Circle the best single letter choice for each of the following questions before transferring your answers to your computer sheet.
Note: *Questions may have 3, 4 or 5 choices.*

1. The eyespot in *Chlamydomonas* and the human eye are distinctly different, yet they share some interesting characteristics.

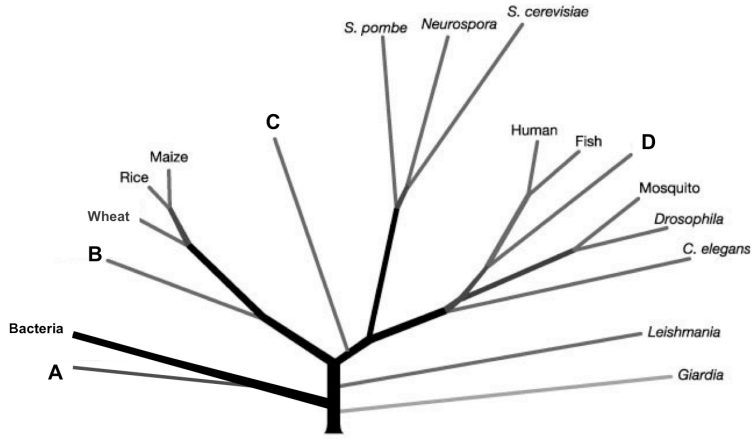
   Which of the following statements accurately coveys the relationship between these two organs?

A. The two organs contain similar pigment/proteins because they evolved from the same ancient ancestor.
B. In both organs, a pigment absorbs a photon of light, triggering a change in the shape of a protein.
C. Unlike the human eye, the eyespot requires the expression of only a single gene.
D. The lack of complexity of the eyespot is because it evolved before the eye.

---

2. The image at right is a phylogenetic tree.

   Where on this tree should *Chlamydomonas* be placed?



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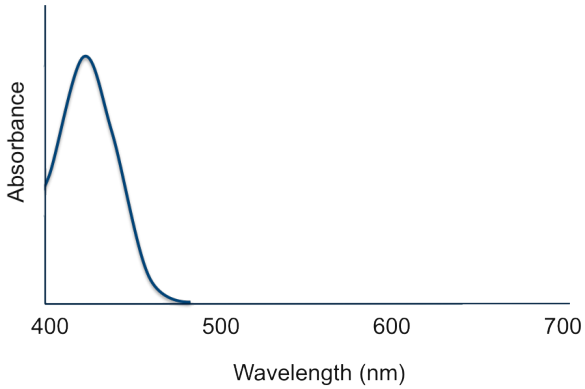
3. Exposure to high levels of ultraviolet light (UV) can cause what is referred to as "photobleaching" of chlorophyll, resulting in a white colour.

   Which of the following photo-physical explanations of UV-induced photobleaching is most likely?

A. UV light oxidizes chlorophyll breaking its conjugated bonding.
B. UV light increases the number of double bonds in chlorophyll.
C. UV light donates electrons to chlorophyll changing its structure.
D. UV light breaks the bonds that bind chlorophyll to the protein.

---

4. Imagine that NASA's Spirit Rover discovers a photosynthetic bacterium on Uranus that contains a single pigment. By using an onboard spectrophotometer, the pigment is found to have the absorption spectrum shown at right.



Which of the following conclusions about this pigment can be deduced from the spectrum shown?

1. The pigment fluoresces green photons.
2. The pigment is blue in colour.
3. The pigment has a single excited state.
4. The pigment reflects high-energy light.

A. 1,2 and 3
B. 1 and 3
C. 2 and 4
D. 4 only
E. All of 1, 2, 3 and 4 are correct.

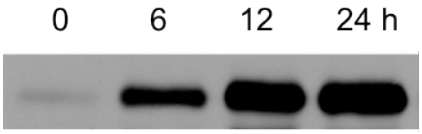
---

5. Which of the following is NOT considered a photochemical reaction?

A. Formation of $P700^+$ by light.
B. Creation of excited state chlorophyll by light.
C. Ionization of DNA by UV light.
D. Isomerization of retinal by light.

---

6. The figure at right shows the change in abundance of Heat Shock Protein (HSP) following a shift from 25°C to 45°C in *Chlamydomonas*.



Which of the following explanations most likely accounts for the increase in protein abundance at 24 h relative to 0 h?

A. The increased abundance is because of a decrease in the rate of transcription.
B. The increased abundance is because of an increase in the rate of mRNA decay.
C. The increased abundance is because of an increase in the rate of translation.
D. The increased abundance is because of an increase in the rate of protein breakdown.

---

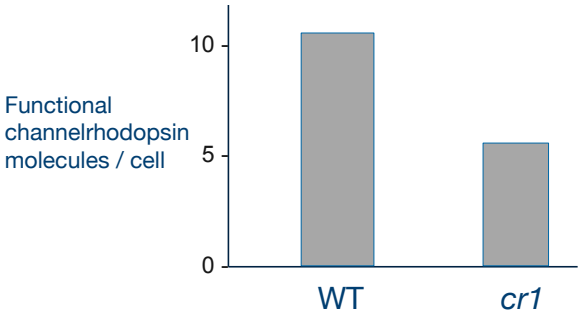
7. Which of the following proteins is synthesized on free (cytosolic) ribosomes?

A. Hexokinase
B. D1 protein of PSII
C. CFTR
D. Channelrhodopsin

---

8. The figure at right shows the presence of channelrhodopsin in normal (wild-type, WT) and *cr1* mutant cells of *Chlamydomonas*.

   Which of the following explanations best accounts for the data presented for the cr1 mutant compared to WT?



A. Inhibition of protein import into the chloroplast.
B. Mutation to the gene that codes for beta-carotene, a precursor of retinal.
C. Misfolding of the rhodopsin apoprotein preventing retinal binding.
D. Mutation that lowers the activity of an enzyme.

---

9. The enzyme hexokinase isolated from a thermophilic bacterium has stronger bonding arrangements in its tertiary structure than hexokinase isolated from a mesophilic bacterium.

   What is the underlying biochemical basis for this difference in bonding arrangements between the two enzymes?

A. The thermophilic enzyme folds into a different, stronger conformation even thought it has the same amino acid sequence as the mesophilic enzyme.
B. In the thermophile hexokinase requires a cofactor to function.
C. The enzyme from the thermophile catalyses a distinctly different reaction.
D. The primary structure of the two enzymes is different.

---

10. Proper folding is essential for most proteins to function.

    Which of the following statements about protein folding is correct?

1. Because its an endergonic process, protein folding requires ATP.
2. Denaturation often alters the primary structure of the protein.
3. Enzymes represent one group of proteins where proper folding is not important.
4. Denaturation results in a protein that has higher free energy than the native conformation.

A. 1,2 and 3
B. 1 and 3
C. 2 and 4
D. 4 only
E. All of 1,2,3 and 4 are correct

---

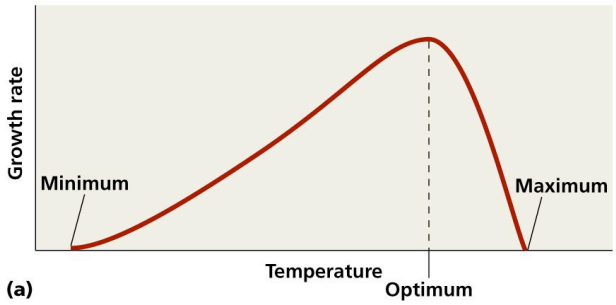
11. Why was the development of enzymes fundamental to the evolution of life?

A. Enzymes reduced the cellular demand for ATP.
B. Enzymes allowed for reactions to occur spontaneously.
C. Enzymes allowed for high rates of catalysis at relatively low temperatures.
D. Without enzymes, the energy of activation (E_A) for essential reactions was too low.

---

12. The figure at right shows the growth rate of a bacterium (cell divisions/hr) as a function of time.

Which of the following descriptions of cell physiology best characterizes growth at Optimum?



A. At Optimum, membrane fluidity is at its highest.
B. At Optimum, the rate of DNA replication is at its lowest.
C. At Optimum, the rate of protein denaturation is at its lowest.
D. At Optimum, the rate of enzyme-catalyzed reactions is at its highest.

---

13. The notation below shows a common chemical reaction.
(The nomenclature (l) refers to a liquid and (g) to a gas.)

$$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$$

Which of the following statements about this reaction is correct?

1. The reaction is exergonic.
2. The carbon compound is oxidized.
3. The reaction results in an increase in entropy.
4. The reaction is endothermic.

A. 1,2 and 3
B. 1 and 3
C. 2 and 4
D. 4 only
E. All of 1,2,3 and 4 are correct

---

14. The transition state is an important intermediate that can influence the rate of an exergonic reaction.

Which of the following statements about the transition state is correct?

A. At the transition state reacting molecules are the most stable.
B. The more molecules that can reach the transition state the faster the reaction will be.
C. Catalysts increase reaction rates but don't alter the free energy of the transition state.
D. If the transition state is high enough the reaction can move from being exergonic to being endergonic.

---

15. Diffusion of molecules across membranes can be "simple" or "facilitated".

Which of the following statements correctly differentiates between simple diffusion and facilitated diffusion?

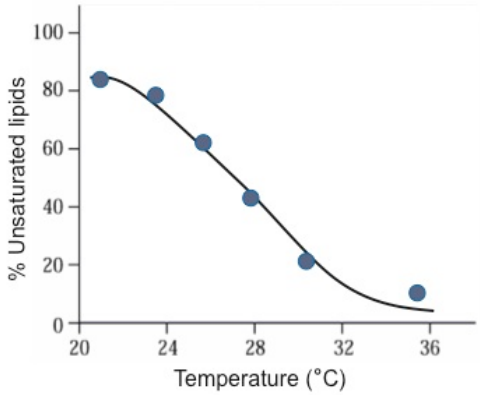
1. Only simple diffusion is driven by an increase in entropy.
2. Mutation of a single gene can specifically block facilitated diffusion, but not simple diffusion.
3. To get into mitochondria, O_2 moves by facilitated diffusion.
4. Unlike simple diffusion, the rate of facilitated diffusion can become saturated by substrate.

A. 1,2 and 3
B. 1 and 3
C. 2 and 4
D. 4 only
E. All of 1,2,3 and 4 are correct

---

16. To study changes in unsaturation, Nassir measured the lipids in the bacterium *E. coli* at various temperatures. Starting with a culture grown at 22°C, he slowly shifted it to 36°C over the course of 2 hours.

The data from samples he took during the shift are plotted at right.



Which of the following mechanisms most likely explains the change in unsaturated lipids as temperature increases?

A. Increase in the expression of desaturase enzymes.
B. High expression of an enzyme that removes double bonds.
C. Spontaneous conversion of unsaturated lipids into saturated lipids.
D. Membrane turnover resulting in the incorporation of more saturated lipids.

---

17. The overall balanced equation of photosynthesis is shown below:

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

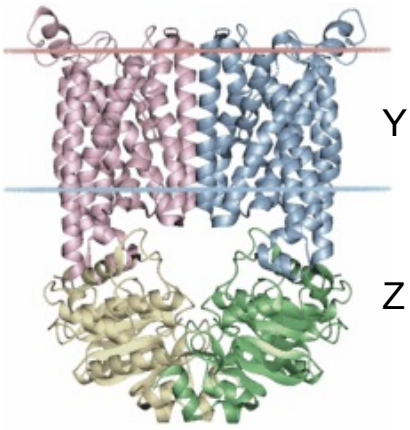
One interpretation of the above reaction is: the synthesis of a *carbohydrate* ($C_6H_{12}O_6$) as a result of water reacting with (or *hydrating*) the *carbon* in CO_2.

In what way is this description of the equation for photosynthesis misleading?

A. The oxygen in a carbohydrate doesn't come from water.
B. In plants and algae, photosynthesis does not require H_2O.
C. The product of the Calvin Cycle of photosynthesis is not actually a carbohydrate.
D. The two reactants, CO_2 and H_2O, do not directly interact in photosynthesis.

---

18. An ABC transporter consists of two domains: the transmembrane domain (shown here as Y) and the ATP-binding cassette domain (shown here as Z).



Which of the following statements correctly identifies a difference between these two domains?

1. The hydropathy index is higher for Y than Z.
2. A mutation to Z will be less severe to transporter function than a mutation to Y.
3. Exchanging domain Z with the same domain from a different ABC transporter will not alter the specificity of transport, but swapping Y domains will.
4. Alpha helices are only found in the Y domain.

A. 1,2 and 3
B. 1 and 3
C. 2 and 4
D. 4 only
E. All of 1,2,3 and 4 are correct

---

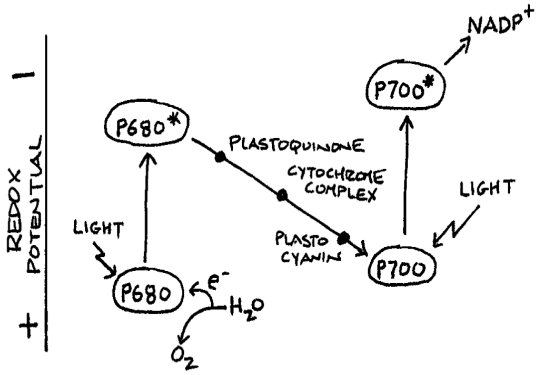
19. The ΔF508 mutation of the CFTR gene is the cause of most cases of cystic fibrosis (CF). One focus of research into a cure for CF is "gene therapy" — inserting normal copies of the CFTR gene into the cells of CF patients.

Which of the following areas of CF research is most likely to improve symptoms for CF patients?

A. Inserting extra copies of genes that code for the proteosome.
B. Studying the chaperone proteins of the endoplasmic reticulum (ER).
C. Improving the lung function of people who are carriers of the CF allele (Cc).
D. Stabilizing the plasma membrane were the ΔF508 form of the protein accumulates.

---

20. Danielle is studying photosynthesis with her roommate Stuti. She sketches this model of electron transport and gets Stuti to check that she has it right.



Which of the following mistakes has Daniele made on her sketch that Stuti can nicely point out?

A. H_2O donates electrons to PSI as well as PSII.
B. The Cytochrome Complex actually comes after P700, not before.
C. Absorption of light by P680 produces $P680^+$, not P680*.
D. The redox potential of $NADP^+$ is greater than P700*, not less than P700*.

---

21. The Calvin Cycle enzyme rubisco is regulated (activated or inhibited) by a range of factors that ensure that this enzyme is active only when needed by the cell.

Which of the following situations likely activates rubisco activity?

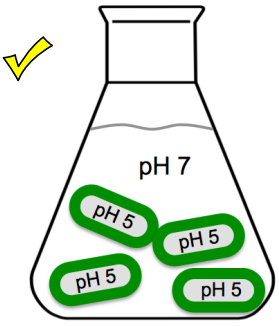
1. Low $NADP^+$/NADPH ratio.
2. Low ribulose-bisphosphate (RuBP) levels.
3. High H^+ concentration in the thylakoid lumen.
4. High glyceraldehyde 3-phosphate (G3P) levels.

A. 1,2 and 3
B. 1 and 3
C. 2 and 4
D. 4 only
E. All of 1,2,3 and 4 are correct

---

22. The picture at right shows a preparation of isolated thylakoid membranes suspended in a buffer at pH 7. The preparation is in complete darkness.

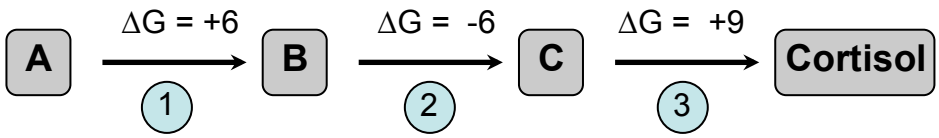
Which of the following is required in order for the thylakoids to generate ATP?



A. Addition of ADP and Pi to the buffer.
B. Incubation in the light plus ADP and Pi.
C. Incubation in the light plus addition of ADP, Pi and $NADP^+$
D. Isolated thylakoid membranes are not able to synthesize ATP.

---

23. The image below shows the biosynthetic pathway of the hormone cortisol. It is a multi-step pathway with compound **A** being converted into **B**, **C** and finally **cortisol.** (ΔG values are given in kcal/mol).



Which of the following statements about this pathway is correct?

1. B contains more free energy than A.
2. Coupling the breakdown of one molecule of ATP to reaction 3 would make it occur spontaneously.
3. The pathway is anabolic.
4. The components of the pathway (A,B,C) are each encoded by a gene.

A. 1,2 and 3
B. 1 and 3
C. 2 and 4
D. 4 only
E. All of 1,2,3 and 4 are correct

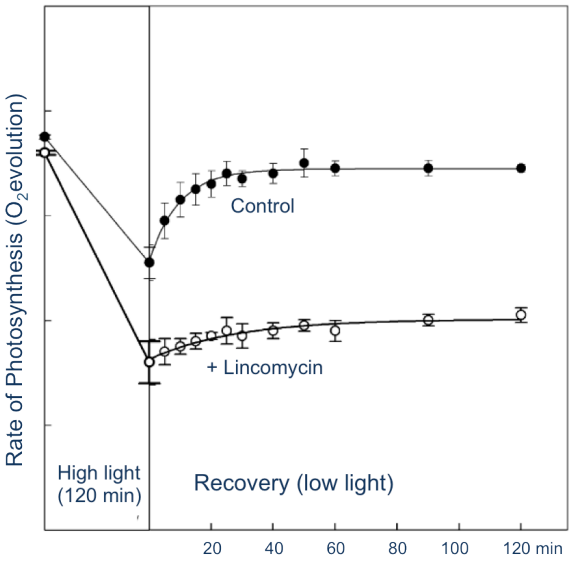
---

24. The graph at the right shows data collected from a photoinhibition experiment. Two flasks of *Chlamydomonas* cells were exposed to high light for 2 hours then allowed to recover at low light.

Prior to the experiment, 20 μM of the antibiotic lincomycin was added to one of the flasks.

Which of the following explanations most likely accounts for the response in the presence of lincomycin?

A. The Calvin Cycle is permanently inhibited.
B. Damaged photosystems cannot be repaired.
C. The cells lack enough $NADP^+$.
D. Inhibition is temporary; given enough time cells will recover in the presence of lincomycin.



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25. Imagine that you are lifting weights at the gym with your roommate Spike (a Sociology student) when he suddenly passes out. After being rushed to the emergency room at University Hospital doctors soon suspect that Spike may have ingested an excessive dose of the drug *RippedFreak*.

Which of the following pieces of evidence would have supported the diagnosis that Spike had ingested an uncoupler?

1. A high ADP/ATP ratio in his blood.
2. An elevated body temperature.
3. High rate of breathing.
4. Build up of NADH in his blood.

A. 1,2 and 3
B. 1 and 3
C. 2 and 4
D. 4 only
E. All of 1,2,3 and 4 are correct

---

26. The model system *C. elegans* is a eukaryotic worm that has been used to study the phenotypic effects of mutations. Mutants of *C. elegans* have been isolated that do not synthesize functional hypoxia-inducible factor protein, HIF-1β.

Which of the following phenotypic consequences would most likely result from an inability to produce HIF-1β?

A. Under higher than normal O_2 conditions the mutants would display slower growth than wild-type worms.
B. Since HIF-1β is not functional by itself there would not be an effect.
C. Under low O_2 the mutants would have a build-up of pyruvate within the mitochondria.
D. Under hypoxic conditions the cells would increase the rate of NADH oxidation.

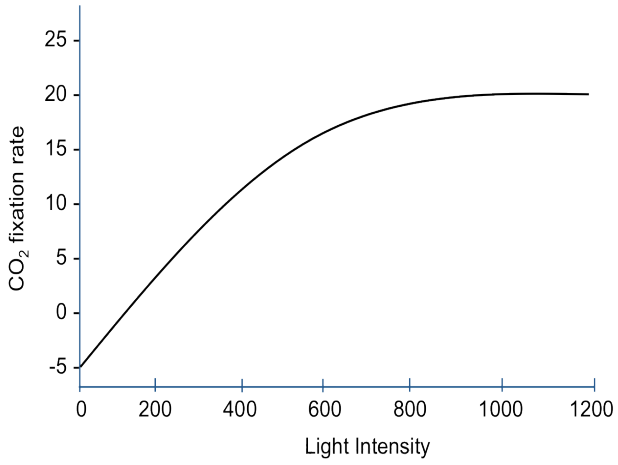
27. *Chlamydomonas* has the ability to grow heterotrophically in the dark. Yet, when cells are placed in the dark in growth media containing glucose as the carbon source they die.

    Which of the following explanations most likely accounts for the inability of *Chlamydomonas* to grow on glucose?

A. It lacks mitochondria.
B. Its lacks a glucose transporter.
C. It lacks the enzyme hexokinase required to breakdown glucose.
D. It lacks the ability to transport carbohydrates from the chloroplast.

Use this figure to answer the following two questions.

The figure at right shows a light response curve for CO_2 fixation in *Chlamydomonas* cells; both mitochondria and chloroplasts are functional.



28. At what light intensity is the rate of photosynthesis equal to the rate of cellular respiration?

A. 0
B. 800
C. 100
D. 50

---

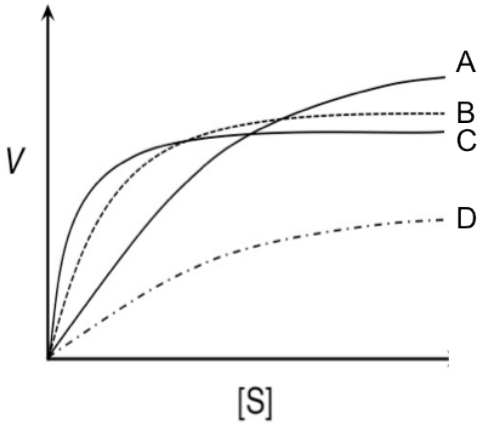
29. At light saturation (i.e. above 800), what is the actual rate at which the Calvin Cycle is fixing CO_2?

A. 20
B. -5
C. 50
D. 25

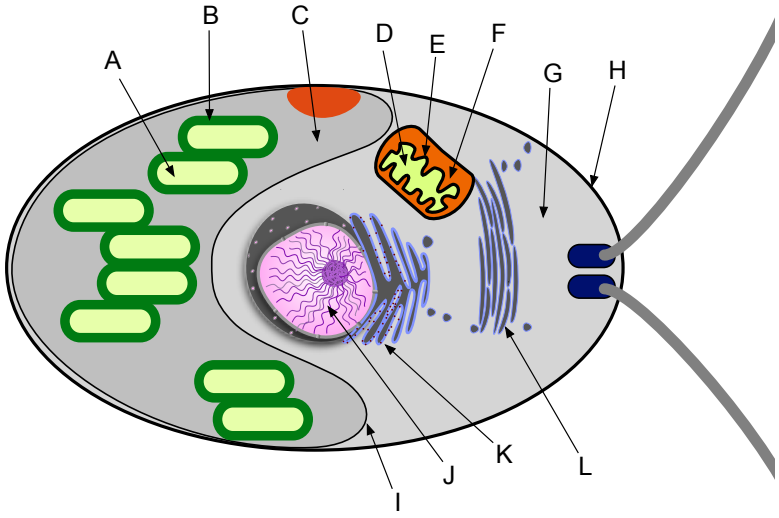
---

30. Some enzymes function to break down highly toxic compounds that, if allowed to accumulate to high concentration, could cause death.

    Which of the enzyme kinetic curves shown is most likely for an enzyme that catalyzes the breakdown of a highly toxic compound?



Use this labeled diagram of a *Chlamydomonas* cell to address the following two questions.



31. Which of the following statements **DOES NOT** correctly match a function or component with its labelled feature?

A. DNA can be found in **C**.
B. mRNA can be found in **J**.
C An action potential can be generated at **H**.
D. Proteins destined for the plasma membrane can be found in **G**.

---

32. Which of the following statements correctly explains biochemical processes that occur during photoautotrophic growth?

A. Reduced carbon produced in **C** is transported into **G**
B. Acetate is transported from **G** into **D**.
C. ATP generated in the chloroplast is transported into **G**.
D. Respiratory metabolism in **G** prevents pyruvate import into **D**.

---

33. When searching online for reliable information, it is important to be able to distinguish peer-reviewed journal articles from peer-reviewed web sites. Although these two sources sometimes appear similar on the screen, they have distinguishing features.

Which of the following features is most likely to indicate that you are looking at a journal article, rather than a website?

A. A URL that ends in ".gov" (US) or ".gc.ca" (Canada)
B. Authors names prominently displayed
C. An Abstract section
D. A relatively recent date

---

34. A 2012 publication in *Proceedings of the National Conference on Undergraduate Research* (NCUR) showcased undergraduate student research on Blackworm (*Lumbriculus variegatus*) heart rate (BPM) after treatment with extracts from *Hosta* plant varieties.

    The blackworm was used as a model organism for testing the inhibitory effects of allelochemicals found in three *Hosta* varieties: Guacamole (G), Fragrant Bouquet (FB) and Queen Josephine (QJ). The students' results are shown in the table below.

Table 1. The effect on blackworm pulse beats for four different doses of aqueous *Hosta* extracts for two incubation times, for three different *Hosta* varieties (N=54).

Extract Concentration	Incubation Time	Guacamole (G)	Fragrant Bouquet (FB)	Queen Josephine (QJ)
Full		**BPM**	**BPM**	**BPM**
	15 min	X	6	X
	7.5 min	X	6	X
½				
	15 min	37	6	X
	7.5 min	28	6.1	X
¼				
	15 min	31	8	X
	7.5 min	21	8	39
⅛				
	15 min	15.2	12	36.2
	7.5 min	14.1	13	35

Note: "X" indicates that no measurements could be taken due to the deaths of the worms during the incubation periods. The average basal rate was 14 BPM (N=12).

Which of the following conclusions is NOT consistent with the data provided in the table?

A. G and FB contain allelochemicals that are lethal to blackworms.
B. Null hypothesis is rejected based on the data provided.
C. Blackworms are viable model-organisms for drug testing.
D. QJ is a stronger stimulant than G.

---

35. In a controlled experiment, a student group is studying how long it takes for blackworms of different sizes to recover from the treatment.

    Which of the following is the manipulated variable?

A. The size of the blackworms
B. The number of drops of test solution
C. The length of exposure time to the drug
D. The time it takes for the blackworms to recover
