AP® BIOLOGY
2007 SCORING GUIDELINES

Question 1

Membranes are essential components of all cells.

(a) **Identify** THREE macromolecules that are components of the plasma membrane in a eukaryotic cell and **discuss** the structure and function of each. **(6 points maximum; 1 point for each macromolecule + structure, 1 point for each macromolecule + function)**

NOTE: Only first three molecules mentioned will be scored.

Macromolecule	Structure	Function (must match selected macromolecule)
Phospholipids OR Lipid with phosphate	• Glycerol, two fatty acids, and polar head group w/phosphate • Amphipathic • Hydrophilic or polar (head) and hydrophobic or nonpolar (tails) • Forms a lipid bilayer	• Selectively permeable • Fluidity • Creates compartment/ separates cell from environment; barrier • Signals, inositol pathway (IP3) diacylglycerol (DAG)
Cholesterol	• Ring structure • Steroid • Amphipathic • Embedded in bilayer	• Moderates fluidity • Stabilizes membrane
Proteins OR <u>The following specific types must indicate that they are proteins</u> Integral Peripheral Pump Receptor Transport Recognition Tight junction Desmosomes Gap junctions Integrins Enzyme Channel	<u>General Structure</u> • Polypeptides; amino acids • 2°, 3°, 4° structure description <u>Specific Structure</u> • Integral, transmembrane, embedded; forms a channel • Peripheral, on surface • Structure fit to substrate or ligand	• Transport • Enzyme, catalysis • Signal transduction • Attachment: extracellular matrix (ECM)-cytoskeleton • Recognition • Cell junction
Glycolipid/Glycoprotein	• Carbohydrate (chains) linked to lipid/protein	• Cell recognition • Attachment to external molecule or another cell

AP® BIOLOGY
2007 SCORING GUIDELINES

Question 1 (continued)

(b) **Explain** how membranes participate in THREE of the following biological processes:
(6 points maximum; 2 points maximum per section)

Muscle contraction

- Motor neuron or axon terminal releases neurotransmitter or acetylcholine (ACh)
- ACh binds to receptors
- Depolarization or Na^+ moves in through membrane channels or membrane depolarizes
- Action potential propagates along cell membrane (sarcolemma) or T tubules
- Depolarization changes permeability of sarcoplasmic reticulum (SR) or Ca^{2+} released from SR
- Ca^{2+} active transport into SR (reuptake of Ca^{2+})
- Repolarization or maintenance of membrane potential (Na^+/K^+ pump)
- Smooth or cardiac muscle gap junctions directly transfer membrane potential between cells

Fertilization of an egg

- Part of the acrosomal reaction or sperm acrosome releases hydrolytic enzymes (by exocytosis)
- Sperm binds to receptors on egg
- Fusion of sperm and egg plasma membranes
- Change in membrane electrical charge or fast block (depolarization) to prevent further fertilization (polyspermy)
- Cortical reaction or slow block by exocytosis (prevents polyspermy) or "hardening" of membrane
- Separation of fertilization membrane (envelope)
- Fusion of egg and sperm nuclear membranes or nuclei

Chemiosmotic production of ATP

- Electron transport chain (ETC) in membrane pumps H^+ across membrane
- H^+ gradient established across membrane
- H^+ move through ATP synthase embedded in membrane to produce ATP
- Membrane infolding increases surface area

Intercellular signaling

- Release of chemical signals by exocytosis
- Receptors in membrane bind ligands or chemical signals or chemical signals pass through the membrane (examples: neurotransmitters, hormones, pheromones)
- Ligand-gated ion channels opening/closing
- Cascade of cellular events, including enzymatic reactions and second messengers (examples: G-proteins, cAMP, IP_3, Ca^{2+})
- Antibodies activate immune function
- Descriptions of gap junctions, plasmodesmata (communicating junctions)

1A,

BIOLOGY
SECTION II
Time—1 hour and 30 minutes

Directions: Answer all questions.

Answers must be in essay form. Outline form is not acceptable. Labeled diagrams may be used to supplement discussion, but in no case will a diagram alone suffice. It is important that you read each question completely before you begin to write. Write all your answers on the pages following the questions in this booklet.

1. Membranes are essential components of all cells.

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   (b) **Explain** how membranes participate in THREE of the following biological processes:

   - Muscle contraction
   - Fertilization of an egg
   - Chemiosmotic production of ATP
   - Intercellular signaling

(a) The most common structural component in the plasma membrane is the phospholipid. Phospholipids are lipids containing one saturated and one unsaturated fatty acid attached to a phosphorous-containing, hydrophilic head. The fatty acid portion of a phospholipid is hydrophobic, which, combined with the hydrophilic head, causes phospholipids to form a bilayer membrane in water, with the fatty acids toward each other and the heads partially dissolved in the surrounding water. It is this phospholipid bylayer that maintains the separation between the interior and exterior of the cell.

The phospholipids in the plasma membrane are free to move laterally to some degree. The temperature of the cell can change that fluidity. To maintain normal plasma membrane fluidity the plasma membrane contains cholesterol. Cholesterol is a type of lipid known as a sterol, and it functions to increase

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the fluidity of the plasma membrane, so that the cell can maintain membrane fluidity during cold temperatures.

The plasma membrane also includes a wide variety of proteins, which serve a number of functions such as structural support, anchoring, cell-to-cell recognition, ion transport, and, on specialized membranes, even compound synthesis. Many proteins in the plasma membrane are glycoproteins, meaning that they are attached to long polysaccharide chains. Glycoproteins often serve as anchors to the extracellular matrix (in animals) and as cell recognition factors to bind to neighboring cells' receptors.

(b) Intercellular signaling must occur through the cell membrane, excepting cases where cells share a continuous membrane. A few types of intercellular signals, such as steroids, can pass freely through the cell membrane, but most must be translated through trans-membrane receptor proteins. When a signal binds to a trans-membrane receptor, it has one of a number of responses including opening or closing an ion channel or activating an intercellular membrane complex. Usually the result of primary signal reception is the release of a second messenger into the cell, which then directly affects gene translation or transcription or activates or deactivates one or more proteins.

One of the key functions of any cell membrane is the maintenance of a concentration gradient of one or more substances. One example of the use of a concentration gradient occurs in the mitochondria, where the citric acid cycle uses pyruvate to reduce NAD^+ and FAD^+ and uses the energy

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from their products, FADH and NADH, to create a gradient of H^+ ions. The concentration gradient in a mitochondria consists of very high H^+ levels in the mitochondrial matrix, which then naturally seeks to return to the high-pH intermembrane space. Because H^+ cannot diffuse freely across the mitochondrial membrane, it must pass through the only available H^+ channel – ATP synthase. ATP synthase uses the energy from the transport of H^+ to synthesize ATP.

An example of both cross-membrane signaling and maintinence of a concentration gradient can be found in muscle cells. Muscle contractions occur through the sliding together of myosin bundles and actin microfilaments. The proteins that power the contraction require high concentrations of Ca^+ ions – which are controlled by the plasma membrane of the endoplasmic reticulum. Under normal conditions, most Ca^+ in the muscle cell is held inside the endoplasmic reticulum. When signaled, however, the plasma membrane of the endoplasmic reticulum opens its ion channels, allowing Ca^+ to flow back into the rest of the cell, where it powers muscular contraction.

1B,

BIOLOGY
SECTION II
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   - Fertilization of an egg
   - Chemiosmotic production of ATP
   - Intercellular signaling

The membranes of all organisms serve vital roles. The two major membranes, Plasma and cell wall, both serve the cell in multiple ways. A plasma membrane found in many eukaryotic cells is thought to be composed of a lipid bilayer which forms the majority of the membrane. This bilayer is believed to be composed of two layers of phospholipids, each with the hydrophilic heads facing out. The bilayer's center is composed of the hydrophobic tails of each lipid. The function of these lipids is to not only form the majority of the membrane, thus holding together the cell, but also to ensure that nothing enters the cell unaccounted for. The hydrophilic lipid heads form a barrier

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1B2

which prevents unwanted materials from entering the cell.

Materials that need to enter and exit the cell through the membrane must go through the proteins embedded in the lipid bilayer. These proteins are spread out along the membrane and serve as a checkpoint for all entering and exiting material. This aids the cell by maintaining equalibrium and ensuring the flow of necessary materials into the cell. Another vital part of most plasmamembranes is the lipid signals attached to the membrane. This stick out from the membrane and serve as identification. An example of this would be blood types. Each type has a different signal on the membrane of the blood cell.

Membranes aid in fertilization by providing for protection as well as a source of nutrients. The membrane is ment to protect the developing organism from harmful chemicals by filtering them out. Membranes also serve as the barrier that must supply the organism with a source of food. Nutrients flow into the cell through the membrane and waste flows out. Membranes also aid in cellular respiration. The membranes of the mitochondria (cristae) are folded to extend surface area and allow

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for more H^+ to pass thrugh the bilayer. This process leads the the creation of ATP in the mitochondria. This the more area of membrane the more ATP can be made. A similar event occurs in the chloroplast of plants when e⁻ filled with energy go through the membranes of the grana to create energy. In this process membrane space is also extended in an attempt to maximize energy output.

Membranes serve another role important to the cell known as intercellular comunication. The membranes of cells packed together, including plant cells with cell walls, can for tight junctions, and gap junctions. These two forms of intercellular connections allow for communication between cells. This communication leads to more efficient cellular work as well as certain actions undergone in unison.

Membranes serve so many different and equally important role in the all of almost all organisms.

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1C1

BIOLOGY
SECTION II
Time—1 hour and 30 minutes

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   - Fertilization of an egg
   - Chemiosmotic production of ATP
   - Intercellular signaling

(a) Three macromolecules that are compooents of the plasma membrane in a eukaryotic cell include phospholipids, proteins, and cholesterol.

The phospholipids form a bilayer with hydrophobic heads and hydrophyllic tails; the hydrophobic heads prevent excess water intake and contribute to the membrane's semi-permeability. The hydrophyllic tails' function consists of, essentially, the facilitation of "material flow." The phospholipid bilayer, as a major proponent in the cell's selective permeability, is responsible for the discriminant quality of the entity known as the cell. without this component, organelle containment and the cell's exchange with the

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environment would be certainly impossible

proteins come in two general forms when it comes to the membrane: peripheral and integral. The only definitive structure that characterizes any protein of the membrane would be its amino acid composition. Otherwise, the specific structure of the proteins depends on the exact type. As stated earlier, membranous proteins can be either integral, integrated into the membrane, or peripheral, remaining on the outer surface. Integral proteins can be involved in the reception and release of certain molecules, functioning as a channel or pathway through which the cell exchanges materials with the environment (for example, the sodium-potassium pump utilizes integral proteins). Peripheral proteins can be involved in inhibition and often interact with the integral proteins

Cholesterol, in the form and structure of hydrophobic lipid chains, could have two possible functions. They are either involved in cell-to-cell communication or simply in the membrane's attempt to remain semipermeable.

b) Membranes participate in the fertilization

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of an egg, the chemiosmotic production of ATP and intercellular signaling.

In the fertilization of an egg, the membrane's function is crucial. Only one sperm cell may permeate the membrane in order to have successful fertilization and eventually the production of a viable offspring.

Membranes participate in the chemiosmotic production of ATP in their control of the various chemical "pumps" and even in the electron transport chain.

In intercellular signaling, the various sites and enzymes involved are all integrated in the membrane.

AP® BIOLOGY
2007 SCORING COMMENTARY

Question 1

Overview

The intent of this question was to assess students' understanding of membrane structure and function. The two-part question asked them to describe the structure and function of macromolecular components of the plasma membrane and to discuss the role of membranes in several cellular and biological processes.

Sample: 1A
Score: 10

In part (a) the student describes the phospholipid structure and function and received 2 points. (The response contains more than one structural detail, but only 1 point could be earned for the structure of each macromolecule.) Two points were awarded for cholesterol structure and function. The student also explains the structure and function of glycoproteins, as a subset of proteins, and received 2 points.

In part (b) intracellular signaling is described; 1 point each was awarded for steroid diffusion through the membrane and the release of second messengers in the cell. The student confuses the direction of the H^+ flow in mitochondria but earned 1 point for describing ATP synthesis by ATP synthase. The response also received 1 point for describing the release of calcium ions by the endoplasmic reticulum during muscle contraction.

Sample: 1B
Score: 6

In part (a) the response received 2 points for phospholipid structure and function and 2 points for protein structure and function. The student mentions lipid signals and blood types but does not explain that these are glycolipid functions.

In part (b) the response correctly states that the infolding of the mitochondrial cristae increases surface area, earning 1 point. An additional point was earned by indicating that gap junctions allow for intercellular communication. The student makes an error in that tight junctions do not function in the same manner but was not penalized for this.

Sample: 1C
Score: 4

In part (a) the response received 2 points for phospholipid structure and function; the student makes an error in equating the head groups with hydrophobic regions but earned the structure point by mentioning that phospholipids form a bilayer. An additional 2 points were granted for protein structure and function; peripheral proteins are cell surface, and some integral proteins function in the transport of materials. There was a potential structure point for describing integral proteins as channels, but the student had already earned the protein structure point.

The student does not provide enough details in part (b) to merit any points.