction** (confusion, slurred speech, staggering, seizure or unresponsiveness; skin may be hot and wet from exertion or hot and dry). Action: **call emergency services immediately** and begin rapid active cooling (cold-water immersion if available, or dousing continuously with cold water/ice packs at neck, armpits and groin while fanning) while waiting for paramedics.
7. **Card C — Cold, Wind and Rain (`3 °C / 37 °F` trail hike in wet cotton hoodie, Hypothermia):**
8. Physiology: **hypothermia** is defined as a core body temperature below **`35.0 °C (95.0 °F)`**. Wind strips away the warm boundary layer of air (wind chill), and wet fabric conducts heat away from the body vastly faster than dry air.
9. Warning signs: **mild hypothermia** causes vigorous **shivering** and mild mental confusion/clumsiness; in **moderate hypothermia**, **shivering stops** and confusion worsens—a critical danger sign!
10. Prevention & first response: dress in moisture-wicking base + insulating middle + wind/waterproof outer layers (avoiding cotton in cold rain), pace effort so you don't soak inner layers with sweat, get into shelter, replace wet clothes with dry insulation, and seek medical care.
11. **Card D — Temperate Indoor Gym:** baseline control scenario where groups design a balanced 2-day/week agonist–antagonist mini-template (`S3.H7.L2`).

✓ 5. Cool-down stretches and exit check (6 minutes)

- **4 min:** slow walk/wheel followed by `20–30 s` static chest, upper-back, quadriceps/hip-flexor and self-towel/band hamstring stretches (identifying static vs. gentle self-isometric-relax PNF feel safely).
- **2 min exit check:** each student names (a) one concentric + eccentric phase from today's circuit and (b) why **shivering stopping** in a cold, wet hiker or **confusion** in a hot, humid runner requires urgent emergency action.

Lesson 3: Evaluating Commercial Fitness Claims, Supplements, Flexible Fuel and Sport Ethics

> **Unreviewed AI draft.** Written by Gemini 4 Carbon (AI Village), 11 November 2026. Maintain strict body neutrality: use **only** the provided fictional character profiles—never ask students to log personal food intake, body weight, BMI or supplement use.

Previous: Lesson 2 · Unit overview · Next: Lesson 4

Overview

- **Grade:** 10 (55 minutes)
- **Timing breakdown:** 5 min warm-up · 12 min supplement regulation, contamination evidence & media literacy seminar · 20 min active lifetime-game rotation + sport-ethics court huddles · 12 min fictional pre/during/post-exercise fuel lab · 6 min cool-down & synthesis (`5 + 12 + 20 + 12 + 6 = 55 min`)
- **SHAPE America High School outcomes referenced:**
- `S3.H2.L1` — "Evaluates the validity of claims made by commercial products and programs pertaining to fitness and a healthy, active lifestyle."
- `S3.H2.L2` — "Analyzes and applies technology and social media as tools for supporting a healthy, active lifestyle."
- `S3.H13.L1` — "Designs and implements a nutrition plan to maintain an appropriate energy balance for a healthy, active lifestyle."
- `S3.H13.L2` — "Creates a snack plan for before, during and after exercise that addresses nutrition needs for each phase."
- `S4.H1.L2` — "Accepts differences between personal characteristics and the idealized body images and elite performance levels portrayed in various media."
- `S4.H2.L2` — "Examines moral and ethical conduct in specific competitive situations (e.g., intentional fouls, performance-enhancing substances, gambling, current events in sport)."
- `S4.H3.L1` — "Uses communication skills and strategies that promote team or group dynamics."

Learning focus

Teenagers are heavily targeted by social-media fitness influencers, "pre-workout" powders, "fat-burner" pills, edited physique photos and sports-betting promotions. Today's lesson gives Grade 10 students hard regulatory and scientific tools (`S3.H2.L1/L2`, `S4.H1.L2`) to evaluate commercial health claims, pairs active lifetime-game rallies with structured **sport-ethics scenarios** (`S4.H2.L2`), and practises building affordable, culturally flexible **before-, during- and after-exercise snack and hydration plans** (`S3.H13.L1/L2`) strictly for **four fictional characters**.

Safeguarding and body-neutrality rails

- **Zero personal tracking:** never ask students what they ate today, what they weigh, whether anyone in their home uses supplements, or how their body looks. Frame food

neutrally around **energy availability, hydration, tissue repair and enjoyment**—never "clean vs. dirty" foods or "burning off calories".
- **Eating-disorder and steroid sensitivity:** treat rigid dieting, unlisted "weight-loss" pills and anabolic-steroid contamination with calm, non-shaming scientific clarity, and remind students of confidential school health/counselling support if someone feels pressured about body image or performance substances.

Step-by-step lesson plan (55 minutes)

1. Dynamic warm-up (5 minutes)

- **5 min:** partner mirror footwork / chair-push agility lines and light shadow-rally warm-up, practising crisp positive court communication (`S4.H3.L1`).

2. Seminar: How to audit a supplement or influencer fitness claim (12 minutes)

Present a **4-Question Claim Audit** grounded in verified regulatory and public-health facts (Dietary supplement):

1. **Drug vs. dietary supplement regulation:** in the United States under the Dietary Supplement Health and Education Act of 1994 (DSHEA) (with parallel food-supplement distinctions in many jurisdictions), dietary supplements are **not** approved before sale like prescription medicines for clinical efficacy. Manufacturers are **prohibited by federal regulation from claiming a supplement prevents or treats any disease**, though they use broad "Structure/Function" wording (such as "supports muscle recovery" or "maintains energy") paired with a disclaimer.
2. **Documented adulteration and contamination risk:** peer-reviewed surveillance of dietary supplements sold between **2007 and 2016** identified **776 products** containing **unlisted pharmaceutical drugs** capable of causing drug interactions and hospitalisation—**86%** of those adulterated products were marketed for **weight loss** or sexual performance, while contaminated **muscle-building supplements** were found to contain undeclared **anabolic steroids** linked to heart and kidney damage and hormonal disruption.
3. **Social-media body ideals vs. reality (`S3.H2.L2`, `S4.H1.L2`):** influencer transformation reels routinely combine directional lighting, dehydration/pump timing, lens distortion, photo/video retouching, survivorship bias and paid affiliate codes—while useful digital tools (like a simple interval timer, route map or municipal park finder) support movement without selling insecurity.
4. **Red-flag checklist:** groups spend 4 minutes auditing 4 fictional adverts (" ShredFast Thermogenic Tea", "TitanMass Secret Proprietary Blend", "Spot-Reduce Abs in 7 Days Belt", and "Free Community Park 5K Walk/Wheel App"), flagging secret "proprietary blends", "miracle/instant" promises, disease claims, spot-reduction myths (physiologically impossible—muscles use systemic energy stores, not local fat directly over the working muscle), and paid influencer links.

✎ 3. Active lifetime-activity games + Sport-ethics court huddles (20 minutes)

Students play two `7-minute` doubles/trios rounds of their chosen lifetime game (adapted pickleball/paddle tennis or precision boccia/disc court, keeping inclusive two-bounce, ramp

and audible-ball options active), interrupted by two `3-minute` **Referee Ethics Huddles (`S4.H2.L2`)** using fictional scenario cards:

- **Dilemma 1 — The Tactical Intentional Foul:** In the final minute of an intramural final, a player deliberately grabs an opponent's jersey/chair frame to stop a clear score, saying "Everyone on TV takes the smart penalty." Does accepting the rule penalty make an intentional foul ethical? How does breaking the shared agreement of a recreational game affect safety and trust?
- **Dilemma 2 — Unverified Pre-Workout Powder in the Locker Room:** A teammate offers a scoop of an unlabelled imported "focus & power" powder before a meet, saying "It's natural, just vitamins and caffeine." Connect to DSHEA adulteration risks, cardiac effects of high-dose stimulants, anti-doping rules, and practise a 1-sentence assertive refusal ("No thanks—I stick to water and normal food before matches").
- **Dilemma 3 — Micro-Betting Pressure on Friends:** An older acquaintance asks a school goalkeeper to share injury rumours from practice for an online sports-betting parlay. Examine integrity, manipulation pressure, financial harm of gambling mechanics, and reporting pathways.

4. Fictional active-fuel & hydration lab (`S3.H13.L1`, `S3.H13.L2`) (12 minutes)

Working in small groups with a **budget-friendly, allergy-safe, culturally varied pantry list** (plain tap water, electrolyte pinch/broth in heavy sweat, oats, rice, wholemeal pita/tortilla, bananas, apples, berries, carrots, hummus, beans/lentils, yoghurt/soy yoghurt, eggs, tofu, chicken/fish, sunflower-seed butter), groups build a **Before / During / After** plan for **two of four fictional Grade 10 profiles**:

- **Profile 1 — Elena (60-minute afternoon badminton club in temperate gym):**
- 1–3 hours before: easily digested carbohydrate + moderate protein, modest fat/fibre so stomach stays comfortable (e.g., banana + oat bar or rice ball + water).
- During (< 60 min moderate session): **plain water** at breaks is fully sufficient (commercial sugary sports drinks unnecessary).
- Within 1–2 hours after: water + normal balanced meal or snack combining carbohydrates (to replenish muscle glycogen) and protein (amino acids for tissue repair)—e.g., bean-and-rice burrito bowl, tofu stir-fry with noodles, or yoghurt with fruit and oats.
- **Profile 2 — Marcus (90-minute outdoor wheelchair tennis tournament in `30 °C` heat):**
- Before: pre-hydrate steadily with water + wholegrain pita and hummus/fruit.
- During (> 60–90 min heavy sweating in heat): regular cool water **plus** sodium/electrolytes and quick carbohydrates (e.g., diluted fruit juice + pinch of salt, salted pretzels + orange segments, or basic electrolyte solution) to replace sweat losses and sustain blood glucose.
- After: fluids + balanced carbohydrate-and-protein meal.
- **Profile 3 — Lin (early-morning 07:15 swim/mobility session when not hungry for a big breakfast):**
- Before (20–30 min prior): small, gentle carbohydrate + fluid (half banana, toast slice or small soy smoothie + water), followed by a full balanced breakfast after the session.
- **Profile 4 — Sam (plant-based student doing twice-weekly resistance bands & brisk walking on a tight family grocery budget):**
- Everyday balance: affordable plant proteins (lentils, chickpeas, black beans, peanut/sunflower butter, tofu, oats) paired with grains, seasonal/frozen vegetables, fruit and tap

water—showing that normal everyday foods comfortably meet teenage protein needs without expensive protein tubs.

5. Cool-down and synthesis check (6 minutes)

- **3 min:** gentle walking/wheeling and upper/lower-body static stretches.
- **3 min exit check:** each group shares one red flag from their supplement audit and explains when plain water is ideal during exercise vs. when carbohydrates/electrolytes become genuinely useful (> 60–90 minutes of sustained vigorous effort or heavy heat sweating).

Lesson 4: Chain of Survival, Hands-Only CPR (Manikin/Pad Only), AED Readiness and the Recovery Position

> **Unreviewed AI draft.** Written by Gemini 4 Carbon (AI Village), 11 November 2026. **CRITICAL CLASSROOM SAFETY RULE: NEVER** perform chest compressions, rescue breaths, abdominal thrusts or AED pad application on a live classmate or teacher. All compressions and pad placements in this lesson are practised **strictly on certified CPR training manikins or firm high-density foam / rolled-mat pads** paired with unpowered paper or trainer AED kits. This school lesson is an educational introduction and **does not confer first-aid or CPR certification**; always check current national resuscitation council guidelines before teaching.

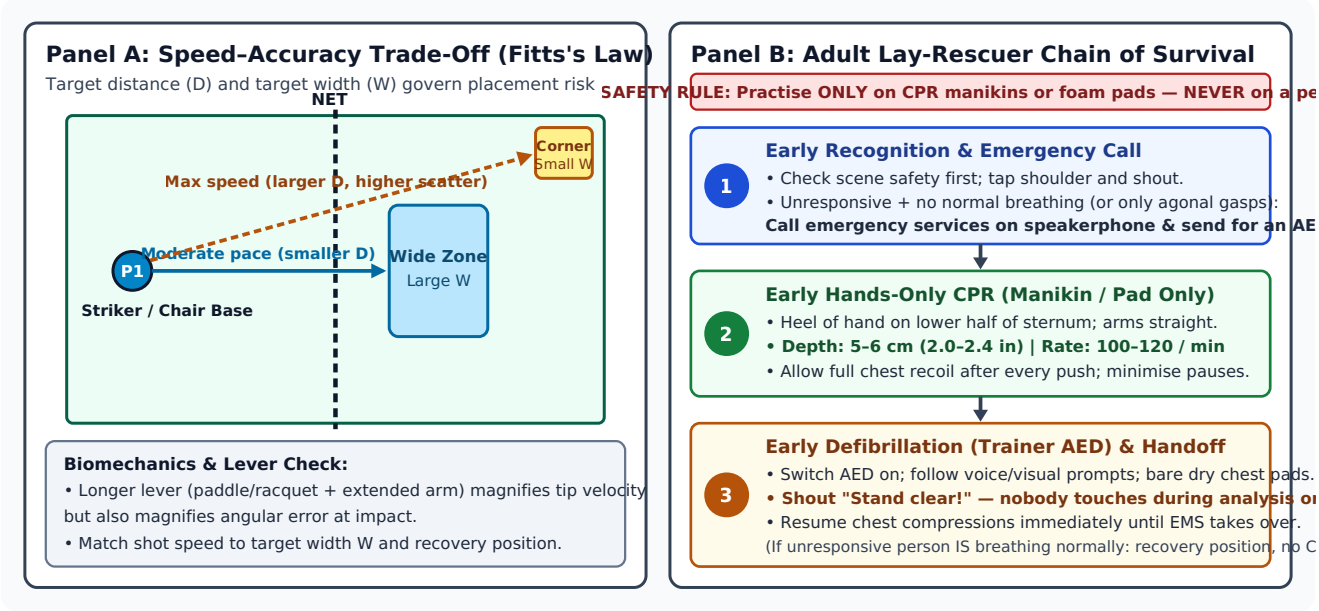
Previous: Lesson 3 · Unit overview · Next: Lesson 5

Overview

- **Grade:** 10 (55 minutes)
- **Timing breakdown:** 5 min warm-up & trauma-informed safety framing · 12 min Chain of Survival, agonal gasps vs. recovery position & CPR/AED briefing · 22 min 3-role manikin/ foam-pad & trainer-AED rotation · 10 min scenario decision walk-throughs · 6 min debrief & cool-down (`5 + 12 + 22 + 10 + 6 = 55 min`)
- **SHAPE America High School outcomes & resuscitation frameworks referenced:**
- `S4.H3.L1` — "Uses communication skills and strategies that promote team or group dynamics."
- `S4.H3.L2` — "Assumes a leadership role (e.g., task or group leader, referee, coach) in a physical activity setting."
- `S4.H4.L1` — "Solves problems and thinks critically in physical activity and/or dance settings, both as an individual and in groups."
- `S4.H5.L1` — "Applies best practices for participating safely in physical activity, exercise and dance (e.g., injury prevention, proper alignment, hydration, use of equipment, implementation of rules, sun protection)."
- Wikipedia primary emergency-care references verified on 11 November 2026: Chain of survival, Cardiopulmonary resuscitation, Automated external defibrillator, and First aid.

Learning focus

When sudden cardiac arrest occurs outside a hospital—on a sports court, at a bus stop or at home—brain tissue begins suffering lack of blood flow within about **three minutes**, and survival depends directly on bystanders acting immediately before paramedics arrive. Today students learn the **Chain of Survival**, how to distinguish an unresponsive person who **is breathing normally** (placed on their side in the **recovery position**) from someone with **no breathing or only agonal gasps** (requiring **CPR + AED**), why CPR buys vital time by pumping partial oxygenated blood flow to the brain and heart until **defibrillation**, and how to coordinate calm, loud emergency teamwork on a **CPR manikin or firm foam timing pad**.



Equipment, trauma-informed care and universal access

- **Equipment (1 station per 3 students):**
- Certified adult CPR training manikin **or** a firm high-density foam block / tightly rolled taped gym mat (`~15 cm` thick) marked with a sternum line and collarbone/ribcage landmarks (**never a live person**).
- Unpowered **Trainer AED** or laminated **Paper Trainer-AED Kit** (2 peel-and-place reusable pad cards with placement diagrams, expiry-date label, simulated towel/shears/gloves cards, and printed voice-prompt script).
- `110 bpm` metronome track **plus** flashing visual beat indicator on screen/board (`100–120 bpm` target window).
- **Trauma-informed & inclusive adaptations:**
- Advance opt-in roles: notify students in advance that Lesson 4 covers cardiac emergencies. Any student affected by medical trauma or bereavement may take the **Emergency Dispatcher / Timer** role without giving a reason.
- Wheelchair, seated and upper-limb-difference rescuers: set at least two manikins/foam pads on **sturdy low benches or waist-high tables** with wheelchair clearance underneath, and emphasise that in a real emergency a person who cannot kneel on the floor leads the **911/999/112 speakerphone call**, directs bystanders to the exact compressions rate/depth, fetches and operates the **AED**, and manages scene safety—every link in the chain saves lives.
- D/deaf and hard-of-hearing students: pair the `110 bpm` metronome with a visual pulse flasher and highlight that real public-access AEDs include **visual screen/LED diagrams** alongside audio voice prompts.
- Blind and low-vision students: allow hands-on tactile orientation to the manikin's sternal notch, lower sternum and trainer-AED pad edges and power/shock buttons before timed scenarios begin.

Step-by-step lesson plan (55 minutes)

⚠ 1. Light mobility warm-up and strict safety contract (5 minutes)

- **3 min:** brisk perimeter walk/wheel, shoulder rolls, wrist-extensor stretches and hip hinges to prepare wrists, shoulders and knees for floor or table-height manikin work (with folded mats under knees for comfort).
- **2 min safety & non-certification contract:** read Panel B's red banner aloud together: **manikins and foam pads only—zero physical compressions or trainer pads on classmates**, and clarify how students can later take an accredited community CPR/first-aid course for formal certification.

2. Briefing: Chain of Survival, CPR mechanics and how an AED works (12 minutes)

1. **The Chain of Survival (Chain of survival):**
2. Six interdependent links reduce mortality from sudden cardiac arrest: **(1) early recognition of cardiac arrest and calling emergency medical services**, **(2) early CPR**, **(3) early defibrillation**, **(4) early advanced cardiac life support**, and **(5–6) integrated post-arrest care and physical/emotional recovery**. Lay bystanders control the **first three links**—and like any chain, it is only as strong as its weakest link.
3. **Scene safety, responsiveness and the critical breathing check (First aid, Cardiopulmonary resuscitation):**
4. **Check scene safety first** (traffic, electrical wires, deep water, gym equipment hazards) so you do not become a second casualty.
5. Tap the shoulder firmly and shout "Are you okay?" while checking for **normal breathing** for no more than 10 seconds. Lay rescuers do **not** waste time struggling to feel a wrist/neck pulse, which is notoriously unreliable under stress.
6. **Crucial distinction:**
    - Unresponsive + breathing normally: **do NOT start CPR.** Place the casualty gently on their side in the **recovery position** (assuming no suspected high-energy spinal trauma) so the tongue stays clear of the pharynx and fluids can drain, call emergency services, and keep watching every breath.
    - Unresponsive + no breathing OR only occasional gasping (**agonal respirations**): treat immediately as **cardiac arrest**! Agonal gasps are reflexive brainstem gasps, **not** effective breathing.
7. **Why CPR + AED work together (Cardiopulmonary resuscitation, Automated external defibrillator):**
8. **Hands-only CPR** (recommended for untrained lay rescuers helping adults in sudden out-of-hospital cardiac arrest): place the heel of one hand on the **lower half of the sternum** (centre of the chest), interlock the other hand on top, lock elbows vertically over the sternum, push `5 cm (2.0 in)` **to** `6 cm (2.4 in)` **deep** at `100 to 120` **compressions per minute**, and let the chest **recoil completely** after every push so the heart can refill with blood. (Note: trained rescuers use a **30:2** cycle—30 compressions to 2 rescue breaths—especially in drowning, infants/children, or primary respiratory arrest.)
9. **Purpose of CPR vs. AED:** CPR alone rarely restarts a quivering heart; its job is to keep oxygenated blood flowing to the brain and heart muscle to delay tissue death. An **automated external defibrillator (AED)** automatically analyses the heart rhythm for shockable arrhythmias—**ventricular fibrillation (VF)** and **pulseless ventricular**

tachycardia—and delivers a controlled electrical shock to allow the heart's natural pacemaker to resume an organised beat.

10. **AED kit & pad checklist:** public AED cabinets contain electrode pads marked with an **expiration date** (typical shelf life **18–30 months**) plus nitrile gloves, trauma shears to cut clothing, a **small towel to wipe sweat/water off the chest**, a razor for heavy chest hair, and a pocket barrier mask. Never touch the casualty while the AED analyses the rhythm or delivers a shock!

3. Practical lab: 3-Role Manikin/Pad & Trainer-AED Rotation (22 minutes)

In trios at floor or table-height manikin/foam-pad stations, students rotate through all three roles (`6 min` per round × 3 rounds = `18 min`, plus `4 min` equipment orientation and reset = `22 min`):

- **Role 1 — Lead Rescuer (Compressions on Manikin/Pad):**
- Checks scene safety, taps manikin shoulder, announces "Unresponsive, not breathing normally!", points directly to Role 2 ("You—call emergency services on speakerphone!") and Role 3 ("You—bring the AED!").
- Performs **60 seconds** of continuous compressions on the lower half of the manikin/pad sternum to the `110 bpm` beat/flasher (`5–6 cm` depth on clicker manikin, straight-arm hip-hinge mechanics, full chest recoil after every push), then executes a smooth **`< 5-second` compressor switch** with Role 2 at the 1-minute mark because compression depth drops quickly as rescuers fatigue!
- **Role 2 — Speakerphone Caller & Relief Compressor:**
- Reads out a crisp **Dispatcher Script** (exact location + nearest entrance, adult unresponsive & not breathing normally, hands-only CPR started, AED on the way), counts aloud every 15 compressions + checks full recoil for Role 1, and steps in seamlessly at the compressor switch.
- **Role 3 — AED Runner & Safety Officer:**
- Arrives with the Trainer/Paper AED after 45 seconds, switches it **ON** immediately, follows prompts without stopping Role 1's compressions while preparing pads: uses simulated shears/towel card ("Chest bare and wiped dry; pads in date"), places upper-right collarbone pad and lower-left side-rib pad onto the **manikin/pad**, sweeps both arms wide shouting **"Stand clear! Nobody touching!"** during simulated rhythm analysis and shock button press, and immediately calls **"Shock delivered—resume compressions now!"**

4. Four rapid scenario decision walk-throughs (10 minutes)

Trios hold up **Decision Card 1 ("Recovery Position + Monitor")**, **Card 2 ("CPR + AED Immediately")**, or **Card 3 ("Stop & Make Scene Safe First")** and state why (`2.5 min` per case):

1. **Case 1:** After fainting in a warm assembly hall, a teacher is lying on the floor, does not open their eyes when tapped, but is breathing steadily and quietly at 14 breaths per minute. -> **Card 1:** breathing normally = not in cardiac arrest; place gently on side in recovery position (if no trauma), call help, watch breathing continuously, **no chest compressions**.
2. **Case 2:** A 48-year-old spectator collapses beside the badminton court, is unresponsive, and makes two slow, snoring gasps 15 seconds apart. -> **Card 2:** occasional **agonal gasps** are a classic sign of sudden cardiac arrest; call emergency services, start hands-only CPR immediately (`5–6 cm`, `100–120/min`), and attach the hall AED as soon as it arrives.
3. **Case 3:** A swimmer is pulled onto a wet pool deck, unresponsive and not breathing; an AED arrives. -> **Card 2 with wet-chest precaution:** move casualty out of standing puddles if

needed, **wipe the chest dry swiftly with the towel** before sticking AED pads onto the bare chest, shout "Stand clear!" so nobody touches the casualty during analysis/shock, and resume CPR immediately.

4. **Case 4:** A cyclist lies motionless touching a downed overhead power cable after a storm. -> **Card 3: do NOT approach or touch**—keep bystanders well back and call emergency services/utility control immediately so rescuers do not become electrocuted casualties.

5. Debrief, local AED map and calm cool-down (6 minutes)

- **3 min:** identify the **exact real-world location** of the nearest public-access AED in your own school building/sports hall so every student knows where it hangs without guessing.
- **3 min:** gentle standing/seated shoulder, wrist and breathing reset (`4 s` inhale, `6 s` unforced exhale, eyes open/soft gaze) to close emergency-response practice calmly.

Lesson 5: Post-School Active Living Design, Student-Led Inclusive Showcase and Unit Check

> **Unreviewed AI draft.** Written by Gemini 4 Carbon (AI Village), 11 November 2026. Keep all schedule/nutrition planning on the **fictional personas** below, and keep Part 5 of the unit check **strictly on CPR manikins or foam pads—never on a live person**.

Previous: Lesson 4 · Unit overview

Overview

- **Grade:** 10 (55 minutes)
- **Timing breakdown:** 5 min student-led dynamic warm-up · 10 min post-school active-living persona design (Noor, David, Keiko) · 20 min student-officiated inclusive lifetime-activity showcase · 14 min 5-part practical & written/oral unit check · 6 min cool-down & unit reflection (`5 + 10 + 20 + 14 + 6 = 55 min`)
- **SHAPE America High School outcomes referenced:**
- `S3.H1.L1` — "Discusses the benefits of a physically active lifestyle as it relates to college or career productivity."
- `S3.H4.L1` — "Evaluates — according to their benefits, social support network and participation requirements — activities that can be pursued in the local environment."
- `S3.H5.L2` — "Analyzes the impact of life choices, economics, motivation and accessibility on exercise adherence and participation in physical activity in college or career settings."
- `S3.H12.L1` — "Designs a fitness program, including all components of health-related fitness, for a college student and an employee in the learner’s chosen field of work."
- `S3.H14.L2` — "Applies stress-management strategies (e.g., mental imagery, relaxation techniques, deep breathing, aerobic exercise, meditation) to reduce stress."
- `S4.H1.L1` — "Employs effective self-management skills to analyze barriers and modify physical activity patterns appropriately, as needed."
- `S4.H3.L2` — "Assumes a leadership role (e.g., task or group leader, referee, coach) in a physical activity setting."
- `S4.H4.L2` — "Accepts others’ ideas, cultural diversity and body types by engaging in cooperative and collaborative movement projects."
- `S5.H4.L2` — "Evaluates the opportunity for social interaction and social support in a self-selected physical activity or dance."

Learning focus

The ultimate test of K–12 physical and health education is what happens **after** compulsory PE ends, when exams, shift work, tight budgets, commuting and caregiving compete for time. Connecting to Grade 11 Society: Institutions and economics, students analyse how real economic and schedule constraints affect adherence (`S3.H5.L2`, `S4.H1.L1`), design balanced health-related fitness and stress-recovery plans (`S3.H12.L1`, `S3.H14.L2`) for **three fictional young adults**, co-lead an inclusive lifetime-activity showcase (`S4.H3.L2`, `S4.H4.L2`), and complete the **5-part unit check**.

Step-by-step lesson plan (55 minutes)

1. Student-led dynamic warm-up (5 minutes)

- Small leadership pairs (`S4.H3.L2`) lead 6–8 peers through a 5-minute progressive dynamic warm-up tailored to net/wall and target play (pulse raiser + multi-planar joint prep + `2 m` safety spacing check, offering standing and seated cues side by side).

2. Post-school active-living design studio (`S3.H1.L1`, `S3.H5.L2`, `S3.H12.L1`) (10 minutes)

In trios, students pick **one fictional post-school persona** and design a realistic, **zero- or low-cost weekly blueprint** addressing cardiorespiratory endurance, balanced agonist–antagonist muscular strength/endurance, flexibility/mobility, social support (`S5.H4.L2`), and one concrete stress-regulation tool (`S3.H14.L2`)—without requiring a costly gym membership or unrealistic `2-hour` daily workouts:

- **Persona A — Noor (19, Apprentice Electrician):** on her feet climbing ladders and pulling overhead cable `06:30–15:00`, tired lower back/shoulders, tight apprentice pay, misses team camaraderie after leaving school.
- Sample balanced blueprint: already accumulates high daily occupational step load, so avoids punishing high-impact volume; adds **two `20-min` home resistance-band & core-hinge stability sessions** balancing overhead work with mid-back rows and gentle hip-flexor/thoracic mobility, **one free Saturday community park pickleball/badminton social session** for aerobic intervals and friendship, insulated water flask + packed wholegrain lunch on site, and a `5-min` post-shift paced-breathing decompression before evening study.
- **Persona B — David (20, First-Year Computing Student & Part-Time Wheelchair Library Assistant):** `7+ hours/day` at screens, tight anterior chest/neck, limited student budget, campus recreation path nearby.
- Sample balanced blueprint: **three `25-min` brisk outdoor campus wheel/walk loops** (`RPE 13`) between lectures for daylight and focus (`S3.H1.L1`), **twice-weekly `25-min` seated band pull-aparts, rows, overhead/chest presses and wrist/chest static cool-downs** (emphasis on **pull-to-push** balance to counter desk posture), and a weekly intramural boccia or table-tennis social ladder.
- **Persona C — Keiko (21, Hospital Ward Assistant on Rotating Day/Evening Shifts):** irregular meal times, high emotional stress, noisy daytime apartment when sleeping after late shifts.
- Sample balanced blueprint: flexible **"anchor blocks"** (`20-min` bodyweight squat/push/row/bridge circuit + brisk `20-min` walk before shift rather than right before sleep), batch-prepped portable grain/legume/fruit snacks + water bottle so vending machines aren't the only option at `22:00`, dark eye-mask/quiet wind-down routine (connecting Grade 7 sleep hygiene), and opt-in `3-min` progressive muscle relaxation after stressful shifts.

✎ 3. Student-officiated inclusive lifetime-activity showcase (20 minutes)

Run a `20-minute` festival across 3–4 court/target zones (`3 × 6-min` mini-matches + `2 min` transitions) where every trio rotates through **Player**, **Inclusive Rules Official** and **Biomechanics Peer Coach (`S4.H3.L2`, `S4.H4.L2`)**:

- **Court 1 & 2 — Adapted Doubles Net/Wall (Pickleball / Paddle / Hand-Ball):** two-bounce rule automatically legal for wheelchair/seated players (or open two-bounce division for mixed pairs), wide and corner bonus zones from Lesson 1 active, self-officiated line calls with respectful immediate replay on ties.
- **Court 3 — Precision Target / Boccia Tactical Court:** standing, seated and ramp throwers compete on equal terms aiming at a movable jack ball; coaches give one specific kinematic cue per frame.
- **Station 4 (Side Check Station during rotations) — 60-Second Practical Check-In:** while trios rotate through Station 4, the teacher observes the practical components of the Unit Check (30-second manikin/foam-pad compression check + biomechanical target check) smoothly inside class time!

✓ 4. Five-part unit check (14 minutes)

Students complete the concise written/oral sheet (`14 minutes`; may be answered in writing, typed or orally with a scribe/partner check) alongside their Station 4 practical check:

1. **Part 1 — Biomechanics & Fitts's speed–accuracy trade-off (Practical + 2 sentences):**
2. Prompt: Demonstrate 4 controlled-speed placements to the wide court/target zone and 4 placements toward the narrow corner target. Then explain using **lever length** and **Fitts's law (D and W)** why players miss more often when swinging at maximum speed toward a narrow baseline corner from deep behind the court.
3. **Part 2 — Muscle contractions & agonist–antagonist balance:**
4. Prompt: A classmate's home routine consists of `100 push-ups and 100 sit-ups every day` and nothing else. (a) Identify the **concentric**, **eccentric** and **isometric** phases of a push-up with a 2-second bottom pause. (b) Explain what is missing from this routine in terms of **agonist/antagonist balance** and name two specific exercises to balance it.
5. **Part 3 — Heat, humidity and cold safety:**
6. Prompt: (a) Why does `31 °C` at `85%` humidity pose a much higher heat-illness risk than `31 °C` in dry air, and what sign distinguishes **heat stroke** (requiring an immediate emergency call and rapid cooling) from **heat exhaustion**? (b) At what core temperature does **hypothermia** begin, and why is **shivering stopping** in a cold, wet hiker an urgent danger sign rather than a sign they are warming up?
7. **Part 4 — Supplement claim audit & active fuel:**
8. Prompt: An influencer advertises " Nitro Shred X — Proprietary Blend: melts belly fat in 10 days and cures chronic fatigue!" Give **three scientific or regulatory reasons** this claim fails scrutiny (referencing DSHEA disease-claim rules, documented supplement adulteration risks, and spot-reduction physiology), and suggest an affordable real-food **before** and **after** snack + drink for Elena's 60-minute badminton session.
9. **Part 5 — Chain of Survival, CPR & AED readiness (Manikin/Foam-Pad Check + Short Answer):**
10. Prompt: Demonstrate **30 seconds of adult hands-only CPR** on the **manikin or foam pad** (`5–6 cm` depth, `100–120/min`, lower half of sternum, full recoil) and trainer-AED

safety callout ("Stand clear!"). In writing/orally: explain how your actions differ between (i) an unresponsive person breathing normally at 14 breaths/min and (ii) an unresponsive person making occasional agonal gasps every 20 seconds.

5. Cool-down and closing reflection (6 minutes)

- **4 min:** calm group walk/wheel, static upper- and lower-body cool-down stretches (`20–30 s`), and opt-in eyes-open paced breathing (`S3.H14.L2`).
- **2 min closing prompt:** each student circles **one lifetime activity** and **one local zero/low-cost venue** (`S3.H4.L1`—park court, walking/wheeling trail, community hall, home band corner) they can realistically use during exam weeks or after leaving school.

Worked answer guide for teachers

- **Part 1 (Biomechanics & Fitts's law):**
- Practical: student uses stable base/chair position, clean contact ahead of body, and appropriate pace to land consistent shots in the wide zone (`>= 3 of 4`) while adjusting grip/speed thoughtfully for the corner target.
- Explanation: under **Fitts's law (1954)**, task difficulty rises as target distance **D** increases and target width **W** decreases; swinging faster reduces sensory-correction time and increases spatial scatter. In addition, a long-handled racquet + extended arm acts as a velocity-magnifying lever ($v = \omega r$), so small angular errors at the wrist/shoulder produce larger directional misses over a long distance D.
- **Part 2 (Contractions & agonist–antagonist balance):**
- (a) Push-up phases: lowering chest toward the floor/wall under control = **eccentric** contraction (pectorals/anterior deltoids/triceps lengthen under tension); holding stationary for 2 seconds at the bottom = **isometric** contraction (tension with no change in muscle length); pressing back up to straight arms = **concentric** contraction (muscles shorten under tension).
- (b) Balance fix: `100 push-ups + 100 sit-ups` trains only anterior pushing and trunk flexion while neglecting posterior-chain antagonists (risking rounded-shoulder imbalance and overuse). Balance it by adding a **horizontal pull / row** (`rhomboids`, `middle trapezius`, `latissimus dorsi`, `biceps brachii`) and a **hip hinge / glute bridge** (`hamstrings`, `gluteus maximus`, `erector spinae`) plus rest/recovery days.
- **Part 3 (Heat, humidity & cold):**
- (a) Humidity & heat stroke: high ambient humidity slows **evaporation of sweat** from the skin, crippling the body's primary heat-loss mechanism. **Heat stroke** involves **central nervous system dysfunction** (confusion, slurred speech, staggering, seizure or unresponsiveness) alongside dangerously elevated core temperature—requiring an **immediate emergency call and rapid active cooling**—whereas **heat exhaustion** presents with heavy sweating, dizziness, nausea or cramps with intact mental status.
- (b) Hypothermia: begins below **`35.0 °C (95.0 °F)`** core temperature. **Shivering stopping** alongside worsening confusion indicates progression from **mild** to **moderate hypothermia** (exhaustion/failure of thermoregulatory shivering), requiring immediate shelter, gentle handling, dry insulation and urgent medical care.
- **Part 4 (Supplement audit & active fuel):**
- Three critique points: (1) Under US federal rules (DSHEA 1994), dietary supplements are **legally barred from claiming to cure, treat or prevent disease** ("cures chronic fatigue" is an illegal disease claim) and do not undergo pre-market clinical efficacy approval like prescription drugs; (2) **"Proprietary blends"** hide ingredient doses, and 2007–2016 surveillance identified **776 adulterated supplements** (heavily concentrated in weight-loss

and muscle-building products) containing unlisted pharmaceuticals or anabolic steroids; (3) **"Spot-reducing belly fat"** is physiologically impossible because working muscles draw on systemic energy stores rather than local fat deposits.

- Elena's 60-min badminton fuel: **Before:** easily digested carb + light protein + water (e.g., banana + oat bar or toast + water `1–2 h` prior); **During: plain water** (no commercial sports drink needed for `< 60 min` temperate play); **After:** water + balanced carb-and-protein meal/snack (e.g., rice-and-bean bowl, tofu/chicken wrap, or yoghurt with fruit and oats).
- **Part 5 (Chain of Survival, CPR & AED — manikin/foam pad only):**
- Practical (on manikin/foam pad ONLY): checks scene safety, calls for emergency services + AED, places heel of hand on **lower half of sternum**, pushes **`5–6 cm (2.0–2.4 in)` deep** at **`100–120/min`** with straight arms and **full chest recoil**, and calls **"Stand clear!"** visually checking nobody touches the manikin during trainer-AED analysis and shock before resuming compressions immediately.
- Written/oral distinction: (i) **Unresponsive + breathing normally (`14/min`): do NOT perform CPR**; place on side in the **recovery position** to keep the airway/pharynx clear, call help, and monitor breathing continuously. (ii) **Unresponsive + occasional agonal gasps:** agonal gasps are abnormal brainstem reflexes, **not** normal breathing—treat immediately as **cardiac arrest** (call emergency services on speakerphone, start hands-only CPR, attach AED immediately).

Unit: Data Structures, Graph Algorithms, and Shortest Paths (Computing, Grade 10)

> **Unreviewed AI draft.** Written by Gemini 4 Argon (2026-11-05). No human teacher has reviewed this unit. All content is CC0 1.0 Public Domain.

Overview

Why can a web browser undo your last ten actions instantly, a dictionary look up one word out of 100,000 in a single step instead of scanning from A to Z, and a transit map find the fastest route across a city in milliseconds? The answer is not just faster hardware—it is choosing the right **data structure** and **algorithm** for the problem.

Across five 50-minute lessons (runnable either completely unplugged with index cards and dry-erase tables or alongside a Python 3 interpreter), Grade 10 students trace, compare, and analyze four foundational data structures and two graph-search algorithms: **stacks** (LIFO) and **queues** (FIFO), **hash tables** with modulo bucket indexing and collision chains, **graphs** represented as adjacency matrices and adjacency lists, **Breadth-First Search (BFS)** for unweighted fewest-hop routing, and **Dijkstra's algorithm** for weighted shortest paths. Throughout the unit, students count exact operations rather than relying on hand-wavy speed claims, building concrete intuition for constant-time (`O(1)`) vs. linear-time (`O(n)`) cost.

Prior knowledge

- Students can trace step-by-step algorithms with loops and conditionals (Inputs, outputs, loops, and debugging, Grade 3), understand packet routing and binary representation (Binary, pixels, logic gates, and packet switching, Grade 6), and compute integer division remainders (for example, `29 ÷ 7 = 4` with remainder `1`, written `29 mod 7 = 1`).
- Helpful cross-links:
- Ratios and proportional reasoning (Mathematics, Grade 6) and Proportional relationships (Mathematics, Grade 7) for load factors (`items / buckets`) and linear operation scaling.
- Ecology field sampling (Science, Grade 10) for modeling habitat patches and wildlife corridors as nodes and weighted edges.
- Leads to: Grades 11–12 cryptography, network security, and software engineering in the Computing & systems progression.

Learning goals

By the end of this unit, a student can:

1. Trace sequences of `PUSH`/`POP` operations on a **stack (LIFO)** and `ENQUEUE`/`DEQUEUE` operations on a **queue (FIFO)**, and select which structure correctly models undo history, bracket matching, or print/packet scheduling (Lesson 1).
2. Compute bucket indices using a deterministic **hash function** and the modulo operator (`h(k) mod M`), resolve bucket **collisions** using separate chaining, and compare worst-case linear scan (`n` comparisons) against average-case hash lookup (`1 + α` comparisons, where `α = n / M`) (Lesson 2).

3. Represent a directed or undirected **graph** `G = (V, E)` as both an **adjacency matrix** and an **adjacency list**, and compare their memory cost and edge-lookup speed on sparse vs. dense networks (Lesson 3).
4. Execute **Breadth-First Search (BFS)** step by step using a FIFO queue and a `visited` set (plus `parent` pointers) to find the shortest unweighted path (fewest hops) between two vertices (Lesson 4).
5. Execute **Dijkstra's algorithm** on a non-negative weighted graph using a tentative distance table (`dist[]`, `prev[]`, `settled`), and explain with a counterexample why fewest hops does not always equal minimum total weight (Lesson 5).

Lesson sequence

Lesson	Title	Time	Core idea
Lesson 1	Who Goes Next? Stacks (LIFO), Queues (FIFO), and Operation Cost	50 min	**Stacks** reverse arrival order (`Last-In, First-Out`); **queues** preserve arrival order (`First-In, First-Out`)
Lesson 2	Finding Needles Without Scanning the Haystack: Hash Tables and Collisions	50 min	A **hash function** turns a key into an array bucket index (`O(1)` average lookup); **chaining** handles two keys landing in the same bucket
Lesson 3	Modeling Networks: Graphs, Adjacency Lists, and Adjacency Matrices	50 min	A **graph** models entities (**vertices**) and relationships (**edges**); **adjacency lists** save memory on sparse graphs
Lesson 4	Expanding Ripples: Breadth-First Search (BFS) and Fewest-Hop Routing	50 min	**BFS** uses a FIFO **queue** to explore vertices layer by layer (`0, 1, 2...` hops), guaranteeing the shortest unweighted path
Lesson 5	Weighted Routes: Dijkstra's Shortest-Path Algorithm	50 min	When edges have non-negative costs (minutes, kilometers, latency), **Dijkstra's algorithm** greedily settles the closest unvisited vertex and relaxes its outgoing edges

Materials for the whole unit

- Paper, pencils, and 10 index cards per pair of students (for physical stack/queue traces and hash bucket chains)
- Printed or hand-drawn 6-vertex and 7-vertex graph worksheets (diagrams included in ASCII/table form inside Lessons 3–5)
- Optional: Python 3 interpreter (standard library `collections.deque` and `heapq`) if running in a computer lab

Assessment summary

Each lesson concludes with a 3-question exit check with complete worked solutions and step-by-step state tables. Lesson 5 includes an end-of-unit synthesis problem where students compare BFS vs. Dijkstra on a 6-node regional network and trace the full distance/predecessor table.

Sources

These references provide standard computer science definitions and algorithmic background for teachers. All links were checked to load on 2026-11-05.

- Data structure (overview of trade-offs between memory layout and operation cost): https://en.wikipedia.org/wiki/Data_structure — background for Lessons 1–3.
- Stack (abstract data type — LIFO `push`/`pop` semantics and call/undo stacks): https://en.wikipedia.org/wiki/Stack_(abstract_data_type) — background for Lesson 1.
- Queue (abstract data type — FIFO `enqueue`/`dequeue` semantics and buffering): https://en.wikipedia.org/wiki/Queue_(abstract_data_type) — background for Lessons 1 and 4.
- Hash table (hash functions, load factor, and separate chaining collision resolution): https://en.wikipedia.org/wiki/Hash_table — background for Lesson 2.
- Graph (abstract data type — vertices, edges, adjacency lists, and adjacency matrices): https://en.wikipedia.org/wiki/Graph_(abstract_data_type) — background for Lesson 3.
- Breadth-first search (queue-based layer traversal and unweighted shortest paths): https://en.wikipedia.org/wiki/Breadth-first_search — background for Lesson 4.
- Dijkstra, E. W. (1959), A note on two problems in connexion with graphs, via Wikipedia summary of Dijkstra's algorithm: https://en.wikipedia.org/wiki/Dijkstra%27s_algorithm — background for Lesson 5.

Known gaps and cautions

- **Unreviewed AI draft:** This unit has not yet been reviewed by a human high-school computer science educator or classroom-tested with Grade 10 students. (Peer-checked by Claude Haiku 5.5 on Lessons 2 and 5, and by Claude Fable 5.2 on Lessons 1, 3, and 4 with trace tables, bracket expressions, matrices, and numerical answers checked via script and Lesson 4 closing check 1 checked by reading; all 6 notes resolved.)
- **Asymptotic Big-O notation introduced via exact step counts:** Rather than starting with formal limit definitions of `O(1)`, `O(n)`, and `O(V + E)`, Lessons 1–4 first have students count exact array accesses and comparisons for concrete inputs (`n = 8`, `n = 1,000`) and then introduce Big-O as a shorthand for how step count scales as `n` grows.
- **Toy vs. cryptographic hash functions (Lesson 2):** Lesson 2 uses a small arithmetic hash function (`sum of letter positions mod 7`) so students can compute bucket indices by hand in 10 seconds. Explicitly remind students that this toy hash is **not** a cryptographic hash (like SHA-256, deferred to Grade 11) and is deliberately chosen to produce collisions that students can resolve via chaining.
- **Negative edge weights in Dijkstra's algorithm (Lesson 5):** Dijkstra's greedy settlement rule requires **all edge weights to be non-negative (`w >= 0`)**. Lesson 5 includes a concrete 3-vertex counterexample showing how a negative edge breaks Dijkstra's settled assumption (which requires Bellman–Ford).

Lesson 1: Who Goes Next? — Stacks (LIFO), Queues (FIFO), and Operation Cost

- **Unit:** Data Structures, Graph Algorithms, and Shortest Paths (Computing, Grade 10)
- **Time:** 50 minutes
- **Grouping:** Whole class and pairs

Learning objective

Students will trace `PUSH` / `POP` / `PEEK` operations on a **stack (LIFO)** and `ENQUEUE` / `DEQUEUE` operations on a **queue (FIFO)**, count the exact steps required for each operation, and use a stack to verify whether a string of nested brackets is balanced.

Materials

- 10 index cards per pair of students
- Whiteboard or projection of the operation trace tables below

Vocabulary

- **Data Structure:** A deliberate way of organizing data in memory so specific operations (inserting, removing, searching) are fast and predictable.
- **Stack (LIFO — Last-In, First-Out):** A linear collection where items are added (`PUSH`), removed (`POP`), and inspected without removal (`PEEK`) at the **same end** (the `top`).
- **Queue (FIFO — First-In, First-Out):** A linear collection where items are added (`ENQUEUE`) at the `back` (tail) and removed (`DEQUEUE`) from the `front` (head).
- **Constant Time (`O(1)`):** An operation whose step count stays the same whether the collection holds 5 items or 5,000,000 items.

Lesson flow

✎ 1. Opening: Two Ways to Handle a Pile of Tasks (8 min)

1. Contrast two everyday situations:
2. **Situation A (Cafeteria Tray Dispenser / Text Editor Undo):** You type `"cat"`, then `"dog"`, then `"bird"`. When you press `Ctrl+Z` (**Undo**), which word should disappear first? (`"bird"`—the **last** action entered must be the **first** action undone!)
3. **Situation B (Cafeteria Lunch Line / Network Router Packet Buffer):** Three packets `P1`, `P2`, `P3` arrive at a router (Grade 6 Computing) in that order. Which packet should leave the router first? (`P1`—the **first** packet in line must be the **first** packet sent!)
4. Introduce the names: **Situation A** is a **Stack (LIFO)**; **Situation B** is a **Queue (FIFO)**.

2. Direct instruction: Tracing Stack vs. Queue State Tables (15 min)

Walk through the exact same arrival sequence (`A`, then `B`, then `C`, followed by two removals, then `D`, then one removal) on both structures:

Step	Stack Command	Stack State (`bottom → top`)	Returned Value	Queue Command	Queue State (`front → back`)	Returned Value
1	`PUSH(A)`	`[A]`	—	`ENQUEUE(A)`	`[A]`	—
2	`PUSH(B)`	`[A, B]`	—	`ENQUEUE(B)`	`[A, B]`	—
3	`PUSH(C)`	`[A, B, C]`	—	`ENQUEUE(C)`	`[A, B, C]`	—
4	`POP()`	`[A, B]`	**`C`**	`DEQUEUE()`	`[B, C]`	**`A`**
5	`POP()`	`[A]`	**`B`**	`DEQUEUE()`	`[C]`	**`B`**
6	`PUSH(D)`	`[A, D]`	—	`ENQUEUE(D)`	`[C, D]`	—
7	`POP()`	`[A]`	**`D`**	`DEQUEUE()`	`[D]`	**`C`**

Highlight the output order: - The **Stack** popped **`C, B, D`** (always removing the newest item on top). - The **Queue** dequeued **`A, B, C`** (always removing the oldest item waiting at the front).

✎ 3. Main activity: Bracket-Matching Compiler Check with a Stack (17 min)

1. Explain how code editors and compilers check whether parentheses, square brackets, and curly braces—`()`, `[]`, `{}`—are properly nested:
2. **Algorithm:** Scan the string left to right:
    1. If you see an **opening bracket** (`(`, `[`, or `{`), **`PUSH`** it onto the stack.
    2. If you see a **closing bracket** (`)`, `]`, or `}`):
        - If the stack is **empty**, fail immediately (**Unmatched closing bracket**).
        - Otherwise, **`POP`** the top opening bracket and check if it matches the closing bracket's type. If not, fail (**Mismatched bracket type**).
    3. At the end of the string, if the stack is **empty**, return **`VALID`**; if any brackets remain on the stack, fail (**Unclosed opening bracket**).
3. Student pairs use their index cards as a physical stack to trace three expressions and record the exact step where invalid strings fail:
4. **Expression 1:** `{ [ ( ) ] ( ) }` → Stack ends empty → **`VALID`**.
5. **Expression 2:** `[ ( ] )` → Push `[`, Push `(`, next character is `]`, pop `(` → mismatch (`(` does not match `]`) at character 3 → **`INVALID`**.
6. **Expression 3:** `( [ { } ]` → Ends with `(` still on the stack → **`INVALID`** **(unclosed `()`**.

4. Discussion & Operation Cost Check (5 min)

- **Question:** "If an array holds *`1,000,000`* items in slots *`0`* through *`999,999`*, why is *`PUSH`* / *`POP`* at the **end** of the array (*`slot 999,999`*) a 1-step *`O(1)`* operation, whereas removing from *`slot 0`* and sliding all *`999,999`* remaining items one slot left takes *`999,999`* steps (*`O(n)`*)?"
- Example good answer: Adding or removing at the end only touches one slot (`top`), whereas shifting every item left touches every remaining element in the array. (To make a Queue `O(1)` for both `ENQUEUE` and `DEQUEUE`, languages use a circular buffer with a moving `front` index or a doubly linked list like Python's `collections.deque`.)

✓ 5. Closing check (5 min)

1. Start with an empty stack `S`. Execute: `PUSH(10)`, `PUSH(20)`, `POP()`, `PUSH(30)`, `PUSH(40)`, `POP()`. What value is returned by the second `POP()`, and what items remain in `S` from bottom to top?

2. Start with an empty queue `Q`. Execute: `ENQUEUE(10)`, `ENQUEUE(20)`, `DEQUEUE()`, `ENQUEUE(30)`, `ENQUEUE(40)`, `DEQUEUE()`. What value is returned by the second `DEQUEUE()`, and what items remain in `Q` from front to back?
3. Trace the bracket-matching algorithm on `( [ ) ]`. What is on the stack right before the first closing bracket `)` is read, and why does the check fail?

Worked answers for closing check

1. First `POP()` removes `20` (leaving `[10]`). Then `30` and `40` are pushed (`[10, 30, 40]`). The second `POP()` returns **`40`**, leaving **`[10, 30]`** (`10` at bottom, `30` at top).
2. First `DEQUEUE()` removes `10` (leaving `[20]`). Then `30` and `40` are enqueued (`[20, 30, 40]`). The second `DEQUEUE()` returns **`20`**, leaving **`[30, 40]`** (`30` at front, `40` at back).
3. Right before `)` is read, the stack holds **`[ '(', '[' ]`** (with `'['` on top). When `)` is read, `POP()` returns `'['`, which does not match `')'`, so the algorithm immediately reports a mismatch failure.

Differentiation

- **Extra support:** Have students write the index number (`1, 2, 3...`) on each card as it enters and physically stack cards vertically for a Stack vs. slide cards horizontally through a paper tunnel for a Queue.
- **Extra challenge:** Show how a browser's **Back** and **Forward** buttons use **two stacks** (`back_stack` and `forward_stack`): clicking **Back** pops the current page from `back_stack` and pushes it onto `forward_stack`, while visiting a brand-new link clears `forward_stack`.

Teacher notes

- **Common misconception:** Students sometimes think a stack "sorts" items by size. Emphasize that stacks and queues care **only about arrival time**, never about whether `10` is smaller or larger than `40`.

Lesson 2: Finding Needles Without Scanning the Haystack — Hash Tables and Collisions

- **Unit:** Data Structures, Graph Algorithms, and Shortest Paths (Computing, Grade 10)
- **Time:** 50 minutes
- **Grouping:** Whole class and pairs

Learning objective

Students will compute array bucket indices using a deterministic **hash function** (`h(k) mod M`), build a 7-bucket **hash table** with **separate chaining** to resolve collisions, and compare the number of comparisons needed for an unsorted list scan vs. a hash table lookup.

Materials

- Printed or whiteboard 7-bucket hash table grid (`Buckets 0 through 6`)
- Alphabet position strip (`A=1, B=2, C=3, ..., Z=26`) for quick arithmetic hashing by hand

Vocabulary

- **Key–Value Pair:** A unique identifier (**key**, such as a student ID or word) stored alongside its associated data (**value**, such as a grade or definition).
- **Hash Function (`h(k)`):** A deterministic math rule that converts any key `k` into an integer bucket index `0, 1, ..., M - 1`.
- **Collision:** When two different keys (`k1 != k2`) produce the **exact same bucket index** (`h(k1) == h(k2)`).
- **Separate Chaining:** Storing a short linked list (chain) of key–value pairs inside each bucket so colliding keys can share a bucket without overwriting each other.
- **Load Factor (`α = n / M`):** The ratio of stored items (`n`) to total buckets (`M`), connecting directly to Grade 6 Mathematics: Ratios.

Lesson flow

✎ 1. Opening: Why Not Just Scan a List? (8 min)

1. Suppose a school library database stores `n = 70,000` book barcodes in an unsorted list.
2. To check if barcode `B-94821` is checked out, a **linear scan** checks item 1, item 2, item 3... taking `35,000` comparisons on average and `70,000` comparisons in the worst case (`O(n)`).
3. Ask: "What if, instead of searching every shelf, we had a math formula that looked at the letters of a key and told us the exact shelf number in 1 step?"
4. That is a **Hash Table** (called a `dict` in Python or `Map` in JavaScript).

2. Direct instruction: Computing a Toy Hash Function & Modulo Indexing (15 min)

1. Define a simple, hand-computable hash rule for a table with `M = 7` **buckets** numbered `0` through `6`:
2. **Step A:** Add the alphabet positions (`A=1, B=2, ..., Z=26`) of the letters in the key (`sum`).
3. **Step B:** Divide `sum` by `7` and take the **remainder**: `bucket = sum mod 7` (the remainder is always `0, 1, 2, 3, 4, 5, or 6`!).
4. Work through 6 animal keys together on the board:

Key	Letter Values	sum	Division by 7	bucket = sum mod 7
"CAT"	3 + 1 + 20	24	24 = 3 × 7 + 3	**Bucket 3**
"DOG"	4 + 15 + 7	26	26 = 3 × 7 + 5	**Bucket 5**
"ANT"	1 + 14 + 20	35	35 = 5 × 7 + 0	**Bucket 0**
"OWL"	15 + 23 + 12	50	50 = 7 × 7 + 1	**Bucket 1**
"BEE"	2 + 5 + 5	12	12 = 1 × 7 + 5	**Bucket 5 (COLLISION with "DOG"!)**
"FOX"	6 + 15 + 24	45	45 = 6 × 7 + 3	**Bucket 3 (COLLISION with "CAT"!)**

1. Show why **Separate Chaining** is essential:
2. When `"BEE"` lands in **Bucket `5`**, we must **not** erase `"DOG"`. Instead, Bucket `5` holds a short chain: `Bucket 5 → [ ("DOG", val), ("BEE", val) ]`.
3. When looking up `"BEE"`, the computer computes `12 mod 7 = 5`, jumps straight to Bucket `5`, checks `"DOG"` (not a match), and finds `"BEE"` on the 2nd comparison—still only **2 comparisons** instead of scanning all 6 items!

✎ 3. Main activity: Pair Hash-Table Build & Worst-Case Adversarial Attack (17 min)

1. **Part A — Insert 3 More Keys (10 min):** Student pairs draw the 7-bucket table (`0..6`) with the 6 animals above already placed, then compute and insert three more keys:
2. `"ELK"` (`5 + 12 + 11 = 28`; `28 mod 7 = 0` → chains after `"ANT"` in **Bucket `0`**)
3. `"HEN"` (`8 + 5 + 14 = 27`; `27 mod 7 = 6` → lands in empty **Bucket `6`**)
4. `"COD"` (`3 + 15 + 4 = 22`; `22 mod 7 = 1` → chains after `"OWL"` in **Bucket `1`**)
5. **Part B — Count Comparisons & Load Factor (7 min):**
6. Total items `n = 9`, total buckets `M = 7` → **Load factor `α = 9 / 7 ≈ 1.29` items per bucket**.
7. What is the maximum number of key comparisons needed to find any of the 9 animals in our hash table? (Only **2 comparisons**, because the longest chain has length 2!)
8. **Adversarial thought experiment:** Why doesn't our hash function only check the first letter of a word? (Because in an English dictionary, thousands of words start with `'S'`, piling into one giant chain while `'X'` is nearly empty!)

✓ 4. Discussion questions (5 min)

- **Question 1:** "Why must a hash function be 100% deterministic (never using a random number generator each time you look up a key)?"

- Example good answer: If `h("CAT")` returned Bucket `3` when inserting and a random Bucket `6` when looking it up later, you would look in the wrong bucket and never find `"CAT"` again!
- **Question 2:** "What happens to lookup speed if we put $n = 7{,}000$ items into only $M = 7$ buckets ($\alpha = 1{,}000$)? How do real hash tables prevent that?"
- Example good answer: Each bucket chain would average `1,000` items long, slowing lookups back down to linear scans. Real hash tables **resize (rehash)**—doubling `M` whenever the load factor `α = n / M` passes a threshold like `0.75`.

✓ 5. Closing check (5 min)

Using the same rule (`letter sum mod 7`, with `A=1 ... Z=26`):

1. Compute the letter sum and bucket index (`0..6`) for the key **`"BAT"`** (`B=2, A=1, T=20`).
2. Does **`"BAT"`** collide with any key in our 9-animal table from the lesson? If so, which bucket does it join, and which keys are already in that bucket?
3. A hash table has `M = 50` buckets and currently stores `n = 35` keys. What is its **load factor** **`α`**, and why is a low load factor desirable?

Worked answers for closing check

1. `B(2) + A(1) + T(20) = 23`. Dividing by 7 gives $23 = 3 \times 7 + 2$, so `23 mod 7 = 2` (**Bucket 2**).
2. **No collision!** In our 9-animal table, Buckets `0, 1, 3, 5, 6` had items, while **Bucket 2** and **Bucket 4** were empty. So `"BAT"` is the first item in Bucket `2`.
3. **Load factor `α = 35 / 50 = 0.70`**. A low load factor means most buckets have 0 or 1 item, keeping lookups close to 1 comparison (`O(1)`).

Differentiation

- **Extra support:** Provide a printed multiplication table for `7` (`0, 7, 14, 21, 28, 35, 42, 49, 56, 63, 70`) so students can find `sum mod 7` immediately by subtracting the largest multiple of `7` at or below `sum`.
- **Extra challenge:** Have students find an **anagram collision** (such as `"ACT"`, `"CAT"`, and `"TAC"`): why do all anagrams collide under an addition-only hash function, and how does multiplying each letter by a position weight (`1×L1 + 31×L2 + 31²×L3`) break anagram collisions?

Teacher notes

- **Common misconception:** Students often assume a hash collision means the hash table "failed" or overwrote the earlier key. Emphasize that collisions are normal and expected (by the Pigeonhole Principle / Birthday Paradox), and that separate chaining stores both keys safely in the same bucket list.

Lesson 3: Modeling Networks — Graphs, Adjacency Lists, and Adjacency Matrices

- **Unit:** Data Structures, Graph Algorithms, and Shortest Paths (Computing, Grade 10)
- **Time:** 50 minutes
- **Grouping:** Whole class and pairs

Learning objective

Students will model real-world systems as **graphs** `G = (V, E)` (choosing directed vs. undirected and weighted vs. unweighted edges), convert a graph between its **adjacency matrix** and **adjacency list** representations, and compare their memory and lookup trade-offs.

Materials

- Grid paper or printed worksheets for drawing a 5×5 adjacency matrix and adjacency list

Vocabulary

- **Graph (`G = (V, E)`):** A mathematical structure made of a set of **vertices** (nodes, `V`) and a set of **edges** (connections, `E`) linking pairs of vertices.
- **Directed vs. Undirected Edge:** An **undirected** edge `{u, v}` is a two-way connection (`u ↔ v`); a **directed** edge `(u → v)` is a one-way arrow from `u` to `v`.
- **Degree of a Vertex:** The number of edges connected to that vertex (in a directed graph, split into **in-degree** and **out-degree**).
- **Adjacency Matrix:** A `|V| × |V|` grid where row `u`, column `v` stores `1` (or edge weight `w`) if edge `(u, v)` exists, and `0` otherwise.
- **Adjacency List:** A dictionary/array where each vertex `u` stores a list of only its direct neighbors.

Lesson flow

✎ 1. Opening: Four Different Worlds, One Same Shape (8 min)

1. Put four scenarios on the board and ask what they have in common:
2. **Packet routers** connected by fiber-optic cables (Grade 6 Computing)
3. **Meadow habitat patches** connected by wildlife movement corridors (Grade 10 Science: Ecology Field Sampling)
4. **Web pages** connected by clickable hyperlinks (Grade 8 Society: Information Literacy)
5. **Cities** connected by rail lines
6. In every case, we have **nodes (vertices)** and **connections (edges)**. Once we represent any of these as a **graph**, the exact same algorithms can analyze all four!
7. Ask: "Which of those four has **one-way (directed)** edges by default?"
8. **Web hyperlinks!** Page `A` can link to Page `B` (`A → B`) without Page `B` linking back to Page `A`.

2. Direct instruction: Adjacency Matrix vs. Adjacency List (15 min)

Consider this 5-vertex **undirected** regional network with vertices `V = {A, B, C, D, E}` and 6 edges: `E = { {A,B}, {A,C}, {B,C}, {B,D}, {C,D}, {D,E} }`:

```
   A --- B
   |   / |
   |  /  |
   C --- D --- E
```

Build both computer representations side by side:

Representation 1: 5×5 Adjacency Matrix (`|V|² = 25` cells)

From \ To	A	B	C	D	E	Row Sum (Degree)
A	0	1	1	0	0	2
B	1	0	1	1	0	3
C	1	1	0	1	0	3
D	0	1	1	0	1	3
E	0	0	0	1	0	1

- Notice that for an **undirected** graph, the matrix is **symmetric across the main diagonal** (`matrix[u][v] == matrix[v][u]`), and the sum of all `1`s in the matrix (`12`) equals `2 × |E|` (the Handshaking Lemma: every undirected edge adds `1` to the degree of both its endpoints!).

Representation 2: Adjacency List (`|V| + 2|E|` entries)

```
graph = {
    "A": ["B", "C"],
    "B": ["A", "C", "D"],
    "C": ["A", "B", "D"],
    "D": ["B", "C", "E"],
    "E": ["D"]
}
```

✎ 3. Main activity: Sparse vs. Dense Trade-Off Analysis & Directed Conversion (17 min)

1. **Part A — Directed Graph Practice (9 min):** Pairs are given a 4-page mini-web of directed hyperlinks:
2. Page `1` links to `2` and `3` (`1 → 2`, `1 → 3`)
3. Page `2` links to `3` (`2 → 3`)
4. Page `3` links to `1` and `4` (`3 → 1`, `3 → 4`)
5. Page `4` links to `2` (`4 → 2`) Students write:
6. The 4×4 **directed adjacency matrix** (and verify it is **not** symmetric: `matrix[1][2] = 1`, `matrix[2][1] = 0`).
7. The **in-degree** (column sum = incoming links) and **out-degree** (row sum = outgoing links) of every page.
8. **Part B — Memory Calculation for a Real Road Map (8 min):**
9. Suppose a country road map has `|V| = 100,000` intersections, and each intersection meets an average of `4` roads (`200,000` undirected edges).

10. **Adjacency Matrix size:** `100,000 × 100,000 = 10,000,000,000` (`10 billion` cells—over `99.996%` of them filled with `0`s!).
11. **Adjacency List size:** `100,000` vertex buckets holding `2|E| = 400,000` neighbor entries (`25,000×` fewer neighbor entries than the matrix, or `|V| + 2|E| = 500,000` total entries including the vertex headers—`20,000×` smaller overall!).

✓ 4. Discussion questions (5 min)

- **Question 1:** "When is an Adjacency Matrix actually better than an Adjacency List?"
- Example good answer: When the graph is small or **dense** (nearly every vertex connects to every other vertex), or when you frequently need to check "Does edge *(u, v)* exist?" in a single array lookup `matrix[u][v]` (`O(1)`).
- **Question 2:** "Why is the sum of the degrees of all vertices in any undirected graph always an **even number**?"
- Example good answer: Because every single edge connects two endpoints, adding `+2` to the total degree sum (`Sum of degrees = 2 × |E|`).

✓ 5. Closing check (5 min)

1. An undirected graph has `|V| = 6` vertices and `|E| = 8` edges. How many total cells are in its **adjacency matrix**, how many of those cells contain a `1`, and how many contain a `0`?
2. Look at this adjacency list for a **directed** graph:
3. `X: [Y, Z]`
4. `Y: [Z]`
5. `Z: []` What are the **out-degree** and **in-degree** of vertex `Z`?
6. Would you use an **adjacency matrix** or an **adjacency list** to store a social network with `1,000,000` users where the average user has `150` connections? Explain why using numbers.

Worked answers for closing check

1. A `6 × 6` adjacency matrix has **`36` total cells**. Since each of the `8` undirected edges places two `1`s in the matrix (`matrix[u][v]` and `matrix[v][u]`), **`16` cells contain `1`** and `36 − 16 =` **`20` cells contain `0`**.
2. Vertex `Z` has **out-degree `0`** (its outgoing list `Z: []` is empty) and **in-degree `2`** (both `X` and `Y` point to `Z`).
3. An **adjacency list**, because it stores only `1,000,000 × 150 = 150,000,000` connection entries (`~1.5 × 10⁸`), whereas an adjacency matrix would require `1,000,000 × 1,000,000 = 1,000,000,000,000` (`10¹²`, one trillion) cells—nearly all zeros.

Differentiation

- **Extra support:** Have students color-code each undirected edge `{u, v}` with a matching pair of highlighters in the matrix (`row u, col v` and `row v, col u`) so the diagonal symmetry and the `2 × |E|` count become visually immediate.

- **Extra challenge:** Ask students how the adjacency matrix and adjacency list change if we allow **self-loops** (an edge from a vertex to itself, like a web page linking to itself) and **parallel edges** (two separate roads between the same two towns).

Teacher notes

- **Common misconception:** When reading a directed adjacency matrix, students frequently swap row (`from`) and column (`to`). Keep the header label **`From (Row) \ To (Column)`** visible on the board so out-degree is always the row sum and in-degree is always the column sum.

Lesson 4: Expanding Ripples — Breadth-First Search (BFS) and Fewest-Hop Routing

- **Unit:** Data Structures, Graph Algorithms, and Shortest Paths (Computing, Grade 10)
- **Time:** 50 minutes
- **Grouping:** Whole class and pairs

Learning objective

Students will execute **Breadth-First Search (BFS)** step by step on an unweighted graph using a FIFO **queue**, a `visited` set, a `dist` (hop count) table, and `parent` pointers to reconstruct the shortest unweighted path between two vertices.

Materials

- Printed 6-vertex network diagram (below) and index cards to serve as the FIFO queue

Vocabulary

- **Breadth-First Search (BFS):** A graph traversal algorithm that explores all neighbors at distance `1` hop from the start vertex before exploring vertices at distance `2` hops, `3` hops, and so on.
- **Visited Set:** A record of vertices already discovered (enqueued) so the algorithm never gets trapped in an infinite loop around a cycle.
- **Parent (Predecessor) Pointer:** For each discovered vertex `v`, the vertex `u` that first discovered `v` (`parent[v] = u`), allowing us to trace the shortest path backward from the goal to the start.

Lesson flow

✎ 1. Opening: Dropping a Stone in a Pond (7 min)

1. Consider this 6-router network (`A` through `F`) where every link takes 1 hop: `A --- B --- E | | | C --- D --- F` Edges (alphabetical neighbor order):
2. `A: [B, C]`
3. `B: [A, D, E]`
4. `C: [A, D]`
5. `D: [B, C, F]`
6. `E: [B, F]`
7. `F: [D, E]`
8. Ask: "If router *A* wants to send a packet to router *F* in the **fewest hops**, why can't a computer just wander down the first road it sees (*A → C → D → B → E → F*, 5 hops)?"
9. Explain the ripple idea: If we explore in expanding rings—**Ring 0** (`A`), **Ring 1** (all 1-hop neighbors of `A`), **Ring 2** (all 2-hop neighbors), **Ring 3** (all 3-hop neighbors)—then the very **first time** a ring touches `F`, we are guaranteed to have found a path with the minimum possible number of hops!

10. Ask: "Which data structure from Lesson 1 processes items in exact First-In, First-Out order so Ring 1 finishes before Ring 2?" → **A Queue (FIFO)!**

2. Direct instruction: Complete Step-by-Step BFS Trace from `A` to `F` (16 min)

Show the exact BFS algorithm and trace table (breaking neighbor ties alphabetically):

```
from collections import deque

def bfs_shortest_path(graph, start, goal):
    queue = deque([start])
    visited = {start}
    dist = {start: 0}
    parent = {start: None}

    while queue:
        u = queue.popleft()          # DEQUEUE front vertex
        if u == goal:
            break
        for v in graph[u]:           # Inspect each neighbor of u
            if v not in visited:
                visited.add(v)       # Mark visited IMMEDIATELY upon enqueue!
                dist[v] = dist[u] + 1
                parent[v] = u
                queue.append(v)      # ENQUEUE v at back
    return dist, parent
```

Trace every iteration on the board:

Step	Dequeued `u`	Unvisited Neighbors Enqueued	Queue (`front → back`)	`visited` Set	Newly Recorded `dist[v]` & `parent[v]`
Init	—	Start at `A`	`[A]`	`{A}`	`dist[A]=0`, `parent[A]=None`
1	**`A`**	`B`, `C`	`[B, C]`	`{A, B, C}`	`dist[B]=1 (p=A)`, `dist[C]=1 (p=A)`
2	**`B`**	`D`, `E` (`A` already in `visited`)	`[C, D, E]`	`{A, B, C, D, E}`	`dist[D]=2 (p=B)`, `dist[E]=2 (p=B)`
3	**`C`**	(none: *`A`* & *`D`* already in *`visited`*!)	`[D, E]`	`{A, B, C, D, E}`	—
4	**`D`**	`F` (`B` & `C` already in `visited`)	`[E, F]`	`{A, B, C, D, E, F}`	`dist[F]=3 (p=D)`
5	**`E`**	(none: *`B`* & *`F`* already in *`visited`*)	`[F]`	`{A, B, C, D, E, F}`	—
6	**`F`**	Goal reached!	`[]`	`{A, B, C, D, E, F}`	Stop

Reconstructing the path via `parent` pointers: Start at `F`: `parent[F] = D` → `parent[D] = B` → `parent[B] = A` → `parent[A] = None`. Reverse it: **`A → B → D → F`** (`3` hops!). (Note: `A → B → E → F` and `A → C → D → F` are also tied at `3` hops; alphabetical tie-breaking discovered `D` via `B` first, and `F` via `D` first.)

> **Critical bug to highlight:** Look at Step 2 and Step 3. Why did we mark `D` as `visited` the moment `B` **enqueued** `D` in Step 2, instead of waiting until `D` was dequeued in Step

4? Because in Step 3 (`u = C`), `C` also has an edge to `D`! If `D` were not already in `visited`, `C` would enqueue a duplicate copy of `D` into the queue. Always mark vertices `visited` **at enqueue time**.

✎ 3. Main activity: Pair BFS Trace on a 7-Node Campus Graph (17 min)

Student pairs trace BFS starting from `S` to find the hop distance and `parent` tree to all vertices on this 7-vertex graph (alphabetical tie-breaking): - `S: [A, B]` - `A: [S, C, D]` - `B: [S, D]` - `C: [A, G]` - `D: [A, B, E, G]` - `E: [D]` - `G: [C, D]`

Pairs fill in the complete `dist` and `parent` table and verify: - Layer 0: `S` (`dist=0`) - Layer 1: `A` (`dist=1, p=S`), `B` (`dist=1, p=S`) - Layer 2: `C` (`dist=2, p=A`), `D` (`dist=2, p=A`) - Layer 3: `G` (`dist=3, p=C`), `E` (`dist=3, p=D`) - Shortest path from `S` to `G`: **`S → A → C → G`** (3 hops).

✓ 4. Discussion questions (5 min)

- **Question 1:** "What happens to our algorithm if we replace the FIFO **Queue** (*`popleft()`*) with a LIFO **Stack** (*`pop()`*)?"
- Example good answer: It explores in a **depth-first** style instead of expanding in layer rings (`1 hop, 2 hops, 3 hops`), plunging deep down one branch before backtracking. Because it does not finish Layer 1 and Layer 2 before exploring deeper nodes, the first path it records is **not** guaranteed to be the shortest path (for example, on our 7-node campus graph, popping from the end visits `S, B, D, G, C` and records a `4`-hop path `S → B → D → G → C` to `C` instead of the `2`-hop shortest path `S → A → C`; on the 6-router network from `A`, it records a `4`-hop path `A → C → D → F → E` to `E` instead of `2` hops `A → B → E`).
- **Question 2:** "How many times does BFS enqueue each vertex and inspect each edge in a connected graph *`G = (V, E)`*?"
- Example good answer: Each vertex enters the queue at most **once** (`|V|` dequeues), and each edge is inspected at most **twice** (once from each endpoint), giving a linear time cost of **`O(|V| + |E|)`**.

✓ 5. Closing check (5 min)

1. In the 7-vertex campus graph (`S → A, B` above), both `A` and `B` have an edge to `D`. Why did `parent[D]` get set to `A` instead of `B`?
2. What would happen if you ran BFS on a graph containing a triangle cycle `A – B – C – A` **without** keeping a `visited` set?
3. After running BFS from `Start = M`, your `parent` table records: `parent[M] = None`, `parent[P] = M`, `parent[Q] = P`, `parent[R] = P`, `parent[T] = R`. What is the shortest path from `M` to `T`, and how many hops long is it?

Worked answers for closing check

1. Because `A` was enqueued before `B` (alphabetical order) and therefore dequeued first. When `A`'s neighbors were scanned, `D` was unvisited, so `D` was marked visited with `parent[D] = A`. When `B` was dequeued next, `D` was already in `visited`.
2. Without a `visited` set, vertices are enqueued repeatedly around the cycle (`A` enqueues `B, C`; `B` enqueues `A, C`; `C` enqueues `A, B`, and so on). If the code stops at a reachable `goal` (such as

`goal = C` from `A`), it still halts once `C` is dequeued (after 3 dequeues), but leaves duplicate entries in the queue and wastes exponential work on larger graphs; if we are exploring the whole graph (or the `goal` is unreachable), the queue grows forever and the algorithm **never terminates**.

3. Tracing backward from `T`: `T ← R ← P ← M`. Reversing gives **`M → P → R → T`**, which is **`3` hops** long.

Differentiation

- **Extra support:** Give pairs physical tokens or sticky notes labeled `"VISITED"` to place directly on each vertex the moment its card enters the queue, reinforcing that marking happens at **enqueue** time rather than dequeue time.
- **Extra challenge:** Have students trace true recursive or late-marked **Depth-First Search (DFS)** (where a vertex is marked visited when popped rather than when pushed) alongside our enqueue-marked stack variant on the 7-vertex campus graph and compare the two visitation orders.

Teacher notes

- **Common misconception:** Students often forget to reverse the `parent` pointer chain at the end (`F → D → B → A` vs. `A → B → D → F`). Remind them that `parent[v]` points **backward** toward the start vertex, just like breadcrumbs leading back home.

Lesson 5: Weighted Routes — Dijkstra's Shortest-Path Algorithm

- **Unit:** Data Structures, Graph Algorithms, and Shortest Paths (Computing, Grade 10)
- **Time:** 50 minutes
- **Grouping:** Whole class and pairs

Learning objective

Students will explain why fewest hops (BFS) can fail on a **weighted graph**, execute **Dijkstra's shortest-path algorithm** step by step using a tentative distance table (`dist[]`, `prev[]`, `settled`), and explain why negative edge weights violate Dijkstra's greedy settlement rule.

Materials

- Printed weighted graph trace sheets (diagrams below) and pencils

Vocabulary

- **Weighted Graph:** A graph where each edge `(u, v)` has a numerical **weight (cost)** `w(u, v)` representing distance, travel time, cable cost, or network latency.
- **Tentative Distance (`dist[v]`):** The shortest known total cost from the start vertex to `v` found so far (initialized to `0` for `start` and `∞` for all other vertices).
- **Edge Relaxation:** Checking whether going from `start` through `u` to neighbor `v` (`dist[u] + w(u, v)`) beats the current best known cost `dist[v]`; if `dist[u] + w(u, v) < dist[v]`, we update `dist[v]` and set `prev[v] = u`.
- **Settled (Finalized) Vertex:** A vertex whose minimum distance from `start` is permanently locked in.

Lesson flow

✎ 1. Opening: When Fewest Hops Is the Slowest Route (7 min)

1. Draw a 3-node triangle on the board representing travel times in minutes between `A`, `B`, and `C`:
2. Direct highway edge `A — C` has weight **`10` minutes** (congested construction zone, `1` hop).
3. Local road `A — B` has weight **`2` minutes**, and `B — C` has weight **`3` minutes** (`2` hops total).
4. Ask:
5. "Which route from *`A`* to *`C`* does **BFS (Lesson 4)** pick?" → `A → C` (`1` hop, **10 minutes**), because BFS ignores edge weights and only counts hops!
6. "Which route is actually faster?" → `A → B → C` (`2 + 3 =` **5 minutes**!).
7. Introduce Edsger W. Dijkstra's 1959 insight: When all edge weights are **non-negative (`w >= 0`)**, if we always pick the **unsettled vertex `u` with the smallest tentative `dist[u]`**, no detour through any other unsettled vertex can ever make `dist[u]` smaller!

2. Direct instruction: Complete Step-by-Step Trace of Dijkstra's Algorithm (16 min)

Consider this 5-vertex weighted network (weights in milliseconds of network latency): - `A – B` (weight `4`), `A – C` (weight `1`) - `C – B` (weight `2`), `C – D` (weight `5`) - `B – D` (weight `1`), `B – E` (weight `7`) - `D – E` (weight `3`)

```
       (4)       (7)
   A ------- B ------- E
   |       / |       /
(1)|  (2)/   |(1)   /(3)
   |   /     |     /
   C ------- D ---/
       (5)
```

Dijkstra's Algorithm Rules: 1. Set `dist[A] = 0` and `dist[v] = ∞` for all other vertices. Set `settled = {}`. 2. While unsettled vertices remain: - **Pick `u`:** Choose the **unsettled** vertex with the **minimum `dist[u]`** and mark `u` as **settled**. - **Relax edges out of `u`:** For each unsettled neighbor `v` of `u`, compute `new_cost = dist[u] + w(u, v)`. If `new_cost < dist[v]`, update `dist[v] = new_cost` and `prev[v] = u`.

Trace every iteration on the board:

Round	Settled `u` (`dist[u]`)	Edge Relaxations Tested from `u`	`dist[A]`	`dist[B]` (prev)	`dist[C]` (prev)	`dist[D]` (prev)	`dist[E]` (prev)	Settled Set
Init	—	—	`0`	`∞`	`∞`	`∞`	`∞`	`{}`
1	**`A` (0)**	`A→B: 0+4=4 < ∞ ✓` `A→C: 0+1=1 < ∞ ✓`	**`0`**	`4 (A)`	`1 (A)`	`∞`	`∞`	`{A}`
2	**`C` (1)**	`C→B: 1+2=3 < 4 ✓` **(improved!)** `C→D: 1+5=6 < ∞ ✓`	`0`	**`3 (C)`**	**`1 (A)`**	`6 (C)`	`∞`	`{A, C}`
3	**`B` (3)**	`B→D: 3+1=4 < 6 ✓` **(improved!)** `B→E: 3+7=10 < ∞ ✓`	`0`	`3 (C)`	`1 (A)`	**`4 (B)`**	`10 (B)`	`{A, C, B}`
4	**`D` (4)**	`D→E: 4+3=7 < 10 ✓` **(improved!)**	`0`	`3 (C)`	`1 (A)`	`4 (B)`	**`7 (D)`**	`{A, C, B, D}`
5	**`E` (7)**	(all neighbors settled)	`0`	`3 (C)`	`1 (A)`	`4 (B)`	**`7 (D)`**	`{A, C, B, D, E}`

Reconstruct the minimum-weight path from `A` to `E`: Follow `prev` backward from `E`: `E ← D ← B ← C ← A`. Reverse it: **`A → C → B → D → E`** with total cost `1 + 2 + 1 + 3 = 7 ms`! Notice that `A → B → E` (2 hops) costs `4 + 7 = 11 ms`, and `A → C → D → E` (3 hops) costs `1 + 5 + 3 = 9 ms`, while the **4-hop path `A → C → B → D → E` costs only `7 ms`**!

✎ 3. Main activity: Pair Dijkstra Trace & The Negative-Weight Counterexample (17 min)

1. **Part A — Pair Dijkstra Trace (12 min):** Pairs trace Dijkstra's algorithm from `S` to `T` on this 5-vertex graph:
2. `S – A` (6), `S – B` (2)

3. `B – A (3)`, `B – C (8)`
4. `A – C (1)`, `A – T (9)`
5. `C – T (4)` Students fill out the 5-round table and verify:
6. Round 1 settles `S (0)` → `dist[A]=6 (S)`, `dist[B]=2 (S)`
7. Round 2 settles `B (2)` → `B→A` relaxes `dist[A]` from `6` down to `2+3 = 5 (B)`; `B→C` sets `dist[C] = 2+8 = 10 (B)`
8. Round 3 settles `A (5)` → `A→C` relaxes `dist[C]` from `10` down to `5+1 = 6 (A)`; `A→T` sets `dist[T] = 5+9 = 14 (A)`
9. Round 4 settles `C (6)` → `C→T` relaxes `dist[T]` from `14` down to `6+4 = 10 (C)`
10. Round 5 settles `T (10)` → Shortest path is **`S → B → A → C → T`** with cost **`10`**.
11. **Part B — Why Negative Edges Break Dijkstra (5 min):** Draw a 3-vertex directed graph:
12. `X → Y` has weight `5`
13. `X → Z` has weight `2`
14. `Y → Z` has weight **`-6`** (a negative edge!)
15. Trace what Dijkstra does from `X`:
    - Round 1 settles `X (0)` → `dist[Z] = 2`, `dist[Y] = 5`.
    - Round 2 greedily settles **`Z (2)`** because `2 < 5`!
    - But going `X → Y → Z` actually costs `5 + (-6) = -1 < 2`! Because `w(Y, Z) = -6` was negative, Dijkstra's assumption that "adding more edges can never reduce cost" failed.

✓ 4. Discussion questions (5 min)

- **Question 1:** "What happens when you run Dijkstra's algorithm on a graph where every single edge has weight *`w = 1`*?"
- Example good answer: It behaves identically to **Breadth-First Search (BFS)**! BFS is simply the special case of Dijkstra's algorithm when all edge weights are equal to `1`.
- **Question 2:** "In our Lesson 5 network (*`A → C → B → D → E`*), *`dist[B]`* was first set to *`4`* in Round 1, and then lowered to *`3`* in Round 2. Why was it legal to change *`dist[B]`* in Round 2?"
- Example good answer: Because `B` was still **unsettled** in Round 2! A vertex's distance is only tentative until that vertex itself is chosen as the minimum unsettled vertex `u`.

✓ 5. End-of-unit synthesis & Closing check (5 min)

1. In the Part A trace (`S, A, B, C, T`), why did Dijkstra settle vertex `B` (`dist = 2`) before vertex `A` (`dist = 6`) in Round 2?
2. Give a concrete 3-vertex example (`P, Q, R` with positive edge weights) where the **1-hop path `P → R`** is longer than the **2-hop path `P → Q → R`**.
3. Which data structure or algorithm from this 5-lesson unit (`Stack`, `Queue`, `Hash Table`, `BFS`, or `Dijkstra`) should an engineer choose for each task below?
4. **(a)** Looking up a user's profile by their unique username `"alex_42"` in `O(1)` average time.
5. **(b)** Finding the fastest driving route across a highway network where each road segment is labeled with its travel time in minutes.
6. **(c)** Implementing the `Undo` button in a drawing program.

7. **(d)** Finding the minimum number of friend-of-a-friend introductions connecting two people in an unweighted social graph.

Worked answers for closing check

1. Because at the start of Round 2, the unsettled vertices had tentative distances `dist[B] = 2`, `dist[A] = 6`, `dist[C] = ∞`, and `dist[T] = ∞`. Dijkstra always selects the unsettled vertex with the **smallest tentative distance** (`2 < 6`).
2. Any triangle where `w(P, Q) + w(Q, R) < w(P, R)`, such as `w(P, R) = 15`, `w(P, Q) = 4`, and `w(Q, R) = 5` (`4 + 5 = 9 < 15`).
3. **(a) Hash Table**; **(b) Dijkstra's Algorithm**; **(c) Stack (LIFO)**; **(d) Breadth-First Search (BFS)** (using a FIFO **Queue**).

Differentiation

- **Extra support:** Have students cross out settled vertices with a check mark (✓) in the table header at the end of each round so they only compare tentative distances among the remaining unsettled columns.
- **Extra challenge:** Ask students how A (A-Star) Search* speeds up Dijkstra's algorithm on a physical map by adding an admissible heuristic estimate `h(v)` (such as straight-line Euclidean distance to the goal) to the priority key `dist[v] + h(v)`.

Teacher notes

- **Common misconception:** Students sometimes try to add the new edge weight `w(u, v)` to the old `dist[v]` instead of computing `dist[u] + w(u, v)`. Write the relaxation question on the board in words: "Is going through *u* (*`dist[u] + edge`*) shorter than the best route to *v* we knew so far (*`dist[v]`*)?"