AP® BIOLOGY
2009 SCORING GUIDELINES

Question 2

ATP and GTP are primary sources of energy for biochemical reactions.

(a) **Describe** the structure of the ATP or the GTP molecule. **(1 point each; 2 points maximum)**
- Adenosine + 3 phosphates or guanosine + 3 phosphates.
- Elaborating on the phosphate bonds, e.g., unstable, negatively charged. Mentioning without explaining "high-energy bonds" is insufficient.
- Adenosine or guanosine described as adenine or guanine bound to ribose.

Note: adenine + ribose + 3 phosphates earns 2 points.

(b) **Explain** how chemiosmosis produces ATP. (**1 point each; 3 points maximum)**
- Electron transport, e.g., linked to proton pumps, coenzymes, NADH.
- H+ pumped to one side of the membrane, photosynthesis—inside thylakoid, respiration—outside cristae.
- Proton gradient established, has potential energy or capacity to do work.
- ATP synthases or channel proteins generate ATP.

(c) **Describe** TWO specific cell processes that require ATP and explain how ATP is used in each process. **(4 points maximum)**

	Description of process **(1 point per process; 2 points maximum)**	**How ATP is used** **(1 point per process; 2 points maximum)**
Mechanical	Muscle, sliding filament; cilia or flagella, propulsion; chromosome movement in mitosis or meiosis	ATP → ADP + P connected to process or energy coupling, e.g., conformational change in myosin head
Transport	Active transport or transport against gradient; sodium-potassium pump; endocytosis or exocytosis	ATP → ADP + P connected to process, e.g., phosphorylating the transport protein
Chemical	Hydrolysis or synthesis; specific chemical reaction, e.g., photosynthesis or glycolysis; kinase activity	ATP → ADP + P connected to process or energy coupling, e.g., phosphorylating glucose in glycolysis or PGA in Calvin cycle

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Question 2 (continued)

(d) An energy pyramid for a marine ecosystem is shown below. **Label** each trophic level of the pyramid and provide an example of a marine organism found at each level of this pyramid. **Explain** why the energy available at the top layer of the pyramid is a small percentage of the energy present at the bottom of the pyramid. **(3 points maximum)**

	Explanation **(1 point per box; 3 points maximum)**
Label trophic levels	Producer or autotroph → 1° consumer or herbivore → 2° consumer or carnivore → 3° consumer; no point for mentioning detritivores or decomposers
Examples of <u>marine</u> organisms	Algae → zooplankton → small fish → shark Type of plankton must be specified if used above producer level; "fish" can be used <u>once</u> if unspecified; top level may include terrestrial organisms
Energy transfer	Energy transferred due to metabolic activities, heat, work, entropy Mentioning without explaining 10% energy transfer between trophic levels is insufficient

Note: Students must receive points in all four sections to earn a score of 10.

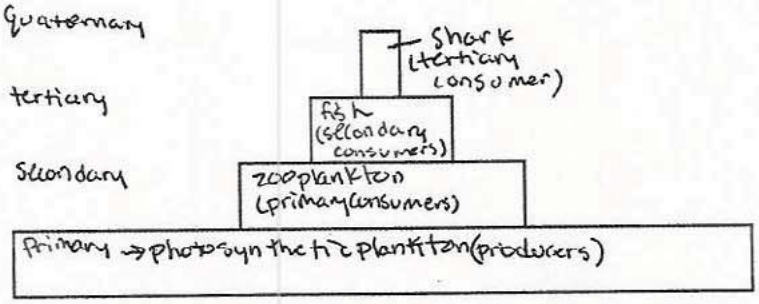
2. ATP and GTP are primary sources of energy for biochemical reactions.

(a) **Describe** the structure of the ATP or the GTP molecule.

(b) **Explain** how chemiosmosis produces ATP.

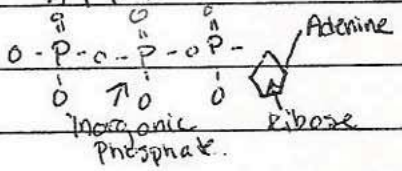
(c) **Describe** TWO specific cell processes that require ATP and explain how ATP is used in each process.

(d) An energy pyramid for a marine ecosystem is shown below. **Label** each trophic level of the pyramid and provide an example of a marine organism found at each level of this pyramid. **Explain** why the energy available at the top layer of the pyramid is a small percentage of the energy present at the bottom of the pyramid.



a. ATP and GTP consist of three bonded phosphate groups attached to a ribose sugar. Also attached to the ribose is the nitrogenous base Adenine or Guanine. ATP provides energy by phosphorylation, or the transfer of one phosphate to another molecule, which then is "high energy" and unstable.

ATP:

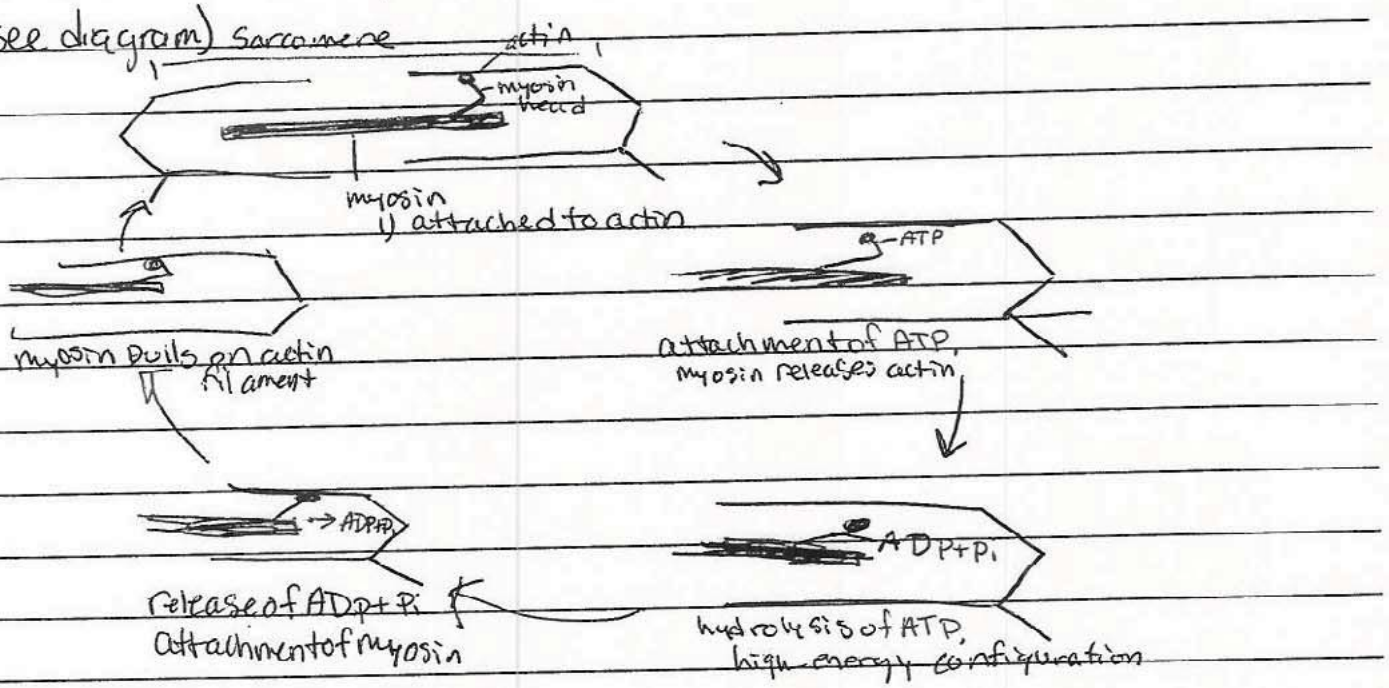


b. Chemiosmosis harnesses the energy of ~~electrons~~ Protons flowing down a concentration gradient to produce ATP. First, the electron transport chain uses the energy of falling electrons to pump H^+ ions across a membrane, creating an electrochemical gradient (difference in charge and concentration) across the membrane. The H^+ ions then flow back to the other side of the membrane through ATP synthase a protein shaped almost like a rotor which is embedded in the membrane. ATP synthase uses the energy of H^+ ions turning the protein to help catalyze the reaction of $ADP + P_i \rightarrow ATP$.

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

One cell process which requires ATP is Active Transport. Protein molecules which are embedded in the plasma membrane hydrolyze (break ATP into ADP + Pi) ATP, which causes them to change shape. These molecules transport nutrients and ions from areas of low concentration to areas of high. an example of an active transport mechanism is the Sodium-Potassium pump in nerve cells which generate resting Potential (one cell charge when not conducting an impulse) ATP is required to change the shape of the protein and provide energy for movement

Muscle Movement is another cell process that requires ATP. a functional unit in a muscle cell is called a sarcomere. this consists of alternating, overlapping thick myosin filaments and thin actin filaments. the actin and myosin bind during muscle contractions. ATP is necessary to change the shape of the myosin head. and the binding of ATP causes myosin & actin to come apart, hydrolysis of ATP results in the high-energy formation, and release of the ADP and Pi; this causes the actin to pull on the myosin filaments (see diagram) Sarcomere



ADDITIONAL PAGE FOR ANSWERING QUESTION 2

d. The energy available to the organism at the top of a food pyramid is much less than that available to one at the bottom due to heat lost. Approximately 10% of all energy transferred is loss to heat in each trophic level, greatly diminishing the available energy for the top consumer. Some energy is also used in metabolic processes by each organism, again reducing the amount available for use by each successive level.

2. ATP and GTP are primary sources of energy for biochemical reactions.

   (a) **Describe** the structure of the ATP or the GTP molecule.

   (b) **Explain** how chemiosmosis produces ATP.

   (c) **Describe** TWO specific cell processes that require ATP and explain how ATP is used in each process.

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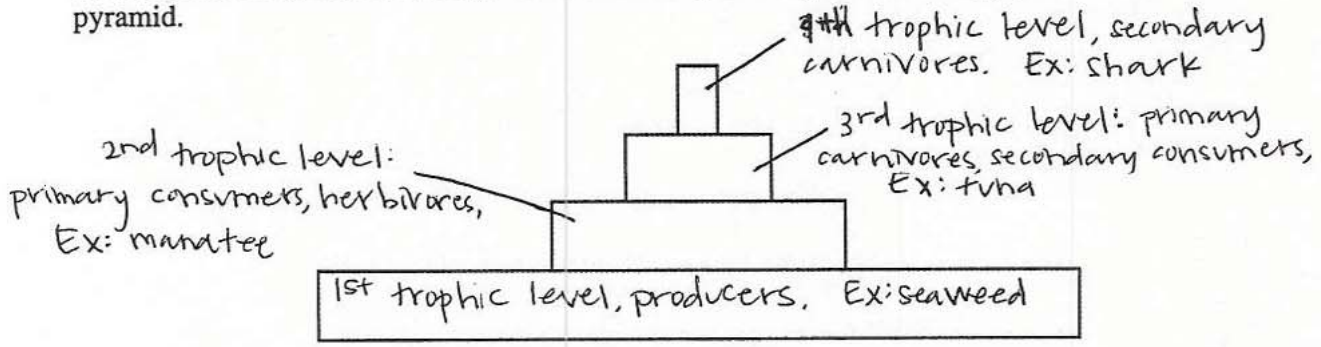

a. ATP is made of the nucleotide adenine, a ribose, and three phosphate groups (adenosinetriphosphate)

b. Chemiosmosis produces ATP by establishing a chemical gradient. For example, in oxidative phosphorylation, NADH or $FADH_2$ are oxidized, creating H^+ and electrons. The H^+ ions are pumped into the intermembrane space of the mitochondria. An increased concentration of H^+ outside the matrix creates an electrochemical gradient. The only way H^+ ions can move inside the matrix is by passing through an ATP synthase channel. As the H^+ passes through, ATP is synthesized from an ADP and a phosphate.

c. ATP is used in the beginning of respiration. 2 ATP molecules are used to start glycolysis, which in turn creates 2 pyruvate molecules and 4 ATP.

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

c(continued)

ATP is used in the dark reactions of photosynthesis. ATP made in the light reactions are used to fix carbon from CO_2 into 2 3GP molecules.

ATP is also used in muscle contraction. When ATP binds to myosin, the myosin head unhooks from the actin filament. When ATP is broken, the myosin hooks onto the actin. When ADP+P leaves the myosin, it "pulls" down the muscle. Then ATP binds and releases the myosin again.

d. (see picture under prompt for labels) ☺

As you move up the pyramid, the trophic levels decrease in size because less energy is available. For example, the primary consumers only recieve 10% of the energy available from the producers. The rest of the energy is lost as heat or waste. The secondary consumers only recieve 10% of the energy from the primary consumers, so only 1% of the available energy of the producers. The trophic levels get smaller and rarely exceed 5 because of this loss of energy. This means the tertiary consumers must eat 100 times what the primary consumers eat in order to gain the same energy. This is called the 10% rule.

2C1

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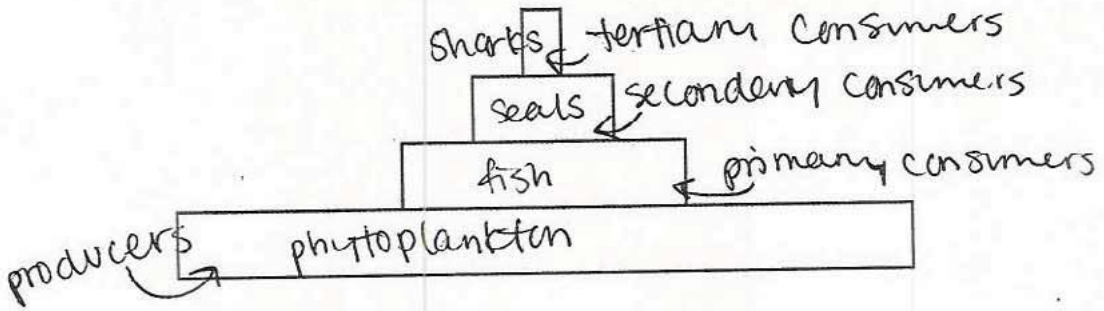

a. ATP, or adenosine triphosphate, consists of an adenosine and three phosphates. Adenosine is a ring and the phosphate groups are attached. Sometimes, during certain reactions, a phospate will break free, resulting in ADP and an inorganic phosphate (Pi)

b. Chemiosmosis, which occurs during cellular respiration, helps produce ~~ATP~~ ATP. The H^+ protons given off by the electron transport chain's redox reactions flow into the inner membranal space of the mitochondria. They then move through ATP synthase, which is a chemiosmotic pump. The movement of these protons creates the energy to bind ADP to Pi.

c. ATP has many uses throughout the human body. For example, they enable the sodium/potassium pumps in neurons to run. This process is called active transport. If the Na^+/K^+ pump is phosphorolized,

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

or has a Pi molecule attached to it, it allows for the transport of the two kinds of molecules across the membrane. For every two potassiums it brings in, it throws three into the synapse.

d. As energy is moved up the food chain by different consumers, a little energy is expended and therefore lost by each individual who consumes the energy. By the time the energy of plankton is consumed by sharks, energy has already been consumed by fish and seals.

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Question 2

Overview

Energy transfer is a fundamental requirement of living organisms—and an AP Biology theme. This question tested student knowledge of the structure, production, and use of ATP in cells. Students were asked to describe the structure of ATP (or GTP) and explain ATP synthesis, including chemiosmosis. They were then asked to describe two cell processes that require ATP, including specific information on how ATP hydrolysis altered reactions at the molecular level. Students were then asked to identify the trophic levels through which ATP energy flows in a four-trophic-level system and to identify actual organisms that would be found at each level in a marine system. The question concluded by asking students to explain why there is less energy available at the top than at the bottom of the food chain.

Sample: 2A
Score: 10

In part (a) the response earned both available structure points by stating that "ATP and GTP consist of three bonded phosphate groups attached to a ribose sugar" and "[a]lso attached . . . is . . . Adenine or Guanine." In this case the points would have been awarded for either the ATP structure or the GTP structure; the student did not have to describe both. This response is an example of how 2 points could be earned by stating the three parts of ATP. One point is the elaboration point earned by breaking down adenosine into ribose and adenine.

In part (b) the response earned 3 chemiosmosis points. One point was earned for connecting the electron transport chain to the proton pumps with the statement that "the electron transport chain uses the energy of falling electrons to pump H^+ ions." A second point was earned when the previous phrase was followed with the statement that the H^+ ions create "an electrochemical gradient." A third chemiosmosis point was earned by explaining that the H^+ ions move back through ATP synthase and that "ATP synthase uses the energy of H^+ ions . . . to help catalyze the reaction" that forms ATP.

In part (c) the response earned 1 point for explaining the use of ATP in active transport by writing that ATP causes "[p]rotein molecules . . . embedded in the plasma membrane . . . to change shape." One point was then earned by describing active transport as the "transport [of] nutrients and ions from areas of low concentration to areas of high." A second description point was earned for describing muscle contraction as "overlapping thick myosin filaments and thin actin filaments" that "bind during muscle contractions." The response then earned 1 point for explaining how ATP is used in the contraction process by stating that "ATP is necessary to change the shape of the myosin head."

In part (d) the response earned 1 point for the correct identification of the trophic levels by labeling them as "producers," "primary consumers," "secondary consumers," and "tertiary consumer." Other terms were written well outside the actual boxes in the pyramid. Since the pyramid was so clearly and accurately labeled inside the boxes, the other terms were ignored as irrelevant material. The response could have earned 2 more points, but at this point the total score had reached the maximum available 10 points. One point could have been earned for the correct examples of trophic-level organisms ("photosynthetic plankton," "zooplankton," "fish," "shark"). Another point could have been earned for the explanation of energy transfer loss "due to heat."

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Question 2 (continued)

Sample: 2B
Score: 8

In part (a) the response provides an example of how a single sentence could earn 2 points for ATP structure. One point was earned for the elaboration of the structure of adenosine ("adenine [and] a ribose"), and 1 point was earned for the overall structure ("adenine, a ribose, and three phosphate groups").

In part (b) one chemiosmosis point was earned for stating that "H^+ ions are pumped into the intermembrane space of the mitochondria." A second chemiosmosis point was earned for indicating the presence of a proton gradient with the phrase "increased concentration of H^+ outside the matrix creates an electrochemical gradient." A third chemiosmosis point was earned for the ATP synthase generation of ATP with the statement "H^+ ions can move . . . by passing through an ATP synthase channel. . . . ATP is synthesized from . . . ADP and a phosphate."

In part (c) no point was earned for a description of glycolysis since the substrate (glucose) is not given. One point was earned for the description of photosynthesis with the statement that the dark reactions involve the fixation of "carbon from CO_2 into 2 3GP [*sic*] molecules." Although the description of muscle contraction is generally accurate, it could not earn points because the response already covers two examples (glycolysis and the dark reactions). Additional examples could not earn points.

In part (d) 1 point was earned for the correct identification of the trophic levels ("producers," "primary consumers/herbivores," "primary carnivores/secondary consumers," "secondary carnivores"). No point could be earned for examples of organisms as tuna do not eat manatees. One point was earned for the explanation of energy transfer loss with the statement that "energy is lost as heat."

Sample: 2C
Score: 6

In part (a) 1 point was earned for the structure of ATP with the statement that ATP "consists of an adenosine and three phosphates."

In part (b) 1 chemiosmosis point was earned by the statement that "protons . . . flow into the inner membranal space of the mitochondria." A second chemiosmosis point was earned by stating the role of ATP synthase: protons "then move through ATP synthase, which . . . bind[s] ADP to Pi."

In part (c) 1 point was earned for giving the role of ATP in active transport: "the Na^+/K^+ pump is phosphorolized [*sic*], or has a Pi molecule attached to it." No point was earned for the description of the Na^+/K^+ pump since there is no indication of moving substances against the concentration gradient.

In part (d) 1 point was earned for a correct identification of trophic levels ("producers," "primary consumers," "secondary consumers," "tertiary consumers"). One point was also earned by listing correct examples of trophic-level organisms ("phytoplankton," "fish," "seals," "sharks"). No point could be earned for the explanation of energy transfer loss because the statement "a little energy is expended" is not specific about a metabolic use.