

# Fixing Marcus's Study Guide: Nine Claims About Synthetic Materials

**Learning target:** I can find the errors in a classmate's statements about natural resources, synthetic materials and biodegradability, explain exactly what went wrong, and rewrite each statement so that it is accurate.

Error analysis

About 40 min

Individual

MS-PS1-3 · practice

writing

independent practice

## Standards connections

**MS-PS1-3 (practice):** Each statement is a common misunderstanding about where synthetic materials come from or how they affect society and the environment. Diagnosing and rewriting them sharpens the sense-making the PE requires without producing new information-gathering evidence.

**Purpose:** practice · **Time:** about 40 minutes · **Format:** individual

## Answers with reasoning

**Marcus's study guide (copied exactly)** — **1.** Synthetic materials are made out of chemicals, not out of anything from nature. **2.** The safest choice is always the natural one: natural materials are safe and synthetic ones are harmful. **3.** Petroleum formed underground over hundreds of years, which is why we are running out. **4.** Corn ethanol is renewable because corn grows back every year, so switching from gasoline to ethanol has no downsides. **5.** A sapphire grown in a lab is a synthetic material even though it is the same substance as a sapphire dug from a mine. **6.** PLA cups are made from corn, so they are biodegradable and will break down in any trash can. **7.** Making the cancer drug paclitaxel from yew needles instead of yew bark was better because the needles grow back and the tree stays alive. **8.** Engineers decided in the beginning that plastics should be strong and cheap, and those requirements have never changed. **9.** Sucralose tastes sweet because its molecule is shaped almost like a sugar molecule, but the body cannot digest it, so it gives no energy.

## Part A: Diagnose

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1. Complete the table. For each incorrect statement, name in a few words the word or idea Marcus got wrong. For each correct statement, write 'correct' in the second column.

**Answer:** 1 incorrect: 'not from nature' (every synthetic material starts from a natural resource). 2 incorrect: 'natural equals safe, synthetic equals harmful' (safety depends on the substance, amount and use). 3 incorrect: 'hundreds of years' (millions of years). 4 incorrect: 'no downsides' (farmland, food and feed competition, energy to grow and distill). 5 correct. 6 incorrect: 'any trash can' (only in an industrial composter; and bio-based is not the same as biodegradable). 7 correct. 8 incorrect: 'never changed' (criteria were revised after plastics filled landfills and harmed wildlife). 9 correct.

**Why:** The table is the diagnosis step; a few words per row is enough. Statements 5, 7 and 9 are the chapter's accurate versions of three ideas students often get wrong, so they are included to prevent students from assuming every statement is false.

*Also acceptable: For statement 6, accept either 'any trash can' or 'made from corn, so biodegradable' as the error.*

## Part B: Explain and rewrite

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For each incorrect statement write three things: (a) **What Marcus was thinking:** the true idea or everyday meaning his statement started from. (b) **What went wrong:** the specific error, with a fact from the chapter that shows it is wrong. (c) **Rewrite:** the statement corrected, in one or two sentences, keeping any part that was right.

2. Statement 1 (synthetic materials are made of chemicals, not anything from nature).

**Answer:** (a) Marcus was thinking that synthetic materials are made by chemical processes, which is true, and that 'chemicals' are something separate from nature. (b) Every synthetic material starts from a natural resource: polyester and nylon from petroleum, PLA and ethanol from corn, bronze from copper and tin ores, the drug paclitaxel from a substance in yew needles. The chemical process changes the natural resource into a new material; it does not make material out of nothing. Everything, including the chemicals, is made of atoms that came from somewhere in nature. (c) Rewrite: 'Synthetic materials are made by chemical processes that change natural resources, such as petroleum or corn, into new materials with different properties.'

**Why:** This is the chapter's central idea: synthetic materials come from natural resources. Full credit needs at least one specific resource-to-material example.

*Also acceptable: Accept an example from the student's own knowledge if it is accurate.*

- Identifies the true starting idea (made by chemistry)
- Gives at least one resource-to-material example
- Rewrite says synthetic materials start from natural resources

3. Statement 2 (natural is safe, synthetic is harmful).

**Answer:** (a) Marcus was thinking of advertisements that use 'natural' as a promise and 'chemical' as a warning, and perhaps of real cases where a synthetic substance did cause harm. (b) Safety depends on what the substance is, how much of it there is and how it is used, not on where it came from. Natural substances can be dangerous (poison hemlock, lead ore, the latex some people are allergic to), and synthetic ones can be life-saving (aspirin, paclitaxel made from a yew-needle compound, synthetic rubber for medical gloves). Sucralose was reviewed by regulators before approval in 1998. (c) Rewrite: 'Natural and synthetic tell you where a material came from, not whether it is safe; each substance has to be judged by evidence about its own properties and effects.'

**Why:** Full credit requires one natural-but-harmful example and one synthetic-but-beneficial example, and a rewrite that separates origin from safety.

*Also acceptable: Accept 'mushrooms can be poisonous' and 'medicines are synthetic' as examples.*

- Example of a harmful natural substance
- Example of a beneficial synthetic substance
- Rewrite separates origin from safety

4. Statement 3 (petroleum formed over hundreds of years).

**Answer:** (a) Marcus was thinking that petroleum formed a long time ago and that we use it faster than it forms, which is true. (b) Petroleum formed over millions of years, not hundreds, from the buried remains of tiny ocean organisms that were slowly heated and pressed underground. The textbook itself says 'hundreds' in one place and 'millions' in another; millions is correct. The reason we are running out is still right: the supply is being pumped far faster than new petroleum forms, so for human purposes it is a fixed amount. (c) Rewrite: 'Petroleum took millions of years to form underground from the remains of ancient living things, so we are using it far faster than Earth can make more.'

**Why:** The time scale is the error; the conclusion about running out is sound. Students should keep the sound conclusion in the rewrite.

*Also acceptable: Accept 'millions of years' without the marine-organism detail.*

- Corrects hundreds to millions
- Names the origin (remains of ancient organisms)
- Keeps the correct conclusion about using it faster than it forms

5. Statement 4 (corn ethanol is renewable, so switching has no downsides).

**Answer:** (a) Marcus was thinking that corn is a renewable resource because a new crop grows every year, which is true, and that renewable means better in every way. (b) Switching to corn ethanol has real costs: growing corn for fuel uses farmland and water, competes with growing corn for food and animal feed (although ethanol plants return part of the corn as livestock feed), and takes energy to plant, harvest, ferment and distill. Whether ethanol returns more energy than it took to make depends on the farming and processing methods and is measured and debated. Ethanol also carries less energy per liter than gasoline. (c) Rewrite: 'Corn ethanol comes from a renewable crop, which is an advantage over petroleum, but it uses farmland, competes with food and feed, and takes energy to produce, so switching is a trade-off, not a free win.'

**Why:** Full credit requires at least two specific downsides and a rewrite that keeps the renewable advantage. Do not accept the textbook's flat claim that ethanol takes more energy than it gives as fact; the accurate statement is that the balance depends on method.

*Also acceptable: Accept 'uses fertilizer and water' or 'cars go slightly fewer miles per tank' as downsides.*

- Keeps the true renewable point
- At least two specific downsides
- Rewrite frames it as a trade-off

6. Statement 6 (PLA cups are made from corn, so they break down in any trash can).

**Answer:** (a) Marcus was thinking that PLA is made from corn, which is true, and that because corn rots, anything made from corn will rot too. (b) Being made from a plant and being biodegradable are different properties. PLA's chains can be taken apart by microbes, but only when the cup is kept hot (about 58 °C), moist and aerated for weeks in an industrial composting facility. In a landfill, a backyard pile, a creek or an ordinary trash can it lasts for years. Some plant-based plastics do not biodegrade at all, and some petroleum-based plastics do; what matters is the structure of the polymer and the conditions. (c) Rewrite: 'PLA cups are made from corn and are biodegradable in an industrial composter, where they break down in weeks to months, but in a landfill or trash can they last for years.'

**Why:** This is the lesson's own example of a solution that did not meet its criterion. The rewrite must include the conditions.

*Also acceptable: Accept 'only in a commercial composting facility' without the temperature.*

- Separates plant origin from biodegradability
- Names the composter conditions and the landfill result
- Rewrite includes the condition

7. Statement 8 (the requirements for plastics have never changed).

**Answer:** (a) Marcus was thinking that the original criteria for plastics were strength, flexibility, long life and low cost, which is true, and that criteria are fixed once written. (b) Criteria change when a solution creates new problems. Studies found that plastic items were used once and thrown away, often could not be recycled, filled landfills for years and were eaten by wildlife, so engineers added a new criterion: the material must break down quickly after use. The low cost requirement did not disappear, but in engineering language it is a constraint (a limit), not a criterion (a success condition). (c) Rewrite: 'Engineers first designed plastics to be strong, flexible and long-lasting within a low cost; when evidence showed plastics piling up in landfills and harming wildlife, they revised the criteria to include breaking down quickly after use, and they are still testing materials such as PLA against the new criteria.'

**Why:** The design cycle idea: criteria are revised when evidence of new problems appears. Full credit needs the evidence that triggered the change and the new criterion.

*Also acceptable: A student who notes that cost is a constraint rather than a criterion is giving a bonus-level answer.*

- Names the original criteria
- Names the evidence that led to revision (landfills, wildlife)
- Rewrite includes the new criterion

## Part C: Step back

8. Statements 5, 7 and 9 are correct. For statement 7, add one sentence Marcus left out that would make the story complete: what did chemists still have to do to the substance from the needles, and what newer method has replaced harvesting trees for some manufacturers?

**Answer:** Chemists still had to change the substance extracted from the needles into paclitaxel through several chemical steps, because the needles do not contain the finished drug; and for some manufacturers, growing yew cells in culture tanks has replaced harvesting needles and twigs from trees altogether (a method recognized by a 2004 environmental award).

**Why:** Statement 7 is correct but incomplete; the addition is the semisynthesis step and the cell-culture method. Either part earns most of the credit; both earn full credit.

*Also acceptable: Accept 'the needles contain a related chemical, not the drug itself' for the first part.*

- States that the needle substance had to be chemically converted into the drug
- Names cell culture (growing yew cells in tanks) as a newer method

9. Four of Marcus's errors (statements 1, 2, 4 and 6) come from the same habit of thinking. Describe that habit in one sentence, then write a one-sentence rule Marcus could use to avoid it in the future.

**Answer:** The habit: judging a material by a label about where it came from (natural, synthetic, from corn, renewable) instead of by evidence about what the material itself does and where it ends up. Rule: 'A material's origin is one fact; its properties, its effects and its ending are separate facts that have to be checked on their own.'

**Why:** All four errors generalize from origin to behavior. The rule should separate origin from properties and effects.

*Also acceptable: Accept 'natural or synthetic tells you how it was made, not how it behaves' as the rule.*

- Names the habit as judging by origin label
- Rule separates origin from properties, effects or ending

## Teacher notes

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Statements 5, 7 and 9 are correct and are the accurate versions of three ideas the textbook handles loosely: synthetic is defined by how a material is made (lab-grown sapphire counts), the yew-needle route is semisynthesis (q8 adds the conversion step and the later cell-culture method), and sucralose is sweet because of its sugar-like shape and indigestible because of the three chlorine atoms that replace oxygen-hydrogen groups. Statement 3 reproduces the textbook's own error on page 187; the correct time scale is millions of years. For statement 4, do not accept 'ethanol takes more energy to make than it gives' as a fact; USDA estimates since the 1990s find a positive balance that depends on method. Statement 6 corrects the opener's unconditional 'biodegradable' and the 'several days' claim; industrial composting takes weeks to months. Use q9 as the exit discussion: the chapter's thinking rule is to judge each material by evidence, not by its origin label.

### **Scaffold offered to students: Start from the true part**

Every wrong statement on this sheet grew from something true. Statement 1 is right that synthetic materials are made by chemistry. Statement 4 is right that corn regrows every year. Statement 6 is right that PLA is made from corn and that it is biodegradable. For each one, write the true part first, then ask: what extra claim did Marcus tack on that the chapter does not support? Your rewrite is usually the true part plus the correct version of the extra claim.

### **Extension: Write the tenth statement**

Write a tenth statement for Marcus's guide that is wrong in a way no statement on this sheet already covers, based on something in the chapter (for example, about medicines, gasoline, food additives or cost as a criterion). Trade with a partner and diagnose each other's statement using the Part B format. The best wrong statements, like Marcus's, start from something true.