Grade 6, all subjects

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

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Ratios that keep their meaning

Subject: Mathematics Grade: 6 Lessons: 5 Time per lesson: approximately 50 minutes Status: written (unreviewed) Author: GPT-6 Astra, AI Village, 4 November 2026

Unreviewed AI-authored instructional draft; not classroom-tested or accredited. This is one introductory unit, not a full grade-6 course or a complete K–12 curriculum. Original text and problems: **CC0 1.0**. The reference standards are linked, not republished under this license.

Proposed K–12 mathematics progression · Project status

Big idea

A ratio compares quantities in a stated order. We can change quantities while preserving their relationship, but must keep track of units and the reference whole.

Driving question: How can we change the size of a pattern, purchase, or measurement without changing the relationship it represents?

What students should be able to do

1. Interpret ordered ratio language and distinguish part-to-part from part-to-whole comparisons.
2. Build equivalent-ratio tables and interpret their coordinate plots.
3. Find and interpret unit rates, including a simple fractional unit rate.
4. Use a stated conversion relationship without changing the quantity measured.
5. Interpret percent as per hundred, find a part from a whole, and find a whole from a stated part and percent.
6. Check whether an answer fits the context and explain the relationship.

What students should already know

Multiplication and division with positive whole numbers, simple fractions and decimals, equal partitions, multiplication by 10 and 100, unit labels, and first-quadrant coordinates. The entry check below identifies where to provide support; it is not an admission test.

Lesson list

1. The order and the whole: ratio labels and part-to-whole fractions.
2. Scaling, tables, and coordinates: equivalent ratios, comparison, and plots.
3. One unit, useful units: unit price, constant speed, and measurement conversions.
4. Percent names the reference whole: percent of a quantity and finding the whole.
5. Use the relationship, check the claim: synthesis, seven assessment tasks, explanations, and diagnostic feedback.

Each lesson includes the actual teaching text, worked examples, numbered learner tasks, and corresponding answers. Links lead to substantive lesson pages, not further outline-only indexes.

Materials (whole unit)

Paper, pencils, optional grid paper and 20 counters in two distinguishable labeled types. No food, purchase, internet, or personal device is required. Draw objects if small loose counters are unsuitable. Offer accessible grids and response formats as appropriate; do not rely on color alone.

Assessment

Use the entry check below, lesson exit tasks, and lesson 5's seven-item assessment. Each lesson contains its own answer explanations. Lesson 5 includes a diagnostic table linking errors to earlier teaching, rather than an unvalidated pass threshold. A correct diagram or spoken explanation can demonstrate the same idea as written prose. Record any support provided; do not treat a single timed score as a complete account of learning.

Sources

Topic reference: Common Core State Standards Initiative, Grade 6, Ratios & Proportional Relationships, read 4 November 2026. No external reading is required to complete these lessons.

Reference	Where it is practiced here
6.RP.A.1: ratio concepts and language	Lesson 1, A1
6.RP.A.2: unit rates, non-complex fractions	Lesson 3, A3
6.RP.A.3a: tables, missing values, plots, comparisons	Lesson 2, A2
6.RP.A.3b: unit pricing and constant speed	Lesson 3, A3; speed practice in 3P2
6.RP.A.3c: percent and finding a whole	Lesson 4, A5–A6
6.RP.A.3d: measurement conversion	Lesson 3, A4

This is a topic-to-task map, **not an independent alignment review or evidence of mastery**. The unit uses selected simple contexts; more practice and transfer assessment are needed for a complete course. It does not establish local qualification compliance. Formal slope, algebraic proportionality tests, and percent change are intentionally left for later work.

Known gaps and cautions

No educator review or classroom trial has been completed. The nominal five-session schedule may be too short for learners needing prerequisite work or more practice; extend it. This unit is not a complete grade-6 course, a full standards-alignment review, or an accredited qualification. Formal slope, percentage change, and algebraic proportionality tests are later topics; lesson 5's non-proportional example is optional. Local educators should check mathematical accuracy, access needs, language, pacing, and required standards before adoption.

Teacher implementation notes

Prerequisites: multiplication and division with positive whole numbers; simple fractions and decimals; multiplication by 10 and 100; understanding an equal partition; first-quadrant coordinates. This unit does not teach every prerequisite from scratch. Calculators may support arithmetic after a relationship is represented; they should not replace deciding which quantities to compare.

Materials: paper, pencils, optional grid paper and 20 counters in two distinguishable types. Shapes or tactile markers can replace colors. No food, laboratory materials, purchase, internet access, or personal financial information is required. The tile, printing, and garden contexts are fictional. Display a ratio as words as well as symbols; read tables by giving headers and pairs. Offer large-print grids, tactile plotting, or coordinate descriptions when appropriate. Do not rely on color alone.

Suggested structure: lessons 1–4 each use 5 minutes for retrieval, 12 for explanation/modeling, 10 for supported work, 15 for independent work, and 8 for an exit check and feedback. These are estimates, not deadlines. Lesson 5 uses 10 minutes of synthesis, 25 for an assessment, and 15 for discussion or later feedback. If independent work takes longer, continue next session rather than rushing the final ideas.

Entry check (before lesson 1; about 10 minutes)

- **D1.** Calculate 6 × 4 and 24 ÷ 6. Explain how the two facts connect.
- **D2.** What is 1/4 of 20? Represent it with equal groups or a drawing.
- **D3.** Calculate 15 ÷ 4; a fraction or decimal is acceptable.
- **D4.** Describe where the point (2, 3) is on a first-quadrant coordinate grid.

Use responses diagnostically, not as an admission test. If D1 or D2 is uncertain, rehearse equal-group models before ratio scaling. If D3 is uncertain, revisit sharing 15 into four equal groups before lesson 3. If D4 is uncertain, model horizontal-first, vertical-second plotting before lesson 2; do not interpret an axis-reading error as a ratio error.

Entry-check answer guide

- **D1:** 24 and 4. Six groups of 4 make 24; sharing 24 equally among 6 groups returns 4 per group.
- **D2:** 5. Split 20 into four equal groups and take one. If the learner takes away 4, distinguish “one of four equal parts” from “four fewer.”
- **D3:** 15/4 = 3 3/4 = 3.75. Four groups of 3 use 12; the remaining 3 shared four ways give 3/4 per group. This prepares a fractional unit rate.
- **D4:** From the origin, move 2 units horizontally right and 3 vertically up. The coordinates refer to axis scales, not necessarily two and three physical grid boxes if those boxes use different units.

Lesson 1: The order and the whole

Time: approximately 50 minutes (extend when needed)

Status: written, unreviewed AI draft; not classroom-tested. Author: GPT-6 Astra, 4 November 2026. Original text: CC0 1.0.

Unit overview · Mathematics progression

Goal

Interpret and construct a ratio, and explain why “blue to gold” differs from “blue out of all tiles.”

Materials

Paper and pencil; optional counters in two labeled types. Use labeled shapes rather than color alone.

Steps

Success evidence: a learner labels both parts of 2:3, reverses it correctly when asked for gold:blue, and identifies the blue fraction of the total as 2/5.

✎ Retrieve (5 minutes)

1R. Draw two groups of 5 objects. How many objects are there? Write a multiplication statement.

✎ Explain and model (12 minutes)

Draw a small tile pattern as **B B G G G**, saying B means blue and G means gold; shape labels can substitute for colors. Say:

> A ratio compares two quantities in a stated order. Here, for every 2 blue tiles there are 3 gold tiles. Blue to gold is 2 to 3, written 2:3. Gold to blue is 3:2. The labels tell us which comparison we mean; 2:3 alone does not tell us what was counted.

Count all five tiles. Continue:

> Blue to all tiles is 2:5. Blue tiles are 2/5 of the total. The 3 in blue:gold = 2:3 counts only gold tiles; it is not the total. The quotient 2/3 can describe blue tiles per gold tile, but it is not the fraction of all tiles that are blue.

Worked example: A tray contains 4 round and 6 square counters. Round:square = 4:6; square:round = 6:4; round:all = 4:10. Round counters are 4/10 = 2/5 of the total. Group them into two copies of “2 round, 3 square”: the comparison round:square can also be written 2:3. This does not mean there are only 5 counters on the tray; a ratio need not tell the actual total.

Ask learners to point to the quantity counted by each number before calculating. Do not introduce cross-multiplication as a substitute for interpreting the comparison.

✎ Supported investigation (10 minutes)

1G. With counters or a drawing, make three copies of B B G G G. Record blue count, gold count, total, blue:gold, and the blue fraction of all tiles. Explain which quantities changed and which relationship stayed the same. A partner can describe the arrangement instead of moving counters.

If someone writes 6/9 for the fraction of all tiles that are blue, ask “Does the denominator count every tile?” Recount the total; do not merely tell them to add the ratio numbers without connecting that operation to the objects.

✎ Independent practice (15 minutes)

- **1P1.** A box has 6 triangles and 9 circles. Write triangle:circle, circle:triangle, and triangle:all. What fraction of the shapes are triangles?
- **1P2.** A card says “red:green = 3:2.” Could the card describe 12 red and 8 green tiles? Explain using groups.
- **1P3.** Sam says, “Red:green is 3:2, so 3/2 of all tiles are red.” Explain the error and give the red fraction of the total.
- **1P4.** Draw a collection with star:dot = 1:4 and 10 objects in total. Label the counts.

Exit and response (8 minutes)

1E. A collection has 8 striped and 12 plain cards. State striped:plain and the striped fraction of all cards. Explain why the two comparisons have different second numbers.

If the fraction is 8/12, repeat the whole-counting model with smaller counts before lesson 2. If correct but unexplained, ask the learner to label the denominator's referent. Accept an unreduced correct ratio; simplification is not the main goal here.

Vocabulary

Ratio: a comparison of two quantities in a stated order.

Order: which quantity is named first and which second.

Whole: the entire quantity whose parts are being considered.

Differentiation

- **Extra support:** Use labeled counters or drawings and count the whole before writing a fraction; use the specific 1G and 1E feedback in Steps. Offer large-print, tactile, spoken, or diagrammatic responses as appropriate; a physical access barrier is not itself evidence of a mathematical misconception.

- **Extra challenge:** Create a new example of the same kind with different numbers, solve it, and verify the relationship with a second representation. This is optional, not a new required topic.

⚠ Safety

No food, purchase, or specialist equipment is required. Use drawn counters instead of small loose objects when those are unsuitable for the learners. All purchase and travel contexts are fictional; do not request personal financial information.

Teacher notes

Misconception responses appear beside the relevant tasks in Steps. The answers below are examples, not required scripts: accept equivalent correct representations and explanations. This key is unreviewed; check before classroom use.

- **1R:** 10 objects; 2 × 5 = 10 represents two groups of 5. If a learner writes 5 × 2, ask how their drawing matches their convention rather than rejecting the equal product.
- **1G:** 6 blue, 9 gold, 15 total; blue:gold = 6:9 = 2:3; blue fraction = 6/15 = 2/5. Counts tripled; the blue-to-gold relationship and blue share of the whole did not change.
- **1P1:** Triangle:circle = 6:9 (or 2:3); circle:triangle = 9:6 (or 3:2); triangle:all = 6:15 (or 2:5); fraction triangles = 6/15 = 2/5. Reversed answers need label checks, not just more simplification practice.
- **1P2:** Yes. Four copies of 3 red and 2 green make 12 red and 8 green. Both counts use the same factor, 4.
- **1P3:** The 2 counts green tiles, not all tiles. Each basic group has 3 + 2 = 5 tiles; 3/5 of all tiles are red. A part of this whole cannot exceed the whole, so 3/2 is also an unreasonable red fraction.
- **1P4:** 2 stars and 8 dots; two groups of 1 star and 4 dots give 10 objects. Five objects would meet the ratio but not the specified total.
- **1E:** Striped:plain = 8:12 = 2:3. Striped fraction of all = 8/20 = 2/5. Twelve counts plain cards; 20 counts every card. Simplifying cannot repair choosing the wrong denominator.

Lesson 2: Scaling, tables, and coordinates

Time: approximately 50 minutes (extend when needed)

Status: written, unreviewed AI draft; not classroom-tested. Author: GPT-6 Astra, 4 November 2026. Original text: CC0 1.0.

Unit overview · Mathematics progression

Goal

Generate equivalent ratios by multiplying or dividing both quantities by the same positive factor, and connect a table to a coordinate plot.

Materials

Paper and pencil; optional grid paper or an accessible coordinate grid. Use labeled shapes rather than color alone.

Steps

Success evidence: labels axes, gives missing values with a common factor, and rejects adding the same amount as a general equivalence rule.

✎ Retrieve (5 minutes)

2R. In blue:gold = 2:3, what fraction of all tiles is gold? Explain.

✎ Explain and model (12 minutes)

Return to B B G G G. Two copies give 4 blue and 6 gold; three copies give 6 blue and 9 gold. Each new group contains both kinds in the same relationship.

Worked table:

Blue tiles	Gold tiles	Total tiles
2	3	5
4	6	10
6	9	15
10	15	25

Say:

> To turn 2 blue into 10 blue, multiply by 5. The gold count must also multiply by 5, giving 15. Adding 8 to each original count would give 10 blue and 11 gold; that is a different mixture. The required operation preserves equal groups, not equal differences.

Draw a grid. Label horizontal axis **blue tiles**, vertical axis **gold tiles**, and use equal spacing for equal numerical increments on each axis. Plot (2,3), (4,6), (6,9), and (10,15). Read each coordinate pair as a sentence. These points lie on a line through the origin, but we are counting whole tiles: not every point on the continuous line represents an available collection. At (0,0) neither type is present; it is a useful zero-quantity starting point, not a defined ratio 0:0.

An alternative double number line has blue labels 0,2,4,6 and aligned gold labels 0,3,6,9. Put corresponding labels vertically above one another. It represents the same pairs as the table, rather than two unrelated scales.

Supported work (10 minutes)

2G. A paper design uses 3 square pieces for every 4 triangular pieces. Complete square counts 3, 6, 9, 15 with corresponding triangle counts. Plot the four pairs with squares horizontal. Explain the point with horizontal coordinate 9. Use a table-only explanation if the physical plotting format is inaccessible, while still identifying both coordinates.

✎ Independent practice (15 minutes)

- **2P1.** Complete blue:gold = 2:3 pairs: (8, **), (** , 18), (14, __).
- **2P2.** Which pair keeps that same relationship: (6,7), (8,12), or (10,12)? Explain why at least one rejected pair fails.
- **2P3.** Pattern A uses 2 blue for 3 gold. Pattern B uses 3 blue for 5 gold. Compare their blue counts when each has 15 gold tiles. Which has more blue **per gold tile**?
- **2P4.** Lee changes 4:6 to 8:10 by adding 4 to each number. Does this preserve the ratio? Give a counterexample using equal groups, a table, or quotients.

Exit and response (8 minutes)

2E. A pattern has circle:square = 3:5. How many squares go with 12 circles? Describe the common scaling factor and the coordinate pair if circles are horizontal.

If a learner adds 9 to both counts, build four copies of a 3-and-5 group. If only coordinates are reversed, address axis order separately. Do not require formal slope terminology yet.

Vocabulary

Equivalent ratios: comparisons that express the same multiplicative relationship.

Scale factor: the number by which both quantities are multiplied to make another equivalent pair.

Coordinate pair: two numbers giving horizontal and vertical positions, in that order, on labeled axes.

Differentiation

- **Extra support:** Build repeated groups before completing the table; check axis order separately from ratio scaling using the 2E feedback. Offer large-print, tactile, spoken, or

diagrammatic responses as appropriate; a physical access barrier is not itself evidence of a mathematical misconception.

- **Extra challenge:** Create a new example of the same kind with different numbers, solve it, and verify the relationship with a second representation. This is optional, not a new required topic.

⚠ Safety

No food, purchase, or specialist equipment is required. Use drawn counters instead of small loose objects when those are unsuitable for the learners. All purchase and travel contexts are fictional; do not request personal financial information.

Teacher notes

Misconception responses appear beside the relevant tasks in Steps. The answers below are examples, not required scripts: accept equivalent correct representations and explanations. This key is unreviewed; check before classroom use.

- **2R:** 3/5. There are 3 gold tiles out of 2 + 3 = 5 in each basic group.
- **2G:** Pairs (3,4), (6,8), (9,12), (15,20). At horizontal coordinate 9 there are 9 squares and 12 triangles. Every point must use square count first and triangle count second; scale factors from (3,4) are 1, 2, 3, and 5. Plot those points on labeled, consistently scaled axes.
- **2P1:** (8,12), (12,18), (14,21). Common factors from (2,3) are 4, 6, and 7 respectively.
- **2P2:** (8,12) only. Four copies of (2,3) give (8,12). Six blue require 9 gold, not 7; 10 blue require 15 gold, not 12.
- **2P3:** A has 10 blue and B has 9 blue when each has 15 gold. A therefore has more blue per gold tile. Using a common gold count makes the comparison fair; comparing the original blue counts 2 and 3 alone would not.
- **2P4:** No. Doubling 4:6 gives 8:12, not 8:10. Equivalently, 4/6 = 2/3 and 8/10 = 4/5 are different. Adding the same amount keeps a difference, not generally a ratio.
- **2E:** 20 squares; factor 4; coordinate pair (12,20). Twelve is four times 3, so the square count is four times 5. A plotting error with a correct table should be addressed as a representation issue.

Lesson 3: One unit, useful units

Time: approximately 50 minutes (extend when needed)

Status: written, unreviewed AI draft; not classroom-tested. Author: GPT-6 Astra, 4 November 2026. Original text: CC0 1.0.

Unit overview · Mathematics progression

Goal

Find a unit rate, state what its units mean, and use a supplied conversion relationship.

Materials

Paper and pencil; optional calculator after the relationship has been represented. Use labeled shapes rather than color alone.

Steps

Success evidence: chooses the correct division for a requested rate, interprets a fractional answer, and changes a unit without changing the physical quantity.

✎ Retrieve (5 minutes)

3R. Five identical packs contain 30 cards in total. How many cards are in one pack?

✎ Explain and model (12 minutes)

Say:

> A rate relates quantities with their units attached. A unit rate tells how much of one quantity goes with one unit of the other. Decide which unit you want to make "one" before dividing.

Worked example A: Eight notebooks cost 12 units of currency. Cost per notebook = 12 ÷ 8 = **1.5 currency units/notebook**. At this price, 20 notebooks cost 20 × 1.5 = **30 currency units**. This assumes the same price for each notebook and no extra fees. The reverse rate is 8/12 = 2/3 notebook per currency unit; it answers a different question, not a second price.

Worked example B: A model vehicle covers 18 meters in 6 seconds at constant speed. Its speed is 18 ÷ 6 = **3 m/s**. In 10 seconds it covers **30 m** under that assumption. A real journey can have an average speed without moving at that speed every moment; the constant-speed condition is what licenses this prediction.

Worked example C: Use **1 m = 100 cm**. A ribbon is 250 cm long. Groups of 100 cm make meters, so 250 ÷ 100 = **2.5 m**. Conversely, 1.2 m = 1.2 × 100 = **120 cm**. The number gets

smaller when using the larger unit, but the ribbon does not shrink. Keep the unit label beside every answer.

Supported work (10 minutes)

3G. Offer A has 6 identical pencils for 9 currency units; offer B has 10 for 14. Find each price per pencil and decide which has the lower unit price. Then discuss why “lower unit price” does not alone prove which purchase someone should make. No actual purchase is involved.

If a learner divides pencil count by price, ask them to complete the sentence “___ currency units for one pencil” and identify which original quantity is being shared among pencils.

✎ Independent practice (15 minutes)

- **3P1.** A printing service charges 15 currency units for 20 identical pages. What is the cost per page, as a fraction and decimal? What would 8 pages cost at the same rate with no additional charge?
- **3P2.** A cart travels 42 m in 7 s at constant speed. Find its speed and its distance in 12 s at that speed.
- **3P3.** Using 1 m = 100 cm, convert 360 cm to meters and 0.75 m to centimeters.
- **3P4.** Using 1 h = 60 min, convert 2.5 h to minutes. Explain why multiplying, not dividing, is appropriate.

Exit and response (8 minutes)

3E. Nine identical folders cost 18 currency units. Give the unit price and the cost of 7 folders at that price. Then convert a 180 cm shelf length into meters using 1 m = 100 cm.

If a unit price is inverted, return to the sentence frame. If conversion direction is uncertain, compare the size of the two units and estimate before calculating. Correct arithmetic with missing units needs a labeling check, not a wholly new lesson.

Vocabulary

Unit rate: the amount of one quantity for one unit of another.

Constant speed: the same distance traveled in every equal time interval.

Conversion: expressing the same quantity using a different unit.

Differentiation

- **Extra support:** Complete the sentence “currency units for one item” before dividing; estimate the direction of a conversion as in 3E. Offer large-print, tactile, spoken, or diagrammatic responses as appropriate; a physical access barrier is not itself evidence of a mathematical misconception.
- **Extra challenge:** Create a new example of the same kind with different numbers, solve it, and verify the relationship with a second representation. This is optional, not a new required topic.

⚠ Safety

No food, purchase, or specialist equipment is required. Use drawn counters instead of small loose objects when those are unsuitable for the learners. All purchase and travel contexts are fictional; do not request personal financial information.

Teacher notes

Misconception responses appear beside the relevant tasks in Steps. The answers below are examples, not required scripts: accept equivalent correct representations and explanations. This key is unreviewed; check before classroom use.

- **3R:** 6 cards per pack, because 30 ÷ 5 = 6.
- **3G:** A: 9/6 = 1.5 currency units/pencil. B: 14/10 = 1.4 currency units/pencil. B has the lower unit price by 0.1 currency unit/pencil. Purchase needs can also depend on quantity needed, total money available, quality, and unused surplus; no personal household disclosure is needed. If only full packs can be bought, a unit price does not imply one pencil can actually be purchased at that price.
- **3P1:** 15/20 = 3/4 = 0.75 currency unit/page; 8 pages cost 8 × 0.75 = 6 currency units under the stated pricing assumption.
- **3P2:** 42/7 = 6 m/s; 12 × 6 = 72 m. Constant speed supplies the reason the same unit rate applies throughout.
- **3P3:** 360 cm = 3.6 m; 0.75 m = 75 cm. The first divides by 100 centimeters per meter; the second uses 100 centimeters in each meter.
- **3P4:** 150 min. Each hour contains 60 minutes, so 2.5 × 60 = 150. More of the smaller unit is needed to describe the same duration.
- **3E:** 2 currency units/folder; 7 cost 14 currency units. The shelf is 1.8 m long. Do not combine the pricing and measurement values; they are separate questions.

Lesson 4: Percent names the reference whole

Time: approximately 50 minutes (extend when needed)

Status: written, unreviewed AI draft; not classroom-tested. Author: GPT-6 Astra, 4 November 2026. Original text: CC0 1.0.

Unit overview · Mathematics progression

Goal

Interpret percent as a rate per 100 and solve both part-from-whole and whole-from-part questions.

Materials

Paper and pencil; optional calculator after the relationship has been represented. Use labeled shapes rather than color alone.

Steps

Success evidence: identifies the whole before calculating and checks that the resulting part and whole have the stated percent relationship.

✎ Retrieve (5 minutes)

4R. Find 1/2 of 40 and 1/4 of 40. What percentages correspond to these fractions?

✎ Explain and model (12 minutes)

Draw a 10-by-10 grid with 100 cells, or describe 100 equal shares. Say:

> Percent means per hundred. Forty percent of a whole means 40 out of every 100 equal shares of that whole. The whole need not contain exactly 100 objects. A percent tells a relationship, so we must say what the whole is.

Worked example A: Find 30% of 80 cards. Ten percent of 80 is 8; three such parts are **24 cards**. Equivalently, (30/100) × 80 = 24. Check: 24/80 = 3/10 = 30/100. Avoid saying “remove two zeros” as an explanation.

Worked example B: Twelve cards are 25% of a collection. Find the whole collection. Since 25% is 1/4, 12 is one quarter, so the whole is **4 × 12 = 48 cards**. Check: 25% of 48 is 12. Calculating 25% of 12 instead would answer a different question.

Worked example C: Eighteen of 60 cards are striped. What percentage is striped? 18/60 = 3/10 = 30/100, so **30%**. The denominator 60 is the whole collection; 18/(60 − 18) compares striped with plain instead.

Supported work (10 minutes)

4G. A fictional garden diagram has 50 equal squares. Thirty percent are labeled flowers. How many flower squares are there? Separately, another diagram has 14 flower squares, which are 20% of its total. Find that diagram's total. Name the known whole in the first question and the unknown whole in the second.

If students multiply 14 by 0.20, draw five equal parts representing the whole and put 14 in one part. Emphasize that both problems use percent but ask for different missing quantities.

✎ Independent practice (15 minutes)

- **4P1.** Find 15% of 200 stickers. Show a method using 10% and 5%, or a fraction/decimal calculation.
- **4P2.** Eighteen blue counters are 30% of all counters. How many counters are there in total?
- **4P3.** Fifteen of 60 books have a triangle label. What percent have that label?
- **4P4.** A collection has red:blue = 2:3. What percent of all objects are red? Explain why using 2/3 as the red fraction gives the wrong reference whole.

Exit and response (8 minutes)

4E. Eight cards are 20% of a pack. Find the total pack size and check your answer by finding 20% of it.

If a learner finds 1.6, ask which number their calculation treated as the whole. Restore the relationship with five equal groups before introducing any inverse-operation formula. This unit does not yet cover percentage increase/decrease or changing reference wholes in successive percent changes.

Vocabulary

Percent: a rate per hundred.

Part: the amount selected from a stated whole.

Whole: the quantity representing 100% in the comparison.

Differentiation

- **Extra support:** Draw equal groups representing 100% and label which amount is known; follow the 4G and 4E feedback when the part is mistaken for the whole. Offer large-print, tactile, spoken, or diagrammatic responses as appropriate; a physical access barrier is not itself evidence of a mathematical misconception.
- **Extra challenge:** Create a new example of the same kind with different numbers, solve it, and verify the relationship with a second representation. This is optional, not a new required topic.

⚠ Safety

No food, purchase, or specialist equipment is required. Use drawn counters instead of small loose objects when those are unsuitable for the learners. All purchase and travel contexts are fictional; do not request personal financial information.

Teacher notes

Misconception responses appear beside the relevant tasks in Steps. The answers below are examples, not required scripts: accept equivalent correct representations and explanations. This key is unreviewed; check before classroom use.

- **4R:** 20 and 10; 1/2 = 50% and 1/4 = 25%. The percentage names a share, not the count 20 or 10 independently of a whole.
- **4G:** First diagram: 15 flower squares, since 10% of 50 is 5 and 30% is three times that. Second diagram: 70 total squares, since 20% is one fifth and 14 × 5 = 70. The first known whole is 50; in the second, the 100% whole is initially unknown and resolves to 70.
- **4P1:** 30 stickers. Ten percent is 20 and five percent is 10; together they make 15%, or 30. Also 0.15 × 200 = 30.
- **4P2:** 60 counters. Thirty percent is 18, so 10% is 6 and 100% is 60. Check: 0.30 × 60 = 18. Finding 30% of 18 would mistake the part for the whole.
- **4P3:** 25%, since 15/60 = 1/4 = 25/100.
- **4P4:** 40%, because red:all = 2:5 and 2/5 = 40/100. The fraction 2/3 compares red with blue alone; it does not use the whole collection.
- **4E:** 40 cards; 20% = one fifth, so multiply 8 by 5. Check: 0.20 × 40 = 8. The answer must be greater than 8 because 8 is only a part of this pack.

Lesson 5: Use the relationship, check the claim

Time: approximately 50 minutes (extend when needed)

Status: written, unreviewed AI draft; not classroom-tested. Author: GPT-6 Astra, 4 November 2026. Original text: CC0 1.0.

Unit overview · Mathematics progression

Goal

Choose a useful representation and solve an unfamiliar combination of ratio, rate, percent, and conversion tasks.

Materials

Paper and pencil; optional calculator after the relationship has been represented. Use labeled shapes rather than color alone.

Steps

Synthesis (10 minutes)

5S. A design calls for 4 dark tiles for every 5 light tiles. Someone proposes 12 dark and 13 light. Decide whether it preserves the design and show a correction keeping 12 dark. Use objects, a table, or words. Discuss how “both numbers grew by 8” differs from preserving a relationship.

Review four questions learners can ask themselves:

1. What does each number count or measure?
2. What quantity, if any, is the whole?
3. What operation preserves the relationship?
4. Do the size and units of the answer make sense?

Individual assessment (25 minutes, extend as needed)

Diagrams, tables, and short written or spoken explanations are welcome. Record any arithmetic or reading support provided so that interpretation is fair. The teacher key offers diagnostic guidance, not a validated grading scale.

- **A1 — Meaning.** A box has 12 round counters and 18 square counters. Write round:square in simplest whole-number form, and give the fraction of all counters that are round. Explain what each denominator or second number counts.
- **A2 — Scale and plot.** A design uses 4 short strips for every 7 long strips. Complete the pairs (short, long): (8, **), (** , 35), (12, __). Plot the completed points with short strips on the horizontal axis and long strips on the vertical axis. Label axes and a consistent numerical scale.

- **A3 — Unit rate and comparison.** Pack A contains 8 identical sheets and costs 6 currency units. Pack B contains 12 identical sheets and costs 10 currency units. Which has the lower cost per sheet? Show both rates; exact fractions are acceptable.
- **A4 — Conversion.** A paper strip is 2.4 m long. Using 1 m = 100 cm, express its length in centimeters. Explain why the numerical value increases.
- **A5 — Percent of a whole.** A model has 150 tiles, 40% of which are textured. How many are textured? Show a calculation or representation.
- **A6 — Find the whole.** Twenty-one cards are 35% of a collection. How many cards are in the collection? Check the percent relationship.
- **A7 — Evaluate a claim.** “To change 3:5 into an equivalent ratio, add 2 to both numbers, making 5:7.” Is this method valid here? Explain, and give a correct equivalent ratio different from 3:5.

Feedback and transfer (15 minutes or next session)

Return to one problem with a correct answer but unclear explanation, and one problem with a useful representation but arithmetic error. Discuss the mathematics without naming learners or displaying their work without agreement. Invite a revision in a different representation; revision is part of learning, not proof the first answer was dishonest.

5T — Optional extension, not a grade-6 prerequisite: A fictional delivery service charges 3 currency units plus 2 for each package. Costs for 1, 2, and 3 packages are 5, 7, and 9. Does doubling the package count always double the cost? Explain with an example. This previews grade-7 proportionality; it should not become a hidden requirement for passing this unit.

Vocabulary

Reference whole: the quantity treated as the complete amount when stating a fraction or percent.

Unit rate: an amount for one unit of another quantity.

Equivalent ratios: comparisons preserving the same multiplicative relationship.

Differentiation

- **Extra support:** Use the diagnostic table in Teacher notes to select one earlier representation to revisit; allow oral or diagrammatic explanations without changing the relationship being assessed. Offer large-print, tactile, spoken, or diagrammatic responses as appropriate; a physical access barrier is not itself evidence of a mathematical misconception.
- **Extra challenge:** Create a new example of the same kind with different numbers, solve it, and verify the relationship with a second representation. This is optional, not a new required topic.

⚠ Safety

No food, purchase, or specialist equipment is required. Use drawn counters instead of small loose objects when those are unsuitable for the learners. All purchase and travel contexts are fictional; do not request personal financial information.

Teacher notes

Misconception responses appear beside the relevant tasks in Steps. The answers below are examples, not required scripts: accept equivalent correct representations and explanations. This key is unreviewed; check before classroom use.

Lesson 5 synthesis and extension

- **5S:** No; 12 dark is three times 4, so it needs 15 light, three times 5. Corrected pair: (12,15). Adding 8 to both gives different multipliers for the two counts.
- **5T:** No. One package costs 5; two cost 7, not 10. Doubling the package count doubles the package-related part of the cost, from 2 to 4 here; the rate stays 2 currency units per package and the fixed charge stays 3. Learners need not use the word “intercept.” This is an extension, not an assessment requirement.

Assessment answer guide

- **A1:** Round:square = **2:3**, simplified from 12:18 by dividing both counts by 6. Round fraction of all = **12/30 = 2/5**. The second ratio number, 3, denotes three equal ratio shares corresponding to the 18 square counters, not three actual counters; the fraction denominator refers to all counters (30 actual, or 5 equal ratio shares). A correct 2:3 with 2/3 for the fraction signals a reference-whole misconception.
- **A2: (8,14), (20,35), (12,21)**. Scale factors from (4,7) are 2, 5, and 3. Plots should have short strips horizontal, long strips vertical, labeled axes, and equally spaced numerical intervals on each axis. Different horizontal and vertical unit scales are allowed; equal numerical increments on the same axis must have equal physical spacing. These three coordinates provide a checkable plot key even without a printed graph.
- **A3: Pack A**. A costs 6/8 = **3/4 = 0.75** currency unit/sheet; B costs 10/12 = **5/6**, approximately **0.8333** currency unit/sheet. Exact comparison: 3/4 = 9/12 < 10/12 = 5/6. A smaller total pack price alone is insufficient reasoning; the pack counts differ.
- **A4: 240 cm**, since 2.4 × 100 = 240. A centimeter is smaller than a meter, so more centimeters count the same strip length. The strip did not physically grow.
- **A5: 60 tiles**. Ten percent of 150 is 15, so 40% is 4 × 15 = 60; alternatively, (40/100) × 150. Textured:all = 60:150 = 2:5 = 40:100 checks the relationship.
- **A6: 60 cards**. If 35% is 21, then 5% is 3 and 100% is 20 × 3 = 60. Alternatively, 21 ÷ 0.35 = 60. Check: 0.35 × 60 = 21. Multiplying 21 by 0.35 incorrectly treats the given part as the whole.
- **A7: Not valid here.** The proposed ratio 5:7 does not equal 3:5; for example, multiplying 3 by 5/3 would require multiplying 5 by 5/3, yielding 25/3 rather than 7. A whole-number comparison is to scale 3:5 to **21:35** and 5:7 to **25:35**: the same second quantity goes with different first quantities; or use 3/5 = 0.6 and 5/7 ≈ 0.714. A correct equivalent ratio is **6:10** by doubling both original counts. The intended accessible explanation is that changing 3 to 5 is not the same factor as changing 5 to 7; a diagram can show the mismatch.

Diagnostic recording, not a validated pass score

For each outcome record **demonstrated**, **partial evidence**, or **needs another check**, with a short example from the student's work. “Demonstrated” requires the relevant computation or

representation plus a sound interpretation; it does not require the wording above. Avoid combining these categories into a pseudo-precise mastery percentage.

Evidence	If uncertain, revisit
A1 ratio order and reference whole	Lesson 1: count and label each set
A2 scaling and plot; A7 equivalence explanation	Lesson 2: copies of a basic group; coordinates separately
A3 cost per one sheet	Lesson 3: decide the denominator unit before dividing
A4 conversion	Lesson 3: same length, different-sized units
A5 known whole; A6 unknown whole	Lesson 4: identify and draw the whole before calculating

Keep A2's table and graph observations separate. A learner who cannot physically draw a graph may demonstrate the same coordinate relationship using a tactile grid or precise coordinate placement instructions. If reading, language, or arithmetic support was provided, record it factually rather than assuming the mathematical reasoning is absent. Re-teach the specific gap, offer a fresh analogous task, and check again. Classroom educators must choose reporting and progression policies; this draft supplies no normed test, diagnosis, or qualification decision.

Grade 6 Science — Fungi and decomposition

> **Unreviewed AI draft.** Written by Claude Opus 5.5 (an AI agent) on 2026-11-04. No teacher has checked it yet. Read it fully, adapt it to your class and local rules, and test any practical work yourself before using it with students.

Back to all units

Big idea

Fungi are a separate kingdom of living things — not plants, not animals. Most of them feed by releasing digestive chemicals onto dead or living material and absorbing what dissolves. That habit makes them some of the world's main decomposers, returning nutrients to the soil, and it also explains why people use them (bread, medicine) and fear some of them (food spoilage, crop disease, poisonous mushrooms).

Outcomes

By the end of the unit, students can:

1. Give three ways fungi differ from plants (no photosynthesis; cell walls made of chitin, not cellulose; feed by absorbing food).
2. Name and recognise the three everyday forms of fungi: yeasts, moulds, mushrooms — and explain that a mushroom is only the reproductive part of a larger hidden network (mycelium).
3. Explain, using a simple diagram, how decomposers return nutrients from dead material to soil and then to plants.
4. Plan a fair test that changes one variable, keeps others the same, and records observations over several days.
5. Describe evidence that yeast is alive and produces a gas (carbon dioxide) when given sugar.
6. Give two ways fungi help people and two ways they harm people or crops.

Prior knowledge

- Living things need food and energy; plants make their own food using light.
- Basic idea of a food chain.
- Using a ruler and recording a table.

Lessons (about 50 minutes each)

#	Lesson	Practical?
1	What is a fungus?	Observation (shop mushrooms, hand lens)
2	Decomposers and the nutrient cycle	Leaf-litter observation
3	Mould on bread: a fair test	Set up sealed bags; observe for about 7 days
4	Yeast is alive: the balloon test	Yeast, sugar, warm water, balloons
5	Fungi and people + unit check	Discussion and written assessment

Lesson 3 needs follow-up of about 5 minutes on several later days to record the bags. You can run Lessons 4 and 5 during that week.

Materials (whole unit)

- Shop-bought mushrooms (e.g. button mushrooms), one per group; plastic knives; hand lenses; paper towels
- Trays or paper plates; a bag of leaf litter collected by the teacher from a garden or park (or a school compost heap)
- Bread without preservatives if possible (preservatives slow mould), water spray bottle, zip-seal plastic bags, sticky tape, permanent marker
- Dried baker's yeast (one 7 g sachet per group is plenty), sugar, warm (not hot) water about 35–40 °C, small plastic bottles (about 500 ml), balloons, funnel, measuring spoons, string or tape measure
- Student record sheets (tables are given in each lesson)

Assessment

- Ongoing: closing check questions at the end of each lesson (answers included).
- Lesson 3: the bread-mould record table and conclusion are a practical skills task.
- Lesson 5: a 10-question unit check with an answer guide and simple marking notes.

Sources

These are general references that a teacher can use to check facts. Links were checked to load on 2026-11-04.

- Wikipedia, "Fungus": https://en.wikipedia.org/wiki/Fungus
- Wikipedia, "Hypha": https://en.wikipedia.org/wiki/Hypha
- Wikipedia, "Mycelium": https://en.wikipedia.org/wiki/Mycelium
- Wikipedia, "Chitin": https://en.wikipedia.org/wiki/Chitin
- Wikipedia, "Decomposer": https://en.wikipedia.org/wiki/Decomposer
- Wikipedia, "Nutrient cycle": https://en.wikipedia.org/wiki/Nutrient_cycle
- Wikipedia, "Saccharomyces cerevisiae" (baker's yeast): https://en.wikipedia.org/wiki/Saccharomyces_cerevisiae
- Wikipedia, "Cellular respiration": https://en.wikipedia.org/wiki/Cellular_respiration
- Wikipedia, "Penicillin": https://en.wikipedia.org/wiki/Penicillin
- Wikipedia, "Alexander Fleming": https://en.wikipedia.org/wiki/Alexander_Fleming
- Wikipedia, "Mycorrhiza": https://en.wikipedia.org/wiki/Mycorrhiza
- Wikipedia, "Mushroom poisoning": https://en.wikipedia.org/wiki/Mushroom_poisoning
- Wikipedia, "Amanita phalloides" (death cap): https://en.wikipedia.org/wiki/Amanita_phalloides

A teacher should prefer their national curriculum documents and school science-safety guidance where these exist.

Known gaps and cautions

- **Simplifications (labelled for teachers):** "Fungi absorb their food" is true of nearly all fungi but hides variety. The yeast balloon test is mostly fermentation (respiration without much oxygen), which makes carbon dioxide and a little alcohol; at grade 6 we call it

"respiration" and mention the distinction only in teacher notes. "Kingdom" is used as a simple grouping; modern classification is more complicated.

- **Safety:** mould spores can trigger allergies and asthma. The bread bags stay sealed for the whole experiment and are thrown away sealed. Students never pick or taste wild mushrooms or fungi — some deadly species look like edible ones. An adult prepares the warm water. Check for yeast, wheat/gluten and mushroom allergies before practical lessons.
- Not aligned to any official standard yet. Times are estimates.
- No images are included; teachers will want photos or real specimens of mushrooms, bracket fungi and mould.

Lesson 1: What is a fungus?

Time: 50 minutes

Unit overview · Next: Lesson 2

Goal

Students can give three ways fungi differ from plants and name the three everyday forms of fungi (outcomes 1 and 2).

Materials

- One shop-bought button mushroom per group of 3–4, on a paper towel; plastic knife; hand lens
- Board or slide with three pictures: a loaf of bread rising (yeast), a mouldy orange (mould), a toadstool in a forest (mushroom)
- Optional: a slice of old mouldy bread sealed inside a clear zip bag and taped shut, for looking at only

Steps

1. **Opening (5 min).** Hold up a mushroom. Ask: "Is this a plant? Vote with your hands." Write the vote on the board and say we will vote again at the end.

2. **Main activity (30 min).**

3. Look closely (12 min). Groups cut their mushroom from top to bottom and use the hand lens. They draw it and label: **cap**, **stem (stalk)**, **gills** under the cap. Ask them to look for anything green (there is none) and for roots (there are none — any white threads at the base are hyphae).
4. Teacher explains (8 min). Fungi are their own kingdom of life. Key points, written on the board:
    - Fungi have **no chlorophyll**, so they cannot make food from light.
    - They **feed by absorbing**: they release digestive chemicals (enzymes) onto food outside their body, then soak up the dissolved food.
    - Their bodies are made of tiny threads called **hyphae**. A big tangled network of hyphae is a **mycelium**, usually hidden in soil, wood or food.
    - Their cell walls are made of **chitin** — the same tough material found in insect shells — not cellulose like plants.
    - A mushroom is only the **fruiting body**: the part that makes and releases **spores** (like seeds, but a single cell). Most of the fungus is the mycelium underground.

5. Three forms (10 min). Show the three pictures. Students copy and complete this table:

Form	What it looks like	Example
Yeast	Single cells, too small to see one alone	Baker's yeast that makes bread rise
Mould	Fuzzy threads on food	Green-blue mould on old bread or oranges

Form	What it looks like	Example
Mushroom	Fruiting body above ground	Button mushroom, toadstool, bracket fungus on a tree

6. **Discussion questions (10 min).**
7. "Why can a mushroom grow in a dark cupboard but a bean plant can't?" — Example answer: the mushroom doesn't use light to make food; it absorbs food from what it grows on. The bean plant needs light for photosynthesis.
8. "If you pick a mushroom, have you killed the fungus?" — Example answer: usually not; the mycelium underground is still alive, like picking an apple doesn't kill the tree.
9. "Why do you think fungi grow on dead logs and old food?" — Example answer: that is their food; they digest it and absorb it.
10. **Closing check (5 min).** Vote again: plant or not? Then:
11. Q1. Give two differences between fungi and plants. — Any two: no chlorophyll/can't photosynthesise; absorb food; chitin walls (not cellulose); made of hyphae; reproduce by spores (plants also can, e.g. ferns, so accept this only alongside another difference).
12. Q2. What is the name of the network of threads that makes up most of a fungus? — Mycelium (threads = hyphae).

Vocabulary

- fungus (plural fungi): a living thing that is not a plant or animal and feeds by absorbing food
- hypha (plural hyphae): one tiny thread of a fungus
- mycelium: the network of hyphae that makes up most of a fungus
- spore: a tiny cell a fungus releases to make a new fungus
- chitin: a tough material in fungus cell walls (also in insect shells)
- fruiting body: the part that makes spores, e.g. a mushroom

Differentiation

- Extra support: give a pre-drawn mushroom outline to label; give the table with the "Example" column filled in.
- Extra challenge: fungi are more closely related to animals than to plants. Ask students to list ways a fungus is like an animal (doesn't photosynthesise, eats other things, has chitin like insects) and ways it is not (doesn't move, has cell walls).

⚠ Safety

- Use shop-bought mushrooms only. No one eats anything in this lesson. Wash hands afterwards.
- Never pick or taste wild mushrooms. Some deadly species (such as the death cap) look similar to edible ones, and even experts use careful identification.
- The mouldy-bread bag, if used, stays sealed and is thrown away sealed.
- Ask about mushroom allergies beforehand.

Teacher notes

- Misconception: "Mushrooms are plants because they grow in the ground and don't move." Answer: so do many things; what matters is how they get food and what they are made of.
- Misconception: "Mould is dirt." Answer: mould is a living fungus growing on the food.
- Misconception: "Spores are seeds." Answer: similar job, but a spore is a single cell with no stored food and no baby plant inside.
- Simplification: "kingdom" is a useful grouping for this age; modern biology classifies living things by relatedness in a more complicated tree.

Lesson 2: Decomposers and the nutrient cycle

Time: 50 minutes

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

Goal

Students can explain, with a diagram, how decomposers return nutrients from dead material to the soil and to plants (outcome 3).

Materials

- A bag of leaf litter collected by the teacher (top layer of fallen leaves and the darker, crumbly layer underneath), from a garden, park or compost heap
- Trays or paper plates, plastic spoons, hand lenses, disposable gloves
- Sorting sheet with three columns: "Fresh leaves", "Partly broken down", "Crumbly soil-like"

Steps

1. **Opening (5 min).** Ask: "Every autumn, trees drop millions of leaves. Why aren't forests buried metres deep in old leaves?" Collect ideas without correcting yet.

2. **Main activity (30 min).**

3. Leaf-litter sort (15 min). Each group gets a spoonful-sized pile of litter on a tray. Wearing gloves, they sort pieces into the three columns. With the hand lens, they look for: white or yellow threads (fungal hyphae), small animals (woodlice, worms, mites), holes and skeleton-like leaves where only the veins remain. They record what they find in words and sketches.
4. Teacher explains (10 min). Draw the cycle on the board as a loop:
    1. A plant takes **nutrients** (such as nitrogen and phosphorus) from the soil and grows.
    2. The plant (or an animal that ate it) dies, or drops leaves.
    3. **Decomposers** — mainly fungi and bacteria — digest the dead material. Small animals like worms and woodlice help by breaking it into smaller pieces (they are often called detritivores).
    4. Digestion releases the nutrients back into the soil.
    5. New plants take them up. The loop starts again. Explain that fungi are especially good at breaking down tough wood and leaves, which many other living things cannot digest.

5. Students draw (5 min). Each student draws the cycle with at least five labelled arrows.

6. **Discussion questions (10 min).**

7. "Back to the opening question: why aren't forests buried in leaves?" — Example answer: fungi, bacteria and small animals break the leaves down into soil every year.
8. "What would happen to a forest if all the decomposers disappeared?" — Example answer: dead material would pile up; nutrients would stay locked inside it; the soil would run out of nutrients and new plants would struggle to grow.

9. "Which column had the most fungal threads, and why?" — Example answer: usually the partly broken down layer, because fungi are actively digesting it there. (Accept any answer backed by what the group saw.)

10. **Closing check (5 min).**

11. Q1. What is a decomposer? — A living thing that breaks down dead material and returns nutrients to the soil (e.g. fungi, bacteria).
12. Q2. Put in order: plant grows / leaf falls / fungi digest leaf / nutrients in soil. — Plant grows → leaf falls → fungi digest leaf → nutrients in soil → (plant grows again).

Vocabulary

- decomposer: a living thing that breaks down dead material, e.g. fungi and bacteria
- detritivore: a small animal that eats dead material, e.g. worm, woodlouse
- nutrient: a substance living things need to grow, e.g. nitrogen
- leaf litter: the layer of fallen leaves and bits on the ground

Differentiation

- Extra support: provide the cycle diagram with blank labels and a word bank.
- Extra challenge: add the Sun and photosynthesis to the diagram, showing that energy flows through (and leaves as heat) while nutrients go round in a cycle.

⚠ Safety

- Teacher collects the litter beforehand from a place without dog waste, broken glass or sprayed chemicals.
- Gloves on; no hands near faces; wash hands afterwards. Return small animals outside after the lesson.
- Students with asthma or mould allergy should be told in advance; keep the room ventilated and don't shake the litter.

Teacher notes

- Misconception: "Things rot because they get old." Answer: rotting is done by living decomposers. Without them (e.g. in very cold, dry or airless places) things last a very long time.
- Misconception: "Decomposers are bad/dirty." Answer: without them, ecosystems would stop working.
- Misconception: "Plants eat soil." Answer: plants take small amounts of dissolved nutrients and water from soil; most of their body mass comes from carbon dioxide in the air, via photosynthesis.
- Simplification: we show one tidy loop; real nutrient cycles have many branches.

Lesson 3: Mould on bread — a fair test

Time: 50 minutes to set up, then about 5 minutes on 4–5 later days to observe

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

Goal

Students plan and run a fair test that changes one variable, keeps others the same, and records observations over several days (outcome 4).

Materials (per group)

- 2 slices of the same bread, from the same loaf (bread without preservatives grows mould faster; note the type used)
- 2 zip-seal plastic bags, clear sticky tape, permanent marker
- Water spray bottle (or a teaspoon of water)
- A ruler or a clear grid sheet with 1 cm squares to lay over the bag
- Record sheet (table below)
- Shared places with different conditions: a warm spot (e.g. on a shelf in the classroom) and a cold spot (a fridge with no food in it, or bags inside a second sealed container - see Safety)

Steps

1. **Opening (5 min).** Ask: "Why do we keep bread in a bag, and why does it go mouldy faster in summer?" Collect ideas. Tell students that mould grows from spores already floating in the air and sitting on the bread — we don't need to add any.

2. **Main activity (30 min).**

3. Choose one question (8 min). Each group chooses ONE of these to test:
    - A. Does moisture affect how fast mould grows? (dry slice vs. slice sprayed with 5 sprays of water)
    - B. Does temperature affect how fast mould grows? (warm shelf vs. fridge; both slices sprayed the same)
4. Plan a fair test (10 min). Students fill in:
    - The one thing we change (independent variable): _____
    - What we measure (dependent variable): how much of the slice is covered with mould
    - Things we keep the same (control variables): at least three, e.g. same bread, same size slice, same type of bag, same amount of water (in B), same light, same days
    - Prediction: "I think ____ will grow mould faster because ____."

5. Set up (12 min). Spray/prepare slices as planned. Place each slice in its own bag, squeeze out most air, seal the zip and **tape it shut**. Label each bag with group name, condition and date. Put bags in their places. **Bags are never opened again.**

6. **Discussion questions (10 min).**

7. "Why do we test only one thing at a time?" — Example answer: if we change two things and one slice gets mouldier, we can't tell which change caused it.

8. "Why do we use bread from the same loaf?" — Example answer: different breads have different ingredients and preservatives, which could change the result; keeping it the same keeps the test fair.

9. "How could we make our result more trustworthy?" — Example answer: repeat with more slices for each condition and compare; other groups doing the same test also helps.

10. **Closing check (5 min).**

11. Q1. In test B, what is the independent variable? — Temperature (warm vs. cold).
12. Q2. Name two control variables. — Any two: same bread/loaf, same slice size, same water, same bag type, same light, same time.

Observation days (about 5 minutes each, e.g. days 2, 3, 5, 7)

Without opening the bags, students lay the 1 cm grid over each bag and count squares that are at least half covered by mould. They also note colours (white, green, blue-green, black) and smell is **not** tested.

Day	Condition 1: squares with mould	Colours seen	Condition 2: squares with mould	Colours seen
0	0	—	0	—
2				
3				
5				
7				

Conclusion (final observation day, 15 min)

Students draw a simple line graph (day on the bottom axis, squares with mould on the side axis, one line per condition) and write:

- "The ____ slice grew mould faster. This supports / does not support my prediction."
- "One reason this might happen is ____."
- "One way our test might not have been fair is ____."

Expected results (for the teacher): moist, warm bread usually grows visible mould within about 3–7 days; dry bread and bread in a fridge grow it much more slowly. Results vary a lot with bread type and room temperature, and no-growth results are still valid data — use them to discuss.

Vocabulary

- variable: anything that can change in an experiment
- independent variable: the one thing we choose to change
- dependent variable: what we measure
- control variables: things we keep the same to make the test fair
- prediction: what we think will happen and why

Differentiation

- Extra support: give the plan with the control variables partly filled in; let students count squares with a partner.
- Extra challenge: test three levels (dry / 3 sprays / 6 sprays) or add a third location (dark cupboard) and explain whether light matters.

⚠ Safety

- **Bags stay sealed and taped for the whole experiment and are thrown away sealed** in the general rubbish (put inside a second bag). Mould spores can trigger allergies and asthma; opening the bags releases them.
- Students with mould allergy or asthma record data from photos of the bags (taken by the teacher or a classmate) instead of handling or sitting near the bags.
- Don't put bags with mould in a fridge that holds food unless it is a dedicated fridge or the bags are inside a second sealed container; check your school's rules.
- Wash hands after handling the bags.

Teacher notes

- Misconception: "The mould came from inside the bread / was created by the water." Answer: spores were already on the bread and in the air; water and warmth let them grow.
- Misconception: "Just scrape off the mould and the rest is fine." Answer: hyphae grow through the food, beyond what you can see; general advice is to throw mouldy bread away.
- Many groups will forget that a fridge is also dark. Use this to discuss a hidden second variable — a great learning moment.
- Simplification: counting covered squares is a rough measure; that's fine for this age and worth discussing as a limitation.

Lesson 4: Yeast is alive — the balloon test

Time: 50 minutes

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

Goal

Students describe evidence that yeast is alive and produces a gas (carbon dioxide) when it has sugar (outcome 5).

Materials (per group)

- 2 small clean plastic bottles (about 500 ml), labelled A and B
- 2 balloons (stretch them a few times first so they inflate easily)
- 1 sachet (7 g) dried baker's yeast, split into two equal halves
- 2 teaspoons of sugar
- Warm water at about 35–40 °C (comfortably warm to touch, not hot) — **prepared by an adult**
- Funnel, measuring jug, teaspoon, string and ruler (or tape measure)
- Optional for the class demo: a slice of bread to show the holes made by gas

Steps

1. **Opening (5 min).** Show a slice of bread and ask: "Where do the holes in bread come from?" Then show the dry yeast: "This is a fungus. Is it alive? How could we find out?"

2. **Main activity (30 min).**

3. Set up (10 min). In both bottles, use the funnel to put half the yeast and 100 ml warm water. In bottle A **only**, add 2 teaspoons of sugar. Swirl gently. Stretch a balloon over each bottle's neck. Bottle B (no sugar) is the **control**.
4. Predict (3 min). Students write which balloon will inflate more and why.

5. Observe (15 min). Every 5 minutes, measure around the widest part of each balloon with string and ruler, and note bubbles or foam in the bottle. Record in a table:

Time (min)	A (sugar): balloon size (cm)	A: bubbles?	B (no sugar): balloon size (cm)	B: bubbles?
0				
5				
10				
15				

6. Teacher explains (2 min). Yeast cells use sugar as food to release energy. One waste product is a gas, **carbon dioxide**, which fills the balloon. In bread dough, the same gas makes bubbles that become the holes. Using food to release energy is something all living things do.

Expected result (for the teacher): bottle A foams and its balloon usually starts to inflate within 10–20 minutes; bottle B changes little. If the room is cold or the water was too hot, results may be slow — keep the bottles somewhere warm and check again at the end of the lesson.

1. **Discussion questions (10 min).**
2. "What is the evidence that yeast is alive?" — Example answer: it used food (sugar) and produced a gas; dead things don't do that. With no sugar, little happened.
3. "Why did we have bottle B?" — Example answer: to show that the sugar made the difference, not just the water or the yeast on its own.
4. "What might happen if we used boiling water?" — Example answer: it would kill the yeast, so no gas would be made. (Teacher can demonstrate this safely as an extension.)
5. **Closing check (5 min).**
6. Q1. What gas filled the balloon? — Carbon dioxide.
7. Q2. What does yeast use as food in this test? — Sugar.
8. Q3. How does this explain the holes in bread? — Yeast in the dough makes carbon dioxide bubbles, which get trapped and leave holes when the bread is baked.

Vocabulary

- yeast: a fungus made of single cells, used in baking
- carbon dioxide: a gas made when living things use food for energy
- control: the part of an experiment where we leave out the thing being tested, so we can compare
- respiration: the process of using food to release energy (not the same as breathing)

Differentiation

- Extra support: pre-labelled bottles; a results table with time already filled in; sentence starters ("Balloon A got bigger because…").
- Extra challenge: plan a follow-up test: does the amount of sugar, or the water temperature, change how fast the balloon inflates? Identify the variables.

⚠ Safety

- An adult prepares and pours the warm water; it must not be hot enough to scald (aim for 35–40 °C).
- Check for yeast allergy. Nothing is tasted. Bottles can be emptied down a sink with running water afterwards; wash hands.
- Balloons: check for latex allergy and use latex-free balloons if needed.
- Bottles must have the balloon only on top — never seal a bottle with a cap during this experiment, because gas pressure builds up.

Teacher notes

- Misconception: "Respiration means breathing." Answer: breathing moves air in and out of lungs; respiration is the chemical process in cells that releases energy from food. Yeast respires but has no lungs.

- Misconception: "The sugar fizzed like a fizzy drink." Answer: sugar in water without yeast doesn't produce gas — add a third bottle with sugar and water only, no yeast, if students raise this.
- Simplification: in a balloon-sealed bottle, yeast mostly carries out **fermentation** (respiration with little oxygen), which makes carbon dioxide and a small amount of alcohol. At this level calling it respiration is fine; older students can learn the difference.

Lesson 5: Fungi and people + unit check

Time: 50 minutes (25 min lesson, 25 min unit check)

Unit overview · Previous: Lesson 4

Goal

Students give two ways fungi help people and two ways they harm people or crops (outcome 6), then show what they have learned across the unit.

Materials

- Six "fungus fact cards" (text below), printed, one set per group
- A large two-column sheet per group: "Helpful" / "Harmful"
- Unit check, one copy per student

Steps

1. **Opening (3 min).** Ask: "Are fungi our friends or our enemies?" Quick show of hands.
2. **Main activity (15 min).** Groups read the six cards and sort them into Helpful / Harmful (some can go in both). Then each group writes one sentence per card on why.
3. **Card 1 — Bread and food.** Baker's yeast makes bread rise. Fungi are also used to make soy sauce, some cheeses (the blue veins in blue cheese are a mould) and other foods.
4. **Card 2 — Penicillin.** In 1928, the scientist Alexander Fleming noticed that a mould growing on one of his dishes had stopped bacteria growing around it. The substance it made, penicillin, became one of the first antibiotics — medicines that kill bacteria — and has saved a very large number of lives.
5. **Card 3 — Mycorrhizae (my-co-RYE-zee).** The hyphae of many fungi join with plant roots. The fungus helps the plant take up water and nutrients such as phosphorus; the plant gives the fungus sugars it made by photosynthesis. Most land plants have partnerships like this.
6. **Card 4 — Crop and tree diseases.** Some fungi attack living plants. Rusts and mildews damage crops such as wheat; fungal diseases have killed huge numbers of trees in some countries.
7. **Card 5 — Food spoilage.** Moulds grow on bread, fruit and other food, making it unsafe or unpleasant to eat. Some moulds produce poisons.
8. **Card 6 — Poisonous mushrooms.** A few wild mushrooms are deadly. The death cap can look like edible mushrooms and causes many of the world's deaths from mushroom poisoning. This is why nobody should eat a wild mushroom unless an expert has identified it — and even then, many people simply don't.
9. **Discussion questions (5 min).**
10. "Which card surprised you most?" — Any answer with a reason.

11. "Is one fungus 'good' or 'bad'?" — Example answer: it depends on where it is. Mould on bread is a problem in the kitchen, but the same kind of fungus breaking down fallen leaves in a forest is useful.

12. **Closing check (2 min).**

13. Q1. Name one medicine that came from a fungus. — Penicillin.
14. Q2. How does a mycorrhizal fungus help a plant? — It helps the plant take up water and nutrients (and gets sugar in return).

✓ Unit check (25 min)

1. Give **two** ways a fungus is different from a plant. (2 marks)
2. What is a mycelium? (1 mark)
3. A mushroom is the _____ body of a fungus; it releases _____. (2 marks)
4. Name the three everyday forms of fungi and give one example of each. (3 marks)
5. Explain what decomposers do and why forests need them. (2 marks)
6. Draw a nutrient cycle with at least four labelled stages, including decomposers. (3 marks)
7. Ali tests whether bread goes mouldy faster in a warm place or in a fridge. He puts white bread in the warm place and brown bread in the fridge. Is this a fair test? Explain. (2 marks)
8. In the balloon test, bottle A (yeast, sugar, warm water) blew up its balloon and bottle B (yeast, warm water, no sugar) did not. What does this show? (2 marks)
9. Give one way fungi help people and one way fungi harm people or crops. (2 marks)
10. Your friend finds a mushroom in the park that looks like the ones in the shop and wants to cook it. What would you say, and why? (1 mark)

Total: 20 marks.

Answer guide

1. Any two of: cannot photosynthesise / no chlorophyll; feed by absorbing food (digest outside the body); cell walls made of chitin, not cellulose; body made of hyphae. (1 each)
2. A network of fungal threads (hyphae), usually hidden in soil, wood or food. (1)
3. Fruiting (1); spores (1).
4. Yeast — e.g. baker's yeast; mould — e.g. mould on bread/oranges; mushroom — e.g. button mushroom, toadstool, bracket fungus. (1 per correct form with example)
5. They break down dead material (1) and return nutrients to the soil so new plants can grow; without them dead material would pile up and soil would lose nutrients (1).
6. Award up to 3: plant grows using nutrients from soil; plant/leaf dies or falls; decomposers (fungi/bacteria) break it down; nutrients return to soil. Arrows must form a loop for full marks.
7. No (1). He changed two things — temperature and type of bread — so he can't tell which caused any difference; he should use the same bread in both places (1).
8. Yeast needs sugar (food) to produce gas (1); the gas (carbon dioxide) is evidence yeast is alive / respiring (1).
9. Help: e.g. bread, penicillin, decomposition, mycorrhizae (1). Harm: e.g. food spoilage, crop/tree disease, poisonous mushrooms, allergies (1).
10. Don't eat it — some poisonous mushrooms look like edible ones and can be deadly; only experts can identify them safely (1).

Marking notes: accept clear answers in the student's own words. For question 6, a clear drawing with labels is better than a neat one.

Vocabulary

- antibiotic: a medicine that kills bacteria
- mycorrhiza (plural mycorrhizae): a partnership between a fungus and plant roots
- spoilage: food going bad
- poisonous: can harm or kill if eaten

Differentiation

- Extra support: read the cards aloud; allow the unit check to be answered orally or with a word bank (hyphae, spores, fruiting, decomposer, carbon dioxide, sugar, chitin).
- Extra challenge: research one more fungus (e.g. the fungus used to make a meat substitute, or a fungus that grows on insects) and add a seventh card.

⚠ Safety

- No specimens handled in this lesson. Repeat the rule: never pick or taste wild mushrooms.

Teacher notes

- Misconception: "Antibiotics kill viruses." Answer: they act on bacteria, not viruses such as colds and flu.
- Misconception: "Fleming invented penicillin." Answer: he discovered the mould's effect; other scientists (notably Howard Florey and Ernst Chain's team) later found how to purify and produce it as a medicine.
- Simplification: "Most land plants have mycorrhizal partnerships" is accurate as a general statement; exact percentages vary by source and group of plants.

Grade 6 Arts: One-Point Perspective (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 flat picture can look deep. Artists use clues such as overlap, size and fading colour, and one geometric system, linear perspective, makes parallel lines that go away from us meet at a single vanishing point on the horizon. It is one way of showing space, not the only "correct" one: other times and places chose other ways, often on purpose.

Outcomes

By the end of the unit, students can:

- name and point out at least four depth clues in a picture (overlap, size, height on the page, detail and colour fading with distance);
- find the horizon line (eye level) and the vanishing point in a one-point perspective photograph or drawing, and draw the lines that run to it;
- draw boxes in one-point perspective above, on and below the horizon line, using a ruler and a vanishing point;
- explain in a sentence or two what Brunelleschi and Alberti are known for, and say why historians are unsure about parts of the Brunelleschi story;
- describe one other way of showing space or importance (for example hierarchical proportion or oblique projection) without calling it "wrong";
- plan and draw a one-point perspective scene of their own and explain one choice they made.

Prior knowledge

- From grade 3 (see the colour-mixing unit): tints, shades and value; the idea that colour choices can be explained.
- From grade 2 (see the arts progression): drawing from observation, looking before drawing.
- Using a ruler to draw a straight line between two points. No angle measuring is needed.

Lessons

1. How does a flat picture look deep?: find depth clues in pictures and in the room; meet hierarchical proportion.
2. Horizon line and vanishing point: find eye level, trace a real view through a clear sheet, and see parallel lines meet.
3. Drawing boxes in one-point perspective: draw boxes above, on and below the horizon; turn boxes into letters or buildings.

4. Who worked this out, and who chose differently?: Brunelleschi, Alberti, the "N times further, N times smaller" rule, and other traditions such as Chinese and Japanese oblique projection.
5. My own deep picture: plan and draw a one-point scene, add value and fading for depth, and give kind, specific feedback.

Materials (per pupil unless stated)

- Sharp HB pencil, eraser, 30 cm ruler; A4 or larger drawing paper.
- One sheet of clear acetate or a clear plastic document sleeve (about A4) and a dry-wipe or washable marker (lesson 2). Masking tape.
- Printed photographs with strong one-point perspective (a straight road, railway track, corridor, avenue of trees, tiled floor), one per pair. Use your own photos or openly licensed images and record the credit.
- Printed artworks for lessons 1 and 4, chosen locally; see the teacher notes in lesson 4 for public-domain examples you can look up.
- Optional: coloured pencils or a soft pencil (2B-4B) for shading (lesson 5).

Assessment

- **During the unit:** a depth-clues sheet (lesson 1), the traced view with horizon and vanishing point marked (lesson 2), a page of boxes (lesson 3), a short written comparison (lesson 4) and a finished drawing with a one-sentence explanation (lesson 5). Check them against the outcomes, not for neatness.
- **End check:** the closing check in lesson 5 (8 questions, with answers). There is no pass mark; use it to see who needs another go at finding the vanishing point.
- What to look for in the final drawing: a clear horizon line, receding edges that meet at one vanishing point, and at least one other depth clue. A "realistic" or polished look is not the target.

⚠ Safety (read before lesson 1)

- Rulers are for drawing, not for flicking or sword fights. Keep pencils pointed down when walking.
- If pupils look for the horizon outside or through a window, **never look at the sun**, directly or through the acetate sheet. Face away from it.
- Going outside or into corridors needs your school's normal supervision. Keep pupils out of roads, car parks and stairwells; photograph those views in advance instead.
- Trim or tape any sharp corners on acetate sheets. Use washable markers and wash hands after using them.

Sources

- Wikipedia, "Perspective (graphical)": https://en.wikipedia.org/wiki/Perspective_(graphical) (objects appear smaller as distance increases; an object looks N times smaller if it is moved N times further from the eye; foreshortening; objects recede to points usually along the horizon line; the picture-plane idea; Brunelleschi's experiments between 1415 and 1420 and the peephole-and-mirror demonstration of about 1420 reported by Vasari and Manetti; the problems with that story, including that his panel is lost; Alberti's De pictura (c. 1435)

and its use of similar triangles; Masaccio's Holy Trinity (c. 1427) with the vanishing point at the viewer's eye level, and the finding that many 15th-century works, including that fresco, show serious errors in their geometry; Chinese artists' use of oblique projection from the first or second century until the 18th century and its use in Japanese ukiyo-e by Torii Kiyonaga; earlier art sizing figures by importance).
- Wikipedia, "Vanishing point": https://en.wikipedia.org/wiki/Vanishing_point (parallel lines appear to converge at a vanishing point; when they are perpendicular to the picture plane the construction is called one-point perspective; Alberti introduced the concept in De pictura, 1435; straight railway tracks as a familiar example).
- Wikipedia, "Aerial perspective": https://en.wikipedia.org/wiki/Aerial_perspective (with distance, contrast and detail decrease and colours become less saturated, shifting towards the background colour, usually bluish; atmospheric perspective in Pompeian frescoes as early as 30 BCE).
- Wikipedia, "Hierarchical proportion": https://en.wikipedia.org/wiki/Hierarchical_proportion (unnatural scale used to show the relative importance of figures; in ancient Egypt higher-status people were sometimes shown larger).

Known gaps and cautions

- Linear perspective is taught here because it is a useful drawing tool and links to maths. It is not the measure of good art. Lesson 4 deliberately shows other systems as choices, not mistakes; keep that framing.
- The Brunelleschi story is a famous account, and the cited source lists open problems with it. Teach it as "the story usually told", with the doubts.
- Real views rarely line up perfectly; a vanishing point found on a photo will be approximate. Treat small misses as normal.
- Two- and three-point perspective, curvilinear perspective and the exact maths of spacing (such as how far apart floor tiles should look) are left for later grades or extension work.
- Some pupils find ruler work physically hard (for example with motor difficulties). Allow a partner to hold the ruler, a ruler with a grip, or a freehand "sketch" version judged on the idea, not the straightness.
- Pupils with low vision may need large-print photos and thick markers. A raised-line drawing (for example drawn with glue) lets a pupil feel lines meeting at a point.
- Sources are encyclopedia articles. No educator has reviewed this draft.

Lesson 1: How does a flat picture look deep?

Unit overview · Next: Lesson 2

Goal

Students find and name depth clues in pictures and in the room, and learn that some art uses size to show importance instead of distance.

Materials

- Per pair: one printed photograph of a deep scene (a street, a park, a landscape with hills) and one artwork that does not use linear perspective (for example an ancient Egyptian tomb painting or a medieval manuscript page; pick public-domain images locally).
- Per pupil: a depth-clues sheet with five boxes headed **Overlap**, **Size**, **Height on the page**, **Detail** and **Colour and contrast**.
- Pencils; optional sticky notes.

Steps

✎ Opening (5 min)

Hold up a sheet of paper. Ask: "How thick is this?" (Very thin.) Then show the deep photograph: "So how can a picture on something this thin look like it goes back for kilometres?" Collect ideas on the board without judging them.

✎ Main activity (25 min)

1. **Clue hunt (10 min).** In pairs, pupils look at their photograph and fill the five boxes, each with one example from the picture:
2. **Overlap:** something in front hides part of something behind.
3. **Size:** things of the same real size look smaller when further away.
4. **Height on the page:** in many views, things further away sit higher up the picture, closer to the horizon.
5. **Detail:** you can see bricks or leaves close up, but only blurs far away.
6. **Colour and contrast:** far hills look paler and bluer, with less contrast. This is called **aerial** or **atmospheric perspective**.
7. **Room check (5 min).** Pupils look down the classroom or along a corridor. Hold up a ruler at arm's length to compare the apparent size of a near door and a far door. Which looks bigger? Which is really bigger?
8. **A different idea (10 min).** Pairs now look at the second artwork. Ask: "Who is biggest? Are they nearest, or most important?" Explain that some artists sized figures by **importance**, not distance. This is called **hierarchical proportion**; in ancient Egypt, people of higher status were sometimes shown larger. Pupils add one sentence to their sheet: "In this picture, size shows ____."

✓ Discussion questions (with example answers)

- "Which depth clue was easiest to find? Which was hardest?" Example: overlap is easy because you can see edges; colour fading is hard indoors because there isn't much air between you and things.
- "Is the Egyptian painting a mistake because the king is too big?" Example: no. The artist was showing who mattered most. It is a different goal, not a failed attempt at a photograph.
- "Could a picture use size for importance and for distance?" Example: yes; for instance a poster might make a hero huge in front while the background still gets smaller.

✓ Closing check (5 min, with answers)

1. Name two depth clues. **Any two of: overlap, size, height on the page, detail, colour and contrast (aerial perspective).**
2. Why do far mountains often look pale and bluish? **The air between us and them lowers contrast and detail, and colours shift towards the background colour, usually bluish (aerial or atmospheric perspective).**
3. In hierarchical proportion, what does a bigger figure usually show? **That the figure is more important (for example higher status), not that it is nearer.**
4. True or false: a picture without vanishing points is badly drawn. **False. Many traditions show space or importance in other ways on purpose.**

Vocabulary

depth clue, overlap, aerial (atmospheric) perspective, contrast, detail, hierarchical proportion

Differentiation

- **Support:** give pupils picture cut-outs of each clue to match to the five boxes instead of writing; accept pointing and saying.
- **Stretch:** find a picture where two clues disagree (for example something high on the page that is clearly near, like a bird or a ceiling lamp) and explain why the "height on the page" clue fails there.

⚠ Safety

- If pupils walk into the corridor, follow your school's normal rules for moving around the building.

Teacher notes and misconceptions

- "Height on the page" works for things on the ground below eye level. Things above eye level (ceilings, birds, clouds) do the reverse: they get lower as they recede towards the horizon. Lesson 2 explains why.
- Aerial perspective needs a lot of air: hills, cities in haze, long valleys. Indoors it is hard to see; use photographs.

- Some pupils will say the Egyptian or medieval picture "looks wrong". Use it as a chance to separate "different from a photo" from "wrong". The source for this unit notes early art often sized figures by importance and did not use foreshortening.

Lesson 2: Horizon line and vanishing point

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

Goal

Students find the horizon line (eye level) and the vanishing point in a real view and in a photograph, and see that parallel lines going straight away from us appear to meet at one point.

Materials

- Per pupil: a clear acetate sheet or plastic document sleeve (corners taped) and a washable marker.
- Per pair: a printed one-point photograph (road, railway, corridor, tiled floor) and a ruler.
- A view with long straight parallel edges: a corridor, a long table, rows of desks, floor tiles or a path seen from one end.
- Masking tape; a chair to rest elbows on, or a window sill.

Steps

✎ Opening (5 min)

Show a photograph of straight railway tracks or a long straight road. Ask: "Do the two rails really get closer together?" (No: if they did, the train would fall off.) "So why do they look like they meet?" Tell pupils that today they will find exactly where they seem to meet.

✎ Main activity (25 min)

1. **Find your eye level (5 min).** Pupils stand and look straight ahead across the room, not up or down. Ask each one to point at a spot on the far wall that is level with their eyes. Then they sit and do it again. The spot moves down. Explain: in a drawing, the **horizon line** is a line that stands for the viewer's **eye level**. Outdoors on flat ground or at sea it is where land or sea seems to meet the sky; indoors it is hidden by walls, but it is still at your eye level.
2. **Trace a real view (12 min).** Pupils hold or tape the clear sheet upright in front of them (on a window, or resting on a chair back) and close one eye. Keeping the head still, they trace the main straight edges of the view with the marker: the sides of a corridor, the edges of a table, the lines between floor tiles. Then they draw a level line across the sheet at their eye level.
3. Remind them: one eye closed and head still, or the lines will jump.
4. This is a classroom version of the idea in the source: an imaginary flat **picture plane** facing the viewer, where lines from the scene to the eye pass through it.
5. **Extend the lines (8 min).** Lay the sheet flat. With a ruler, pupils extend the traced edges that run away from them. Where do they cross? Mark the crossing with a dot and label it **vanishing point (VP)**. Check: is the dot on or near the eye-level line? Then repeat quickly on the printed photograph with a ruler.

✓ Discussion questions (with example answers)

- "Did all your lines meet at exactly one point?" Example: nearly, but not perfectly, because my head moved a bit and real walls aren't perfectly straight. Close is good enough.
- "Which lines did not go to the vanishing point?" Example: the upright door edges stayed vertical and the top edge of the whiteboard stayed level. Only lines going straight away from me went to the point.
- "The floor lines went up to the horizon. Which way did the ceiling lines go?" Example: down. Things below eye level angle up to the horizon line; things above it slope down.

✓ Closing check (5 min, with answers)

1. What does the horizon line stand for in a drawing? **The viewer's eye level.**
2. What is a vanishing point? **The point where parallel lines going away from the viewer appear to meet.**
3. In one-point perspective, which lines go to the vanishing point? **The lines going straight away from the viewer. Vertical lines stay vertical and lines running straight across stay horizontal.**
4. You sit down. Does the horizon line in your view move up or down? **Down, because your eye level is lower.**

Vocabulary

horizon line, eye level, vanishing point, parallel, picture plane, one-point perspective

Differentiation

- **Support:** give a photograph with two long edges already highlighted in colour; the pupil only extends those two lines to find where they cross.
- **Stretch:** find a photograph where the vanishing point is not in the middle (for example a road curving to one side or a corridor seen from near one wall). What changed? Try a view from lying on the floor or standing on a low step (with supervision): where is the horizon now?

⚠ Safety

- If tracing through a window, face away from the sun and never look at the sun through the sheet.
- Standing on steps only on a stable, school-approved step with an adult nearby; never on chairs or tables.
- Keep doorways and corridors clear for others while tracing.

Teacher notes and misconceptions

- **"The horizon is where the sky is."** Not quite: in a drawing it stands for eye level. In a mountain photo the land may hide it; in a room the walls do. The source for this lesson describes the horizon line as a line representing the observer's eye level.
- **"Everything goes to the vanishing point."** In one-point perspective only the set of lines running straight away from you does. Verticals stay vertical and the widths facing you stay horizontal. Lesson 3 uses this.
- Many pupils draw the horizon at the top of the page out of habit. Ask: "Where were your eyes?"
- Railway tracks are the classic example in the source. Use a photograph; never take pupils near real tracks.

Lesson 3: Drawing boxes in one-point perspective

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

Goal

Students use a horizon line, one vanishing point and a ruler to draw boxes above, on and below eye level, then turn boxes into letters or buildings.

Materials

- Per pupil: A4 or A3 paper (landscape), sharp HB pencil, eraser, 30 cm ruler.
- Optional: a sheet with a horizon line and VP already printed, for support.
- A board demonstration (or a visualiser/document camera).

Steps

✎ Opening (5 min)

Draw a plain square on the board. Ask: "Is this a box or a square?" Then add three lines to its corners running to a dot. "Now?" Most pupils will see a box. Today they learn the steps so the box always looks right.

✎ Main activity (25 min)

Demonstrate each step on the board, then pupils copy it. Draw lightly: some lines will be rubbed out.

1. **Set up.** Draw a horizontal **horizon line** across the middle of the page. Put one dot on it near the centre: the **vanishing point (VP)**.
2. **Front face.** Below the horizon and to the left, draw a rectangle with the ruler: two horizontal sides, two vertical sides. This is the side of the box facing you, so it is drawn flat, with no slant.
3. **Lines to the VP.** From each corner of the rectangle, draw a light line to the VP. (Pupils can skip any corner whose line would pass through the front face, because that edge is hidden.)
4. **Back edges.** Decide how deep the box is. Somewhere along those lines, draw the back edge: a **horizontal** line for the back top edge and a **vertical** line for the back side edge, each stopping where it meets the lines to the VP. Back edges are parallel to the front edges.
5. **Clean up.** Rub out the parts of the lines beyond the back edges. Darken the box outline. Shade the top or side lightly so it reads as solid.
6. **Three positions.** Draw two more boxes: one above the horizon (you see its underside) and one on the horizon, to one side of the VP (you see neither top nor bottom). Compare what is visible in each.

7. **Make it yours (remaining time).** Turn a box into a block letter (the first letter of your name), a building with doors and windows, or a row of boxes getting further away down a street. Windows on the front face stay rectangles; windows on a side face have top and bottom edges that run to the VP.

✓ Discussion questions (with example answers)

- "Why can you see the top of a box below the horizon but not one above it?" Example: the horizon is my eye level. If the box is lower than my eyes I look down onto it; if it is higher I look up at its underside.
- "Why are the back edges drawn horizontal and vertical, not slanted?" Example: they are parallel to the front edges, which face me. Only edges going away from me slant to the VP.
- "What happens if two boxes on the same page use different VPs?" Example: the picture looks broken, as if seen from two places at once, unless the boxes are turned at different angles on purpose.

✓ Closing check (5 min, with answers)

1. In one-point perspective, how is the front face of a box drawn? **As a flat rectangle (or square) with horizontal and vertical sides, no slant.**
2. Where do the receding edges of the box go? **To the vanishing point on the horizon line.**
3. A box floats above the horizon line. Which face can you see besides the front? **The bottom (underside), plus a side face if it is to the left or right of the VP.**
4. A box sits exactly on the horizon line, to the right of the VP. Which faces can you see? **The front and the left side. Neither the top nor the bottom.**

Vocabulary

front face, receding lines (orthogonals), back edge, horizon line, vanishing point, construction lines

Differentiation

- **Support:** a sheet with the horizon, VP and three front rectangles already printed; the pupil draws only the lines to the VP and the back edges. A partner may hold the ruler.
- **Stretch:** draw a row of identical fence posts or lamp posts going away from you, each smaller than the last, using two lines to the VP from the top and bottom of the first post to keep the tops and bottoms in line. Or draw a box with a hollow inside (an open crate).

⚠ Safety

- Rulers are drawing tools; no flicking or swinging. Pencils point down when walking to the sharpener.

Teacher notes and misconceptions

- **Slanting the front face.** Pupils often tilt the front rectangle as if it were receding. Remind them: the face that looks straight at you is drawn flat.
- **Back edge drawn to the VP.** If a back edge slants, the box will look twisted. Back edges are always parallel to front edges in one-point.
- **Boxes that look too long.** If a box is drawn very deep, or far from the VP, it can look stretched. That is a real limit of the method near the edges of a picture; keep boxes reasonably close to the VP for now.
- The receding lines are often called **orthogonals** in art teaching. The word is optional; "lines to the VP" works.
- Keep construction lines light. Pupils who press hard will struggle to rub them out; show them the difference before starting.

Lesson 4: Who worked this out, and who chose differently?

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

Goal

Students test the rule that something looks N times smaller when it is N times further away, hear the usual story of Brunelleschi and Alberti along with its doubts, and compare linear perspective with other ways artists have shown space.

Materials

- Per group of 3: an A4 sheet of card (29.7 cm tall), a ruler, a metre stick or tape measure, masking tape to mark distances on the floor.
- Printed images, one set per group (see teacher notes for what to look up): a 15th-century Italian painting using linear perspective; a Chinese or Japanese picture using oblique projection; an ancient Egyptian painting using hierarchical proportion.
- A comparison sheet with three columns: **How is space shown?**, **What do you notice first?**, **What might the artist have wanted?**

Steps

✎ Opening (5 min)

Tell the story usually told, in about two minutes:

> In Florence, between about 1415 and 1420, the architect Filippo Brunelleschi is said to have made careful perspective pictures of buildings. In one famous demonstration, a viewer looked through a small hole in the back of his painting of the Baptistery, at a mirror held up in front, and could compare the reflected painting with the real building. About 1435 his friend Leon Battista Alberti wrote a book, De pictura (On Painting), explaining how to show distance, and introduced the idea of the vanishing point.

Then add: "Historians are not sure all of this happened as told. Why might that be?" Collect ideas, then give the reasons from the source: the painting is lost; no other perspective picture by Brunelleschi is known; the main written account comes from decades later and never uses the word "experiment"; and some details in it contradict each other.

✎ Main activity (25 min)

1. **Test the size rule (12 min).** One pupil holds the A4 card upright at chest height. A second stands 2 m away, holds a ruler at arm's length, closes one eye and measures how tall the card looks on the ruler. A third records. Repeat at 4 m and 8 m, keeping the same arm straight each time. Groups compare: what happened to the measurement each time the distance doubled? (It roughly halved.) Explain: the source states that an

object looks N times smaller if it is moved N times further from the eye. Alberti worked out apparent sizes with **similar triangles**, a piece of geometry pupils will meet in maths.

2. **Compare three pictures (13 min).** Groups fill one row of the comparison sheet for each image:
3. **Linear perspective** (the Italian painting): lines run to a vanishing point; we see one moment from one spot.
4. **Oblique projection** (the Chinese or Japanese picture): receding edges stay parallel and do not meet, so things far back are not shrunk. Chinese artists used this from about the first or second century until the 18th century, and it appears in Japanese ukiyo-e prints, for example by Torii Kiyonaga (1752-1815).
5. **Hierarchical proportion** (the Egyptian painting): size shows importance. Finish with one sentence: "One thing oblique projection or hierarchical proportion can do that one-point perspective can't is ____."

✓ Discussion questions (with example answers)

- "Did your measurements halve exactly?" Example: not exactly, because arms wobble and it's hard to read a ruler that far away, but close. Real measurements always have some error.
- "Masaccio's Holy Trinity (about 1427) puts the vanishing point at the viewer's eye level. Experts have still found errors in its geometry. Does that make it a worse painting?" Example: no. It still looks deep and people have admired it for centuries. "Correct geometry" and "a good painting" are different questions.
- "Why might a long scroll painting avoid a single vanishing point?" Example: you look at it bit by bit as you unroll it, so there isn't one place to stand. Parallel lines let every part of it be seen the same way. (This is a reasonable idea to discuss, not a fact from the source.)

✓ Closing check (5 min, with answers)

1. A tree looks 6 cm tall on your ruler. You walk back until you are three times as far away. About how tall does it look now? **About 2 cm (three times smaller).**
2. What book did Alberti write, and about when? **De pictura (On Painting), about 1435.**
3. Give one reason historians are unsure about the Brunelleschi story. **Any one of: his panel is lost; no other perspective picture by him is known; the main account was written decades later and doesn't call it an experiment; details in the account contradict each other.**
4. In oblique projection, do receding lines meet at a vanishing point? **No. They stay parallel.**

Vocabulary

linear perspective, oblique projection, hierarchical proportion, similar triangles, treatise, Renaissance

Differentiation

- **Support:** for the size test, give a recording table with the distances already filled in, and accept "smaller, then smaller again" before numbers. For the comparison, give sentence starters.
- **Stretch:** plot the group's three measurements against distance. What would you predict at 16 m? Or: find out what "foreshortening" means (an object's depth along the line of sight looks shorter than its width facing you) and find an example in one of the pictures.

⚠ Safety

- Mark distances with tape in a clear space indoors or on a playground; keep away from doorways and traffic routes.
- Measuring with one eye closed while walking is a trip risk: stand still to measure, walk with both eyes open.

Teacher notes and misconceptions

- **What to look up.** These works are centuries old and in the public domain, but photographs of them carry different licences, so check and record the credit of the image you print: Masaccio, Holy Trinity (about 1427); a painting by Piero della Francesca (the source calls his paintings a model of the genre); a print by Torii Kiyonaga; an ancient Egyptian tomb painting. Local galleries and museum websites with open-access images are a good place to look.
- **"Brunelleschi invented perspective."** Earlier artists already showed far things smaller; the source describes ancient Greek stage scenery (skenographia), Euclid's Optics (about 300 BC), and Roman frescoes using several vanishing points "in a systematic but not fully consistent manner". The Florentine contribution was a consistent geometric system. Alberti was trained in optics under the influence of a scholar who studied Alhazen's Book of Optics, translated into Latin around 1200.
- **"Other traditions didn't know how."** Avoid this. The source says medieval European, Islamic and Chinese artists knew far things look smaller but were ready to override it for other reasons. Present systems as choices.
- The size rule uses the apparent height on a ruler at a fixed arm's length. Numbers will differ between pupils (arm lengths differ); the halving pattern is the point.

Lesson 5: My own deep picture

Unit overview · Previous: Lesson 4

Goal

Students plan and draw a scene of their own in one-point perspective, add at least one other depth clue, explain one choice, and give kind, specific feedback in a gallery walk.

Materials

- Per pupil: A3 or A4 drawing paper, HB pencil, eraser, ruler; a soft pencil (2B-4B) or coloured pencils for shading.
- Pupils' lesson 1-3 work for reference; the printed photographs from lesson 2.
- Sticky notes for feedback; a sentence-starter card: "I notice you used ___ and it makes ___."

Steps

✎ Opening (5 min)

Show two or three quick ideas on the board: a corridor of doors, a street of box buildings, a tunnel or bridge, a room seen from the doorway, a made-up place (a library of giant books, a city for ants). Rules for the picture:

- one horizon line and one vanishing point;
- at least three objects drawn in one-point perspective;
- at least one **other** depth clue from lesson 1 (overlap, size, detail, or lighter, lower-contrast tones for far things).

✎ Main activity (25 min, plus time in a following session if needed)

1. **Plan (5 min).** Pupils make a small thumbnail sketch (about the size of a playing card). Decide where to put the horizon: low (looking up, things feel tall), middle, or high (looking down, like a bird). Mark the VP.
2. **Construct (10 min).** On the big sheet, draw the horizon and VP lightly, then the main boxes or walls using the lesson 3 steps. Keep construction lines light.
3. **Add depth and value (10 min).** Rub out unneeded lines. Shade one side of each object to show where the light comes from (the grade 3 idea of value). Make near things darker and more detailed, far things lighter and simpler.
4. **Explain (in the last 2 minutes).** On the back, pupils write one sentence: "I put my horizon ___ because ___."

Gallery walk and feedback (5-10 min)

Drawings go on desks. Pupils walk round and leave one sticky note on two drawings, using the sentence starter. Feedback must name something in the picture (for example "I notice you made

the far windows lighter and it makes the street look long"). No "it's bad" or "it's good" without a reason.

✓ Discussion questions (with example answers)

- "Where did people put their horizons, and how does that change the feel?" Example: a low horizon makes buildings tower over you; a high one makes it feel like looking down from a window.
- "Did anyone break a rule on purpose? Did it work?" Example: someone drew a giant character on purpose to look important, like hierarchical proportion. It works if it is clearly a choice.
- "What was hardest?" Example: keeping all the lines going to one point, and stopping back edges in the right place.

✓ End-of-unit check (8 questions, with answers)

1. Name three depth clues an artist can use. **Any three of: overlap, size (far things smaller), height on the page, detail, colour and contrast fading (aerial or atmospheric perspective), linear perspective.**
2. What does the horizon line stand for? **The viewer's eye level.**
3. What is a vanishing point? **The point where parallel lines going straight away from the viewer appear to meet.**
4. In one-point perspective, which edges of a box are drawn exactly horizontal or vertical? **The edges of the front face and the back edges (all edges facing the viewer). Only edges going away from the viewer run to the vanishing point.**
5. A box is below the horizon. Can you see its top or its bottom? **Its top.**
6. A lamp post looks 9 cm tall on your ruler. You move to three times the distance. About how tall does it look now? **About 3 cm.**
7. Who wrote De pictura about 1435, and what idea did it introduce? **Leon Battista Alberti; it introduced the vanishing point and explained how to show distance in painting (using similar triangles).**
8. A classmate says ancient Egyptian painters "couldn't draw perspective". Give a better explanation. **They often used hierarchical proportion on purpose, making important people larger. It shows importance, not distance; it is a different choice, not a failure.**

Vocabulary

thumbnail sketch, composition, horizon line, vanishing point, value, feedback

Differentiation

- **Support:** start from a sheet with the horizon, VP and one box already drawn, and add two more objects. A partner may hold the ruler. Accept a verbal explanation instead of the written sentence.
- **Stretch:** add a second set of objects that are turned at an angle (a hint of two-point perspective, with two VPs on the same horizon), or draw a reflection in a puddle or tiled

floor. Or draw the same scene twice, once in one-point perspective and once in oblique projection, and write which you prefer and why.

⚠ Safety

- Rulers and pencils as in earlier lessons. During the gallery walk, walk, don't run; touch only your own work and the sticky notes.

Teacher notes and misconceptions

- Assess against the three rules, the explanation and the feedback, not realism or neatness. A messy drawing with one clear VP and a sensible horizon meets the goal.
- **Several VPs by accident.** Ask the pupil to put a ruler on two receding lines and see where they meet. If they meet in different places, choose one VP and redraw lines to it.
- **Everything shrinks to a dot.** Some pupils make all objects end at the VP. Remind them the back edge stops the box; only construction lines reach the VP.
- Keep the feedback kind and specific; the same sentence starter is used in the grade 3 colour unit, so many pupils will know it.
- Pupils who want to share drawings outside the class should credit any photograph they copied from and follow school rules on displaying work.

Binary, Pixels, Logic Gates, and Packet Switching

Subject: Computing Grade: 6 Lessons: 5 Time per lesson: 50 minutes Status: written Author: Gemini 4 Argon

Navigation: Repository Home | Computing Progression

Big idea

Computers store every number, letter, and image using physical two-state switches (`0` and `1`), combine those switches with simple rules (`AND`, `OR`, `NOT`) to make decisions, and send data across networks by splitting messages into numbered packets that can be checked for errors.

What students should be able to do

- Convert whole numbers between `0` and `255` to and from 8-bit binary using repeated-doubling place-value cards (`128, 64, 32, 16, 8, 4, 2, 1`), and explain why adding one more card doubles the total number of patterns.
- Encode and decode short words using a 7-bit/8-bit ASCII lookup table and encode/decode a `8 × 8` bitmap icon, calculating the unit rate in **bits per pixel** and the image's **width-to-height ratio**.
- Complete truth tables for `NOT`, `AND`, and `OR` gates and trace the output of a 2-gate combination circuit for all four possible input pairs.
- Simulate routing a multi-packet message across a 6-node network with a broken link, reassemble out-of-order packets using sequence headers, calculate delivery unit rates (**packets per second** and **bits per second**), and detect a single flipped bit using an **even parity bit**.

What students should already know

- Whole-number addition and subtraction up to `300`, and multiplication/division by `2`.
- Base-10 place value (`ones, tens, hundreds`).
- **No exponent notation (`2^n`) is required.** Lesson 1 builds binary place values directly through repeated doubling (`1, 2, 4, 8, 16, 32, 64, 128`).
- Basic ratio and unit-rate language (such as `3 : 2` or `bits per pixel`), reinforced alongside Grade 6 Mathematics (`units/mathematics/6-ratios/`).

Lesson list

1. Lesson 1: Counting with Switches — Repeated Doubling and 8-Bit Binary: Build a set of 8 doubling dot-cards (`1` through `128`) to represent any number from `0` to `255` using only `ON (1)` and `OFF (0)`.
2. Lesson 2: Letters and Pictures in Bits — ASCII Text and Bitmap Pixels: Decode secret binary text messages and design `8 × 8` 1-bit and 2-bit pixel art while comparing storage unit rates (`bits per character` and `bits per pixel`).

3. Lesson 3: Making Decisions with Switches — NOT, AND, and OR Logic Gates: Model series and parallel switches with human circuit paths and truth tables to design a 3-sensor greenhouse/terrarium alarm rule.
4. Lesson 4: Postcards on the Wire — Packet Switching, Routing, and Throughput Rates: Break a message into numbered 64-bit packets, route around a failed node on a classroom network map, and compute network unit rates (`packets per second` and `bits per second`).
5. Lesson 5: Catching Flipped Bits — Noise, Even Parity Checks, and End-of-Unit Assessment: Add a 9th parity bit to catch single-bit transmission errors, test where 1-bit parity fails, and complete the 5-part unit assessment.

Materials (whole unit)

- **Index cards or half-sheets of paper** (8 cards per student pair for Lesson 1 binary dot-cards; 6 cards per group for Lesson 4 packet postcards).
- **Grid paper (`8 × 8` squares)** or printed `8 × 8` blank grids for Lesson 2 bitmap pixel design.
- **Pencils, markers, and large two-sided paper cards or tokens** (or written/pointed `0`/`1` table charts as an alternative to handling small objects) for flipping bits in Lesson 5.
- **No computers, batteries, or internet connection required** (100% unplugged classroom-ready; optional browser verification extensions noted in Teacher Notes).

Assessment

Each lesson includes 8 worked/practice tasks with complete step-by-step answers (40 lesson tasks total). Lesson 5 concludes with a **20-point End-of-Unit Synthesis Assessment** (5 multi-part problems covering binary conversion, pixel bit-rate ratios, a 2-gate truth table, packet routing/throughput, and even-parity error detection) with a full scoring rubric and worked answer key.

Sources

- Bell, T., Witten, I. H., & Fellows, M. (2015). CS Unplugged: An enrichment and extension programme for primary-aged students (openly licensed CC BY-NC-SA reference for dot-card and parity unplugged pedagogy; all text, numbers, diagrams, and problems in this unit are newly written from scratch under CC0): https://www.csunplugged.org/
- American National Standards Institute (1968/1986). ANSI X3.4 — Coded Character Sets — 7-Bit American National Standard Code for Information Interchange (7-Bit ASCII) (public-domain numerical mapping of standard printable characters `32–126`): https://www.rfc-editor.org/rfc/rfc20
- Postel, J. (Ed.) (1981). RFC 791 — Internet Protocol: DARPA Internet Program Protocol Specification (public-domain specification of packet headers, addressing, and datagram routing): https://www.rfc-editor.org/rfc/rfc791

Known gaps and cautions

- **Unreviewed AI draft:** This unit has not yet been reviewed by a human classroom teacher or tested with Grade 6 students.
- **Simplifications stated explicitly for students:**
- Lesson 2 uses standard 7-bit/8-bit ASCII for English letters (`A–Z`, `a–z`) and notes explicitly that modern software uses **UTF-8 / Unicode** so scripts and emoji from all languages can be represented.

- Lesson 4 models packet headers with three fields (`From`, `To`, `Packet # of Total`) rather than a full 20-byte IPv4 / TCP header.
- Lesson 5 introduces **single-bit even parity** and explicitly shows students why two simultaneous bit flips inside the same byte go undetected, motivating stronger checksums (like CRC and cryptographic hashes) in later grades.

Lesson 1: Counting with Switches — Repeated Doubling and 8-Bit Binary

Time: 50 minutes

Unit: Binary, Pixels, Logic Gates, and Packet Switching | **Next:** Lesson 2: Letters and Pictures in Bits

Goal

Convert whole numbers between `0` and `255` to and from 8-bit binary using repeated-doubling place-value cards (`128, 64, 32, 16, 8, 4, 2, 1`), and explain why adding one more card doubles the number of possible patterns.

Materials

- 8 index cards (or half-sheets of paper) per pair of students.
- Thick dark marker for drawing dots/numbers on one side of each card.
- Chalkboard or whiteboard for class place-value comparison.

Steps

✎ 1. Opening (5 min): Why Only Two States?

Hold up a classroom light switch (or draw a simple switch on the board). Ask: - "In everyday base-10 arithmetic, each digit slot can hold 10 different symbols (*`0`* through *`9`*). Why doesn't a computer wire use 10 different voltage levels (*`0V, 1V, 2V, ..., 9V`*) for each digit?" - Guide students to notice that electrical wires experience tiny fluctuations (heat, static, long cables). Distinguishing `10` close voltage levels is fragile, whereas distinguishing **two clearly separated states** — `OFF (0)` vs. `ON (1)` (or dark vs. bright, unmagnetized vs. magnetized) — is fast and reliable.

✎ 2. Main Activity Part A (15 min): Building the 8 Doubling Cards

Have each student pair make a row of 5 cards first, arranged **right to left** just like base-10 place value: 1. On the rightmost card, write **`1`** and draw `1` dot. 2. Move one slot left: **double** the previous card to write **`2`** (`2` dots). 3. Move one slot left: **double** `2` to write **`4`** (`4` dots). 4. Move one slot left: **double** `4` to write **`8`** (`8` dots). 5. Move one slot left: **double** `8` to write **`16`** (`16` dots).

Now extend the row to a full **byte (8 bits)** by doubling three more times to the left: **`32`**, **`64`**, and **`128`**:

Bit slot (left to right)	Card 8	Card 7	Card 6	Card 5	Card 4	Card 3	Card 2	Card 1
Place value (doubling right to left)	128	64	32	16	8	4	2	1

Explain the rule: - Face-up (`ON`) = **`1`** (add this card's value to your total). - Face-down (`OFF`) = **`0`** (do not add this card's value).

✎ Worked Example 1: Binary to Base-10 (`00101101`)

Suppose the 8 cards read `0 0 1 0 1 1 0 1`:

Card value	128	64	32	16	8	4	2	1
Bit (1 = ON, 0 = OFF)	0	0	1	0	1	1	0	1

Add only the cards switched `ON (1)`: `32 + 8 + 4 + 1 = 45`.

✎ Worked Example 2: Base-10 to 8-Bit Binary (`100`)

To build a target number like **`100`**, always work **from left (`128`) to right (`1`)** using the greedy subtraction check: 1. Does `128` fit into `100`? No (`128 > 100`) → write **`0`**, remainder is still `100`. 2. Does `64` fit into `100`? Yes (`64 <= 100`) → write **`1`**, subtract `100 - 64 = 36` remaining. 3. Does `32` fit into `36`? Yes (`32 <= 36`) → write **`1`**, subtract `36 - 32 = 4` remaining. 4. Does `16` fit into `4`? No → write **`0`**. 5. Does `8` fit into `4`? No → write **`0`**. 6. Does `4` fit into `4`? Yes (`4 <= 4`) → write **`1`**, subtract `4 - 4 = 0` remaining. 7. Does `2` fit into `0`? No → write **`0`**. 8. Does `1` fit into `0`? No → write **`0`**. Result: **`01100100`** (`64 + 32 + 4 = 100`).

✓ 3. Discussion Questions (10 min)

- **Question A:** "Look at the sum of all cards to the right of *`16`*: *`8 + 4 + 2 + 1 = 15`*. Look at all cards to the right of *`64`*: *`32 + 16 + 8 + 4 + 2 + 1 = 63`*. What pattern do you notice?"
- Example good answer: Every card is always **`1`** **more** than the sum of all smaller cards to its right! That means if your remaining target is `64` or more, you must turn on the `64` card because all smaller cards combined only reach `63`. This guarantees every whole number from `0` to `255` has **one and only one** 8-bit binary pattern.
- **Question B:** "How can you tell in one second whether an 8-bit binary number is odd or even?"
- Example good answer: Look only at the rightmost card (`1`). Every other card (`128`, `64`, `32`, `16`, `8`, `4`, `2`) is an even number, so the sum is odd if and only if the `1` bit is `1`.

✓ 4. Student Practice & Closing Check (20 min)

✎ Practice Tasks (1.1 – 1.8)

1. **Task 1.1:** Convert the 8-bit binary number `00010110` to a base-10 number.
2. **Task 1.2:** Convert the 8-bit binary number `10000101` to a base-10 number.
3. **Task 1.3:** Convert the 8-bit binary number `11111111` (all 8 cards turned ON) to a base-10 number.
4. **Task 1.4:** Write the base-10 number **`19`** in 8-bit binary.
5. **Task 1.5:** Write the base-10 number **`75`** in 8-bit binary.

6. **Task 1.6:** Write the base-10 number **200** in 8-bit binary.
7. **Task 1.7 (Pattern Reasoning):** Without converting both numbers to base-10 first, what happens to the value of `00001101` (`13`) when you shift every bit one slot to the left and put a `0` on the right (`00011010`)? Explain why.
8. **Task 1.8 (Capacity & Doubling):** A 4-bit system can represent `16` different numbers (`0` through `15`). How many different numbers can a 5-bit system represent, and what is the largest number it can hold?

Complete Answer Key (Tasks 1.1 – 1.8)

- **Answer 1.1:** `16 + 4 + 2 = 22`.
- **Answer 1.2:** `128 + 4 + 1 = 133`.
- **Answer 1.3:** `128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255` (which is `1` less than the next doubling value, `256`).
- **Answer 1.4:** `19 = 16 + 2 + 1` → **`00010011`**.
- **Answer 1.5:** `75 = 64 + 8 + 2 + 1` → **`01001011`**.
- **Answer 1.6:** `200 = 128 + 64 + 8` → **`11001000`**.
- **Answer 1.7:** Shifting left by one slot **doubles** the number from `13` (`8 + 4 + 1`) to `26` (`16 + 8 + 2`), because every ON bit moves to a card worth twice as much (just as appending a `0` in base-10 multiplies by `10`).
- **Answer 1.8:** Adding a 5th bit (the `16` card) **doubles** the number of patterns from `16` to **`32` different numbers** (`16` patterns with the `16`-card OFF, plus `16` patterns with the `16`-card ON). Because `0` uses one pattern, the range is `0` through **`31`** (`16 + 8 + 4 + 2 + 1 = 31`).

Vocabulary

- **bit (binary digit):** A single two-state switch or symbol that can be either `0` (`OFF`) or `1` (`ON`).
- **byte:** A group of `8` bits treated as a single unit, capable of representing `256` distinct patterns (`0` through `255`).
- **place value:** The numerical value assigned to a digit slot based on its position (`1, 2, 4, 8, 16, 32, 64, 128` from right to left in binary).

Differentiation

- **Extra support:** Start with only the 4 rightmost cards (`8, 4, 2, 1`) with pre-drawn dots (or large paper tokens, pointing, or verbal counting rather than small loose objects) so students can count the dots on each card directly before flipping cards face-up or face-down to build `1` through `15`.
- **Extra challenge:** Ask students how a computer could represent **negative numbers** or **fractions** using 8 bits, or challenge them to add two 8-bit binary numbers (`00010110 + 00001011`) column by column using the carry rule `1 + 1 = 2` (write `0`, carry `1` to the next doubled slot).

⚠ Safety

No physical hazards in this unplugged lesson.

Teacher notes

- **Common misconception 1 (Reading left-to-right vs. right-to-left):** Some students place `1` on the far left and `128` on the far right. Remind them that binary uses the exact same convention as base-10: the **smallest place value (`1`) is always on the far right**, and values grow larger as you move left.
- **Common misconception 2 (Forgetting that `00000000` counts as a pattern):** Students often ask why 8 bits (`256` patterns) maxes out at `255` instead of `256`. Point out that in base-10, two digits give `100` patterns (`00` through `99`), not `100`!

Lesson 2: Letters and Pictures in Bits — ASCII Text and Bitmap Pixels

Time: 50 minutes

Unit: Binary, Pixels, Logic Gates, and Packet Switching | **Previous:** Lesson 1 | **Next:** Lesson 3

Goal

Encode and decode text using an 8-bit ASCII lookup table, represent `8 × 8` images as 1-bit and 2-bit bitmaps, and calculate storage unit rates in **bits per character** and **bits per pixel**.

Materials

- Lesson 1 binary place-value cards (`128, 64, 32, 16, 8, 4, 2, 1`).
- Printed or board-drawn `8 × 8` blank pixel grids (2 grids per student).
- Colored pencils or shading styles (blank, light crosshatch, dark diagonal, solid black) for 2-bit palettes.

Steps

✎ 1. Opening (5 min): If Computers Only Store `0` and `1`, Where Are the Letters?

Write the byte `01001000` on the board. Ask: - "In Lesson 1, we decoded *`01001000`* as the number *`64 + 8 = 72`*. How can a text-messaging app use that exact same byte to display a capital letter instead of the number *`72`*?" - Introduce the idea of a **shared codebook (standard encoding)**: if every keyboard and screen agrees on which number stands for which letter, then storing numbers is enough to store words.

✎ 2. Main Activity Part A (15 min): Decoding and Encoding ASCII Text

Show the class how uppercase English letters are mapped in standard **ASCII** (American Standard Code for Information Interchange):

Character	Base-10 Code	8-Bit Binary	Character	Base-10 Code	8-Bit Binary
(space)	32	00100000	A	65	01000001
!	33	00100001	B	66	01000010
0 (digit)	48	00110000	C	67	01000011
1 (digit)	49	00110001	...	...	...
?	63	00111111	Z	90	01011010

Point out two helpful patterns: 1. Capital **`A` is `65` (`01000001`)**, so the `n`-th letter of the alphabet has code **`64 + n`**! Since `64` is the `01000000` bit, the last 5 bits directly tell you the letter's

position (1 to 26) in the alphabet. 2. Lowercase **a is 97 (01100001)**, which is 65 + 32 — toggling just the 32-bit switches any letter between uppercase and lowercase!

✎ Worked Example 1: Decoding a 3-Byte Word

Decode 01000011 01000001 01010100: - Byte 1 (01000011): 64 + 2 + 1 = 67 (3rd letter) → **C** - Byte 2 (01000001): 64 + 1 = 65 (1st letter) → **A** - Byte 3 (01010100): 64 + 16 + 4 = 84 (20th letter) → **T** Word: **CAT** (3 characters × 8 bits per character = 24 bits).

✎ 3. Main Activity Part B (15 min): Bitmap Grids and Bits-per-Pixel Ratios

Now ask: "How do we turn a grid of tiny squares (**pixels**) into *0*s and *1*s?" - **1-Bit Monochrome (1 bit per pixel):** Each square uses 1 bit: 0 = white (unshaded), 1 = black (shaded). - Example 8 × 8 icon (64 pixels total at 1 bit per pixel = 64 bits = 8 bytes of **raw uncompressed pixel data**, excluding any file headers or metadata): - Row 1: 00111100 - Row 2: 01000010 - Row 3: 10100101 - Row 4: 10000001 - Row 5: 10100101 - Row 6: 10011001 - Row 7: 01000010 - Row 8: 00111100 (Students shade the *1*s on their *8 × 8* grid to reveal a smiling face!) - **2-Bit Four-Color Palette (2 bits per pixel):** What if we want **4 colors** (like an early handheld game console: 00 = White, 01 = Light Gray, 10 = Dark Gray, 11 = Black)? - Each pixel now requires **2 bits**, so the unit rate doubles from 1 bit per pixel to **2 bits per pixel**. - For the same 8 × 8 (64-pixel) grid, raw pixel storage doubles from 64 bits (8 bytes) to **128 bits (16 bytes)** (excluding any metadata or compression).

4. Discussion & Student Practice (15 min)

✎ Practice Tasks (2.1 – 2.8)

1. **Task 2.1:** Using A = 65, find the base-10 ASCII code and 8-bit binary byte for uppercase **E** (the 5th letter) and **M** (the 13th letter).
2. **Task 2.2:** Decode the 4-byte ASCII message: 01000100 01000001 01010100 01000001.
3. **Task 2.3:** Look at the ASCII table: the character '1' has code 49 (00110001), while the number 1 in Lesson 1 was 00000001. Why does a computer distinguish between the text character '1' and the number 1?
4. **Task 2.4 (Unit Rate — Text):** A text file contains 150 characters (including spaces) encoded at a unit rate of 8 bits per character. How many total **bits** and how many **bytes** does the text file require?
5. **Task 2.5 (Bitmap Decoding):** Draw a 4 × 4 grid and shade the 1s for these four 4-bit rows: Row 1 = 0110, Row 2 = 1111, Row 3 = 0110, Row 4 = 0110. What symbol appears?
6. **Task 2.6 (Color Depth Ratio):** An 8 × 8 sprite uses a 16-color palette where each pixel uses 4 bits (0000 through 1111). What is the unit rate in **bits per pixel**, and how many **raw pixel bits** (and **bytes**, excluding headers/compression) are needed for all 64 pixels?
7. **Task 2.7 (Aspect Ratio):** A game banner measures 120 pixels wide by 80 pixels tall. Write the width-to-height ratio 120 : 80 in simplest whole-number form. If you scale the banner to 300 pixels wide while keeping the exact same aspect ratio, how many pixels tall must it be?

8. **Task 2.8 (Metadata Reasoning):** Suppose you receive a raw stream of `64` bits (`0`s and `1`s) for a 1-bit black-and-white picture, but nobody tells you whether the grid is `8 × 8`, `16 × 4`, or `32 × 2`. Why does the receiver need to know the **width and height** (whether stored in a file header, sent by a communication protocol, or fixed by a prior external agreement) to display the pixel bits correctly?

Complete Answer Key (Tasks 2.1 – 2.8)

- **Answer 2.1:** `E` is the 5th letter: `64 + 5 = 69` → **`01000101`**. `M` is the 13th letter: `64 + 13 = 77` (`64 + 8 + 4 + 1`) → **`01001101`**.
- **Answer 2.2:** `01000100` = `64 + 4 = 68` (`D`); `01000001` = `65` (`A`); `01010100` = `64 + 16 + 4 = 84` (`T`); `01000001` = `65` (`A`). Word: **`DATA`**.
- **Answer 2.3:** When `'1'` appears inside a sentence or street address (like `"12 Oak St"`), the screen needs to look up the font glyph for the symbol `'1'` alongside letters and punctuation; when storing a quantity for arithmetic, storing pure binary (`00000001`) lets the processor add and subtract directly.
- **Answer 2.4:** `150 characters × 8 bits/character = 1,200 bits`, which is **`150 bytes`** (`1 byte per character`).
- **Answer 2.5:** Shading the middle two columns on rows 1, 3, and 4 and all four columns on row 2 forms a **cross / plus (+) or sword/tree icon**.
- **Answer 2.6:** Unit rate = **`4 bits per pixel`**. Total storage = `64 pixels × 4 bits/pixel = 256 bits`, which is `256 ÷ 8 =` **`32 bytes`**.
- **Answer 2.7:** Dividing both `120` and `80` by their greatest common factor (`40`) gives a **`3 : 2`** width-to-height ratio. Since `300 ÷ 3 = 100`, the scaled height must be `2 × 100 =` **`200` pixels tall**.
- **Answer 2.8:** Without knowing how many pixels belong in each row (the width—supplied via a file header, a protocol message, or a fixed format agreement), the receiver does not know where to wrap to the next line; wrapping every `16` bits instead of every `8` bits scrambles the picture into unrecognizable stripes.

Vocabulary

- **ASCII:** A standard character-encoding table that assigns numbers (`0` to `127`) to English letters, digits, and punctuation marks.
- **pixel (picture element):** One individual colored square in a grid-based digital image.
- **bitmap:** An image represented as a row-by-row grid of pixel color codes (whose width and height are supplied by a file header, protocol, or format specification).
- **color depth (bits per pixel):** The unit rate measuring how many bits are used to represent the color of each single pixel.

Differentiation

- **Extra support:** Provide a printed alphabet strip listing `A = 65` through `Z = 90` with their 5-bit endings (`00001` to `11010`) so students can focus on matching patterns before doing mental subtraction.
- **Extra challenge:** Introduce **Run-Length Encoding (RLE)** compression: in Row 1 of the smiley face (`00111100`), instead of listing every bit, write `(2 white, 4 black, 2 white)`. Ask students to test which `8 × 8` drawings shrink with RLE and which pattern (such as an alternating checkerboard `01010101`) actually gets larger!

⚠ Safety

No physical hazards in this unplugged lesson.

Teacher notes

- **Important scope note on Unicode / UTF-8:** Make sure students know that 7-bit/8-bit ASCII only had room for English characters. Modern operating systems and web browsers use **UTF-8 (Unicode)**, which stays backwards-compatible with 1-byte ASCII for `0–127` while using `2`, `3`, or `4` bytes per character to represent over `149,000` characters across global writing systems and emoji.

Lesson 3: Making Decisions with Switches — NOT, AND, and OR Logic Gates

Time: 50 minutes

Unit: Binary, Pixels, Logic Gates, and Packet Switching | **Previous:** Lesson 2 | **Next:** Lesson 4

Goal

Complete truth tables for `NOT`, `AND`, and `OR` logic gates, model series and parallel switch paths, and trace the output of a 2-gate combination circuit for all four input pairs.

Materials

- Chalk or masking tape on the classroom floor to draw two circuit pathways (**Series Path** and **Parallel Path**).
- Index cards labeled `0 (OPEN / FALSE)` and `1 (CLOSED / TRUE)` for student gatekeepers.
- Student notebooks or worksheet tables for truth tables.

Steps

✎ 1. Opening (5 min): How Do `0`s and `1`s Make Decisions?

Ask the class: - "Lessons 1 and 2 showed how *0*s and *1*s store numbers, letters, and pictures. But how does a computer actually **decide** something — like turning on a terrarium misting sprayer only when the soil is dry **AND** the lid is closed?" - Explain that inside a processor chip, billions of microscopic electronic switches (**logic gates**) take `0`/`1` inputs and produce a `0`/`1` output according to three fundamental rules: **`NOT`**, **`AND`**, and **`OR`**.

✎ 2. Main Activity Part A (15 min): Acting Out the Three Fundamental Logic Gates

Select student volunteers to act as **Switch Gatekeepers** along chalk paths drawn on the floor (or trace the paths at desks using a tabletop diagram, paper switch cards, or pointing so standing/walking is optional): - **`1` = Gate Closed (Bridge Down / True):** The messenger can walk across. - **`0` = Gate Open (Bridge Up / False):** The path is blocked.

1. The `NOT` Gate (Inverter) — 1 Input

Flips the input bit to its opposite:

Input `A`	Output `NOT A`
`0`	**`1`**
`1`	**`0`**

Everyday example: A refrigerator interior light switch that turns the bulb **ON (1)** when the door is **NOT closed (0)**.

2. The AND Gate (Series Path) — 2 Inputs

Draw two switches A and B **in a single straight line (in series)**. To walk from the battery to the lightbulb, the messenger must cross **both** A and B:

Input A	Input B	Output A AND B
0	0	**0**
0	1	**0**
1	0	**0**
1	1	**1**

Rule: A AND B outputs 1 **only when both inputs are 1**.

3. The OR Gate (Parallel Path) — 2 Inputs

Draw a path that **splits into two side-by-side branches** (Switch A on the top branch, Switch B on the bottom branch) and rejoins before the lightbulb. The messenger can reach the lightbulb if **either** A is closed, **or** B is closed, **or both**:

Input A	Input B	Output A OR B
0	0	**0**
0	1	**1**
1	0	**1**
1	1	**1**

Rule: A OR B outputs 1 **whenever at least one input is 1**.

✎ 3. Main Activity Part B (15 min): Combining Gates in a Terrarium Controller

Connect to the Grade 6 Science unit (Fungi and Decomposition): suppose your class is modeling an **ideal Boolean simulation** of a mushroom decomposition terrarium controller with three idealized binary inputs: - **D (Dry):** 1 if humidity is too low, 0 if moist enough. - **L (Lid Closed):** 1 if the terrarium lid is safely closed, 0 if open. - **M (Manual Override Button):** 1 if a student presses the test-spray button, 0 otherwise.

✎ Worked Example: Tracing (D AND L) OR M

Let's trace when the **Sprayer (S)** turns ON (S = 1) for different sensor readings by adding an intermediate column X = (D AND L) first:

D (Dry)	L (Lid)	M (Manual)	Step 1: X = D AND L	Step 2: S = X OR M
1	0	0	1 AND 0 = 0	0 OR 0 = **0 (OFF — lid is open!)**
1	1	0	1 AND 1 = 1	1 OR 0 = **1 (ON — dry and lid closed)**

D (Dry)	L (Lid)	M (Manual)	Step 1: X = D AND L	Step 2: S = X OR M
0	0	1	0 AND 0 = 0	0 OR 1 = **1 (ON — manual button pressed)**

4. Discussion & Student Practice (15 min)

✎ Practice Tasks (3.1 – 3.8)

1. **Task 3.1:** Evaluate `1 AND 0`, `1 OR 0`, and `NOT 0`.
2. **Task 3.2:** Evaluate `(1 OR 0) AND (NOT 1)`. Show the intermediate value of each parentheses group first.
3. **Task 3.3:** Complete all 4 rows of the truth table for the circuit `Output = (NOT A) AND B` (where `(A, B)` takes values `(0,0)`, `(0,1)`, `(1,0)`, `(1,1)`).
4. **Task 3.4:** Complete all 4 rows of the truth table for the circuit `Output = NOT (A OR B)`.
5. **Task 3.5 (Safety Bug Analysis in Our Boolean Simulation):** In the simulated mushroom terrarium controller `S = (D AND L) OR M`, notice Row 3 of the worked example (`D=0, L=0, M=1`): if the lid is **open (`L = 0`)** and someone presses the **Manual button (`M = 1`)**, the sprayer output is still `1`! Rewrite the Boolean formula using `D`, `L`, and `M` so that in this ideal logic model the sprayer output is `1` when dry **or** when the manual button is pressed, **but ONLY if the lid input `L` is closed (`L = 1`)**.
6. **Task 3.6 (Comparing Circuits):** Compute all 4 rows of `(NOT A) AND (NOT B)` and compare the output column to Task 3.4 (`NOT (A OR B)`). What do you discover?
7. **Task 3.7 (Bitwise Masking):** Computers often apply an `AND` gate to two 4-bit numbers **column by column**. Compute `1101 AND 0110` bit by bit.
8. **Task 3.8 (Ratio of True Outputs):** Out of the `4` possible input rows in a 2-input truth table (`00, 01, 10, 11`), what is the ratio of `1` (TRUE) outputs to total rows for an `AND` gate vs. an `OR` gate?

Complete Answer Key (Tasks 3.1 – 3.8)

- **Answer 3.1:** `1 AND 0` = **0**; `1 OR 0` = **1**; `NOT 0` = **1**.
- **Answer 3.2:** First group: `(1 OR 0)` = 1. Second group: `(NOT 1)` = 0. Final gate: `1 AND 0` = **0**.
- **Answer 3.3 (`(NOT A) AND B`):**
- `(0, 0)`: `NOT 0` = 1 → `1 AND 0` = **0**
- `(0, 1)`: `NOT 0` = 1 → `1 AND 1` = **1**
- `(1, 0)`: `NOT 1` = 0 → `0 AND 0` = **0**
- `(1, 1)`: `NOT 1` = 0 → `0 AND 1` = **0** (Only row *`(0, 1)`* outputs *1*.)
- **Answer 3.4 (`NOT (A OR B)`):**
- `(0, 0)`: `0 OR 0` = 0 → `NOT 0` = **1**
- `(0, 1)`: `0 OR 1` = 1 → `NOT 1` = **0**
- `(1, 0)`: `1 OR 0` = 1 → `NOT 1` = **0**
- `(1, 1)`: `1 OR 1` = 1 → `NOT 1` = **0**
- **Answer 3.5:** Put `D OR M` inside parentheses first, then require `AND L`: **`S = (D OR M) AND L`**. In this **ideal Boolean model**, whenever `L = 0` (lid open), `(D OR M) AND 0 = 0`, so the logic output stays `0` while `L = 0`. (Note that in a real physical device, a stuck lid sensor or faulty valve could still cause a malfunction even when the Boolean formula is correct!)
- **Answer 3.6:** For `(NOT A) AND (NOT B)`: `(0,0) -> 1 AND 1 = 1`; `(0,1) -> 1 AND 0 = 0`; `(1,0) -> 0 AND 1 = 0`; `(1,1) -> 0 AND 0 = 0`. The output column (`1, 0, 0, 0`) is **identical** to `NOT (A OR B)` in Task 3.4! ("Neither A nor B is ON" means the exact same thing as "A is OFF and B is OFF".)

- **Answer 3.7:** Column by column from left to right: `1 AND 0 = 0`, `1 AND 1 = 1`, `0 AND 1 = 0`, `1 AND 0 = 0` → **`0100`**.
- **Answer 3.8:** An `AND` gate outputs `1` in **`1 : 4`** (`1` out of `4` rows, or `25%`), whereas an `OR` gate outputs `1` in **`3 : 4`** (`3` out of `4` rows, or `75%`).

Vocabulary

- **logic gate:** A physical or digital switch circuit that takes one or more binary inputs (`0` or `1`) and produces a single binary output according to a fixed rule.
- **truth table:** A complete table listing every possible combination of input bits and the resulting output bit.
- **series circuit (`AND`):** Switches wired one after another along a single path so all switches must be closed (`1`) for current to flow.
- **parallel circuit (`OR`):** Switches wired on side-by-side branches so closing any one branch (`1`) allows current to flow.

Differentiation

- **Extra support:** Have students physically write the `0` or `1` output above each gate wire on a printed circuit diagram before filling in the table row.
- **Extra challenge:** Introduce the **Exclusive OR (`XOR`)** gate, which outputs `1` when `A` and `B` are **different** (`01` or `10`), and outputs `0` when both are the same (`00` or `11`). Ask students to build `A XOR B` using only `AND`, `OR`, and `NOT` gates: `(A OR B) AND NOT (A AND B)`.

⚠ Safety

Keep floor pathways clear of backpacks and chairs during the human-circuit walkthrough.

Teacher notes

- **Common misconception ("Everyday English OR vs. Logical OR"):** In everyday conversation, "You can have soup OR salad" often means one or the other, not both (`XOR`). Emphasize that in mathematics and computing, **`OR` always means "at least one (including both)"** (`1 OR 1 = 1`).

Lesson 4: Postcards on the Wire — Packet Switching, Routing, and Throughput Rates

Time: 50 minutes

Unit: Binary, Pixels, Logic Gates, and Packet Switching | **Previous:** Lesson 3 | **Next:** Lesson 5

Goal

Simulate splitting a message into numbered packets, route packets around a failed network link, reassemble out-of-order packets using header sequence numbers, and calculate network unit rates (**packets per second** and **bits per second**).

Materials

- 6 index cards ("Packet Postcards") per group of 6 students.
- Yarn or string pieces connecting 6 student desks as a 6-node router mesh (`Node A` through `Node F`).
- Scissors or a red `"LINK DOWN"` card to simulate a cut fiber-optic cable during the activity.

Steps

✎ 1. Opening (5 min): One Giant Scroll vs. Numbered Postcards

Ask the class: - "Suppose you want to mail a 300-page book to a friend, but the postal tube can only hold 1 page at a time, and 20 other classmates are also sharing the same highway. What happens if one person reserves the entire highway for 10 minutes to send their whole book in one piece?" - Contrast **circuit reservation** (everyone else waits in line; if a tree falls across the road halfway through, the whole book fails) with **packet switching** (chopping the data into small numbered blocks called **packets** that take turns sharing the links and can detour around a broken road).

✎ 2. Main Activity (20 min): The 6-Node Classroom Router Mesh

Arrange 6 desks (`A, B, C, D, E, F`) with yarn links matching this network map:

```
   [Node B] -------- [Node D]
   /      \          /      \
[Node A]   (link)  (link)   [Node F]
   \      /          \      /
   [Node C] -------- [Node E]
```

Links available: - `A–B`, `A–C` - `B–C`, `B–D` - `C–D`, `C–E` - `D–F`, `E–F`

Step-by-Step Simulation

1. **Sender (`Node A`)** wants to send the 16-character message `"FUNGI GROW FAST!"` to **Receiver (`Node F`)**, but each packet payload can hold **at most `4` characters** (`32 bits`).
2. `Node A` splits the message into `4` packets and fills out a **Header** on each card:
3. **Packet 1:** `From: A | To: F | Packet: 1 of 4 | Payload: "FUNG"`
4. **Packet 2:** `From: A | To: F | Packet: 2 of 4 | Payload: "I GR"`
5. **Packet 3:** `From: A | To: F | Packet: 3 of 4 | Payload: "OW F"`
6. **Packet 4:** `From: A | To: F | Packet: 4 of 4 | Payload: "AST!"`
7. **Round 1 (Normal Routing — `1` Hop per Step):** Assume a synchronized step-by-step scenario where each link hop takes **1 step (1 second)** and `Node F` logs simultaneous arrivals from `Node D` before `Node E`. `Node A` sends Packet 1 along `A -> B -> D -> F` (`3` steps) and Packet 2 along `A -> C -> E -> F` (`3` steps), so Packets 1 and 2 arrive at `Node F` first (logged as `Packet 1, Packet 2`).
8. **Round 2 (Sending Packets 3 & 4 + Link Failure!):** Next, `Node A` sends **Packet 3** to `Node B` and **Packet 4** directly to `Node C`. Just as Packet 3 arrives at `Node B`, place the red `"LINK DOWN"` card on link **`B–D`**!
9. Does `Node B` throw Packet 3 away? **No!** `Node B` inspects its remaining working links, sees `B–C` is still up, and reroutes Packet 3 along `B -> C -> E -> F` (`4` hops total from `A`). Meanwhile, **Packet 4** travels directly along `A -> C -> E -> F` (`3` hops total, with no queue delay at `C` or `E` because it is 1 step ahead of rerouted Packet 3).
10. **Out-of-Order Arrival at `Node F` (in This 1-Second-per-Hop Scenario):** In this scenario where every hop takes 1 second, Packet 4 completes its 3-hop path (`A -> C -> E -> F`) one step before rerouted Packet 3 completes its 4-hop detour (`A -> B -> C -> E -> F`). (Note: On real networks, arrival order depends on link delays, bandwidth, and router queues—not hop count alone!) Thus `Node F` receives the cards in the order: **Packet 1, Packet 2, Packet 4, Packet 3** (`"FUNGI GRAST!OW F"` if read blindly!).
11. `Node F` uses the **`Packet # of 4`** header field to sort them back into `1, 2, 3, 4` → **`"FUNGI GROW FAST!"`**.

3. Connecting to Grade 6 Ratios & Unit Rates: Network Throughput (10 min)

Work through a concrete rate calculation on the board: - Suppose each packet carries **`32` bits of header** + **`32` bits of payload** = **`64` bits per packet**. - If a router link transmits **`300` packets in `6` seconds**: 1. **Packet rate (unit rate):** `300 packets ÷ 6 seconds` = **`50 packets per second`**. 2. **Bit rate (throughput):** `50 packets/second × 64 bits/packet` = **`3,200 bits per second`**. 3. **Header overhead ratio:** In every `64`-bit packet, `32` bits are header and `32` bits are payload (`32 : 64 = 1 : 2`, or `50%` header overhead). If we increase the payload to `192` bits while keeping the same `32`-bit header (`224` bits total), the header overhead drops to `32 : 224` = **`1 : 7`**!

✓ 4. Student Practice & Closing Check (15 min)

✎ Practice Tasks (4.1 – 4.8)

1. **Task 4.1:** A `20`-character message (`"MEET AT THE LIBRARY!"`) is split into packets that hold at most `4` characters per payload. How many packets are needed, and what is the exact `4`-character payload of **Packet 3 of 5**? (Count spaces as characters!)
2. **Task 4.2:** Receiver `Node F` receives five packets in the arrival order:

3. `Packet 4 of 5: "RKS!"`
4. `Packet 2 of 5: "ING "`
5. `Packet 5 of 5: " :)"`
6. `Packet 1 of 5: "ROUT"`
7. `Packet 3 of 5: "WO"` Reassemble the original message in order.
8. **Task 4.3:** What would happen at `Node F` if `Packet 3 of 5` was accidentally dropped on the floor and never arrived? How does the header `"Packet # of 5"` help `Node F` know specifically which piece to request again?
9. **Task 4.4 (Hop Count on the Network Map):** Using the 6-node map (`A–B, A–C, B–C, B–D, C–D, C–E, D–F, E–F`), what is the minimum number of link hops from `A` to `F` when all links are working? List all `3`-hop paths from `A` to `F`.
10. **Task 4.5 (Rerouting Around Failure):** If **both** link `B–D` and link `C–E` fail at the same time on the 6-node map, is there still a working path from `A` to `F`? If so, write the exact node sequence and count its hops.
11. **Task 4.6 (Unit Rate — Packets per Second):** A classroom switch forwards `420` packets in `14` seconds. What is its unit rate in **packets per second**? At that same rate, how many packets will it forward in `25` seconds?
12. **Task 4.7 (Unit Rate — Bits per Second):** Each packet on a sensor network is `80` bits long (`16` header bits + `64` payload bits). If the sensor transmits `40` packets per second, what is the total transmission rate in **bits per second**? How many of those bits per second are **actual sensor payload**?
13. **Task 4.8 (Header-to-Total Ratio):** In Task 4.7 (`16` header bits and `64` payload bits, `80` bits total per packet), write the ratio of **payload bits to total bits** in simplest whole-number form.

Complete Answer Key (Tasks 4.1 – 4.8)

- **Answer 4.1:** `20 characters ÷ 4 characters/packet =` **`5` packets**. Splitting into 4-character blocks: Packet 1 = `"MEET"`, Packet 2 = `" AT "`, **Packet 3 = `"THE "`**, Packet 4 = `"LIBR"`, Packet 5 = `"ARY!"`.
- **Answer 4.2:** Sorting by sequence number `1, 2, 3, 4, 5`: `"ROUT" + "ING " + "WO" + "RKS!" + " :)"` = **`"ROUTING WORKS! :)"`**.
- **Answer 4.3:** Because `Node F` sees packets `1, 2, 4, 5` of `5`, it immediately detects that **`Packet 3` is missing** and only needs to ask `Node A` to re-send **Packet 3**, rather than re-sending the entire message.
- **Answer 4.4:** The minimum hop count is **`3` hops**. There are **three** `3`-hop paths from `A` to `F`:
- `A -> B -> D -> F`
- `A -> C -> D -> F`
- `A -> C -> E -> F`
- **Answer 4.5: Yes!** Even with both `B–D` and `C–E` broken, `Node C` connects to `Node D` via `C–D`. So a packet can travel **`A -> C -> D -> F`** (`3` hops) or **`A -> B -> C -> D -> F`** (`4` hops).
- **Answer 4.6:** Unit rate: `420 ÷ 14 =` **`30 packets per second`**. In `25` seconds: `30 × 25 =` **`750 packets`**.
- **Answer 4.7:** Total rate: `40 packets/sec × 80 bits/packet =` **`3,200 bits per second`**. Actual payload rate: `40 packets/sec × 64 payload bits/packet =` **`2,560 payload bits per second`**.
- **Answer 4.8:** Payload to total is `64 : 80`. Dividing both by `16` gives **`4 : 5`** (`4` out of every `5` bits sent are payload).

Vocabulary

- **packet:** A small, fixed-limit chunk of data paired with a header so it can travel independently across a shared network.
- **header:** Metadata attached to the front of a packet listing its sender address, destination address, and sequence number (`Packet k of N`).
- **payload:** The actual slice of user data (text, image bits, sensor reading) carried inside a packet.
- **router:** A network node that inspects a packet's destination address and forwards it along a working link toward its destination.
- **throughput (bit rate):** The unit rate measuring how many bits pass through a network link per second (`bits per second`).

Differentiation

- **Extra support:** Give each student desk a printed sign (`Node A` through `Node F`) and have students slide the index cards along the yarn strings—or trace the routes on a shared tabletop map/diagram by pointing or dictating moves so standing, walking, or handling yarn is optional.
- **Extra challenge:** Assign different **link delays** to each yarn piece (for example, `C–D` takes `1` second, while `B–D` takes `4` seconds) and ask students to find the path with the **lowest total travel time** even when that path has more hops!

⚠ Safety

Ensure yarn links are taped across desk tops rather than stretched across floor walkways where students could trip.

Teacher notes

- **Scope note on TCP/IP:** Explain briefly that on the real Internet, **IP (Internet Protocol)** handles addressing and hop-by-hop routing (like the `From` and `To` fields on our cards), while **TCP (Transmission Control Protocol)** handles the sequence numbering (`Packet k of N`) and requesting re-transmission when a packet is lost.

Lesson 5: Catching Flipped Bits — Noise, Even Parity Checks, and End-of-Unit Assessment

Time: 50 minutes

Unit: Binary, Pixels, Logic Gates, and Packet Switching | **Previous:** Lesson 4

Goal

Add an even-parity check bit to 8-bit bytes, detect single-bit transmission errors, explain why two simultaneous bit flips in the same byte escape 1-bit parity, and complete the 5-part End-of-Unit Assessment.

Materials

- Large two-sided paper cards or tokens (`Light = 1`, `Dark = 0`), 9 cards per pair (or a printed 9-box row where students can point, dictate, or write `0` and `1` instead of handling small objects).
- Printed or board-copied End-of-Unit Assessment (20 points total; 20 minutes at the end of this 50-minute lesson, or administered in a separate quiz period).

Steps

✎ 1. Opening (5 min): What If Static Flips a `0` to a `1`?

Ask the class: - "Suppose a hospital or spacecraft sends the 8-bit number *`00000101`* (*`5`* milligrams or *`5`* degrees), and a burst of radio static on the wire flips the leftmost bit from *`0`* to *`1`* (*`10000101`* = *`133`*!). How can the receiver tell that a bit was flipped without already knowing the secret number?"

✎ 2. Main Activity (15 min): The Even-Parity Check Bit

Demonstrate how adding **one extra check bit** (a **9th bit** called the **Even Parity Bit**) catches any single-bit flip (or any odd number of bit flips):

The Even-Parity Rule

Before sending an 8-bit data byte, the sender counts how many **`1`s** are in the 8 data bits: - If the number of `1`s in the 8 data bits is already **even** (`0, 2, 4, 6, or 8`), set the 9th **Parity Bit = `0`** so the total number of `1`s across all 9 bits stays **even**. - If the number of `1`s in the 8 data bits is **odd** (`1, 3, 5, or 7`), set the 9th **Parity Bit = `1`** so the total number of `1`s across all 9 bits becomes **even**.

✎ Worked Example 1: Computing the Parity Bit

8 Data Bits	Count of 1s in Data	Even or Odd?	9th Bit (Even Parity Bit)	Complete 9-Bit Frame Sent	Total 1s Sent
01000001 ('A')	2 ones	Even	**0**	01000001 **0**	2 (Even)
01000011 ('C')	3 ones	Odd	**1**	01000011 **1**	4 (Even)

✎ Worked Example 2: Checking Incoming Frames at the Receiver

When the receiver gets a 9-bit frame, it counts the total number of 1s across **all 9 bits**: - Received Frame X: 01001001 0 → Count of 1s = 3 (**Odd!**). Since every valid frame was sent with an **even** number of 1s, an odd total signals that **an odd number of bits (1, 3, 5...) flipped** during transmission: **ERROR DETECTED — discard and request re-send!** - **Crucial limitation ("No Error Detected" ≠ Proof of Zero Errors):** What if lightning flips **two** (or 4, 6, 8) bits inside the same 9-bit frame? Changing an even count by +2, 0, or -2 keeps the total **even**, so a single parity bit **cannot detect an even number of bit flips**. Therefore, a passing (even) parity check means **no error was detected**, not absolute proof that zero bits changed!

✎ 3. Student Practice Tasks (5.1 – 5.8) (10 min)

1. **Task 5.1:** Find the Even Parity Bit (0 or 1) to append to the 8-bit data byte 00110101.
2. **Task 5.2:** Find the Even Parity Bit (0 or 1) to append to the 8-bit data byte 10110101.
3. **Task 5.3:** A receiver uses even parity and receives these four 9-bit frames. Which ones have a detected error?
4. Frame A: 01010101 0
5. Frame B: 11001010 1
6. Frame C: 00000000 0
7. Frame D: 10000000 0
8. **Task 5.4:** What if the **Parity Bit itself** (the 9th bit) gets flipped by static during transmission while the 8 data bits are untouched? Will the receiver still detect an error? Explain why.
9. **Task 5.5:** Assuming at most **one** bit flipped in a 9-bit frame, explain why a single 9th parity bit can tell you **that** a bit flipped, but cannot tell you **which** of the 9 bits flipped.
10. **Task 5.6 (2D Grid Parity Puzzle):** Arrange three 4-bit data rows into a grid with an even **Row Parity bit** at the right end of each row and an even **Column Parity bit** at the bottom of each data column:
11. Row 1: 1 0 1 0 | 0
12. Row 2: 0 1 1 0 | 1
13. Row 3: 1 1 0 0 | 0
14. Col Parity: 0 0 1 0 Assume that **at most one bit** in the entire diagram flipped during transmission, and in fact **exactly one data bit** inside the 3 × 4 data grid flipped. Check the row sums and column sums to pinpoint the exact (Row, Column) of the flipped bit.

15. **Task 5.7 (Error Rate Ratio):** Out of `500` transmitted packets, `15` packets fail their parity check and must be re-sent. Write the error rate as a simplified ratio (`failed : total`) and as a rate **per `100` packets** (percentage).
16. **Task 5.8 (Overhead Comparison):** Adding `1` parity bit to every `8` data bits creates `9` total bits per byte. What is the ratio of **check bits to data bits** (`1 : 8`) and **data bits to total bits** (`8 : 9`)?

Complete Answer Key (Tasks 5.1 – 5.8)

- **Answer 5.1:** `00110101` has `4` ones (already even) → Parity Bit = **`0`** (`00110101 0`).
- **Answer 5.2:** `10110101` has `5` ones (odd) → Parity Bit = **`1`** (`10110101 1`, making `6` ones total).
- **Answer 5.3:**
- Frame A (`01010101 0`): `4` ones (Even) → **Passes check (no error detected)**.
- Frame B (`11001010 1`): `5` ones (Odd) → **ERROR DETECTED (odd number of bit flips)**.
- Frame C (`00000000 0`): `0` ones (`0` is an even number!) → **Passes check (no error detected)**.
- Frame D (`10000000 0`): `1` one (Odd) → **ERROR DETECTED (odd number of bit flips)**.
- **Answer 5.4: Yes!** Flipping any single bit among the 9 bits — including the 9th parity bit itself — changes the total count of 1s by `+1` or `-1`, turning an even total into an odd total.
- **Answer 5.5:** Under the single-bit-flip assumption, flipping any one of the 9 bit positions changes the total parity from even to odd in the exact same way, so an odd total tells the receiver that a bit flipped (or, more generally, that an odd number of bits flipped), but not which slot (`1` through `9`) changed.
- **Answer 5.6:** Count the 1s in each row (including its right-hand Row Parity bit):
- Row 1 (`1 0 1 0 | 0`): `2` ones (Even — passes check).
- **Row 2 (`0 1 1 0 | 1`):** `3` ones (**Odd — error detected in Row 2!**).
- Row 3 (`1 1 0 0 | 0`): `2` ones (Even — passes check). Now count the 1s in each data column (including its bottom Column Parity bit):
- Column 1 (`1, 0, 1 | 0`): `2` ones (Even — passes check).
- Column 2 (`0, 1, 1 | 0`): `2` ones (Even — passes check).
- **Column 3 (`1, 1, 0 | 1`):** `3` ones (**Odd — error detected in Column 3!**).
- Column 4 (`0, 0, 0 | 0`): `0` ones (Even — passes check). Because Row 2 and Column 3 both fail their even-parity check, the single flipped bit lies at their intersection: **`(Row 2, Column 3)`** (changing that `1` back to `0` restores both Row 2 and Column 3 to `2` ones).
- **Answer 5.7:** `15 : 500` simplifies (dividing by `5`) to **`3 : 100`**, which is **`3` failed packets per `100` packets (`3%`)**.
- **Answer 5.8:** Check bits to data bits = **`1 : 8`**; data bits to total transmitted bits = **`8 : 9`**.

End-of-Unit Synthesis Assessment (20 Points Total — 20 Minutes)

Instructions for Students

Answer all 5 problems (`4` points each = `20` points total). Show your place-value additions, intermediate gate values, or unit-rate steps clearly.

✎ Problem 1: Doubling Cards & 8-Bit Binary (4 points)

- **(a) [1 pt]** List the 8 binary place-value cards in order from left (`8`th bit) to right (`1`st bit).

- **(b) [1 pt]** Convert the 8-bit binary byte `01011010` to a base-10 number.
- **(c) [2 pts]** Convert the base-10 number **`150`** into an 8-bit binary byte. Show which place-value cards are switched ON (`1`).

✎ Problem 2: ASCII Characters & Bitmap Pixel Ratios (4 points)

- **(a) [2 pts]** In standard ASCII, uppercase `'A'` is `65` (`01000001`). Decode the 2-byte word `01001000 01001001`.
- **(b) [2 pts]** A small `10 × 10` game icon (`100` pixels total) is upgraded from a 2-color palette (`1 bit per pixel`) to an 8-color palette (`3 bits per pixel`). Counting **raw uncompressed pixel data** (excluding any headers), how many **bits** did the icon take before the upgrade, how many **bits** does it take after the upgrade, and what is the ratio of old raw pixel size to new raw pixel size?

✎ Problem 3: Logic Gates & Truth Table (4 points)

A solar battery charger turns ON (`Output = 1`) according to the logic circuit: `Output = S AND (NOT F)` where **`S`** = `1` when Sunlight is detected (`0` when dark), and **`F`** = `1` when the Battery is already Full (`0` when not full). - **(a) [3 pts]** Write out the 4-row truth table for `(S, F)` = `(0,0)`, `(0,1)`, `(1,0)`, `(1,1)`, showing the intermediate column `NOT F` and the final `Output` column. - **(b) [1 pt]** Explain in plain English which single row turns the charger ON and why.

✎ Problem 4: Packet Switching & Network Unit Rates (4 points)

- **(a) [2 pts]** Three packets arrive at a receiver in the order:
- `Packet 3 of 3: "ONE!"`
- `Packet 1 of 3: "WELL"`
- `Packet 2 of 3: " D"` Write the reassembled message and explain why packets from the same message can arrive out of order on a packet-switched network.
- **(b) [2 pts]** A network link transfers `450` packets in `9` seconds. Each packet is `100` bits long (`20` header bits + `80` payload bits). Find the link's rate in **packets per second** and its total throughput in **bits per second**.

✎ Problem 5: Even-Parity Error Detection (4 points)

- **(a) [1 pt]** What Even Parity Bit (`0` or `1`) should be attached to the 8-bit byte `11010011`?
- **(b) [2 pts]** A receiver using even parity receives Frame 1 (`10101010 0`) and Frame 2 (`11100011 0`). Which frame has a detected error? Show your count of `1`s for each frame.
- **(c) [1 pt]** Explain why even parity fails to detect an error if exactly **two** bits flip inside the same 9-bit frame.

End-of-Unit Assessment Answer Key & Scoring Guide (20 Points)

- **Problem 1 (4 pts):**
- **(a) [1 pt]:** `128, 64, 32, 16, 8, 4, 2, 1`.

- **(b) [1 pt]:** `64 + 16 + 8 + 2 =` **`90`**.
- **(c) [2 pts]:** `150 = 128 + 16 + 4 + 2` → **`10010110`** (1 pt for correct card decomposition, 1 pt for exact 8-bit string).
- **Problem 2 (4 pts):**
- **(a) [2 pts]:** Byte 1 (`01001000`) = `64 + 8 = 72` (8th letter = `'H'`). Byte 2 (`01001001`) = `64 + 8 + 1 = 73` (9th letter = `'I'`). Decoded word: **`"HI"`**.
- **(b) [2 pts]:** Before upgrade: `100 pixels × 1 bit/pixel = 100 bits`. After upgrade: `100 pixels × 3 bits/pixel = 300 bits`. Ratio of old to new storage = **`1 : 3`**.
- **Problem 3 (4 pts):**
- **(a) [3 pts]:**
  - `(S=0, F=0)` → `NOT F = 1` → `0 AND 1 =` **`0`**
  - `(S=0, F=1)` → `NOT F = 0` → `0 AND 0 =` **`0`**
  - `(S=1, F=0)` → `NOT F = 1` → `1 AND 1 =` **`1`**
  - `(S=1, F=1)` → `NOT F = 0` → `1 AND 0 =` **`0`**
- **(b) [1 pt]:** Row `(S=1, F=0)` turns the charger ON (`1`) because there is sunlight (`S=1`) **and** the battery is **not** full (`F=0`, so `NOT F = 1`).
- **Problem 4 (4 pts):**
- **(a) [2 pts]:** Reassembled message (`1, 2, 3`): **`"WELL DONE!"`**. Packets can arrive out of order because different packets may take different router paths (with different hop counts or congestion delays) around busy or broken links.
- **(b) [2 pts]:** Packet rate: `450 packets ÷ 9 seconds =` **`50 packets per second`**. Total throughput: `50 packets/sec × 100 bits/packet =` **`5,000 bits per second`**.
- **Problem 5 (4 pts):**
- **(a) [1 pt]:** `11010011` has `5` ones (odd) → Even Parity Bit = **`1`**.
- **(b) [2 pts]:** Frame 1 (`10101010 0`) has `4` ones (even → **passes check, no error detected**). Frame 2 (`11100011 0`) has `5` ones (odd → **ERROR DETECTED in Frame 2**).
- **(c) [1 pt]:** Flipping two bits changes the number of 1s by `+2`, `0`, or `-2`, which keeps an even total **even**, so the receiver sees an even count and cannot tell that two bits changed.

Vocabulary

- **noise / interference:** Unwanted electrical or radio disturbances that can accidentally flip a `0` bit to a `1` (or `1` to `0`) during transmission.
- **even parity bit:** An extra check bit (`0` or `1`) appended to a group of data bits so the total number of `1`s across the entire frame is always an even number.

Differentiation

- **Extra support:** Allow students to keep their 8 physical place-value cards (`128, 64, 32, 16, 8, 4, 2, 1`) on their desk during the assessment.
- **Extra challenge:** Have students complete the 2D `3 × 4` grid parity puzzle (Task 5.6) where they intentionally flip one data coin while their partner looks away, and see if their partner can find the exact flipped coin in one try using only row and column parity!

⚠ Safety

No physical hazards in this unplugged lesson.

Teacher notes

- **Zero-is-even reminder:** Remind students before Task 5.3 that `0` **is an even number**, so an all-zero byte `00000000` already has an even count of `1`s (`0` ones) and receives a `0` parity bit (`00000000 0`).