AP® BIOLOGY
2007 SCORING GUIDELINES

Question 3

Compared with other terrestrial biomes, deserts have extremely low productivity.

(a) **Discuss** how temperature, soil composition, and annual precipitation limit productivity in deserts. **(3 points maximum)**

Abiotic factor (description)	**How abiotic factor limits productivity (must be linked) (1 point per factor)**
Temperature	
Increase in transpiration/evaporation	Lowers photosynthetic rate
Desiccation	Lowers plant growth
Loss of water from tissues/guard cells	Lowers biomass production
Not optimal temperatures	PS/metabolic enzymes/proteins hindered
Soil composition	
Low organic content/nutrients	Lowers photosynthetic rate/plant growth
Low water retention	Lowers photosynthetic rate/plant growth
Sandy	Poor root anchorage limits plant growth
Compacted soil	Root limitations decrease photosynthesis
Annual precipitation	
Low rainfall	Little water available for photosynthesis
Seasonal rainfall	Lowers plant growth
	Period of high productivity/wildflowers

Clear definition/discussion of productivity: e.g., a measure of the amount of biomass produced by autotrophs/photosynthetic organism/plants…amount of light energy converted to chemical energy by autotrophs per unit time...reduced community productivity **(1 point)**

(b) **Describe** a four-organism food chain that might characterize a desert community, and **identify** the trophic level of each organism. **(2 points)**

- **Written description** of a minimum of 4 organisms (must include a producer/plant) **(1 point)**
- **Clear identification** of 4 distinct trophic levels of the organisms discussed **(1 point)**
  (producer → primary consumer → secondary consumer → tertiary consumer
  or top carnivore or decomposer or scavenger)

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Question 3 (continued)

(c) **Describe** the results depicted in the graph. **Explain** one anatomical difference and one physiological difference between species *A* and *B* that account for the CO_2 uptake patterns shown. **Discuss** the evolutionary significance of each difference. **(6 points maximum)**

Graph interpretation (3 points)

- Describe graph (plant *A* takes up CO_2 during day AND plant *B* takes up CO_2 at night) **(1 point)**
- Species *B* as CAM **(1 point)**
- Species *A* as C_3 or species *A* as C_4 **(1 point)**

Anatomical difference (1 point)

- Species *A* is C_4 with bundle sheath/wreath/Kranz anatomy
- Stomata location (pits/crypts, underside stems) linked to CO_2 uptake
- Stomata density linked to CO_2 uptake
- In species *B*/CAM vacuole/mesophyll of organic acids (malate)

Physiological difference (1 point)

- Species A stomata open during day
- CAM/species *B* stomata open at night/closed during day
- Species *A* uses C_3 pathway; CAM/ species *B* uses C_4 pathway
- C_3 uses Rubisco/ C_4 uses PEP Carboxylase
- Organic acids synthesis for CO_2 storage
- Carbon fixation during day vs. night

Evolutionary significance (2 points)

Discuss the evolutionary significance linked to each difference **(2 points, 1 point per difference)**
e.g., increased evolutionary success due to decrease in water loss in the desert environment
e.g., C_4 pathway circumvents the problem of photorespiration

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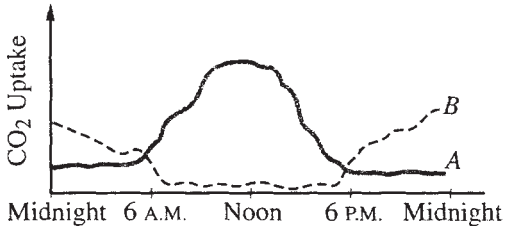
CO_2 UPTAKE FOR TWO SPECIES OF DESERT PLANTS OVER 24 HOURS



3c) High temperatures lower the ~~amount of photosynthesis that~~ plants ~~may~~ photosynthetic rate of plants by increasing their transpirational rates when the stomata are open, yet the stomata must be open for the plant to receive CO_2. If the stomata are closed, CO_2 concentrations will decrease and O_2 concentrations will increase, causing O_2 to bind with RuBP instead of CO_2, lowering photosynthetic output. Yet if the stomata are open, the water required for photosynthesis will evaporate out of the leaf once again lowering photosynthetic output. Because deserts generally consist of a high sand to clay ratio, water and other molecules are not easily trapped in the soil, which lowers the ability for plants to grow and photosynthesize. The low annual precipitation lessens the amount of water available to plants for photosynthesis and ~~etc~~ makes water storage and conservation important to the plant. The low supply of water means that photosynthesis cannot occur at large rates as there is a very limited supply of the H_2O needed to donate electrons, ~~and~~ therefore lowering productivity.

b.) A possible four-organism food chain that might characterize

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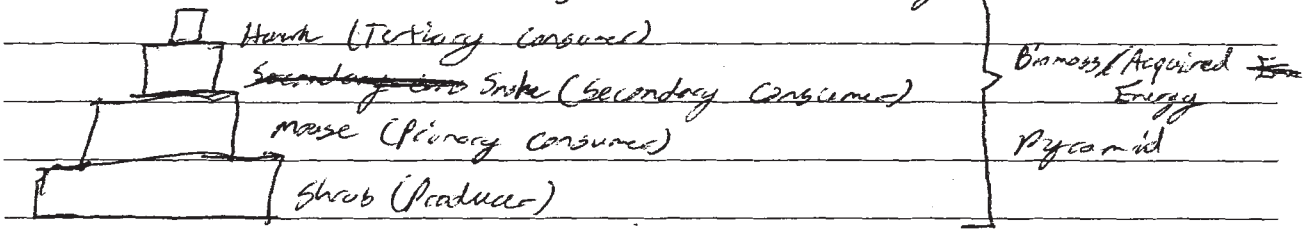
a desert community ~~could be~~ could consist of a desert shrub, a mouse, a rattlesnake, and a hawk. The shrub would act as the producer, which would be eaten by the mouse (primary consumer), which would then be eaten by the rattlesnake (secondary consumer), which would then be eaten by the hawk (tertiary consumer).



c.) Species A is most likely a C_4 plant, while Species B is most likely a CAM plant. Species A will therefore have a separated system of photosynthesis, making use of a different enzyme in an outer layer of cells than the inner layers. The inner layer of cells will perform photosynthesis in a normal manner, using RuBP. However, the outer cells will make use of an enzyme which will bind carbon into a C_4 chain as opposed to a C_3 chain. This molecule also has little affinity to oxygen, allowing the plant's stomata to remain closed during the day. There will be a ring of cells between the inner and outer layers which will help regulate the process of photosynthesis and ensure that the O_2 concentration in the inner layer is not too high. Species B will not have either the specialized enzyme nor the ring of specialized cells. Instead, it will have enzymes to transfer CO_2 ~~into an acid so it~~, which it takes in at night, into an acid which can be easily stored. Species B would also most likely have numerous large vacuoles in order to store this acid. Species A would survive better because of its ability to conserve water through keeping its stomata closed while still being able to perform photosynthesis.

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Species D would be able to keep its stomata closed during the hot days and open during the cool nights, lowering transpirational loss of water while still being able to perform photosynthesis at the required rate.

3 B1

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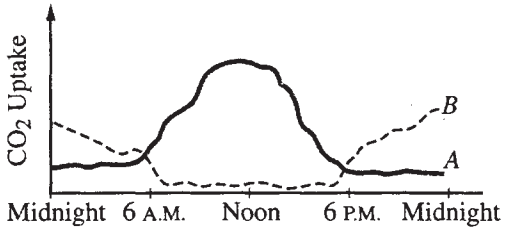
CO_2 UPTAKE FOR TWO SPECIES OF DESERT PLANTS OVER 24 HOURS



The high temperature of deserts can greatly limit productivity by plants through photosynthesis. This is because high temperatures cause a huge amount of drying out and water loss. Water is essential for beginning the light reactions. Water must be split by photolysis so that electrons can be obtained and passed down the electron transport chain. This is why the low annual precipitation of deserts limits productivity also. Another reason why high temperature limits productivity in deserts is because the carbon-fixing enzymes can become denatured. This can dramatically slow down photosynthesis and will eventually bring it to a stop. Soil composition also limits productivity in deserts. This is because it lacks vital nitrogen-fixing bacteria which allow for essential nutrients to be taken up by the plant's roots. Nitrogen is a must have for plants to survive and if they don't have it, they won't be productive.

A possible four-organism food chain in the desert could

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consist of an autotrophic producer such as cacti, a primary consumer such as a scorpion, a secondary consumer such as a rattlesnake, and a tertiary consumer such as an eagle.

The results depicted in the graph show that plant A takes up little CO_2 at night but a lot during the day. This probably means that ther stomata are closed at night and open during the day. Plant B is the opposite. It takes up most of its CO_2 at night with it's stomata open and barely any during the day (stomata closed). Plant B is a CAM plant. It closes its stomata during the day to conserve water. This is because of the harsh, dry arid conditions of the desert. Plant A is probably following the C_3 pathway but most likely has a large central vacuole for storing water.

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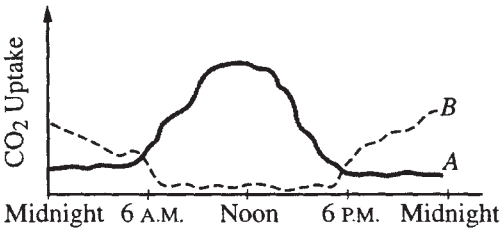

In a desert biome, extreme temperature, low soil nutrients and low annual precipitation all cause low productivity in the desert. Extremely high temperatures cause water in plants to evaporate. In response many desert plants close their stomata during the day to prevent water loss however this limits CO_2 uptake and lowers productivity. Extremely low temperatures in deserts cause H_2O to freeze which kills most plants. Nutrients in the soil in deserts are lacking as low annual rainfall prevents nutrients from seeping into the ground. Plants therefore developed shallow roots to catch more water and nutrients. These however are not enough to compensate for the poor growing conditions.

A four organism food chain may consists of a cactus, a mouse, a snake and a coyote. The cactus is the primary producer and is eaten by the primary consumer the mouse. Mice are then preyed upon by snakes (secondary consumer) which is finally eaten by the coyote (tertiary consumer).

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The results in the graph of plants A and B are because the plants use two different adaptations to desert life. Plant B is a CAM plant where as plant A uses a different adaptation. Plant B physically has a thicker cuticle to protect from water loss where plant A most likely has its stomata in its pits so more water evaporates into the plant. physiologically, plant B opens its stomata at night which explains why its CO_2 uptake is greatest when the sun is absent. This is a CAM plant adaptation, where dark reactions occur during the day. Plant A has its stomata fully open in the hottest part of the day because water loss from exaporation is limited by the location of the stomata in the pits of the plant. This is why its CO_2 uptake is greatest in the middle of the day. The significance of this from an evolutionary stand point is that it shows two ways to prevent being naturally selected against in a single clone. This was most likely a cause of divergent speciation where a single species gave rise to two because two different adaptations allowed a single species to proliferate. over time, each adaptation magnified leading to two different species. This is furthered by the presence of nonologous structres such as the stomata and roots.

AP® BIOLOGY
2007 SCORING COMMENTARY

Question 3

Overview

This question's purpose was to evaluate students' ability to combine ecological concepts with basic plant physiology and to make an evolutionary connection. Part (a) asked how certain abiotic factors limited productivity in a desert biome. Part (b) asked students to describe a four-organism food chain and to identify each trophic level. Part (c) required an interpretation of a graph showing the carbon dioxide uptake patterns of two different desert plants. Students were expected to relate those uptake differences to an anatomical and physiological difference between the two plants. Lastly, students were asked to discuss the evolutionary significance of each of the differences they chose in the previous section of the question.

Sample: 3A
Score: 10

In part (a) the student received the temperature point for relating temperature to a diminished "photosynthetic rate" and to "lowering photosynthetic output." The soil point was earned by connecting soil conditions to the decline of "the ability for plants to grow and photosynthize [*sic*]." The precipitation point was solidly earned when the student linked "low annual precipitation" to not only a lessening of the "amount of water available to plants for photosynthesis" but also to the fact that the photosynthetic rate is decreased owing to "a very limited supply of the H_2O needed to donate electrons . . ." Either of those statements alone would have earned the point.

In part (b) 2 points were awarded for correctly describing the food chain and identifying the correct trophic levels.

In part (c) a point was earned for identifying species A as a C_4 plant and another point for identifying species B as the CAM plant. Although not directly naming the bundle sheath cells, the student does an excellent job of indicating a "separated system" of the photosynthetic processes in a C_4 plant by utilizing an "inner layer of cells" and thus received credit for the anatomy point. Similarly, the student earned the physiology point with an extensive discussion of the differences between C_3 and C_4 pathways, as well as a discussion of how species B has enzymes that allow it to "transfer CO_2 . . . into an acid which can be . . . stored." Finally, the student was granted 1 evolutionary significance point by linking the concept of "better" survival of species A and B to their physiological differences. (The species A discussion is somewhat weak, but the discussion of species B is sufficient.)

Sample: 3B
Score: 7

In part (a) 1 point was earned for linking high temperatures to a loss of water "essential for . . . the light reactions" (photolysis). The precipitation point is a good example of how students may connect two or three of the abiotic factors to the same inhibiting effect on productivity. This student indicates that "low annual precipitation" also limits productivity for the same reasons mentioned for the effect of temperature and therefore received 1 point for precipitation. The student did not merit the soil point because the answer discusses the condition of the desert soil and why the soil may be poor but then only states that the plants "won't be productive."

In part (b) 2 points were earned for correctly describing the food chain and identifying the correct trophic levels.

Question 3 (continued)

In part (c) the student was awarded the graph point for indicating in the first sentence that species A "takes up little CO_2 at night . . ." and then, in the third sentence, finishing the necessary description by indicating that species B "takes up most of its CO_2 at night . . ." (Student responses often separated the description of the graph by several sentences or even paragraphs, but provided that *both* curves were described, they were given the point.) The student earned the physiology point by stating that species A's stomata are "closed at night and open during the day." The statement that species B opens its stomata at night could have gained a point, but the physiology point could only be awarded once. The student earned 1 point by identifying species B as the CAM plant.

Sample: 3C
Score: 5

No points were earned in part (a), as the student never links the abiotic conditions to *how* the conditions affect photosynthesis.

In part (b) 2 points were awarded for correctly describing the food chain and identifying the correct trophic levels.

In part (c) 1 point was received for identifying species B as the CAM plant. The physiology point was earned by stating that "plant B opens its stomata at night . . ." The graph point was awarded for stating that in species B, "CO_2 uptake is greatest when the sun is absent" and then several lines later pointing out that species A uptake "is greatest in the middle of the day." The student begins to discuss the evolutionary significance but then gets sidetracked by a description of divergent evolution and homologous structures that did not merit any points.