

Item Construction for Science Assessment



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Trends in International Mathematics and Science Study (TIMSS)

International Association for the Evaluation of Educational Achievement (IEA)

- Showing different ways of measuring students' understanding in various content and cognitive domains
- Use for
 - To help teachers to create an assessment
 - To obtain feedback on student understanding
 - To benchmark student performance (Grade 8)

Item Construction (TIMSS-based) grade 8

3 types

- Factual **knowledge**
- Conceptual **understanding**
- **Reasoning** and Analysing

Examples

The nucleus of MOST atoms consists of

- (A) neutrons only
- (B) protons and neutrons
- (C) protons and electrons
- (D) neutrons and electrons

TIMSS 2003

Content Domain

Chemistry

Main Topic

Particulate structure of matter

Cognitive Domain

Factual Knowledge

Key

B

A son can inherit traits

- (A) only from his father
- (B) only from his mother
- (C) from both his father and his mother
- (D) from either his father or his mother, but not from both

TIMSS 2003

Content Domain

Life Science

Main Topic

Reproduction and heredity

Cognitive Domain

Conceptual Understanding

Key

C

The table gives the temperature at a certain place at different times of the day for three days.

	6 a.m.	9 a.m.	12 noon	3 p.m.	6 p.m.
Monday	15°C	17°C	20°C	21°C	19°C
Tuesday	15°C	15°C	15°C	5°C	4°C
Wednesday	8°C	10°C	14°C	14°C	13°C

When did the wind become much colder?

- (A) Monday morning
- (B) Monday afternoon
- (C) Tuesday morning
- (D) Tuesday afternoon
- (E) Wednesday afternoon

TIMSS 2003

Content Domain

Earth Science

Main Topic

Earth processes, cycles and history

Cognitive Domain

Reasoning and Analysis

Key

D

(An example)

Ask 3 questions based on this statement

When sweat evaporates, it takes heat away from our body.

(1) What is meant by evaporation?

(recall/remembering/knowledge/factual)

(2) Using kinetic theory of matter, explain how evaporation takes away heat from our body.

(understanding)

(3) Why do you think that we should 'drink 8 glasses of water' everyday to keep healthy?

(reasoning)



Content Domain	Main Topic	Cognitive Domain
BIOLOGY	Characteristics, Classification, and Life Processes of Organisms	Knowing

The uterus (womb) is part of the reproductive system in mammals.
Name one function of the uterus.

Student Responses

Correct Response:

To hold the child while it is developing

Incorrect Response:

giving birth

Content Domain	Main Topic	Cognitive Domain
BIOLOGY	Human Health	Knowing

Long-term immunity against disease

Which of the following can provide the human body with long-term immunity against some diseases?

- A. antibiotics
- B. vitamins
- C. vaccines
- D. red blood cells

Item Number: S032087

Correct Response: C

Content Domain	Main Topic	Cognitive Domain
BIOLOGY	Characteristics, Classification, and Life Processes of Organisms	Applying

Eyes react to changes

Diagram 1



Diagram 2



Diagrams 1 and 2 illustrate the same pair of eyes that have reacted to a change in an environmental condition.

What is the environmental condition and how is it different for the eyes in Diagram 1 and Diagram 2?

SCORING

Correct Response

- Indicates LIGHT and identifies which diagram corresponds to the low/high light level.
- Diagram 1 = dim light, low light level, darkness, or similar
- Diagram 2 = bright light, high light level, or similar
- Example: There is less light in Diagram 1. The pupil has gotten larger to let in more light.
- Other fully correct

Partially Correct Response

- Indicates LIGHT but does not identify which diagram corresponds to low/high light level.
- Example: It is the light level. In Diagram 1, the pupils are bigger. In diagram 2 they are smaller.
- Other partially correct

Incorrect Response

- Indicates LIGHT but reverses the conditions in Diagrams 1 and 2.
- Other incorrect (including crossed out, erased, stray marks, illegible, or off task)

Student Responses

Correct Response:

In diagram 1 the pupils are dilated meaning it must be dark outside

Partially Correct Response:

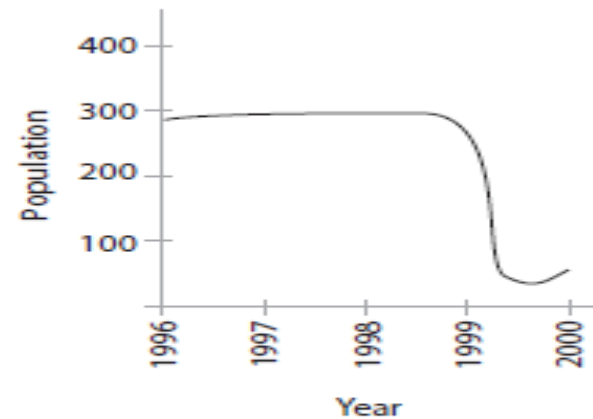
The vironmental condition is the sun. If you stay in the sun a lot there will be some changes on your body including your eyes.

Incorrect Response:

diagram one would be in the sun Or outside with sunlight while diagram 2 is when you've been in the dark and turned on the lights

Content Domain	Main Topic	Cognitive Domain
BIOLOGY	Ecosystems	Reasoning

Antelope population graph



The graph indicates the number of antelopes in a certain area over a period of time. Which of the following factors is most likely to have caused the sudden change in population between 1999 and 2000?

- A. global warming
- B. absence of predators
- C. depletion of the ozone layer
- D. brush fires that destroyed the food supply

Correct Response: D

Content Domain	Main Topic	Cognitive Domain
BIOLOGY	Diversity, Adaptation, and Natural Selection	Applying

Difference in snail shell colors

Some birds eat snails. A species of snail that lives in the forest has a dark shell. The same species of snail that lives in a field has a light-colored shell. Explain how this difference in shell colors helps the snails to survive.

Scoring

Correct Response

- Explanation refers explicitly to BOTH camouflage (blending in with surroundings, or similar) AND protection from birds, predators, enemies, etc.
- Example: The snails that live in the forest have dark shells so the birds cannot see them to eat them.
- Explanation refers only to camouflage, blending in with surroundings, or similar. [Protection from predators NOT explicitly mentioned.]
- Example: It helps the snail to camouflage with their surroundings.
- Other fully correct

Partially Correct Response

- Explanation refers only to not being eaten or seen by predators. [Camouflage NOT referenced.]
- Example: So the birds will not eat them.
- Other partially correct

Incorrect Response

- Mentions only that it is dark in the forest and light in the field. [Does not explicitly refer to camouflage, protection from predators, or similar.]
- Other incorrect (including crossed out, erased, stray marks, illegible, or off task)
-

Answers

Student Responses

Correct Response:

The snails are usual on grass or sand. They have to match it so that the birds will mistake it for being something else.

Partially Correct Response:

Snails use there shells color to hide from predators

Incorrect Response:

Because - one
stays in sun, one
stays in shade

Content Domain	Main Topic	Cognitive Domain
BIOLOGY	Ecosystems	Reasoning

Population in countries: predict

There are more than 6 billion people in the world who share the world's natural resources. Look at the table below. It shows some information for two fictitious countries (1 and 2).

	Country 1	Country 2
Population (millions)	200	500
Annual birth rate (births per 1000 people)	10	40
Annual death rate (deaths per 1000 people)	10	10
Area in square kilometers	2,000,000	2,000,000
Grain production (percentage of world total)	40%	20%
Oil consumption (percentage of world total)	20%	5%

A. Based on the information given in the table, predict how the population of each country will change over the next ten years.
(Check one box in each row.)

	Population Will Increase	Population Will Decrease	Population Will Stay the Same
Country 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Country 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Content Domain	Main Topic	Cognitive Domain
BIOLOGY	Ecosystems	Reasoning

Population in countries: land use

There are more than 6 billion people in the world who share the world's natural resources. Look at the table below. It shows some information for two fictitious countries (1 and 2).

	Country 1	Country 2
Population (millions)	200	500
Annual birth rate (births per 1000 people)	10	40
Annual death rate (deaths per 1000 people)	10	10
Area in square kilometers	2,000,000	2,000,000
Grain production (percentage of world total)	40%	20%
Oil consumption (percentage of world total)	20%	5%

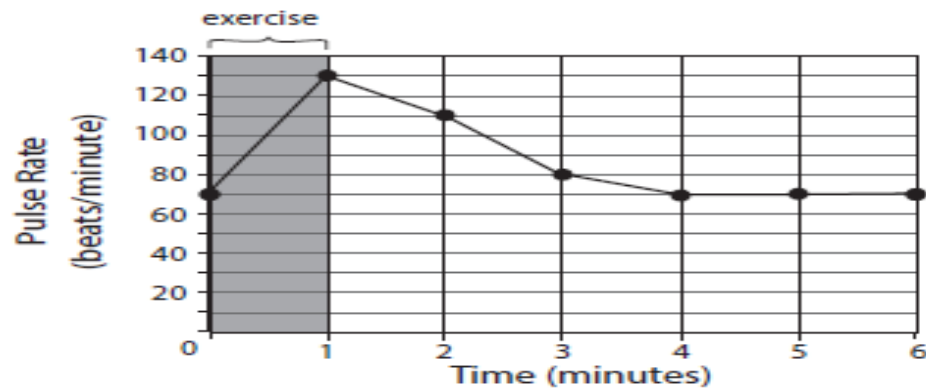
B. Predict how the population of the two countries will affect each of the following environmental factors over the next ten years.

- (i) Land use
- (ii) Pollution

Content Domain	Main Topic	Cognitive Domain
BIOLOGY	Characteristics, Classification, and Life Processes of Organisms	Reasoning

Conclusion from pulse rate-T graph

John measures his pulse rate before he exercises. It is 70 beats per minute. He exercises for one minute and measures his pulse rate again. He then measures it every minute for several minutes. He draws a graph to show his results.



What can be concluded from his results?

- A. His pulse rate increased by 50 beats per minute.
- B. His pulse rate took less time to slow down than to increase.
- C. His pulse rate after 4 minutes was 80 beats per minute.
- D. His pulse rate returned to normal in less than 6 minutes.

Recycling paper

For each of the following, indicate whether or not it is a benefit of recycling paper.

(Fill in one circle in each row.)

	Yes	No
reducing deforestation -----	(A)	(B)
reducing the amount of oxygen in the atmosphere-----	(A)	(B)
reducing the amount of water needed for farming -----	(A)	(B)
reducing the amount of carbon dioxide in the atmosphere -----	(A)	(B)
reducing the amount of garbage going to landfills -----	(A)	(B)

Answers

Option	Rationale	Item: S062189
	(KEY: A) Recycling paper reduces deforestation because paper is made from trees.	
	(KEY: B) Reducing the amount of oxygen in the atmosphere is not a benefit of recycling paper.	
	(KEY: B) Reducing the amount of water needed for farming is not a benefit of recycling.	
	(KEY: A) Recycling paper reduces the amount of carbon dioxide in the atmosphere because trees take carbon dioxide out of the atmosphere.	
	(KEY: A) Recycling paper reduces the amount of garbage going into landfills.	

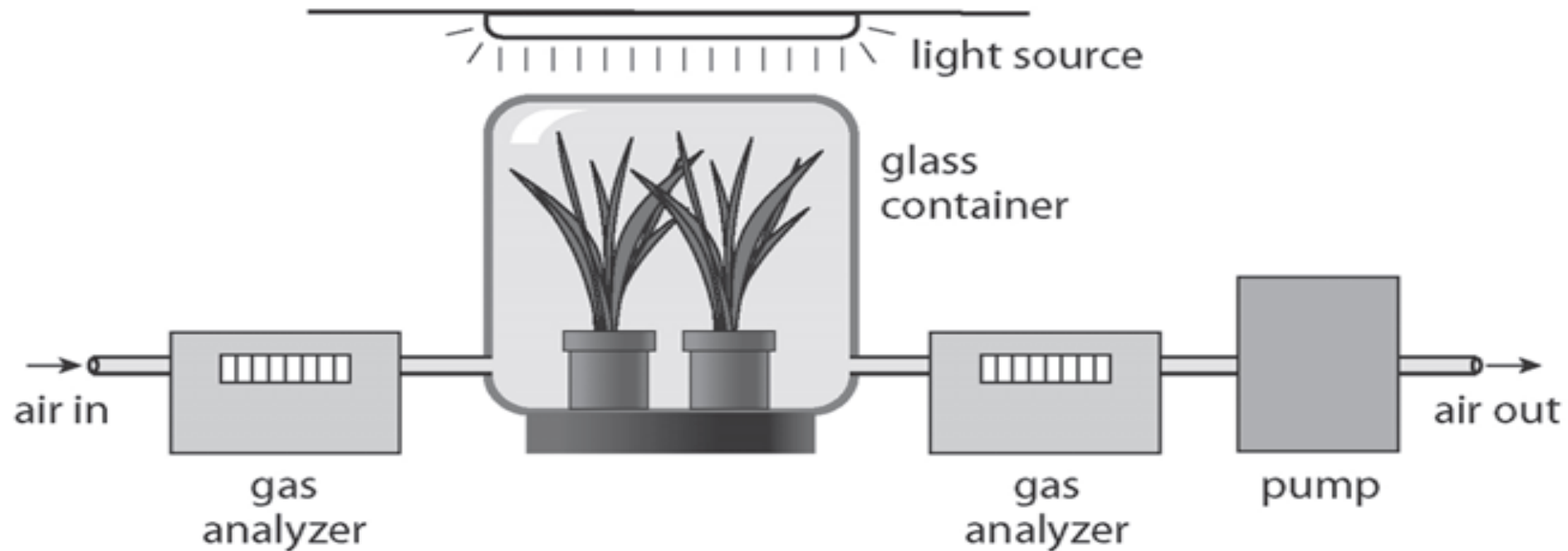
- **Content Domain**
- Earth Science
- **Topic Area**
- Earth's Resources, Their Use and Conservation
- **Maximum Points**
- 2
- **Cognitive Domain**
- Knowing

- **Key**
- A, B, B, A, A

Photosynthesis

Sara is studying how the rate of photosynthesis in plants is affected by the intensity of sunlight on the plants.

She grows plants in a clear glass container. Outside air is pulled through the container by a small pump. Gas analyzers measure the amount of carbon dioxide and oxygen in the air before it enters and after it leaves the container.



A. When a light is shining on the plants, how will the amounts of carbon dioxide and oxygen in the air leaving the container compare to the amounts of carbon dioxide and oxygen entering the container?

	Amount of carbon dioxide leaving the chamber		Amount of oxygen leaving the chamber
Ⓐ	higher	<i>and</i>	higher
Ⓑ	higher	<i>and</i>	lower
Ⓒ	lower	<i>and</i>	higher
Ⓓ	lower	<i>and</i>	lower

Answer

Option	Rationale	Item: S062103A
A	Misconception that photosynthesis increases both the amount of carbon dioxide and the amount of oxygen.	
B	Misconception that photosynthesis increases the amount of carbon dioxide and decreases the amount of oxygen.	
C	KEY	
D	Misconception that photosynthesis decreases both the amount of carbon dioxide and the amount of oxygen.	

- **Content Domain**
- **Biology**
- **Topic Area**
- **Cells and Their Functions**
- **Maximum Points**
- **1**
- **Cognitive Domain**
- **Reasoning**
- **Key**
- **C**

Follow-up question

Sara conducted a test using a low-intensity light source. She then conducted a second test using the same equipment with a high-intensity light source.

B. Sara wants to compare gas analyzer data from both tests.

Write two factors that could affect the rate of photosynthesis that Sara will have to make sure she keeps the same in both tests.

1.

2.

Answer

Code	Response	Item: S062103B
Correct Response		
20	<p>Lists two different factors that could affect the rate of photosynthesis from the list of acceptable responses below. To receive a Code 20, the factors must address two different bullets.</p> <ul style="list-style-type: none"> • Air temperature • Amount of water given to the plants • The humidity in the air • The amount of fertilizer given to the plants • Number of plants • Type of plants (or the same plants) • Time of day of the experiment • Size of the plant (number of leaves) • Amount of carbon dioxide (or carbon dioxide and oxygen) in incoming air • Flow or amount of incoming air • Distance from the light to the plant <p><i>Example:</i></p> <ul style="list-style-type: none"> • 1. Amount of air going in and out. • 2. Make measurements at the same time of day. 	
Partially Correct Response		
10	<p>Lists only one factor from the list of acceptable responses above. The second response may be missing, incorrect, or redundant with the first.</p> <p><i>Example:</i></p> <ul style="list-style-type: none"> • 1. The size of the plants. [correct] • 2. The number of leaves the plant has. [redundant] 	
Incorrect Response		
79	<p>Incorrect (including crossed out, erased, stray marks, illegible, or off task), including the amount of light and the place where the apparatus is set up. Response cannot simply list “plants,” but must include a feature of the plants.</p>	
Nonresponse		
99	Blank	

- **Content Domain**
- Biology
- **Topic Area**
- Cells and Their Functions
- **Maximum Points**
- 2
- **Cognitive Domain**
- Reasoning
- **Key**
- See scoring guide

Programme for International Student Assessment (PISA) by The Organisation for Economic Co-operation and Development (OECD)

- Every three years it tests 15-year-old students from all over the world in **reading, mathematics and science**.
- The tests are designed to gauge how well the students master key subjects in order to be prepared for real-life situations in the adult world.
- Why choose 15-year-olds?
- Because in most countries, at the age of 15, students can decide whether or not they want to continue their education. They therefore need to be equipped for adult life.
- PISA publishes the results of the test a year after the students are tested to help governments shape their education policy.

Scientific Question Categories

SCIENTIFIC COMPETENCIES

- **Explain phenomena scientifically**
 - to recognise, offer and evaluate explanations for a range of natural and technological phenomena.
- **Evaluate and design scientific enquiry**
 - to describe and appraise scientific investigations and propose ways of addressing questions scientifically.
- **Interpret data and evidence scientifically**
 - to analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions.

KNOWLEDGE CATEGORIES

- **Content knowledge**

- refers to the knowledge of theories, explanatory ideas, information and facts

- **Procedural knowledge**

- refers to an understanding of how such knowledge has been derived, the knowledge about the concepts and procedures that are essential for scientific enquiry, and that underpin the collection, analysis and interpretation of scientific data.

- **Epistemic knowledge**

- refers to the nature of that knowledge, an understanding of the nature and origin of knowledge in science, and reflects students' capacity to think and engage in reasoned discourse as scientists do. Epistemic knowledge is required to understand the distinction between observations, facts, hypotheses, models and theories, but also to understand why certain procedures, such as experiments, are central to establishing knowledge in science.

CONTENT AREAS & CONTEXT OF ASSESSMENT ITEMS

- **CONTENT AREAS**

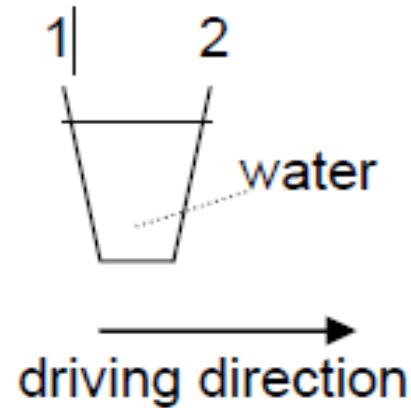
- Knowledge can also be classified according to the major scientific fields to which it pertains:
- **physical systems, living systems, and earth and space systems.**

- **CONTEXT OF ASSESSMENT ITEMS**

- Three context categories identify the broad areas of life in which the test problems may arise:
- “**personal**”, which are contexts related to students’ and families’ daily lives;
- “**local/national**”, which are contexts related to the community in which students live; and
- “**global**”, which are contexts defined by life across the world.

Question 1: BUSES S127Q01

A bus is driving along a straight stretch of road. The bus driver, named Ray, has a cup of water resting on the dashboard:



Suddenly Ray has to slam on the brakes.

What is most likely to happen to the water in the cup?

- A The water will stay horizontal.
- B The water will spill over side 1.
- C The water will spill over side 2.
- D The water will spill but you cannot tell if it will spill at side 1 or side 2.

BUSES SCORING 1

- QUESTION INTENT: Process: Demonstrating knowledge and understanding
- Theme: Forces and movement
- Area: Science in technologies

- **Full credit**
- Code 1: C. The water will spill over side 2.
- **No credit**
- Code 0: Other responses.
- Code 9: Missing.

Question 2: BUSES

Ray's bus is, like most buses, powered by a petrol engine. These buses contribute to environmental pollution. Some cities have trolley buses: they are powered by an electric engine. The voltage needed for such an electric engine is provided by overhead lines (like electric trains).

The electricity is supplied by a power station using fossil fuels. Supporters for the use of trolley buses in a city say that these buses don't contribute to environmental pollution.

Are these supporters right? Explain your answer.

.....

.....

.....

.....

BUSES SCORING

- **QUESTION INTENT:** Process: Demonstrating knowledge and understanding
- Theme: Energy transformations
- Area: Science in Earth and environment
- **Full credit**
- Code1: Gives an answer in which it is stated that the power station also contributes to environmental pollution:
 - No, because the power station causes environmental pollution as well.
 - Yes, but this is only true for the city itself; the power station however causes environmental pollution.
- **No credit**
- Code 0: No or yes, without a correct explanation.
- Code 8: Off task.

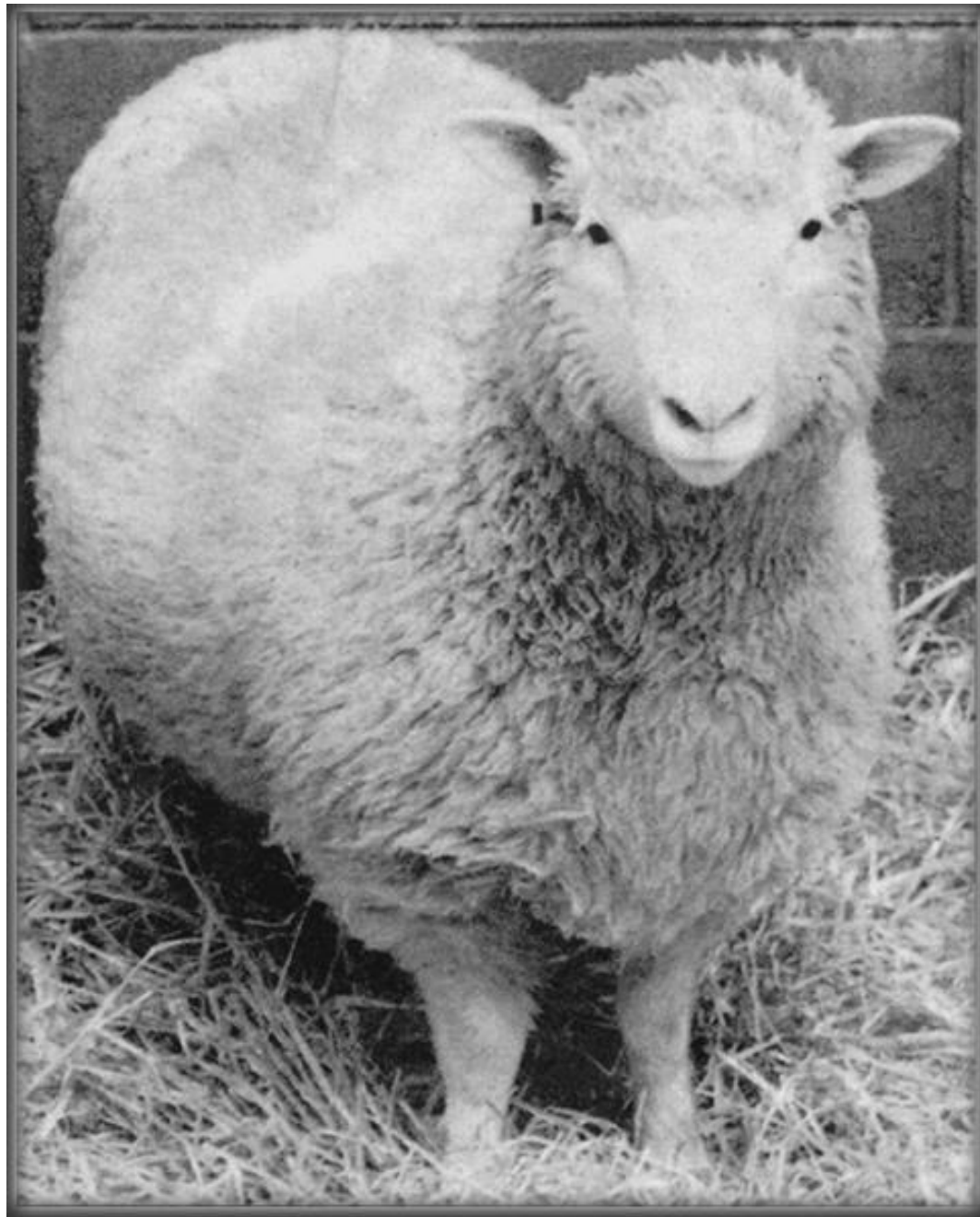
Example responses

- Code 1:
 - Yes and No. The buses don't pollute the city which is good, but the power station does pollute and that's not very good.
 - The buses do contribute to the environmental pollution by using fossil fuels but
 - they're not as harmful as normal buses with all their gases. *[Note: This answer can be given the benefit of the doubt.]*
- Code 0:
 - • Well they have no outlet so no harmful smoke goes into the air which can
 - damage the O-zone layer, and having electricity created by fossil fuels is also
 - more environmental friendly.
 - • Yes, they are. Because electricity isn't harmful for the environment we only use
 - up our Earth's gas.

Cloning

Read the newspaper article and answer the questions that follow.

- Without any doubt, if there had been elections for the animal of the year 1997, Dolly would have been the winner!
- Dolly is a Scottish sheep that you see in the **5** photo. But Dolly is not just a simple sheep. She is a clone of another sheep. A clone means: a copy. Cloning means copying 'from a single master copy'. Scientists succeeded in creating a sheep (Dolly) that **10** is identical to a sheep that functioned as a 'master copy'.
- It was the Scottish scientist Ian Wilmut who designed the 'copying machine' for sheep. He took a very small piece from the **15** udder of an adult sheep (sheep 1).
- From that small piece he removed the nucleus, then he transferred the nucleus into the egg-cell of another (female) sheep (sheep 2). But first he removed from that **20** egg-cell all the material that would have determined sheep 2 characteristics in a lamb produced from that egg-cell. Ian Wilmut implanted the manipulated eggcell of sheep 2 into yet another (female) **25** sheep (sheep 3). Sheep 3 became pregnant and had a lamb: Dolly.
- Some scientists think that within a few years it will be possible to clone people as well. But many governments have already **30** decided to forbid cloning of people by law.



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36

Q & A:

Question 1: CLONING

Which sheep is Dolly identical to?

A Sheep 1

B Sheep 2

C Sheep 3

D Dolly's father

- **CLONING SCORING 1**
- *Full credit*
- Code 1: A. Sheep 1
- *No credit*
- Code 0: Other responses.
- Code 9: Missing.

Question 2: CLONING

In line 14 the part of the udder that was used is described as “a very small piece”.

From the article text you can work out what is meant by “a very small piece”.

That “very small piece” is

- A a cell.
- B a gene.
- C a cell nucleus.
- D a chromosome.

Remember? The questions you may ask...



- Q1 (remembering/knowledge)

What do you see in this picture?

What are the animals in this picture?

- Q2 (understanding/comprehension)

Who is the predator/prey?

- Q3 (applying/application)

Describe another example that shows the same relation between two animals/phenomena / looks like this picture.

- Q4 (analysing/analysis)
- Why do you think that that this deer is not an easy prey for the tiger?
- Q5 (Evaluating/Evaluation)
- Would you think the deer may escape? Why?
- Q6 (creating/synthesis)
- What if there were no tigers in this place?