Medify

GAMSAT Sample Questions

Section III
Reasoning in Biological and Physical Sciences

Questions 1 – 5

The bacterial ribosome is targeted by over 60% of naturally derived antibiotics. Compromising protein synthesis makes metabolism, signalling, motility and many other crucial cellular functions impossible. Targets and mechanisms of action for selected ribosome-targeting antibiotics are described in Table 1 and illustrated in Figure 1.

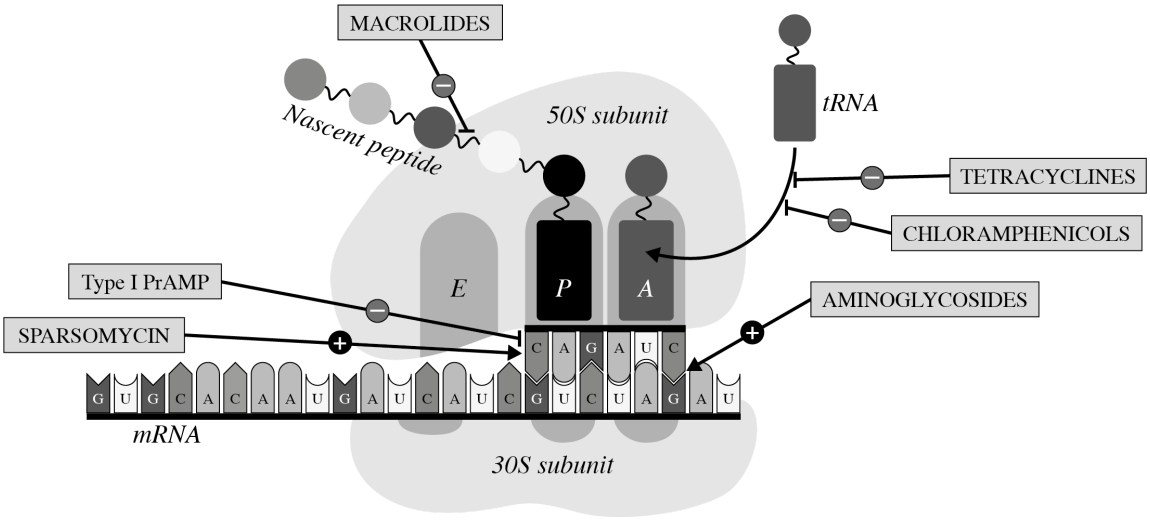


Figure 1

Table 1

Antibiotic class	Target subunit	Mechanism of action
Aminoglycosides	30S	Stabilise bulged-out conformation of 16S rRNA
Tetracyclines	30S	Occupy anticodon binding space near the A site
Chloramphenicols	50S	Occupy aminoacyl binding space near the A site; inhibit ribosomal protein translation; hinder 50S subunit formation
Macrolides	50S	Block nascent protein elongation at the E site, induce premature termination
Sparsomycin	50S	Increase aminoacyl-tRNA affinity to P site, causing premature translocation
Type I PrAMPs	50S	Prevent tRNA transfer from A to P site
Type II PrAMPs	50S	Prevent dissociation of release factors from the ribosome, stalling translating ribosomes and depleting the pool of free release factors for other ribosomes

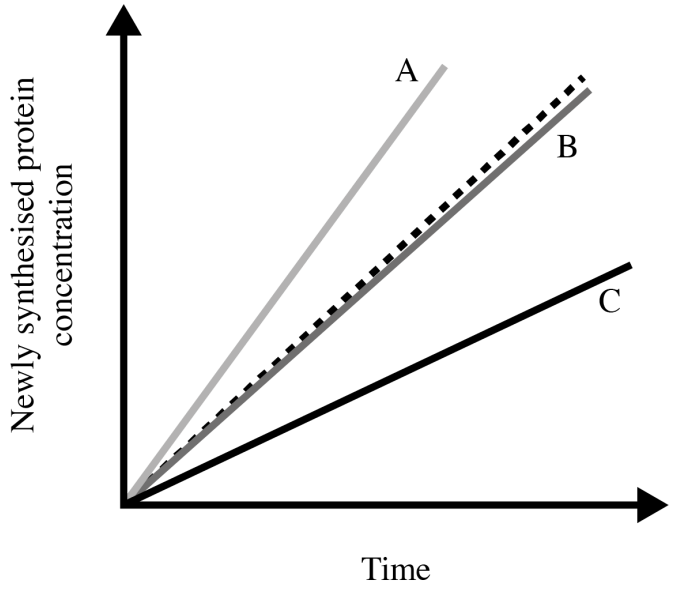
The 30S subunit of the ribosome contains a 16S ribosomal RNA strand, which has a conserved loop of three unpaired adenine residues. When codon–anticodon pairing is correct, this loop bulges out and allows translation to proceed.

Release factors are necessary to recognise STOP codons in mRNA and initiate dissociation of the synthesised protein from the ribosome.

PrAMP stands for proline-rich antimicrobial peptide.

The envelope of Gram-positive bacteria consists of a thick cell wall and one inner plasma membrane. In Gram-negative bacteria, this envelope consists of a thin cell wall and two – inner and outer – plasma membranes.

1 The graph below shows the rate of new protein synthesis in an untreated *Escherichia coli* culture (dashed line) and *E. coli* treated with three different classes of antibiotics (A, B, C). Which types of antibiotics could have been used to treat the cultures?



A A – type II PrAMP, B – sparsomycin, C – tetracycline
B A – sparsomycin, B – aminoglycoside, C – tetracycline
C A – macrolide, B – type II PrAMP, C - chloramphenicol
D A – sparsomycin, B – chloramphenicol, C – type I PrAMP

2 Which of the following adaptations would improve survival of bacteria in presence of type II PrAMPs?

A synthesis of a PrAMP importer
B overexpression of release factors
C loss of the release factor–ribosome binding site
D increase in release factor–ribosome binding affinity

3 Aminoglycoside uptake into bacteria is an energy-demanding process. As a result, aminoglycosides are less effective against

A motile bacteria.
B anaerobic bacteria.
C Gram-positive bacteria.
D colony-forming bacteria.

4 Consider the following statements:

. Prokaryotes use certain codons more or less frequently than eukaryotes.
I. Prokaryotic and eukaryotic ribosomes contain different rRNA and ribosomal proteins.
II. Prokaryotes and eukaryotes express different membrane transport proteins.

Which statement(s) explain why tetracycline is effective against bacteria but harmless to humans?

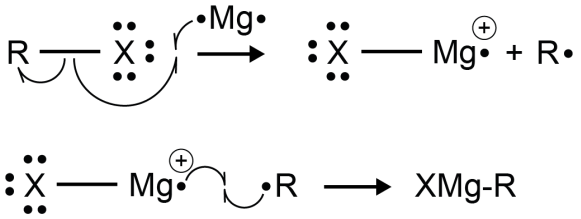
A Statements I, II and III explain tetracycline specificity.
B Statements I and III, but not statement II, explain tetracycline specificity.
C Statements II and III, but not statement I, explain tetracycline specificity.
D Statement II, but not statements I and III, explain tetracycline specificity.

5 A bacterium gains several mutations that cause a complete structural rearrangement of the A site within the 50S ribosomal subunit while still maintaining functionality. This bacterium is likely to be

A non-viable.
B susceptible to type I PrAMPs.
C resistant to chloramphenicol.
D resistant to tetracyclines and aminoglycosides.

Questions 6 – 9

A Grignard reagent is an organomagnesium halide, featuring a covalent carbon-magnesium and an ionic magnesium-halogen bond. A typical formula is R—Mg+X-, where R is an organic residue and X is a halogen. Grignard reagents are synthesised by treating an organohalide, e.g. CH_3Br, with metallic magnesium (note that this mechanism relies on single electron transfer, marked by half-arrows and dots):



Due to their electronegativity properties of component atoms, Grignard reagents are extremely useful for synthesis of new C–C bonds. A common mechanism is a reaction between a Grignard reagent and a carbonyl group:

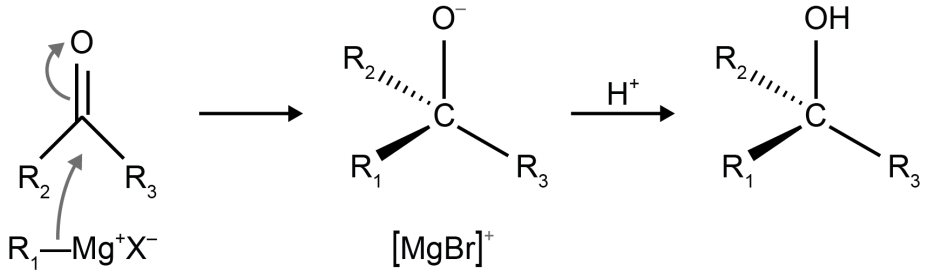


Table 1 lists electronegativity values of some elements.

Table 1

Atom	Electronegativity
Mg	2.39
C	3.15
Br	3.45
Cl	3.50
F	4.00

6 In Grignard reagents, the function of the magnesium atom is to

A attract electrons within the C–Mg bond.
B increase solubility of the organic residue.
C attract carbon atoms for new bond formation.
D induce a partial negative charge to the carbon atom.

7 Grignard reagents are typically synthesised from organic bromides and iodides, but not fluorides, because

A unlike Br and I, F cannot form ionic bonds with Mg.
B covalent C–F bonds are weak and break spontaneously.
C radius of F atoms is too large to accommodate a Mg atom.
D covalent C–F bonds are much more difficult to break than C–Br or C–I bonds.

8 Grignard reagents react with aldehydes and ketones in a 1:1 stoichiometric ratio. However, a reaction between a Grignard reagent and an ester occurs in a 1:2 stoichiometric ratio, because

A esters are much more reactive than aldehydes and ketones.
B esters contain two oxygen atoms, both of which can react with Grignard reagents at the same time.
C esters do not have a carbonyl group, therefore proceed through a different reaction mechanism.
D a by-product of a reaction between a Grignard reagent and an ester is a ketone, which proceeds to react with another Grignard molecule.

9 Due to reactivity of the C–Mg bond, Grignard reagents break down in water. Which equation correctly describes the reaction between water and a Grignard reagent?

A $R—MgX + H_2O \longrightarrow R—H + HO—MgX$
B $R—MgX + H_2O \longrightarrow R—OH + H—MgX$
C $R—MgX + H_2O \longrightarrow R—MgOH + HX$
D $2R—MgX + 2H_2O \longrightarrow R—Mg—R + Mg(OH)_2 + 2HX$

Questions 10 – 13

A standing human body is illustrated in Figure 1 with labels A, B and C corresponding to the locations of the head, heart, and feet respectively. Labels h_A and h_B represent heights of the head and heart from the ground.

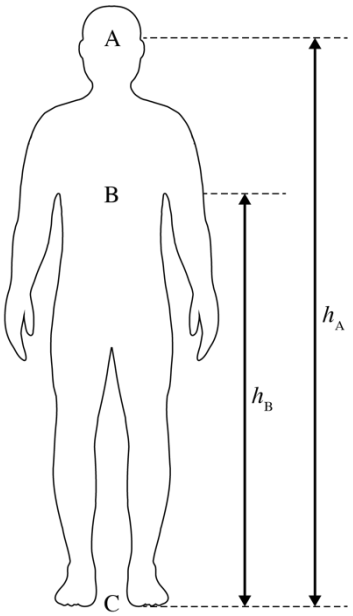


Figure 1

Assuming steady flow, the average pressure inside the arteries can be reasonably determined using the Bernoulli's equation, which is given as:

$$P + \frac{1}{2}v^2 + \rho gh = constant$$

where P = gauge pressure (kPa)
ρ = density of blood (kgm^{-3})
v = velocity of blood inside arteries (m s^{-1})
g = acceleration due to gravity (m s^{-2})
h = height from above the ground (m)

Note: For all calculations, use:
g = 10 m s^{-2}; ρ = 10^3 kg m^{-3}; 1 mm of Hg = 0.133 kPa.

10 Assuming that the velocity of the blood inside the arteries remains constant throughout the body, which of the following inferences is **not** correct?

A Blood pressure in the different parts of the body for a person lying down on the ground will be almost identical.
B Blood pressure in the different parts of the body for an acrobat hanging upside-down from their feet can be arranged in the ascending order C < B < A.
C In the sitting position, the difference in blood pressure between the upper and lower parts of the body will be almost identical to that in the standing position.
D In the standing position, the difference in blood pressure between the upper and lower parts of the body will be greater for a tall person than that for a short person.

11 For a particular person shown in Figure 1, the head is 1.66 m measured from ground up and the heart is 0.33 m below the head. Assume the kinetic energy term in the Bernoulli's equation to be negligible due to the low blood velocity. If the average pressure at the heart (P_B) is given to be 100 mm of Hg, what will be the blood pressure in this person's feet?

A 10 kPa
B 16.6 kPa
C 23.3 kPa
D 26.6 kPa

12 Flow rate is defined as the volume of fluid that passes through a point per unit time. If the kinetic energy term in the Bernoulli's equation had a numerical value of 5, the flow rate inside an artery with a diameter of 4 mm will be closest in numerical value to

A 1.2×10^{-6}.
B 4.8×10^{-6}.
C 1.2×10^{-5}.
D 4.8×10^{-5}.

13 A bag containing blood is placed such that when a needle is inserted into a patient's vein, the blood from the bag enters the vein. The gauge pressure at the point where the needle is inserted is noted to be 1.1 kPa. For the blood to flow inside the vein, the blood bag should be placed at a height of at least

A 9 cm.
B 11 cm.
C 90 cm.
D 110 cm.

Questions 14 – 16

Per- and poly-fluoroalkyl substances (PFAS) are known to be persistent organic pollutants that bioaccumulate in humans and wildlife. PFAS exposure has been linked to various adverse health effects such as thyroid diseases and high cholesterol. The transport and mobility of PFAS in aqueous environments are dependent on the extent to which it dissociates. For example, the dissociation of pentafluoropropionic acid (PFPrA) is shown in Figure 1.

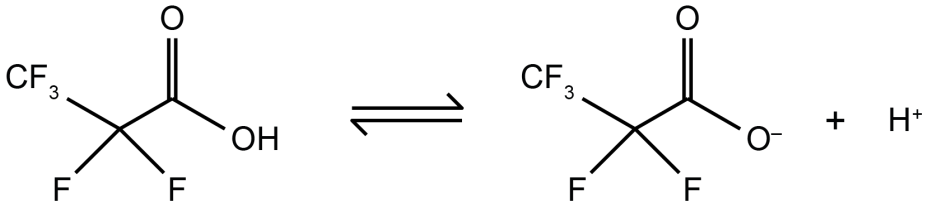


Figure 1

The extent of dissociation of an acid can be related using the Henderson-Hasselbalch equation:

$$pH = pK_a + \frac{[A^-]}{[HA]}$$

Where HA is an acid and A^- is its conjugate base.

Table 1 shows some pK_a values for common PFAS. Assume any conjugate base of PFAS will always be strictly anionic.

Table 1

Name	p*K*a
PFOA	2.5
PFOS	0.15
PFBA	0.08

14 Given that environmental pH typically ranges from 6 to 8, common PFAS in the environment will

A remain in their neutral state.
B always be denser than water.
C virtually always be dissociated.
D virtually never exist in their anionic state.

15 Given that stomach acid has a pH of 1.5, what is the ratio of dissociated to undissociated PFOA in stomach acid?

A $10:1$
B $1:10$
C $1:10^{1.5}$
D $10^{1.5}:10^{2.5}$

16 For any constant pH value, the PFAS listed in table 1 in order of increasing extent of dissociation will be

A PFOS, PFBA and PFOA.
B PFOA, PFOS and PFBA.
C PFBA, PFOA and PFOS
D PFBA, PFOS and PFOA.

Answers to Multiple Choice Questions

Reasoning in Biological and Physical Sciences

1. **B**

Analyse the graph to determine the likely effects of each antibiotic:

Antibiotic A – there is an increased rate of protein synthesis compared to an untreated bacterial culture. This can be caused by increased rate of protein translation, which can only be induced by sparsomycin due to its ability to induce premature translation of the ribosome. An error here would be to consider type II PrAMPs as they cause translation of *extended* proteins; but longer peptide sequences do not equate to more proteins. Thus, sparsomycin is the only possible option, and answers **A** and **C** can be eliminated.

Antibiotic B – the rate of protein synthesis is nearly equal to the rate in an untreated bacterial culture. This occurs if the antibiotic is not designed to hinder protein synthesis, but rather to suppress bacterial growth by producing non-functional proteins. Such proteins can harbour amino acid mutations, which would be induced by aminoglycosides; they can be too short, which would be induced by macrolides; or too long, which would be induced by type II PrAMPs. This only leaves answer **B**.

As a final check, antibiotic C should be considered. In this case, protein synthesis rate is below that of an untreated bacterial culture. This would be caused by an antibiotic which directly blocks protein synthesis, which can be either tetracycline or type I PrAMP.

2. **B**

Answer **B** is correct: overexpression of the release factor would replenish the pool and compensate for the effects of type II PrAMPs.

Answer **A** is incorrect: a PrAMP importer would result in active uptake of the antibiotic, increasing bacterial susceptibility.

Answer **C** is incorrect: loss of the release factor–ribosome binding site would prevent release factor binding. As a result, protein translation would never terminate, resulting in synthesis of extended proteins. This would decrease survival of bacteria even in absence of type II PrAMPs.

Answer **D** is incorrect: an increase in the binding affinity between release factor and ribosome is effectively the same as adding a type II PrAMP, which stabilises the interaction between release factor and ribosome. Thus, survival of the bacteria would also be negatively affected.

3. **B**

Recall that aerobic respiration is much more energetically efficient than anaerobic respiration. Therefore, anaerobic bacteria will have lower energy sources that can be harnessed for aminoglycoside uptake, and these antibiotics will be less effective for anaerobic bacteria. Answer **B** is correct.

Bacterial motility is also an energetically demanding process. On one hand, motile bacteria are likely to also have enough energy to subvert for aminoglycoside uptake; on the other hand, this may not leave enough energy for aminoglycoside uptake. In light of both possibilities, bacterial motility would not be a definitive reason aminoglycoside uptake is more efficient in these types of bacteria. Answer **A** is incorrect.

Gram-positive bacteria are distinguished from Gram-negative bacteria by the structure of their cell envelope, as stated in the stimulus. Gram-positive bacteria may require more energy for aminoglycoside uptake due to the thicker cell wall; but they may also save energy as they only have one plasma membrane instead of two. Again, this is not a definitive reason and answer **C** is incorrect.

Colony formation is a result of bacterial division and secretion of substances that keep them together. It is also an energy-consuming process, but it improves bacterial survival. A bacterial colony may become more resistant to antibiotics, but this is due to its structural organisation (bacteria on the inside of the biofilm are shielded from the environment) rather than energy processing, thus this is also not a definitive explanation and answer **D** is incorrect.

4. **C**
All statements are factually true. However:

Statement I does not explain tetracycline specificity. Even if bacteria use certain codons more frequently than others, tetracycline is not a codon-specific inhibitor: it inhibits any tRNA binding to the 30S subunit.

Statement II is an explanation of tetracycline specificity. Due to differences in ribosome composition between bacteria and humans, even if tetracycline was present in the cell, it would be unable to bind to the eukaryotic ribosome.

Statement III is also a valid explanation for tetracycline specificity. Bacteria possess membrane transporters that take up tetracycline, while human cells do not. Thus, tetracycline is not present inside human cells.

5. **C**
Answer **A** is incorrect: the question stem states that the structurally rearranged 50S subunit is still functional, thus the bacterium should be perfectly viable.

Answer **B** is incorrect: type I PrAMPs prevent A to P transfer of tRNA. It is not clear to which part of the ribosome they bind (if any). If they bind near the A site, then the mutation should reduce binding ability and the bacterium would become resistant to type I PrAMPs; if they bind elsewhere, then the mutation should have no effect.

Answer **C** is correct: a structural rearrangement would prevent chloramphenicol binding to the A site of the 50S subunit, therefore this bacterium is likely resistant.

Answer **D** is incorrect: tetracycline and aminoglycosides act on the A site on the 30S subunit, so the rearrangement of the 50S subunit should have no effect.

6. **D**
Carbon, a non-metal, is much more electronegative than magnesium, an alkaline earth metal. As a result, the carbon atom attracts electrons shared within the covalent C–Mg bond and gains a partial negative charge.

7. **D**
Fluorine is the most electronegative atom, hence it forms very strong and stable covalent bonds with carbon. The radius of a fluorine atom is smaller than that of bromine or iodine, which means the bond is shorter, further enhancing the strength.

8. **D**
Esters do contain a carbonyl group, which can react with Grignard reagents. Since the product also carries a carbonyl group, it may react with another Grignard compound.

9. **A**
The carbon atom has a partial negative charge, hence would attract a partially positively charged hydrogen atom within a water molecule (reaction **A**). This is not to be confused with reaction B, in which case a nucleophilic carbon would attract a nucleophilic oxygen: this is unlikely.
The stem of the question hints at the fact that the C–Mg bond is broken, eliminating reaction **C**. Furthermore, halogen acids (except HF, but fluorides are not used in Grignard reagents) are strong, hence the equilibrium of this reaction would lie on the left.
Products of reaction **D** are a base and an acid. These two would react further, forming two additional water molecules. Since those are also present on the left side of the equation, overall, this reaction would suggest that Grignard reagents react *spontaneously* in a solvent-independent manner to form a R—Mg—R molecule.

10. **C**
As evident from the given equation, blood pressure inside the arteries depends on the height of the body part above the ground, h. The greater this height, the lower will be the blood pressure in that part due to the effect of gravity. This can be mathematically shown from the relationship: $P_A + \rho g h_A = P_B + \rho g h_B = P_C + \rho g h_C$. For a person lying down, $h_A = h_B = h_C$ and therefore the potential energy component remains constant:

$P_A = P_B = P_C$. The only incorrect answer is **C**, as the height of the head from ground up is reduced in the sitting position as opposed to the upright position.

11. **D**

We know that: h_A = 1.66 m, h_B = 1.66 − 0.33 = 1.33 m and h_C = 0.

From Bernoulli's principle of energy conservation, blood pressure at various positions in the body can be calculated by rearranging and equating the Bernoulli's relation as follows:

$$P_A + \rho g h_A = P_B + \rho g h_B = P_C.$$

Using given values of ρ, g, P_B, and h_B, we obtain pressure at the feet:

$$P_C = P_B + \rho g h_B = 100 \times 0.133 \times 10^3 + 10^3 \times 10 \times 1.33 = 26.6 \text{ kPa}.$$

12. **A**

The kinetic energy term is given by $\frac{1}{2} \times \rho \times v^2 = 0.5 \times 10^3 v^2 = 5$. Rearranging the terms gives:

$v = \sqrt{\frac{5}{500}} = 0.1$ m s^{-2}. Flow rate is volume/time (m^3 s^{-1}), or area of the artery (m^2) velocity of blood flowing through the artery (m/s).

Thus, Flow rate $= \pi r^2 \times v = 3.14 \times (2 \times 10^{-3})^2 \times 0.1 \approx 12 \times 10^{-7}$ m^3 s^{-1}.

13. **B**

Using the formula $P = \rho g h$ where P is the gauge pressure, we can calculate the minimum height of the blood bag required: $h = \frac{P}{\rho g} = \frac{1.1 \times 10^3}{10^3 \times 10} = 0.11\ m = 11$ cm. Thus, the blood bag should be placed at a height of 11 cm or more to allow blood to enter the vein.

14. **C**

This question requires an understanding of how the Henderson-Hasselbalch equation works. The ratio of acid to its conjugate base can be expressed as:

$$\frac{[A^-]}{[HA]} = 10^{(pH - pK_a)}$$

When the $pH \gg pK_a$, $\frac{[A^-]}{[HA]}$ will be a large value meaning the concentration of the conjugate base will be high (i.e. most of the acid has dissociated). Taking the lowest pH in the environment of 6 and the highest pK_a of 2.5, one finds that there is 103.5 times more conjugate base than the neutral acid form of PFAS. This can be interpreted as PFAS virtually always dissociating.

15. **A**

Using the Henderson-Hasselbalch equation:

$$pH = pK_a + \frac{[A^-]}{[HA]}$$

$$1.5 = 2.5 + \frac{[A^-]}{[HA]}$$

$$\frac{[A^-]}{[HA]} = 10^{-1} = \frac{1}{10}$$

$$[A^-] = \frac{1}{10}[HA]$$

$$10[A^-] = [HA]$$

Therefore, for every 10 molecules of A^- there is one molecule of HA and hence the ratio is 10:1.

16. **B**

From the Henderson-Hasselbalch equation, the lower the pK_a at any constant pH value, the greater the extent of dissociation. This can be represented mathematically as:

$$\frac{[A^-]}{[HA]} = 10^{(pH-pK_a)}$$

Thus, the PFAS in table one should be listed in order of highest to lowest pK_a, yielding **B** as the answer.