IJSO Theory Solutions

Biology Mock Test no. 1

Problem 1 – Adaptations in Organisms Living in Freezing Conditions (10 points)

Part A. The Molecular Biological Adaptations to the Cold

A.1. Many psychrophilic bacteria possess enzymes that maintain catalytic efficiency at low temperatures. A common molecular strategy to achieve this involves a higher proportion of:

(1.00 points)

Solution:

A. is incorrect because too many phospholipids in the membrane reduce the fluidity/flexibility of the membrane, which reduces catalytic activity.

B. is incorrect as well because increasing rigid protein structures in the membrane decreases membrane fluidity, reducing catalytic activity.

C. is correct because increasing conformational flexibility decreases rigidity, thus increasing catalytic activity by facilitating the movement of molecules interacting in the active site.

D. is incorrect as well, because disulfide bridges that enhance stability make the cell wall more rigid, making it more challenging for these organisms to thrive in the cold.

The correct answer is **C**.

A.2. Fill in the blanks:

(0.50 points)

Solution:

Blank 1: The answer is cryo-protectant. Cryo-protectants prevent biological materials from freezing and thawing.

Blank 2: The answer is unsaturated fatty acids. Unsaturated fatty acids contain double bonds that keep phospholipids at a distance from each other to maintain fluidity. Organisms adapted to the cold will have more unsaturated fatty acids to prevent cell membranes from becoming rigid and dysfunctional.

The correct answers are: **Cryoprotectant; unsaturated fatty acid**s

A.3. Beyond simple freezing point depression, specialized antifreeze proteins (AFPs) in polar fish primarily function by:

(1.00 points)

Solution:

This problem requires knowledge of AFPs and their role in protecting organisms from freezing. Option B is correct because antifreeze proteins (AFPs) bind to ice crystals and inhibit their growth via a mechanism known as adsorption-inhibition. They lower the freezing point of water to prevent large enough ice crystals from damaging cells. Options A, C, and D are incorrect mechanisms.

The correct answer is **B**.

Part B. Physiological Architectures for Enduring Cold

B.1. Endothermic polar animals like arctic foxes and penguins utilize a countercurrent heat exchange system in their extremities (e.g., paws, flippers). This mechanism functions by:

(0.25 points)

Solution:

Option B is correct as it effectively describes the process of countercurrent heat exchange used by arctic foxes and penguins. As described in option B, heat is transferred from the outgoing arterial blood to the cooler returning venous blood, thereby minimizing heat loss to the environment. Options A, C, and D are all ineffective at describing how endothermic animals manage heat exchange in the extremities.

The correct answer is **B**.

B.2. Check all that apply: Non-shivering thermogenesis (NST) in mammals, particularly relevant in cold adaptation, involves which of the following processes in brown adipose tissue (BAT)?

(1.25 points)

Solution:

To solve this problem, it is important to understand that brown adipose tissue contains high concentrations of mitochondria. Therefore, to extract heat from brown adipose tissue, we must focus on generating more energy through mitochondria. Option A is incorrect because it generates more ATP, BUT we want to generate heat. Option B is correct because uncoupling ATP synthase allows it to produce heat as opposed to ATP. Option C is also correct because allowing proton leakage increases the proton gradient and allows more ATP to be produced. Option D is incorrect because the question is asking for a non-shivering thermogenesis, NOT increased shivering. Option E is correct because fueling proton pumping generates more energy, which can be converted to heat.

The correct answer is **B**.

B.3. Some freeze-tolerant organisms, such as the wood frog (*Rana sylvatica*), can survive having up to 65% of their total body water frozen. This is largely achieved by:

(0.25 points)

Solution:

Option A is incorrect because it directly conflicts with what is mentioned in the passage. How can 65% of the body's water be frozen if the body is actively preventing ice formation? Option B is likely correct because it allows for the formation of ice crystals while protecting cells, which keeps the organism alive. Option C is very risky because of constant temperature changes. Organisms are not adapted to constantly thawing and freezing. Option D is incorrect because vitrification does not happen to frogs; it happens to cryo-preserve embryos and oocytes.

The correct answer is **B**.

B.4. The exceptionally low heart rate and metabolic rate observed in some diving marine mammals (e.g., seals, whales) when under ice is an example of:

(0.25 points)

Solution:

To solve this problem, all you need to know is the mechanism by which diving marine mammals maintain themselves for long periods underwater. This mechanism is called bradycardia, the slowing down of the heart rate to prioritize oxygen conservation. The other options are mechanisms used for different situations, not this specific one.

The correct answer is **C**.

Part C. Ecological Dynamics of Polar Life

C1. The formation of sea ice is crucial for the early spring bloom of ice algae (sympagic algae). These algae form the base of the "cryopelagic" food web. Check all that apply regarding the ecological advantages of growing within or on the underside of sea ice for these primary producers:

(0.75 points)

Solution:

A. is correct; plants are effectively shielded from direct, intense UV radiation under.
B. is correct; there are nutrient-rich brine channels with high levels of nitrogen, which foster the perfect environment for algae growth.
C. is correct, zooplankton tend to live in open-water areas, so they wouldn't cross paths with algae in or under sea ice.
D. is incorrect; there is less light penetration, not more!
E. is correct. The ice keeps water movement in check.

The correct answers are **A, B, C, and E**.

C2. The biomagnification of persistent organic pollutants (POPs) is a significant concern in polar food webs. Which of the following statements best explains why apex predators like polar bears accumulate very high concentrations of these toxins?

(1.25 points)

Solution:

To solve this, we must understand what biomagnification is. Biomagnification is the process by which the concentration of a substance increases in organisms as they move to a higher trophic level.

A. is incorrect as biomagnification involves multiple levels, NOT DIRECT consumption.

B. is incorrect; excretion by lower trophic levels has nothing to do with what the apex trophic levels will consume.

C. is correct; it effectively talks about how POPs ACCUMULATE due to biomagnification in higher trophic levels.

D. is incorrect; organisms don't synthesize pollutants, they accumulate.

The correct answer is **C**.

C3. During the polar winter, many marine birds and mammals migrate away from the extreme cold. However, species like Emperor Penguins endure the Antarctic winter. Their survival in breeding colonies during winter relies heavily on:

(0.50 points)

Solution:

A. is incorrect; it is too cold for terrestrial plants to grow. Option B is incorrect.

B. is also incorrect because penguins have adaptations to withstand winter without hibernating.

C. is correct; penguins have blubber and huddle together to conserve heat.

D. is incorrect; increasing metabolic rate would allow MORE heat to be lost through the skin. A great way to familiarize yourself with the behaviour of animals is by watching animal documentaries!

The correct answer is **C**.

Part D: Global Change and the Cryosphere

D1. Fill in the blanks:

(0.50 points)

Solution:

Blank 1: The answer is decomposition. Decomposition releases greenhouse gases like CO2 and CH4. Photosynthesis effectively does the opposite, acting as a carbon sink.

Blank 2: The answer is microbial. Abiotic things are non-living; they can't decompose organic matter. Geological activity rearranges organic matter but does not decompose it. Microbes (like bacteria and fungi) can break down organic matter via assimilation, nutrient release, and mineralization.

The correct answers are **decomposition; microbial.**

D2. Check all that apply: The accelerated melting of Arctic sea ice has several direct and indirect ecological consequences. Which of the following are likely to occur?

(0.75 points)

Solution:

A. is correct; more sunlight means more photosynthesis, which increases primary productivity.

B. is correct, as seen in a lot of animal documentaries, ice-dependent predators struggle to hunt and find space to live without firm ice.

C. is correct. When ice and permafrost melt, they typically erode the coastal rock. This phenomenon is like the "scratches" left behind by receding glaciers.

D. is wrong because an increase in the albedo effect means that the surface reflects MORE light. The albedo effect has a hotter feedback loop, NOT a colder one. When the Earth's surface warms, the ice melts, so instead of having a high albedo (very reflective), the ice turns to water and has a lower albedo because darker surfaces are exposed. Darker surfaces lead to further warming and melting. If that was confusing, please read more about the albedo effect here.

E. is correct because most parasites freeze or die off in very cold temperatures.

The correct answers are **A, B, C, and E.**

D3. Ocean acidification, driven by increased atmospheric CO_2 absorption, poses a particular threat to calcifying organisms in cold polar waters. This is because (fill in the blanks):

(1.25 points)

Solution:

- A is incorrect, cold water holds MORE dissolved CO2. The higher the temperature, the faster CO2 particles move and the faster they escape.
- B is correct, building off of option A, CO2 solubility increases as temperature decreases.
- C is correct, polar organisms are generally more sensitive to temperature changes and pH changes because they have evolved to only survive in colder temperatures and a certain pH range.
- D is incorrect, acidification does lead to shell dissolution, but does NOT increase metabolic rate. It rather increases energy demands for maintaining a stable internal environment as the external environment lowers in pH.

The correct answer is **C.**

D4. Fill in the blank:

(0.50 points)

Solution:

- The correct answer here is the Albedo effect, which was explained in the solution for D2.

The correct answer is the Albedo **effect.**

Problem 2 – Homeostasis (15.00 points)

Part A. Glucose Homeostasis – Fundamental Mechanisms

A1. After a carbohydrate-rich meal, blood glucose levels rise. Which of the following accurately describes the immediate physiological response orchestrated by the pancreas to restore glucose homeostasis?

(0.75 points)

Solution:

The correct answer here is option B. When blood glucose levels rise, insulin is produced to increase glucose absorption by cells to reduce blood glucose levels. Beta cells are responsible for the production of insulin. Alpha cells produce glucagon, but glucagon allows cells to release more glucose into the bloodstream, which would NOT restore homeostasis after a glucose-rich meal. Somatostatin, while involved, does not directly contribute to this type of regulation.

The correct answer is **B.**

A2. Fill in the blanks:

(1.00 points)

Solution:

Blank 1: The answer is adipose tissue. Adipose tissue contains huge amounts of energy, which can be used as a source of glucose if needed.

Blank 2: The answer is GLUT4, which facilitates the uptake of glucose into cells in adipose tissue. SGLT1 is a sodium-glucose cotransporter in the intestine and kidney. Na+/K+, also known as a sodium-potassium pump, is found in neurons and has nothing to do with glucose reuptake.

Blank 3: The answer is glycogen. Glucose is converted to glycogen for storage in the liver. When more glucose is needed in the bloodstream, glycogen is converted to glucose to be used by the body.

The correct answers are **adipose tissue; GLUT4; and glycogen**

A3. Check all that apply:

(0.75 points)

Solution:

- The pancreas has a key role in blood glucose level regulation. It has alpha and beta cells, which produce glycogen and insulin, respectively.
- The liver is also involved, as it stores glucose in the form of glycogen. It responds to hormones like insulin and glycogen.
- Adipose tissues also respond to hormones like insulin and glycogen to regulate blood glucose levels.
- The kidneys do NOT directly connect to blood glucose regulation; their main purpose is blood filtration.
- The hypothalamus INDIRECTLY affects blood glucose regulation. The closest it gets to blood glucose regulation is communicating with the pancreas.

The correct answers are **A, B, and C.**

Part B: Glucose Homeostasis - Clinical Insights

B1. A patient undergoes an Oral Glucose Tolerance Test (OGTT). After consuming a glucose solution, their blood glucose levels are monitored over several hours. In a healthy individual, which of the following glucose level patterns would be observed?

(1.00 points)

Solution:

Option B is likely the correct one because the glucose circulates in the body for a few hours before fully returning to baseline due to the action of insulin. Unfortunately, glucose cannot be immediately absorbed, as the body needs to be aware of this sudden glucose spike before metabolizing it.

The correct answer is **B.**

B2. Check all that apply: Prolonged and uncontrolled hyperglycemia (high blood glucose) in diabetes can lead to severe long-term complications affecting various organ systems. Which of the following are recognized consequences of chronic hyperglycemia?

(1.00 points)

Solution:

Option A is correct and probably the most common consequence of prolonged hyperglycemia because larger blood vessels tend to be thicker and more resistant to higher blood pressure. Option B, while less common, is still plausible because increased blood glucose leads to increased inflammation which damages blood vessels, big or small. Option C is incorrect as there are no benefits to hyperglycemia. In anything at all it leads to a poorer immune response, not a better one. Option D is also correct, it emphasizes option A and gives a more specific example (i.e. neuropathy). Option E is incorrect for the same reason as that of option C.

The correct answers are **A, B, and D.**

B3. Fill in the blanks:

(0.50 points)

Solution:

Blank 1: The answer to this is beta cells. Diabetes mellitus leads to high levels of blood glucose without reabsorption. This is characterized by beta cells as they release insulin.

Blank 2: The answer to this is insulin resistance; the body develops an intolerance to glucose because of repetitive ingestion of glucose.

The correct answer is **beta cells; insulin resistance.**

Part C: Thermoregulation- Maintaining Core Body Temperature

C1. When an individual is exposed to a cold environment, the body initiates several responses to conserve heat. Which of the following accurately describes a primary physiological response mediated by the hypothalamus to prevent excessive heat loss?

(1.00 points)

Solution:

A. is incorrect because, as the blood vessels widen, they get closer to the skin surface and emit heat that way. Vasoconstriction is a lot better at heat conservation, but can lead to atrophy of the extremities.
B. is incorrect, sweating speeds up the cooling down process, NOT conservation of heat.
C. is correct! Erection of the hair on the skin creates a layer of insulation and conserves heat. Shivering also generates heat.
D. is incorrect; brown adipose tissue activity should be activated, NOT inhibited.

The correct answer is **C.**

C2. Check all that apply: Beyond involuntary physiological responses, humans and many other endotherms employ conscious behavioral adaptations to regulate their body temperature. Which of the following are examples of such behavioral thermoregulation?

(0.50 points)

Solution:

It is important that we distinguish physiological adaptations from behavioural ones. Involuntary physiological adaptations are those that happen naturally and are out of our control (e.g. vasodilation). Behavioural adaptations are those that can be voluntarily controlled. Option A is correct as it is a voluntary behavioural adaptation to regulating body temperature by reducing direct access to sunlight. Option B is also correct, it is behavioural as well as option C. Option D and E are PHYSIOLOGICAL, not behavioural as they are processes that happen involuntarily.

The correct answers are **A, B, and C.**

C3. Fill in the blanks:

(0.25 points)

Solution:

Blank 1: The answer here is conduction, the transfer of heat via direct contact.

Blank 2: The answer is convection. Convection is the movement of heat through fluids (including gases). This problem is asking for the transfer of heat from the body to the environment.

The correct answers are **conduction; convection.**

C4. Approximately how much energy (in kJ) does the body use solely to convert 1 liter of cold water (5°C) to body temperature (37°C), without taking into account other metabolic processes? (Specific heat capacity of water = 4.18 J/g°C)

(1.50 points)

Calculation:

When it comes to water, 1 ml = 1g. 1L = 1kg. Therefore, for mass we can input 1kg, the temperature change is 32 degrees Celsius.
$q = mC\Delta T$; q = (1) (4.184) (37 -5) = (4.184) (32) = 133.888 = 134 kJ

Q = 134 kJ

Part D: Interplay of Homeostatic systems

D1. During prolonged strenuous exercise, both glucose homeostasis and thermoregulation are significantly challenged. Which of the following best describes a key physiological adjustment that allows the body to meet the increased energy demand and manage heat production simultaneously?

(1.00 points)

This problem simply requires basic knowledge of blood glucose homeostasis and thermoregulation in humans. During prolonged exercise, the muscles involved are working extremely hard and require a constant supply of glucose (energy). Therefore, increasing insulin secretion to remove glucose from the bloodstream will be detrimental. Increased glucagon levels, however, will ensure that muscles have a constant supply of glucose because it is not being reabsorbed/stored. That means option B is correct for the first portion. When it comes to thermoregulation, the body needs to find a way to get rid of all the heat it is mechanically producing, which can be done via sweating and vasodilation. In conclusion, option B is correct because it accurately describes the more effective mechanisms by which glucose and thermoregulatory homeostasis are managed during prolonged strenuous exercise.

The correct answer is **B.**

D2. Check all that apply: Homeostatic control systems typically operate via negative feedback loops to maintain stability. Which of the following are essential components of a generic negative feedback loop?

(0.75 points)

Solution:

One must simply understand that the negative feedback loop contains the following: stimulus (a condition deviating from set point), sensor (detects stimulus), control (something directing the return to homeostasis), and effector (directly correcting the imbalance). Therefore, options A, B, and C are key components of a negative feedback loop. A positive feedback mechanism is the complete opposite, so it would not contribute to a negative feedback loop. The set point is not directly part of the process; the stimulus is what is important. We don't focus on the set point – we focus on deviations from the set point.

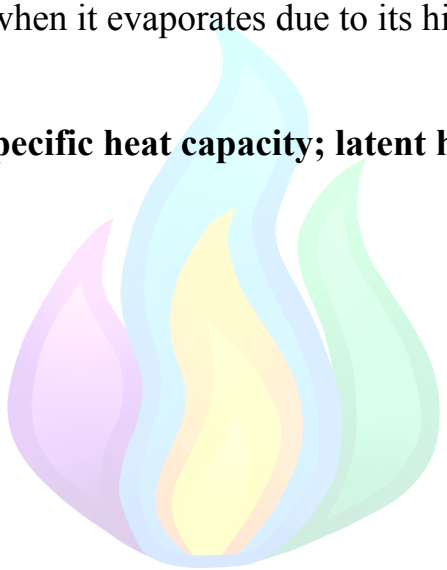
The correct answers are **A, B, and C.**

D3. Fill in the blanks:

(0.25 points)

Blank 1: The answer here is specific heat capacity (because water can withstand high and low heat without changing temperature itself, it can absorb large amounts of heat)

Blank 2: The answer here is the latent heat of vaporization. A high heat of vaporization means it takes a long time to convert the liquid to gas. This also means that the gas leaves with a LOT of energy in the form of heat. Therefore, water is great at evaporative cooling because it can pull a lot of heat from the skin when it evaporates due to its high heat of vaporization.



The correct answers are **specific heat capacity; latent heat of vaporization.**

D4. During intense physical activity in hot conditions, the body can lose up to 2–3 liters of sweat per hour. If an athlete drinks water without replacing electrolytes, what is the most likely physiological outcome?

(1.00 points)

Solution:

First, let's consider what happens physiologically in such a situation. Does it affect sugar levels, sodium levels, or alkaline levels? Sugar levels are affected DURING the workout as muscle cells need a constant supply of glucose. We are focusing on what happens AFTER the workout when an athlete drinks water WITHOUT electrolytes. Furthermore, electrolytes are ions, for example, sodium (Na+) and chloride (Cl-).

Alkaline acidosis occurs when the body has too much basic (alkali) substance in its fluids. An individual with this condition has an elevated blood pH. This is typically caused by a loss of acid (e.g. vomiting leads to loss of stomach acid), kidney problems, or excessive intake of antacids.

Hyponatremia is the closest physiological consequence of such replenishment. The other options do not relate to electrolytes (salts). Hypernatremia is the opposite; there is MORE sodium than required.

The correct **answer is C**.

D5. Which mechanism precisely describes why the body inhibits the secretion of the hormone vasopressin (ADH) in a state of hyperhydration?

(1.00 points)

Solution:

- Remember that "increased osmolality" indicates a higher concentration of dissolved particles (hypertonic). However, being in a state of hyperhydration means there would be DECREASED osmolality. Also note that baroreceptors are mechanoreceptors that record sensory information about blood pressure to the brain. However, baroreceptors are the wrong receptor for this situation; osmoreceptors are triggered by changes in osmolality. Option A is incorrect; baroreceptor activation does not have to do with ADH secretion.
- Low plasma osmolality means there is low solute concentration and high solvent volume, which is what would cause inhibition of ADH production. So far, so good! The hypothalamus indeed produces ADH and then transports it to the posterior pituitary for release. The hypothalamus has control over how much ADH is secreted, so it can very well inhibit ADH production in response to low plasma osmolality. Option B is correct.
- Reduced filtration in glomeruli has nothing to do with ADH/water reabsorption. ADH acts on the COLLECTING DUCTS after everything else has been filtered out. Option C is incorrect
- Option D is incorrect. If we had to wait till our bladders were full before water reabsorption was enforced, it would be too late!

The correct answer is **B.**

Part E: Effects of Physiological Modulators (2.75 points) - 0.4 PER correct sub-answer.

For each physiological process listed below, indicate whether the modulating factor described would typically have an Increasing (I), Decreasing (D), or Unrelated (U) effect on the rate or magnitude of the process.

E1. **Decreasing** (removal of myelin slows down signal transmission due to dissipation of impulse; it's like removing insulation in a thermos - it no longer stores heat for a long time)

E2. **Increasing** (an increase of CO2 levels means more oxygen unloading is required so cells can survive)

E3. **Decreasing** (less blood into the glomerulus = lower glomerular hydrostatic pressure)

E4. **Decreasing** (If there is an increase in solute concentration, the solvent will try to stay in the cell or enter more, NOT leave the cell). Remember, water moves from high to low concentration. If there is high solute concentration there is low solvent concentration so water will more IN, not OUT.

E5. **Decreasing** (Sodium potassium pump depends on the availability of ATP, low ATP means minimal or no Na+/K+ activity)

E6. Decreasing (Low blood osmolarity means low solute concentration and high solvent volume so ADH can be inhibited because reabsorption is not necessary, expulsion is)

E7. **Increasing** (Parathyroid hormone increases Calcium reabsorption)

Problem 3 – Global Warming and Biodiversity in the Arctic

Part A. Glucose Homeostasis – Fundamental Mechanisms

A1. Select the best answer with regards to the passage:

(1.00 points)

The correct answer here is option A. From the text, it is evident that even the SLIGHTEST of changes alters the population size of the Arctic fairy shrimp. Alterations in the population size of Arctic fairy shrimp indirectly alter the population of surrounding species in the food chain (above and below). Snails and insect larvae feed on these shrimps, so they will face food scarcity. The other options are incorrect because they neglect even the slightest of temperature changes.

A2: Determine if the statements are true or false **(4.00 points) –** 0.80 points PER correct answer

1) **False**. Organism B will survive more than organism A because it can withstand a larger valence (range) of the given factor.
2) **True**. Genetics plays a huge role in ecological valence. A larger range of genes is tied to a larger valence.
3) **True**. An isolated population has a restricted gene pool and will not be able to adapt in time with changing non-living factors because of its fixed valence. A population with high gene flow (exchange of genes BETWEEN populations) means there is exposure to a wider variety of genes and thus wider valence.
4) **False**. Climate change and global warming ARE one of the main reasons for species extinction (especially those with very narrow valence).
5) **True**. Bottom-up control is precisely this scenario. If the populations of phytoplankton and algae are impacted, it will have a direct effect on higher trophic levels.