

Mitosisphere June Challenge

Exam Structure

This month's challenge will consist of 10 MCQ questions (1 pt each), 2 MTF questions (2 pts each), 2 FRQ questions (3 pts each), and 1 hard FRQ tiebreak. You will have 20 minutes to complete the exam.

Section 1: MCQ (10 Questions)

Anatomy and Physiology (2 Questions)

Question 1:

How disappointing! After spending 12 years of your life getting a PHD in biology you have returned to your high school to work as a biology teacher. During your lectures about the digestive system one of your students asks you about the difference between Cholecystokinin and Secretin. Recalling your USABO days you immediately state that:

- a: Cholecystokinin is primarily involved in bile release, while Secretin is primarily involved in enzyme production
- b: Cholecystokinin is primarily involved in bile release, while Secretin is primarily involved in enzyme release
- c: Secretin is primarily involved in bile release, while Cholecystokinin is primarily involved in enzyme production
- d: Secretin is primarily involved in bile production, while Cholecystokinin is primarily involved in enzyme release
- e: Secretin is stimulated by amino acids and fats while Cholecystokinin is stimulated by low pH

Solution: Secretin is involved in bile production and Cholecystokinin (CCK) is involved in enzyme release. Hormones are tested frequently; know the key functions and origins.

Question 2:

You are investigating cell membranes in different organisms. Unfortunately, you accidentally ingested some of the shrooms before testing so none of the samples are labeled. However, it seems that you somehow took note of certain compounds found in large quantities in each of the 3 samples. Your data is given below:

Sample 1: Beta-sitosterol

Sample 2: Ergosterol

Sample 3: Cholesterol

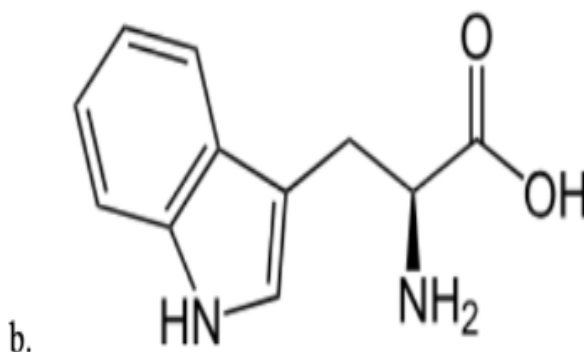
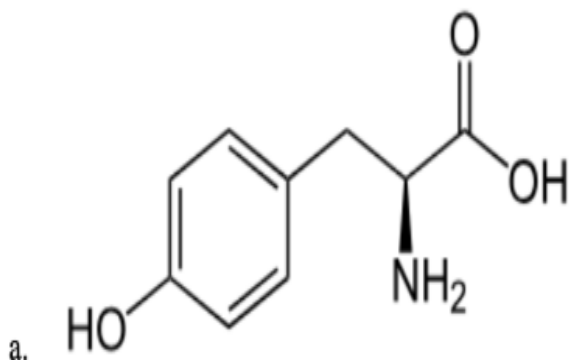
Which of the following could possibly represent an organism for each of these samples?

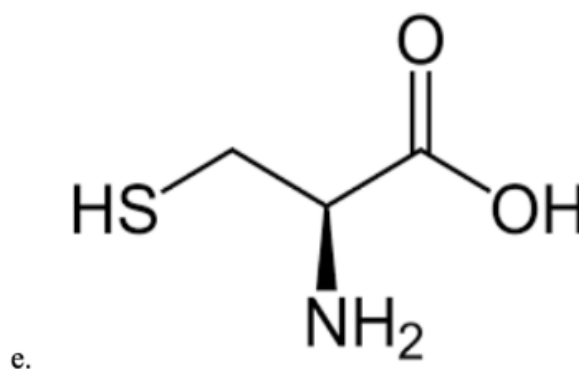
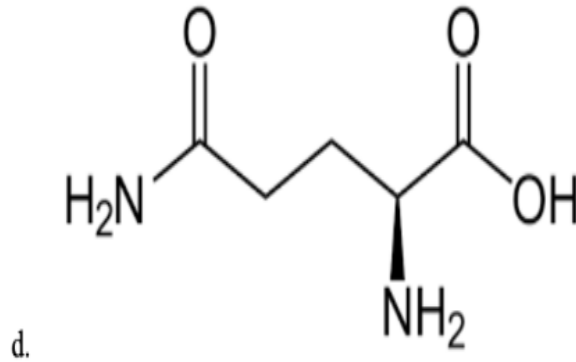
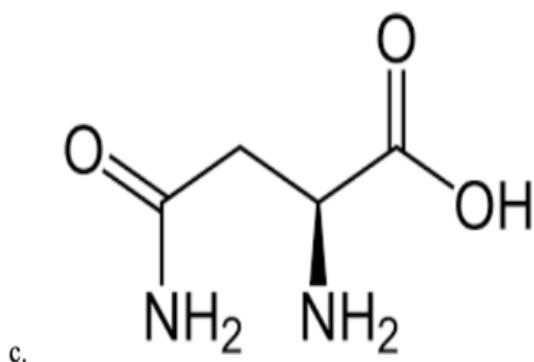
- a: Strawberry, Oyster mushroom, Bat
- b: Shitaki mushroom, Blueberry, Camel
- c: Human, Pineapple, Turtle
- d: Trypanosoma, Agave, Fox
- e: E.coli, Taro, Panda

Solution: *Beta-sitosterol is found primarily in plants, ergosterol is found primarily in fungi, and cholesterol is primarily found in animals. For this reason b is correct because a strawberry is a plant, a mushroom is a fungi, and a bat is an animal.*

Cell Biology (2 Questions)**Question 3:**

You are working at the Mitosisphere clinic when your patient reports symptoms of insomnia, anxiety, and impaired memory. Suspecting a hormonal deficiency, you prescribe which of the following hormone precursors?





Solution: *The symptoms of insomnia, anxiety, and impaired memory heavily suggest that this person is deficient in melatonin. Melatonin is produced from tryptophan. Amino acids are essentially tested in every opens and semis. You should know the properties(hydrophobic, +, -), 1 letter abbreviation, 3 lever abbreviation, and structure of all 20.*

Question 4:

Your lab is currently looking at the mechanisms in which deamination of certain nucleic acids affects their bonding properties. As part of your preemptive research your lab PI has you learn about the deamination of adenine. As a studied USABO student you immediately tell your PI that such research is unnecessary as you already know that:

- a: Xanthine, pairs with adenine
- b: Xanthine, pairs with cytosine
- c: Xanthine, pairs with guanine
- d: Hypoxanthine, pairs with cytosine
- e: Hypoxanthine, pairs with guanine

Solution: *Xanthine is the result of guanine deamination while hypoxanthine is the result of adenine deamination. Hypoxanthine pairs with cytosine while xanthine weakly pairs with guanine.*

Plant Biology (2 Questions)

Question 5:

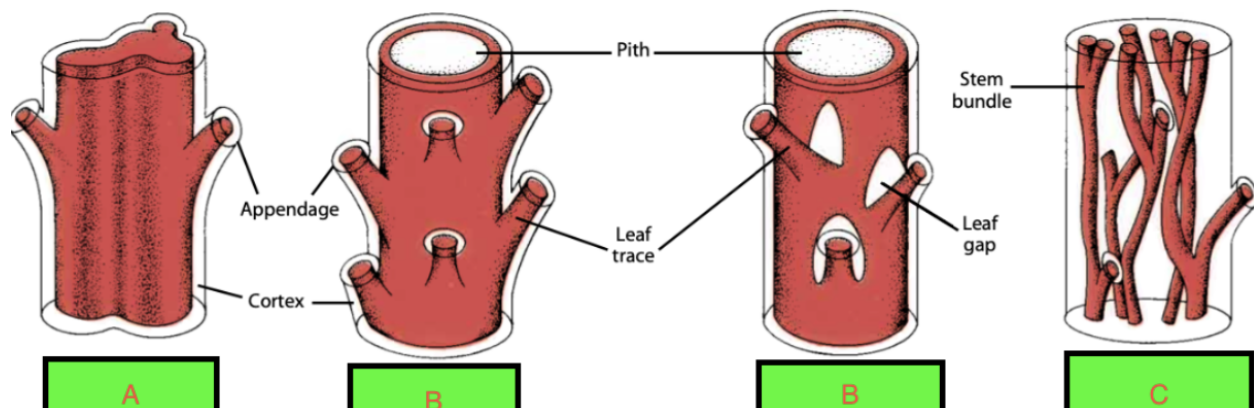
Gibberellins (GAs) were first discovered in 1934 by T. Yabuta and Y. Sumiki during their research on a fungal disease affecting rice. Since then, over 100 different gibberellins have been identified, each playing vital roles in plant development. One key role of GAs is in seed germination, where they promote the production of hydrolytic enzymes. These enzymes break down the stored nutrients in the seed's endosperm, converting them into usable molecules like sugars and amino acids. In barley seeds, the molecules that are created by the broken down endosperm by such enzymes are quickly sent over to what part of the seed to be absorbed?

- a: Pericarp
- b: Aleurone layer
- c: Scutellum
- d: Testa
- e: Coleoptile

Solution: *This is just a stock question from Raven's Biology of the Plants. Like many of the questions on the opens and semis, be careful to not fall into the trap of spending too much time on reading the context. Instead briefly scan it over and just look at what the question is actually asking. From there we can easily identify that C is correct as in grasses the endosperm breakdown products are absorbed in the scutellum.*

Question 6:

Which of the following correctly describes the following type of steles?



- a: Protostele, Sinophostele, Eustele
- b: Sinophostele, Protostele, Eustele
- c: Eustele, Sinophostele, Protostele
- d: Protostele, Eustele, Sinophostele
- e: Sinophostele, Eustele, Protostele

Solution: *A represents a protostele, the simplest type of stele without any leaf gaps or traces. B represents a sinophostele with leaf gaps and traces. C represents a eustele which contains no singular continuous cylinder but instead several.*

Genetics (1 Question)

Question 7:

Eric is researching the **KINDBEFRIENDER** operon, which encodes for the three polypeptides Nice, Caring, and Helpful. These three genes are flanked by an operator (KbO) and a promoter (KbP). He decides to study the activity of the **KINDBEFRIENDER** operon under various conditions as shown in the table below.

Cells exposed to the protein “Mean”

	Nice	Caring	Helpful
KbO+,KbP+	++	+	++
KbO+,KbP-	+	-	+
KbO-,KbP+	+	-	+
KbO-,KbP-	-	-	-

(A “++” indicates significant translation, a “+” indicates baseline level translation, a “-” represents insignificant translation)

Cells exposed to the protein “Nice”

	Nice	Caring	Helpful
KbO+,KbP+	-	+	-
KbO+,KbP-	-	-	-
KbO-,KbP+	+	-	+
KbO-,KbP-	-	-	-

Identify which of the following statements is NOT true.

- a: The protein Mean acts as a positive regulator for transcription of the Helpful gene.
- b: The KINDBEFRIENDER promoter increases expression of all three genes.
- c: The protein Nice acts as a negative regulator for transcription of the Caring gene.
- d: The protein Nice has a baseline level of expression under standard conditions.
- e: The KINDBEFRIENDER operon is repressible.

Solution: *Expression of the protein “Caring” is baseline under both conditions (whether exposed to the protein Nice or Mean) with a WT operator and promoter. However, without the promoter, Nice expression is insignificant under both conditions. It cannot be concluded that exposure to the protein Nice has any correlation to Caring expression since it does not appear to play any role in its level of expression.*

Ecology (1 Question)

Question 8:

In a mark recapture experiment, Daniel labels 30 crocodiles red and releases them. After three days, he returns and is able to locate 50 crocodiles, however only 8 of them are labeled red. Which of the following is closest to the population size of these crocodiles?

- a: 65 individuals
- b: 190 individuals
- c: 545 individuals
- d: 1280 individuals
- e: 12000 individuals

Solution: *For mark recapture, we use the following formula: $N = MS/R$, where M is the number of marked individuals released in the first trial(30 in this case), S is the size of the second sample(50 in this case), and R is the number of marked individuals in the second trial(8 in this case), and N is the estimated population size. Plugging in all of these numbers into the formula we have $(30*50)/8$ or 187.5, the closest choice to this is b, 190 individuals.*

Ethology (1 Question)

Question 9:

You are watching anime when suddenly you question the real life applicability of the word harem within nature. Which of the following relationships best describes a harem of multiple females with a single male?

- a: Polyandry

- b: Polygyny
- c: Polymorphy
- d: Monogamy
- e: Promiscuity

Solution: *Remembering the latin roots for “andry” = man and “gyny” = woman is helpful in remembering the difference between the two (this also shows up in other terminology such as androecium and gynoecium in plant whorls). For this reason, polygyny, or many females, is the correct answer. Polymorphy is not an ecological term, monogamy describes a 1:1 relationship, and promiscuity, while not incorrect, is not the BEST term to describe this relationship.*

Biosystematics (1 Question)

Question 10:

Ryan the red rhino has unfortunately lost his parents and is looking for a new home. However, he is the last member of his species so you decide to instead find the closest related animal to foster him. Which of the following animals would be the best choice?

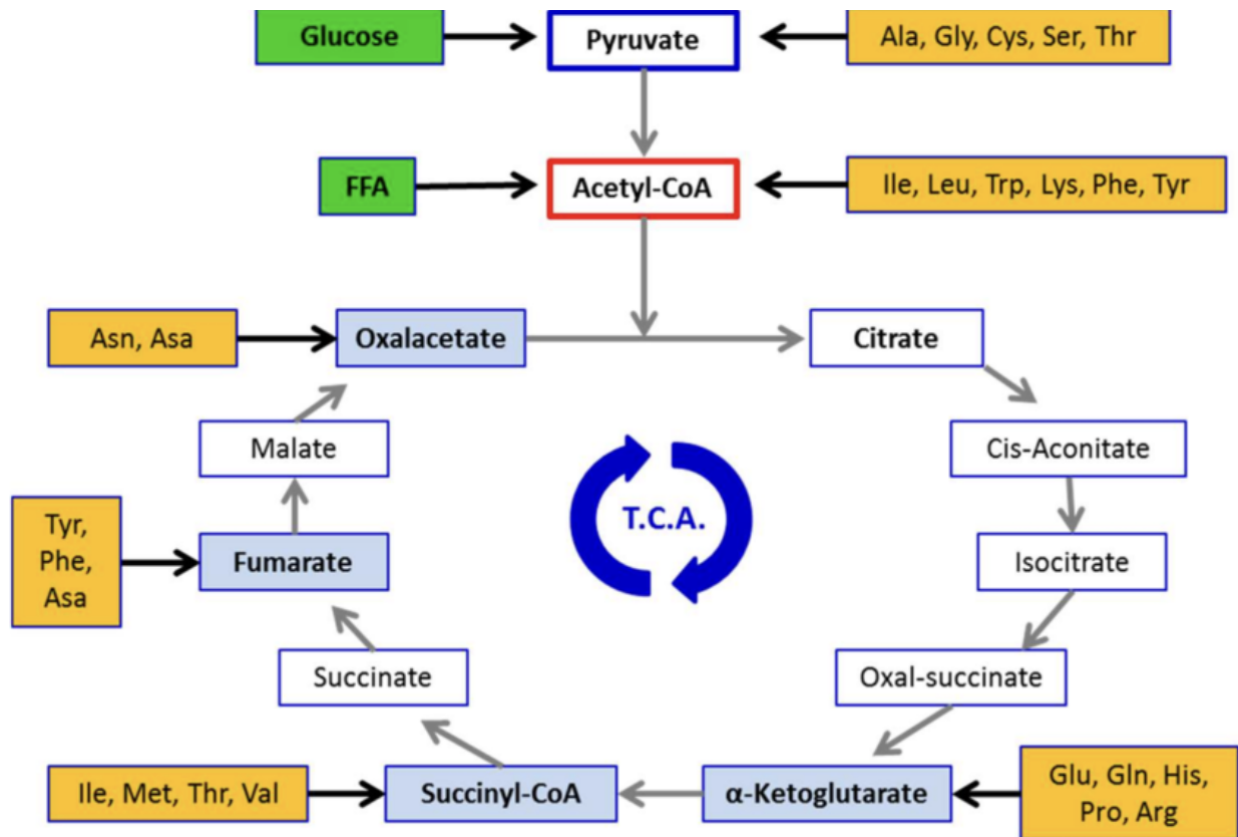
- a: Harry the horse
- b: Greg the gorilla
- c: Sandy the sandshrew
- d: Florence the fox
- e: Curie the camel

Solution: *This question is testing the relationship between even and odd toed ungulates. An easy way to remember the even and odd toed ungulates (large mammals that walk on tip of toes) is REDHOTTAKIZ (rhinos, horses, tapirs, zebras) are odd toed (credit bioly.guide).*

Section 2: MTF (2 Questions)

Question 11:

Using the image below, determine whether the following statements about the krebs cycle are true or false.



- a: Valine to Krebs intermediate yields 1 FADH₂, 1 NADH, 1 ATP
- b: Tyrosine to Krebs intermediate yields 1 FADH₂, 3 NADH, 1 ATP
- c: Succinyl-CoA to succinate is irreversible
- d: Methionine is the only AA from Acetyl-CoA

Source: Pasini, Evasio & Corsetti, Giovanni & Aquilani, Roberto & Romano, Claudia & Picca, Anna & Calvani, Riccardo & Dioguardi, Francesco. (2018). Protein-Amino Acid Metabolism Disarrangements: The Hidden Enemy of Chronic Age-Related Conditions. *Nutrients*. 10, 391. <https://doi.org/10.3390/nu10040391>

Solution: This question is testing which steps of the krebs cycles produce ATP, FADH₂, and NADH. I recommend that you know all of these steps to memory. Valine enters the krebs cycle as Succinyl-CoA so it will produce 1 FADH₂, 1 ATP and 1 NADH, thus [a] is true. Tyrosine enters as Acetyl Co-A so it goes through the entire krebs cycle producing 1 FADH₂, 1 ATP, and 3 NADH, so [b] is true. Only steps 1,3, and 4 are irreversible so [c] is false. No amino acid can be created from Acetyl-CoA so [d] is false.

Question 12:

Would the following situations result(true) or not result(false) in an influx of ions for a hypothetical neuron cell with only voltage gated magnesium and chloride

channels at a membrane equilibrium potential of -60 mV? Use the Nernst equation as given: $61/z(\text{charge}) \cdot \log(\text{Concentration of ion outside} / \text{concentration of ion inside})$

- a: Mg^{2+} : 2 mM outside, 150 mM inside
- b: Mg^{2+} : 0.5 mM inside, 50 mM inside (typo — clarify?)
- c: Cl^- : 2 mM outside, 10 mM inside
- d: Cl^- : 3 mM outside, 35 mM inside

Solution: We use the Nernst equation:

$$E = \frac{61}{z} \log \left(\frac{[\text{ion}]_{\text{out}}}{[\text{ion}]_{\text{in}}} \right)$$

to calculate the equilibrium potential of each ion. The direction of ion flow is determined by comparing the ion's equilibrium potential (E_{ion}) to the membrane potential ($V_{\text{membrane}} = -60 \text{ mV}$). Use the following logic:

- If $E_{\text{ion}} > V_{\text{membrane}}$ and ion is **positive (cation)** $\Rightarrow$ **influx**
- If $E_{\text{ion}} < V_{\text{membrane}}$ and ion is **positive (cation)** $\Rightarrow$ **efflux**
- If $E_{\text{ion}} > V_{\text{membrane}}$ and ion is **negative (anion)** $\Rightarrow$ **efflux**
- If $E_{\text{ion}} < V_{\text{membrane}}$ and ion is **negative (anion)** $\Rightarrow$ **influx**

[a] **Magnesium:** $[\text{Mg}^{2+}]_{\text{out}} = 2 \text{ mM}$, $[\text{Mg}^{2+}]_{\text{in}} = 150 \text{ mM}$, $z = +2$

$$E = \frac{61}{2} \log \left(\frac{2}{150} \right) \approx -52.6 \text{ mV}$$

Since $-52.6 > -60$ and magnesium is a cation, **influx occurs. Result: True**

[b] **Magnesium:** $[\text{Mg}^{2+}]_{\text{out}} = 0.5 \text{ mM}$, $[\text{Mg}^{2+}]_{\text{in}} = 50 \text{ mM}$, $z = +2$

$$E = \frac{61}{2} \log \left(\frac{0.5}{50} \right) \approx -61.0 \text{ mV}$$

Since $-61.0 < -60$ and magnesium is a cation, **efflux occurs. Result: False**

[c] **Chloride:** $[\text{Cl}^-]_{\text{out}} = 2 \text{ mM}$, $[\text{Cl}^-]_{\text{in}} = 10 \text{ mM}$, $z = -1$

$$E = \frac{61}{-1} \log \left(\frac{2}{10} \right) \approx +47.8 \text{ mV}$$

Since $+47.8 > -60$ and chloride is an anion, **efflux occurs. Result: False**

[d] **Chloride:** $[\text{Cl}^-]_{\text{out}} = 3 \text{ mM}$, $[\text{Cl}^-]_{\text{in}} = 35 \text{ mM}$, $z = -1$

$$E = \frac{61}{-1} \log \left(\frac{3}{35} \right) \approx -65.4 \text{ mV}$$

Since $-65.4 < -60$ and chloride is an anion, **influx occurs. Result: True**

Result: Ion influx occurs in situations [a] and [d] are true.

Question 13: Lost in Translation

The Mitosisphere research team is working on creating a transgenic bacterium engineered to express the human alpha hemoglobin gene. You transduce a bacterial cell with a pYES2 yeast plasmid vector and await your results!

- (a) **You have decided to include a special amino acid outside of the normal 20 in your protein sequence. Which amino acid could this be? Compared to other amino acids, what is special about the way this amino acid is incorporated?**

Solution: *Pyrrolysine (O); it is incorporated at the UGA stop codon (or just “stop codon” is acceptable) using a special tRNA and insertion machinery.*

- (b) **After painstakingly figuring out all issues with transcription and gene expression, the protein product is still dysfunctional! Identify *two* possible reasons this could be.**

Solution:

- *Lack of chaperones for proper folding*
- *Lack of posttranslational modifications*
- *Codon usage bias—some codons are so rare in bacteria that the ribosome stalls*
- *Forgot to introduce heme group into bacteria*
- *Missing other two beta chains to prevent degradation*
- *Missing Shine-Dalgarno sequence*
- *Incorrect localization*

- (c) **Propose a strategy to help alleviate *one* of these issues.**

Solution:

- *Co-express bacterial chaperone proteins*
- *Use a eukaryotic expression system such as yeast*

- *Synthesize a codon-optimized version of the gene*
- *Supplement the bacterial growth medium with heme*
- *Introduce beta chain gene into bacteria*
- *Insert Shine-Dalgarno sequence*
- *Remove any eukaryotic signal peptides from the gene; add bacterial localization sequence*

Question 14: Powder Pandemonium

Oh no! Your opponents' powder monkeys are rapidly growing and threaten to end the game. Strangely enough, the growth of the powder monkey population follows a logistic growth curve. Each turn you record data regarding the number of powder monkeys, which is shown below:

Turn	# of Monkeys
0	10
1	15
2	20
3	26
4	32
5	38
6	42
7	45
8	47
9	48
10	49
11	49
12	50
13	50
14	50
15	50

- (a) What is the carrying capacity of this population? In a real-life scenario, is it possible to pass this threshold?

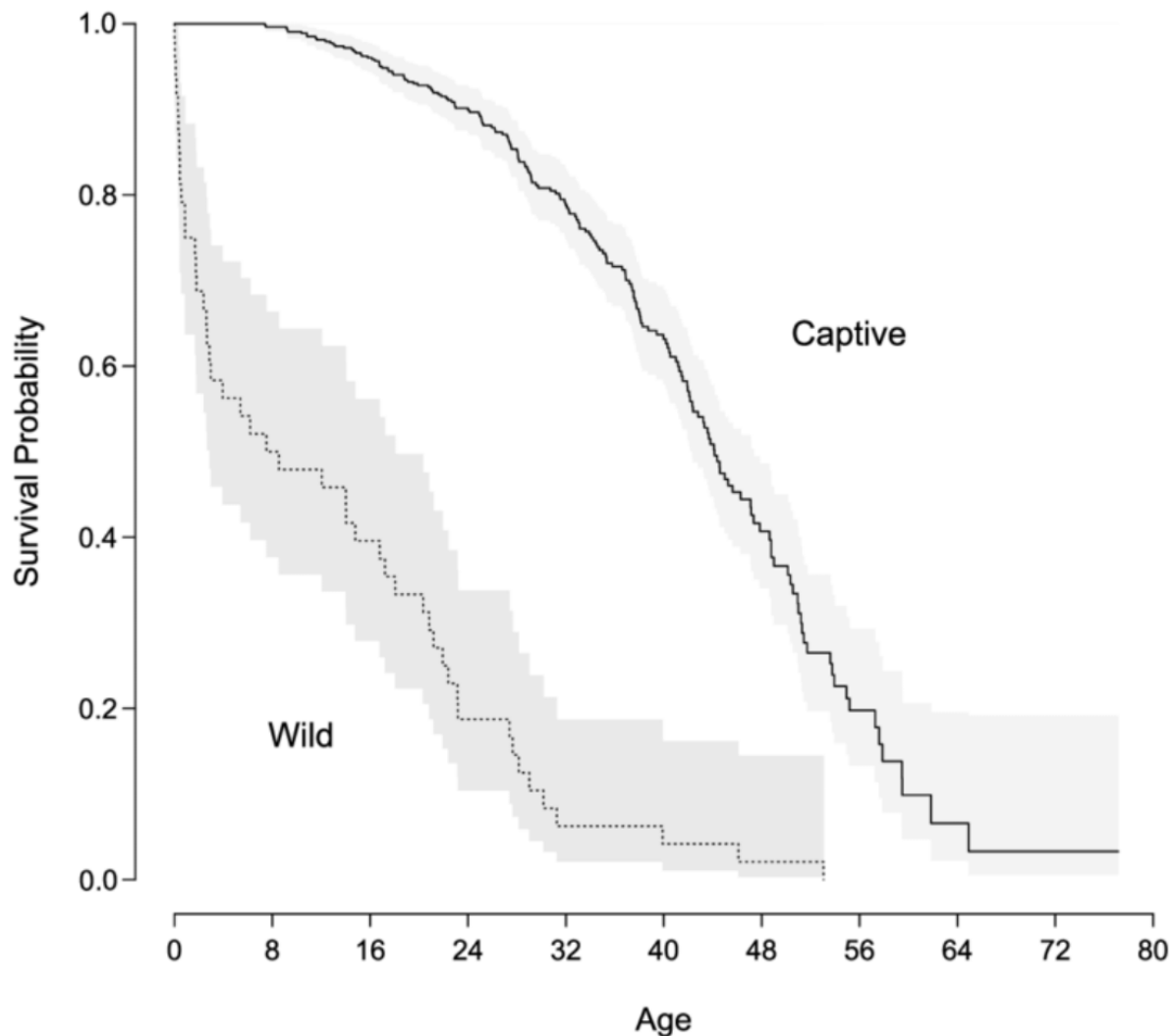
Solution: *50 powder monkeys. Yes, it is possible to overshoot the carrying capacity in real life as conditions are not perfect.*

- (b) Given that the intrinsic rate of growth (r) is 0.5, derive a logistic equation to represent the number of monkeys, N , at a given time t .

Solution:

$$N(t) = \frac{50}{1 + 4e^{-0.5t}}$$

- (c) You decide to test the lifespan of powder monkeys within capacity before they ultimately meet their explosive doom. What type of survivorship curve best describes the captive and wild powder monkeys respectively using the data below?



Solution: *Captive: Type I or intermediate Type I/II both acceptable.*

Wild: Type III or intermediate Type II/III both acceptable.

Tiebreaker!

Metazoa: Identify what animal family the following images are from. This question will only be used in the case of a tiebreak.

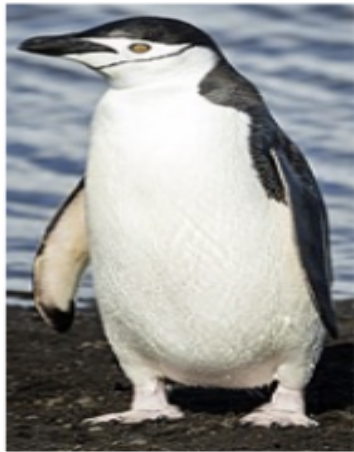
A.



B.



C.



D.





E.

Answer bank: Accipitridae, Anatidae, Aplysiidae, Bovidae, Bufonidae, Canidae, Carcharhinidae, Cervidae, Cheloniidae, Colubridae, Crocodylidae, Dasyatidae, Delphinidae, Equidae, Felidae, Formicidae, Gekkonidae, Hirudinidae, Hominidae, Hyaenidae, Ichneumonidae, Leporidae, Loricariidae, Macropodidae, Muridae, Octopodidae, Papilionidae, Phasianidae, Psittacidae, Ranidae, Scarabaeidae, Sciuridae, Spheniscidae, Sirenidae, Tenrecidae, Testudidae, Tyrannidae, Ursidae, Vespidae, Vulpesidae.

Solution: *Felidae*, *Testudidae*, *Spheniscidae*, *Canidae*, *Hominidae*.

Source: Wikipedia and Altschul et al. (2018) eLife 7: e33781.