

Six Unlabeled Swatches: Which Ones Did Nature Make?

Investigation question: Using only property tests you can run on a desk, which of six unlabeled fabric swatches are made of natural fibers and which are synthetic, and which test gives the most trustworthy evidence?

Evidence-based mystery

Groups of 4

1 session

Setup 5 · Activity 40 · Cleanup 5 min

MS-PS1-3 · practice

Scientific purpose

Groups receive six fabric swatches labeled only A to F. Three are natural fibers (cotton, wool, jute) and three are synthetic polymers made from petroleum (polyester, nylon, acrylic), but students are not told which is which or even how many of each there are. They run four property tests, a water-drop test, a soak-and-weigh test, a crumple test and a hand-lens look at the fibers, record the evidence, and argue a verdict for each swatch. Only after the verdicts are written does the teacher reveal the identities. The lab makes the lesson's claim that synthetic materials are engineered for specific properties into something students measure, and it shows that a single test can mislead.

Why this helps students with this chapter

Students hear that polyester 'wicks' and cotton 'breathes' as slogans. Watching a water drop bead on one swatch and vanish into another, weighing how much each soaks up, and finding that wool fools the drop test but not the scale turns those slogans into evidence. Arguing a verdict before the reveal, and then seeing which tests pointed the right way, also teaches the lesson's larger skill: judge a material by what it does, not by what the label says.

Standards connections

MS-PS1-3 (practice, the properties half: making sense of information about what synthetic materials are like and why they are chosen): Students gather first-hand information about the properties of synthetic and natural fibers, then connect each synthetic swatch to the natural resource and chemical process it came from and to the property it was engineered to have. The PE itself is assessed through source-based work in W3, W8 and Lab 2; this lab builds the property evidence those sources talk about.

Roles (rotate each session)

- **Tester:** Runs each test exactly the same way on every swatch: same drop size, same soak time, same crumple grip, same lens.
- **Timer and measurer:** Times the water drop and the soak, reads the balance, and calls out every value before anyone interprets it.
- **Recorder:** Writes every value in the evidence table as it is called out, and fills the verdict table only after all four tests are finished.

- **Skeptic:** Challenges every verdict with 'which test says so?' and makes sure each swatch has at least two pieces of evidence behind it. Keeps the group from deciding by feel or color.

Materials

Item	Quantity	Per	Note
Fabric swatches, about 10 cm by 10 cm, labeled A to F with a permanent marker on masking tape: woven cotton (muslin or an old T-shirt), 100 percent wool felt, jute or burlap, woven polyester (lining fabric or an old dress shirt), nylon (ripstop, an old windbreaker or nylon organza), and acrylic craft felt	1 set of 6	group	Choose woven cotton and woven polyester of similar weight so that fabric construction does not give the answer away. Check fiber content on the bolt or garment label; many 'wool' felts and 'cotton' shirts are blends.
Strips of the same six fabrics, 2 cm by 10 cm, labeled A to F, for the soak test	1 set of 6	group	Cut ahead of time; the squares stay dry for the drop, crumple and lens tests.
Dropper or plastic pipette	1	group	
Cup of room-temperature water	1	group	
Shallow tray or plate for the soak test	1	group	
Balance reading to 0.1 g	1	group	Two groups can share one balance if the soak tests are staggered.
Stopwatch or phone timer	1	group	
Hand lens (5x to 10x) or a phone camera with zoom	2	group	
Tweezers for pulling a few fibers from a cut edge	1	group	
Paper towels	6 sheets	group	
Recording sheet	1	student	
Sealed envelope with the identity key, opened only after every verdict table is complete	1	group	

Estimated cost: 15 to 22 per class, far less with donated garments (an estimate; Estimate. A quarter yard each of muslin, polyester lining, nylon ripstop and burlap (about \$2 to \$4 each), one sheet of wool felt (about \$3) and one sheet of acrylic felt (under \$1) cut eight sets of squares and strips; droppers, cups, balances and lenses are classroom stock. Old garments with readable fiber labels bring the cost near zero.)

Safety

- No flames anywhere in this lab. The fabric burn test is deliberately not used: synthetic fibers melt and drip, and the fumes from burning acrylic and nylon are harmful. Tell students not to try it at home.
- Water on hard floors is a slip hazard; keep the soak tray on a paper towel and wipe spills at once.
- Jute and burlap shed coarse fibers that can irritate eyes; do not rub eyes after handling it, and wash hands at the end.

- Tweezers are pointed; pull fibers at desk level, pointed away from faces.
- Some students are sensitive to wool; anyone with a known wool allergy handles swatch C with a paper towel or lets a partner run that test.

Teacher preparation and setup

1. Cut one 10 cm square and one 2 cm by 10 cm strip of each fabric per group. Label every piece with a letter on a small masking-tape flag so the letter does not cover the fabric. Suggested key: A = cotton, B = polyester, C = wool felt, D = nylon, E = jute, F = acrylic felt; shuffle the letters between class periods if students talk.
2. Run the four tests yourself on one set the day before. Note your own drop times and mass gains and write them on the identity key, because fabric weight and weave change the numbers; the expected pattern below is a guide, not a target.
3. Write one identity key per group and seal it in an envelope. The key lists the letter, the fiber, whether it is natural or synthetic, and the natural resource it came from.
4. Cover or remove any fabric-care posters or fiber charts in the room. Remind students that the fabric burn test they may have seen online is not part of this lab and is not to be tried at home.
5. Set up a drying rack or a line of paper towels where wet strips can lie flat for the optional drying check at the end of the period.

Investigation design

Independent variable	The fabric swatch (A to F), which differs in the kind of fiber it is made of
Dependent variable	Water-drop soak-in time (s), percent mass gain after soaking, crumple rating (0 to 3), and fiber appearance under the lens
Controlled	Same drop size and drop height for every swatch; Same 60 s soak and 30 s drip for every strip; Same person and the same grip for every crumple; Squares used dry for the drop, crumple and lens tests; strips used for the soak test; Room-temperature water throughout
Trials	One trial per test per swatch within a group; the class pools the drop times and percent gains on the board so each swatch has eight or more values and outliers show.
Comparison	Each swatch's results against the others, and the group's verdicts against the identity key.

Student procedure

1. Lay the six squares out in letter order. Do not guess yet. Each person writes one prediction in q1 of how many of the six are natural, without discussing it.
2. Water-drop test. The tester places one drop of water in the center of square A from a height of about 1 cm. The timer starts at once and stops when the drop has fully soaked in and no shine remains, up to a limit of 120 seconds. Record the time; if the drop is still beaded at 120 s, record 'over 120 s, beads'. Repeat for B through F, same drop size, same spot on the square. Blot each square dry and set it aside.

3. Soak-and-weigh test. Weigh strip A dry and record its mass to 0.1 g. Lay it flat in the tray of water for 60 seconds, lift it with tweezers, hold it above the tray for 30 seconds so loose water drips off, then weigh it again. Record the wet mass. Repeat for B through F. Compute the percent gain for each: (wet mass minus dry mass) divided by dry mass, times 100.
4. Crumple test. Using the dry squares, the tester crushes square A into a tight ball in a fist for 30 seconds, then opens the hand and lets the square lie flat without smoothing it. After 60 seconds, the group rates the wrinkles from 0 (no creases) to 3 (sharp creases everywhere). Repeat for B through F with the same grip.
5. Fiber look. With tweezers, pull three or four fibers from a cut edge of each square. Look at them against a dark surface with the hand lens. For each swatch record: are the fibers all the same thickness or do they vary? Are they smooth and shiny or dull and uneven? Are they straight, crimped or wavy? Are they long and unbroken or short? Sketch two contrasting swatches in the drawing box.
6. Fill in the evidence table completely before anyone argues a verdict. The skeptic checks that every cell has a value.
7. Verdicts. For each swatch, the group decides natural or synthetic and writes the two strongest pieces of evidence and a confidence rating (sure, fairly sure, guessing). The skeptic must hear a test named for every verdict; 'it feels fake' does not count.
8. Only when the verdict table is complete, open the envelope. Record the real identities and mark each verdict right or wrong. Then answer q2 and the analysis questions individually.
9. Optional if time allows: lay the six wet strips flat on paper towels at the same time and check them at the end of the period. Record which are dry to the touch and which are still damp.

Expected observations

- Water drop: cotton and jute soak a drop in within a few seconds to about half a minute; polyester, nylon, acrylic felt and wool felt bead a drop for a minute or longer, with nylon sometimes soaking in slowly near the end.
- Soak and weigh: cotton and jute strips gain well over their own mass (often 100 to 200 percent); wool felt also gains a lot once immersed (often over 100 percent) and stays damp longest; polyester and nylon gain the least, mostly water held between fibers (often under 50 percent); acrylic felt gains a middling amount held in the fluffy structure rather than inside the fibers.
- Crumple: cotton and jute hold sharp creases (rating 2 to 3); wool, polyester, nylon and acrylic spring back (rating 0 to 1). This test puts wool with the synthetics, which groups should notice.
- Fiber look: cotton fibers are short, flat and twisted like ribbon; wool fibers are crimped and vary in thickness; jute fibers are coarse, stiff and woody; polyester and nylon filaments are long, smooth, shiny and all the same thickness; acrylic fibers are also uniform and often deliberately crimped to imitate wool, which makes the wool-versus-acrylic call the hardest in the set.
- Optional drying check: polyester and nylon strips are dry to the touch by the end of the period; cotton, jute and especially wool are still damp.

Likely difficulties

- Groups decide by color, softness or 'it looks cheap' before the tests are done; the skeptic role and the rule that the verdict table stays blank until all four tests are finished are the fix.
- Drop times depend on how hard the drop is squeezed out and whether it lands on a seam; have the tester practice two drops on a paper towel first and always drop from about 1 cm.
- The 30-second drip is inconsistent, which changes percent gain by tens of percent; insist on the timer for the drip, and treat the gain as a rough category (small, medium, large) rather than an exact number.
- Acrylic felt and wool felt look alike to the eye and both resist wrinkles; groups usually need the soak test and the drying check together to separate them, and some will still get one wrong, which makes a good q2.
- Students may want to pull apart the whole swatch to see fibers; three or four fibers from a cut edge are enough.

Structured debrief

1. Pool the drop times and percent gains on the board by letter. Ask which swatches the whole class agreed on and which split the room. Cotton and jute are usually unanimous; wool and acrylic felt split groups, which is the point.
2. Reveal the identities and sort the six into natural (cotton from the cotton plant, wool from sheep, jute from the jute plant) and synthetic (polyester, nylon and acrylic, all built by chemical reactions from small molecules taken out of petroleum). Trace one synthetic swatch on the board: crude oil, refinery, small molecules, polymerization, filaments drawn and woven.
3. Walk through why wool fooled the drop test: the outside of a wool fiber is water-repelling, so a drop sits on it, but once water is forced in the protein inside soaks it up. One property test can mislead; two or three together rarely do. Connect this to the standard's practice of weighing more than one source.
4. Ask which test was least reliable. Most classes name the crumple test or the drop test: how a fabric is woven, felted or finished changes those results as much as the fiber does. The fiber look and the soak-and-weigh test depend on the substance itself, which is why they worked best.
5. Close on the engineering idea: nobody made polyester by accident. Each synthetic fiber was built to have a property a natural fiber lacked (sheds water, dries fast, holds its shape), and each of those gains came with a cost (nonrenewable origin, does not rot, sheds microfibers). That trade-off is Lab 2 and Lab 3.

Recording sheet: what students fill in

Lab 1 recording sheet: Six unlabeled swatches

Fill in every cell of the evidence table before your group decides anything. The verdict table is completed only when all four tests are done, and the identity column only after the envelope is opened.

Evidence table

Swatch	Drop soak-in time (s) or 'beads'	Dry mass (g)	Wet mass (g)	Percent gain	Crumple rating (0-3)	Fibers: same or varied thickness?	Fibers: shiny/smooth or dull/uneven?	Fibers: straight, crimped or wavy?
A								
B								
C								
D								
E								
F								

 Sketch the fibers of two swatches that looked most different under the hand lens. Label each sketch with its letter and write one word for the thickness (same or varied) and one for the surface (shiny or dull).

Answer: Two labeled sketches, for example cotton (short, flat, twisted, varied thickness, dull) beside polyester (long, straight, uniform thickness, shiny), each with the letter and one word for thickness and one for surface.

Why: Grade for the features the lens can actually show: uniformity of thickness, shine and shape. A sketch of 'fuzzy' versus 'smooth' with correct letters is enough.

- Two sketches with letters
- Thickness word (same or varied) for each
- Surface word (shiny or dull) for each

Verdict table (complete before opening the envelope)

Swatch	Our verdict: natural or synthetic	Strongest evidence (name the test and the value)	Second piece of evidence	Confidence (sure / fairly sure / guessing)	Real identity (after the reveal)	Right or wrong?
A						
B						
C						
D						
E						
F						

1. Before testing: how many of the six swatches do you predict are natural fibers, and what made you guess that number?

Answer: Student-specific. Any number from 0 to 6 with a stated reason (for example 'three, because the shiny ones look synthetic') earns credit.

Why: This is a commitment, not a graded answer; it gives the student something to compare against in q2.

- States a number
- Gives a reason, even a weak one

2. After the reveal: how many verdicts were right? For any wrong verdict, which test led you astray and why?

Answer: Group-specific. Typical results: 4 to 6 of 6 right. The common wrong call is wool felt labeled synthetic because the drop beaded and it sprang back from crumpling, or acrylic felt labeled natural because it was crimped and held some water. The misleading test is named.

Why: The answer should name a specific test and say why it pointed the wrong way, which is the lab's main reasoning move.

- Gives the count
- For each wrong verdict names the test that misled and why

Analysis questions: answer key

3. Which test separated natural from synthetic swatches most cleanly, and which test was least reliable? Use values from your table, and explain what besides the kind of fiber could affect the unreliable test.

Answer: Most reliable: the fiber look (uniform, shiny, unbroken filaments for the synthetics; varied, dull, short or crimped fibers for the naturals) and the soak-and-weigh test (natural strips gained far more, for example cotton about 150 percent versus polyester under 50 percent). Least reliable: the crumple test, because wool recovers like a synthetic and because how a fabric is woven, knitted or felted changes how it creases as much as the fiber does; the drop test is also fooled by wool's water-repelling surface.

Why: The lens and the soak test probe the fiber substance; crumpling and drop beading depend partly on fabric structure and surface. Any correct pairing with table values earns credit.

- Names a most-reliable test with a value from the table
- Names a least-reliable test with a value
- Identifies fabric construction or surface coating as a factor besides fiber type

4. Wool felt usually beads a water drop for a long time but gains a lot of mass when soaked. Explain how one material can give two different answers about water, and say which result you would trust more for deciding whether a fiber is natural.

Answer: The two tests measure different things. The drop test measures the surface: a wool fiber's outer layer repels water, so a drop sits on top. The soak test forces water past the surface into the fiber, and the protein inside wool takes up a lot of water. So wool is water-repelling on the outside and water-absorbing on the inside. The soak test is the better guide to whether the fiber is natural, because it measures what the substance does, not just its surface; the drying check backs it up, since wool stays damp longest.

Why: This is the lab's key example of a single test misleading. Students need not use the word 'hydrophobic'; 'the outside repels, the inside soaks' is the target.

- Explains that the drop test measures the surface and the soak test the whole fiber
- Picks the soak test (or soak plus drying) as more trustworthy with a reason

5. Pick one swatch that turned out to be synthetic. Write the natural resource it came from, the kind of chemical process that turned the resource into the fiber, and one property your tests showed that engineers were aiming for.

Answer: Example for polyester (swatch B): natural resource, petroleum (crude oil); process, the refinery separates and cracks the oil into small molecules, and chemical reactions join two of them into long polyester chains that are melted and drawn into filaments; property shown, it beaded water, gained little mass and sprang back from crumpling, which is what engineers wanted for fabric that dries fast and holds its shape. Nylon and acrylic answers follow the same pattern.

Why: The three-part trace (resource, process, material with a property) is the core of MS-PS1-3. The exact molecule names are not required.

- Names petroleum as the resource
- Describes a chemical process (cracking, joining small molecules into chains)
- Names a tested property and connects it to a purpose

6. A company wants a fabric for a lightweight rain jacket that sheds water and comes out of a stuffed backpack without creases. Using your data, recommend one of the six fabrics and name one cost of that choice for people or for the environment.

Answer: Nylon or polyester, because both beaded water for over a minute, gained the least mass when soaked and scored 0 or 1 on the crumple test, so they shed rain and come out of a pack without creases; nylon is the usual choice for lightweight shells. Cost: the fiber comes from petroleum, a nonrenewable resource; the jacket will not rot when thrown away; washing sheds tiny plastic fibers into wastewater; and the oil-based supply chain produces pollution. A cotton or wool jacket would be renewable but would soak up rain and stay wet.

Why: Full credit requires data from the table and a real cost, not just 'it's plastic'.

- Recommends nylon or polyester with at least two test values
- Names a specific cost (nonrenewable origin, does not biodegrade, microfibers, pollution)

7. Cotton fibers are made of cellulose, a polymer of long chains, and polyester is also a polymer of long chains. Yet they behaved very differently with water. What does this tell you about the difference between the words 'polymer' and 'synthetic'?

Answer: 'Polymer' describes the shape of the molecule, a long chain of repeating units, and nature makes polymers (cellulose in cotton, protein in wool) just as factories do. 'Synthetic' describes how the material was made, by chemical processes from natural resources. Cotton and polyester are both polymers, but cotton's chains were built by a plant and carry water-attracting groups, while polyester's chains were built in a factory from petroleum molecules and do not attract water. So polymer does not mean synthetic, and the properties come from what the chain is made of, not from the fact that it is a chain.

Why: Addresses the 'polymer means plastic' misconception and ties properties to molecular structure.

- Defines polymer by chain structure and synthetic by production
- States that natural polymers exist
- Attributes the water difference to what the chains are made of

8. Rayon is made by dissolving wood pulp with chemicals and re-forming the cellulose into smooth, even fibers. Predict how a rayon swatch would behave in your four tests, then decide whether this lesson's definition would call it natural or synthetic, and explain.

Answer: Prediction: rayon is cellulose, the same substance as cotton, so it should soak a drop in quickly, gain a lot of mass, and crease badly in the crumple test; but under the lens its fibers would look smooth, shiny and uniform like a synthetic, because they were re-formed in a factory. By this lesson's definition it is synthetic, or at least partly so: people took a natural resource (wood) and used chemical processing to produce a new fiber. Many textile labels call it 'semi-synthetic' or 'regenerated'. The point is that the property tests tell you what a fiber is made of, not its history, so a fiber can test like cotton and still have been produced by chemistry, just as a lab sapphire tests like a mined one.

Why: Connects the production definition of synthetic (the chapter's repair of the textbook summary) to the limits of property testing. Either 'synthetic' or 'semi-synthetic' earns credit with the production reasoning.

- Predicts cotton-like water and crumple behavior with synthetic-like fiber appearance
- Applies the production definition of synthetic
- Notes that tests reveal substance, not origin

Individual evidence of learning

Each student submits their own evidence table, fiber sketches, verdict table with the reveal column completed, and individual answers to q1 through q8. The verdict table with two named tests per swatch and q3 are the main evidence for reasoning from property tests; q5 and q8 are the evidence for connecting a synthetic material to its natural resource and chemical process.

Assessment criteria

Criterion	Proficient looks like
Evidence collection	All four tests recorded for all six swatches with units, percent gain computed correctly, and fiber observations that describe thickness, surface and shape.
Argument from evidence	Every verdict names at least two tests with their values; wrong verdicts are explained in q2 by identifying the misleading test rather than by 'we guessed'.
Judging the tests	Identifies the fiber look and soak test as depending on the fiber substance and the crumple test as depending partly on weave or felting, with a value from the table as support.
Origins and trade-offs	Traces one synthetic swatch from petroleum through a chemical process to a fiber with an intended property, and names a real cost of choosing it.

Accessibility adaptations

- Provide a partly filled evidence table with one known swatch (for example a seventh square labeled 'cotton, known') so students who need support have an anchor row to compare against.
- Let the verdicts be argued aloud and recorded by a partner or on a device for students who write slowly; the skeptic's 'which test says so?' works as a spoken scaffold.
- Offer larger swatches, a magnifier on a stand and a dark felt mat for students with low vision or limited fine-motor control, and let a partner handle the tweezers while the student directs which fibers to pull.

- Provide a multilingual word card for absorb, bead, crease, fiber, synthetic and natural, and accept q4 and q8 as labeled diagrams.

Low-cost alternative

Use squares cut from donated clothing with readable fiber labels: a cotton T-shirt, a polyester or nylon jacket lining, a wool scarf, an acrylic sweater and a burlap sack. Skip the balance and rank water uptake by eye: lift each soaked strip and count how many drops fall in ten seconds. One hand lens per two groups is enough.

Model limitations

Four desk tests cannot identify a fiber with certainty; textile labs use burn behavior, chemical solubility and microscopes, none of which are used here. The results depend on fabric weight and construction (woven, knit or felt) as well as on the fiber, so a knit polyester and a woven polyester give different crumple and stretch results, and many real fabrics are blends that would confuse every test. Acrylic fibers are crimped on purpose to imitate wool, so the lens test is weakest for that pair. This activity has not been physically tested by the authors; the drop times, percent gains and ratings in the expected observations are estimates from the known behavior of these fibers and should be checked against the teacher's trial run.

Teacher notes

Keep the envelopes sealed until every recorder has a complete verdict table; the comparison between verdict and identity is the evidence. If a group gets wool or acrylic wrong, do not treat it as a failure: the write-up explaining which test misled is worth more than six correct guesses. Replace the expected values with the ones from your own trial run, since fabric weight changes every number. If you lack a true wool felt, substitute a wool scarf or sweater square and say so on the key; a wool-acrylic blend felt will give mixed results and should be avoided.