

AP[®] BIOLOGY
2009 SCORING GUIDELINES (Form B)

Question 3

Water is essential to all living things.

- (a) **Discuss** THREE properties of water.
- (b) **Explain** each of the following in terms of the properties of water. You are not limited to the three properties discussed in part (a):
- the role of water as a medium for the metabolic processes of cells
 - the ability of water to moderate temperature within living organisms and in organisms' environments
 - the movement of water from the roots to the leaves of plants

(a) Discuss THREE properties of water (**6 points maximum**):

Name of property **and** correct description (**2 points**). Points **MUST** provide both property and description.

Property	and Description (2 points jointly)
Polarity of water	Polar covalent bonds created by unequal sharing of electrons between O and H within the molecule
Specific heat/high heat capacity	Heat absorption without temperature change
High heat of vaporization	Water molecules absorb energy as it changes state/breaking of bonds by absorbing energy
Adhesion	Attraction to other molecules that are polar or have charge
Cohesion	Attraction to other water molecules due to polar nature of water/ surface tension
Three states of matter	Ice–liquid–gas (vapor) Kinetic energy differences Expands at 4°C to become less dense
Repels hydrophobic material	Moves aside nonpolar substances

(b) Explain each of the following in terms of water properties (**6 points maximum; 2 points for each part**). To earn 10 points, students must get at least 1 application point for each area.

Water's role as a medium for the metabolic processes of cells (**2 points maximum**):

- Diffusion—allows for movement of materials through an aqueous solution down the concentration gradient
- Osmosis—movement of water across membranes due to water potential differences (down the gradient)
- Solvent—dissociation/ionization of materials
- Buffer—explanation of role water plays in formation of bicarbonate ion

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Question 3 (continued)

Water's ability to moderate temperature within living organisms/environments **(2 points maximum)**:

- Specific heat—moderates climates, maintains stable temperature in cells, constant internal environment
- High heat of vaporization—perspiration cooling, evaporative cooling
- Ice forming and acting as insulator for lakes, keeping water in liquid state

Water from the roots to the leaves of plants **(2 points maximum)**:

- Transpiration—moving water away from leaves due to water potential differences/evaporation through stomata
- Capillary action of water due to adhesion and cohesion
- Root pressure—driven by osmosis/movement of water into roots
- Negative pressure potential—caused by surface tension of water as it is pulled up xylem

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Water is an essential substance for life on earth. Water is a molecule of one oxygen atom bonded covalently to two hydrogen atoms. Oxygen's high electronegativity gives the molecule its polarity and its bent shape. This also gives water its ability to hydrogen bond which gives water its unique properties.

a) Water is known as the universal solvent. Its polar nature allows it to break down ionic bonds as well as polar covalent bonds. No other known substance is able to dissolve the same variety of substances as water. Water also has a high heat capacity due to its hydrogen bonds between hydrogen atoms of one molecule to oxygen atoms of other molecules. This results in a large amount of energy required to raise ~~oxygen~~ water's temperature by just 1 degree Celsius. Cohesion and adhesion are other properties of water that result from hydrogen bonds. Cohesion refers to water's ability to attach to other ^{water} molecules while adhesion refers to water molecules ability to ~~the~~ bond to other substances such as the walls of tracheids in the xylem tissue of plants. Water also exhibits surface tension where water molecules at the surface bind to each other and ~~the~~ ~~water~~ ~~preventing~~ ~~the~~ ~~water~~ ~~from~~ ~~penetrating~~ ~~the~~ ~~surface~~ ~~making~~ ~~the~~ ~~surface~~ ~~difficult~~. This results in being able to fill a glass slightly over the top without ~~any~~ any water spilling out.

b) Water serves an important role in the metabolic processes of the cell. In plants, water is essential for photosynthesis and glucose production because it provides the electrons necessary in order to capture a photon of light and excite it into a state where it can be harnessed to make ATP. Water also plays an important role in the cytoplasm where it acts as a dissolver of the various substrates present. Osmosis through the plasma membrane must be carefully regulated by substrate levels in order to maximize cell functioning.

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Water is also able to moderate temperature in both living organisms and the environment. Water's high specific heat enables it to function as an ~~is~~ absorber of heat inside an organisms body. Water's high heat of vaporization allows the body to cool by ~~sweating~~ ^{perspiration}. When the water evaporates off the skin a lot of heat is ~~released~~ absorbed.

The movement of water from roots to the leaves of plants is hinged upon vaporisation and cohesion and adhesion. As water enters the roots it is pushed up ~~the~~ a short distance by root pressure because of the concentration gradient between the ground and the roots. Water forms a continuous ~~to~~ pillar from leaf to roots because of cohesion. When a water molecule evaporates off a leaf by transpiration, the next molecule is pulled up and ~~off~~ the whole pillar inches upward because of cohesion. This allows water to reach its destination against gravity.

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3a. The chemical structure of water accounts for its many properties that are essential life. Water, or H_2O , ^{is a covalent molecule} consisting of two Hydrogen atoms joined at an angle to an Oxygen atom. This angle is because Oxygen attracts the shared electrons of Hydrogen more because Oxygen is much more electronegative. ~~Water~~ A large number of water molecules together also exhibit cohesion, which is the tendency of water to stick together. This characteristic can be explained by the slightly negative charge of the Oxygen atom, and the slightly positive charge of the Hydrogen atom. When water ~~is~~ molecules are together, the hydrogen atom of one molecule is attracted to the Oxygen atom of the other, and in this way, water molecules stick to one another. Cohesion is important to life because it ~~ensures that~~ enables water to reach a plant's leaves by going against the force of gravity.

The ~~prof~~ Water also exhibits interesting properties as a solid. Ice, ~~is~~ the solid form of water, is less dense than the liquid form of water. This is because the hydrogen bonds keep water molecules at an arm's length apart when it is frozen, accounting for a lot of empty space. This ensures that ice floats above water. In lakes, during the winter, the ~~top~~ uppermost surface of the lake becomes ice, while the water below remains in its liquid state. The ice provides insulation from the cold for the organisms residing in the water, thus ensuring the survival of aquatic organisms during

turnover

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winter, and the ~~evaporation~~ ^{turnover} of lakes in spring is also extremely important. In the spring, when the ice melts, a turnover occurs. The oxygen at the top of the lake ~~is able to~~ goes to the bottom of the lake, enabling organisms living at the bottom of the lake access to oxygen.

The high specific heat of water is yet another important property of water. It is very difficult for water's temperature to be changed, and to ~~evaporate~~ or change ^{liquid} water into a different state of matter, such as to ~~go~~ its gaseous or solid form because of the water's ~~for~~ tendency to form hydrogen bonds. In order to change its state of matter, the temperature ~~of~~ must be high enough to break apart water's hydrogen bonds. This is extremely important for the survival of marine and aquatic organisms because it allows water to ^{act as a} buffer against temperature changes, and thus retain ideal temperatures enabling many ~~of~~ ectothermic organisms dwelling in the ocean and in lakes and rivers to retain homeostasis. The world's oceans, because of water's high specific heat, play an important role in regulating temperatures, especially in the coast.

3b Water also plays an important part as the medium of all the metabolic processes of the cell. The cell resides in an aqueous environment, ~~of~~ ~~is~~ called the interstitial fluid, which consists of solutes dissolved in water. ~~In cellular respiration, water is~~ In order to join together chains of polymers, water is produced, while in the hydrolysis, or breakdown of a polymer, a water molecule is expended.

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3c. Water is also able to moderate temperatures inside an organism. When an organism is overheating, it sweats and releases water, ~~through convection. evapo condensation and evaporation.~~ which helps to lower its body temperature. In addition, ~~the~~ water is also able to absorb heat from the sun due to its high specific heat during hot days, and release that energy ~~of~~ heat during cold days.

3d. The movement of water from the roots to the leaves of a plant is because of transpirational pull and because of the cohesiveness of water. Because of the tendency of water to form hydrogen bonds, water molecules ~~are~~ are attracted to one another. When one molecule of water evaporates through the stomata of a leaf, the adjoining water ~~in~~ molecule subsequently pulls up or attracts the next water molecule in line, thus overcoming the force of gravity.

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a) The structure of water molecule creates polarity properties for water. This also result in water's hydrogen bonding property where the O side ~~is~~ will be attracted to the H side. This principle is also responsible for the cohesive characteristic of water molecules. This structure also causes water to be less dense in solid form than aqueous form. ~~It also has ability to accept electrons by forming~~ ~~to the H molecules~~ (to the H molecules). Water also has high heat capacity and may absorb or keep heat.

b) In the metabolic process of animal cells, the mitochondria is the crucial organelle that functions in respiration. The process of respiration ~~creates~~ creates great electron potential across membrane, a force to create ATP. Molecules such as NADP and FADH releases their electrons to electron transport chain. After the process, it becomes ~~the~~ O's job to get rid of the electrons. H₂O is ~~created~~ ^{created by} respiration (along with CO₂).

For endotherms like human, moderating body temperature is crucial. H₂O serves as a good device to moderate temperature. At high temperature, the body releases liquids (sweat and water). The process "cools" down the body because the H₂O had taken the body heat; the result is evaporation of H₂O, or taking the energy to become gas. At cold temperature, water inside the body is able to contain the energy/heat to keep body warm. This is because of water's capacity of heat principle which makes it ~~not~~ relatively stable in obtaining a certain temperature.

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Water's cohesive property is a ~~major~~ major factor to move H_2O from root to leaves, which is crucial for plant development and survival. Water moves from high water potential to low water potential. ~~Root~~^{Soil} has higher water potential, which allows water to travel into the root. Transpiration at leaves occurs when sun evaporates water. However, because of hydrogen bonding, the water molecules inside the plant act like a single, polymer-like chain. When the tip is lost by transpiration, the entire chain is moved up. Photosynthesis requires H_2O in the process to eventually form glucose as a product. It uses H_2O and CO_2 to convert into PGAL and to glucose. H_2O is removed at the photosystem I and II to obtain electrons.

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2009 SCORING COMMENTARY (Form B)

Question 3

Sample: 3A

Score: 10

For the most part this response follows the structure of the question. In part (a) the response demonstrates how discussion of a property of water must include a description of that property to earn 2 points. The first property the response describes is the polar nature of water, earning 2 points. The response also earned 1 point for describing a use of water as a medium when it includes a solvent, which comes from part (b) but was awarded the point here. This happened often in students' responses, as students would mix in statements from part (b) during a description of a property in part (a). The response describes the properties of specific heat (2 points) and cohesion (2 points). The property of adhesion was also described, but the response had already earned the maximum 6 points in part (a) so this property was not counted in the score.

The response addresses part (b) by explaining each of the three bullets. One point was earned for describing the ability of the high heat of vaporizations to regulate temperature. Two points were earned for addressing the role of the properties of water in the roots and leaves of plants. One point was earned for explaining how root pressure is acquired from diffusion in the root, and 1 point was earned for explaining that capillary action assists water as it rises in the plant by adhesion and cohesion.

Sample: 3B

Score: 8

The response earned all 6 available points for the discussion of three properties of water and 2 points for the explanation of how those properties play out in the biological world.

The response earned its first 2 property points by identifying and describing the polarity of water. The next 2 property points were earned for the identification and description of cohesion of water. Ice is given as the means to regulate temperature in an environment, which relates to part (b) of the question and earned 1 point for that part. The final 2 property points were earned for the description and discussion of specific heat.

The response earned a final point for the discussion of the ability of water to moderate temperature: water creates an environment for stabilizing temperature in relationship to its specific heat.

Sample: 3C

Score: 3

The response is clearly based on the question. However, although it contains the term "polarity" and some description of it, the response is vague in terms of where the attraction takes place (between or within the water molecule). The diagrams provided to left of the description appear accurate, but without the use of labels they do not clarify the description.

The response earned 1 point for providing a role of water in temperature regulation when it describes how water is used to cool the body. One point was earned for explaining that water stabilizes temperature through its ability to hold energy or heat. The response earned a final point for the description of root pressure as water moving from higher to lower in the root.