

**AP<sup>®</sup> BIOLOGY**  
**2011 SCORING GUIDELINES (Form B)**

**Question 1**

The cell cycle is fundamental to the reproduction of eukaryotic cells.

- (a) **Describe** the phases of the cell cycle.  
(6 points maximum)

**Correct order of cycle phases (1 point for entire correct list)**

Interphase → Prophase → (Prometaphase) → Metaphase → Anaphase → Telophase → Cytokinesis

OR

$G_1 \rightarrow S \rightarrow G_2 \rightarrow M$

**Correct description of at least one important structural or molecular characteristic of each phase (1 point each; 5 points maximum)**

- Interphase (including, if specified,  $G_1$ , S,  $G_2$  subphases, correctly ordered): Chromatin dispersed in nucleus; nuclear envelope and nucleoli are intact and functional; DNA is replicated here.
- $G_1$ ,  $G_2$ : Cell growth.
- S: DNA replication.
- Mitosis: Nuclear division.
- Prophase: Chromosomes begin to condense from chromatin; spindle apparatus assembled.
- (Prometaphase): Nuclear envelope disperses, nucleoli disperse, chromosomes connect to spindle apparatus fibers and begin to show motility.
- Metaphase: Chromosomes reach maximum condensation and align on metaphase plate/plane.
- Anaphase: Two-chromatid chromosomes split into two daughter (one-chromatid) chromosomes; chromosomes move to opposite poles of the spindle apparatus.
- Telophase: Chromosomes disperse back to chromatin form, nuclear envelope reassembles, nucleoli reassemble.
- Cytokinesis: If this occurs, it is normally coordinated with telophase; cell division.

- (b) **Explain** the role of THREE of the following in mitosis or cytokinesis.  
(3 points maximum)

- Kinetochores
- Microtubules
- Motor proteins
- Actin filaments

**Correct explanation of function (1 point each; if all four are chosen, only the first three are scored)**

- Kinetochores: Located in centromeres of condensed chromosomes; microtubule attachment sites necessary for chromosome positioning and movement.
- Microtubules: Fundamental structural element of the spindle apparatus; framework on which chromosome motility is generated; define axis of division and cytokinesis.
- Motor proteins (correct location and function must be specified): In kinetochores, move chromosomes during mitosis, including anaphase separation; involves kinesins and dyneins.

OR

In animal cell cleavage furrow, generate force to pinch cell in two; involves myosins.

- Actin filaments: Assemble under the membrane at the cytokinesis site; interact with myosin motor proteins to generate force to pinch cell in two; also interact with astral microtubules of the spindle to position the spindle apparatus in the cell.

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**Question 1 (continued)**

- (c) **Describe** how the cell cycle is regulated and **discuss** ONE consequence of abnormal regulation.  
(3 points maximum)

**Regulation: Correct description of checkpoints, which block cell cycle progress unless specific molecular and/or physical conditions are satisfied (1 point each; 2 points maximum)**

- Action of MPF and CDKs in checkpoint regulation
- Contact inhibition of mitosis
- Hormones; growth factor control of cell cycle activity

**Correct discussion of the consequences of abnormal cell cycle regulation (1 point maximum)**

- Uncontrolled cell proliferation, as in cancer
- Apoptosis
- Non-disjunction/aneuploidy/broken chromosomes from abnormal spindle events

BIOLOGY  
SECTION II

Time—1 hour and 40 minutes

Reading Period—10 minutes

Writing Period—1 hour and 30 minutes

1A

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. The cell cycle is fundamental to the reproduction of eukaryotic cells.

(a) Describe the phases of the cell cycle.

(b) Explain the role of THREE of the following in mitosis or cytokinesis.

• Kinetochore

• Microtubules

• Motor proteins - assemble actin filaments + pinch cell in into spindles

• Actin filaments - make up spindles, elongate + shorten

(a) Interphase

Prophase

Metaphase

Anaphase

Telophase + cytokinesis

(c) Describe how the cell cycle is regulated and discuss ONE consequence of abnormal regulation.

checkpoints  
hormones  
G1 checkpoint

(a) There are 5 phases of the cell cycle called interphase, prophase, metaphase, anaphase and telophase (which includes cytokinesis) in order. Interphase has 3 ~~phases~~ subphases known as G<sub>1</sub>, S and G<sub>2</sub> in order. All three are periods of cell growth, but only during S does the nuclear DNA replicate. Interphase is the longest part of the cell cycle. Then prophase commences in which the nuclear envelope breaks down and chromatin (genetic material) condenses into chromosomes, each containing two sister chromatids. Also the mitotic spindle begins to form at opposite poles of the cell. Then metaphase begins when the chromosomes line up along a center region of the cell called the metaphase plate. The mitotic spindle elongates further and from each pole and attaches to each sister chromatid at its kinetochore. Then Anaphase starts when the mitotic

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spindle shortens while still attached to the chromatid pulling sister chromatids of each chromosome apart at their centromeres (sticky region where sister chromatids attach) to opposite poles of the cell. Finally ~~cytokinesis~~ occurs telophase starts where the mitotic spindle goes away, a nuclear envelope develops at each pole, chromatids decondense into chromatin and cytokinesis occurs. In cytokinesis a cleavage furrow forms pinching the cell ~~is~~ membrane inward dividing the cell completing the cell cycle.

(b) Actin filaments are protein filaments that form the mitotic spindle structure. This structure is essential to anaphase in which the spindles attach to sister chromatids and separate them through elongation and shortening by actin filaments being added to or taken away respectively.

~~Motor proteins help to assemble actin filaments in the mitotic spindle. primarily help to~~

Microtubules form the spindles of the mitotic spindle. They are arranged in a 9+2 formation.

Motor proteins ~~no~~ help the microtubules move by catalyzing reactions.

(c) The cell cycle is regulated by checkpoints, or stages in the cycle when the cell must receive the proper

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## ADDITIONAL PAGE FOR ANSWERING QUESTION 1

signals to continue with the cycle. Such signals usually consist of hormones such as or ions such as  $\text{Ca}^{2+}$  or cAMP. One such checkpoint is the G<sub>1</sub> checkpoint where if the cell does not receive the proper signals in G<sub>1</sub> it will discontinue the cycle and become senescent (non-dividing cell).

The cell cycle is also regulated by environmental factors such as density and anchorage (availability of a substrate). One consequence of abnormal regulation could be a continually dividing state, such as

One consequence of abnormal regulation could be a continually dividing state, such as that of cancer cells. Cancer cells are not density nor anchorage dependent because they do not receive or need signals to end their division due to increased cell density or lack of anchorage.

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BIOLOGY  
SECTION II

Time—1 hour and 40 minutes  
Reading Period—10 minutes  
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1B1

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1. The cell cycle is fundamental to the reproduction of eukaryotic cells.

(a) Describe the phases of the cell cycle.

(b) Explain the role of THREE of the following in mitosis or cytokinesis.

- Kinetochore → contain microtubule filaments on each side
- Microtubules → attach to chromosomes and push to divide
- Motor proteins
- Actin filaments → Pull cell apart

G<sub>1</sub>  
I  
G<sub>2</sub>

grow → check  
interphase - long, duplication

Pro-long  
Met  
Ana  
Telo  
Cytokinesis

check points  
contact inhibition

(c) Describe how the cell cycle is regulated and discuss ONE consequence of abnormal regulation.

cell size  
Cells of the eukaryotic type undergo mitosis to reproduce themselves for growth and repair. Mitosis is the fundamental method cells use to ~~last~~ divide.

The cell cycle begins with a G<sub>1</sub> growth phase in which the cell grows to a size and reaches a check point to continue into interphase. Cells that do not pass this remain in the G<sub>0</sub> or non-dividing stage (Muscle / Nerve cells permanently, Liver cells as needed). Interphase is the longest stage where DNA replication takes place for the cell's next division. The cell then enters a G<sub>2</sub> phase where it prepares for division. The first stage of division is Prophase, the longest in the Mitosis portion. The DNA chromatin forms into visible separate chromosomes and the nuclear membrane along with nucleolus dissolve. Metaphase is next; chromosomes line up in a single file line along the metaphase

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## ADDITIONAL PAGE FOR ANSWERING QUESTION 1

plate; an imaginary line down the middle of the cell. Kinetochores are seen on either side of the ~~cell~~ cell. Anaphase takes place when spindle fiber microtubules attach to the chromosomes at the centromere on both sides. In Anaphase, actin ~~filaments~~ filaments contract and the chromosomes undergo synapsis as they are pulled apart. ~~the~~ sister chromatids are pulled apart and move toward each part of the cell. In telophase the two identical sets of genetic material return to ~~the~~ chromatin inside of two new nuclei which form around them. Finally ~~the~~ the last step, cytokinesis occurs and the cytoplasm is divided in two for each new daughter cell. Organelles are divided ~~in~~ and ~~the~~ equally distributed. Cytokinesis occurs when microtubules pull down the equator of the cell creating a cleavage furrow. They tighten and eventually pinch to create two new cells.

- b) Kinetochores seen in Prophase first have the microtubules. They are only active in cell reproduction. Microtubule fibers are vital to move chromosomal DNA and pinch off the cytoplasm. Actin filaments provide the contractions necessary movement for this movement in cytokinesis and mitosis.
- c) The cell cycle is limited by checkpoints, such as the one between G<sub>1</sub> and Interphase. The cell must pass this stage or go into G<sub>0</sub> nondividing stage. Cells divide if they grow too large as large cells have too much volume and are not effective. Cells divide due to contact inhibition. If the cell is not touching another cell

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1B3

such as when skin is broken, then it will divide until contact is made. Some cells have no contact inhibition, they are abnormally regulated. This lack of inhibition is the reason cancer cells divide uncontrollably.

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**BIOLOGY  
SECTION II**

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1C

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(c) **Describe** how the cell cycle is regulated and **discuss** ONE consequence of abnormal regulation.

The cell cycle has many phases that are essential in carrying out its processes. These phases include prophase, metaphase, anaphase, and telophase. In prophase, the ~~sister~~ chromatids are spread out, in no shape or fashion. In metaphase, the chromatids line up at the 50-yard line. In anaphase, the sister chromatids separate, giving way to telophase which includes cytokinesis.

Motor proteins aid in energy within mitosis. The proteins carry out the functions that are necessary for the cell to proceed in mitosis.

The cell is regulated by proteins, that carry out processes to make sure the cycle is stable. If something in the cell cycle were wrong, then the entire cycle would be wrong. If one step isn't completed correctly, then the cell will be abnormal.

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**AP<sup>®</sup> BIOLOGY**  
**2011 SCORING COMMENTARY (Form B)**

**Question 1**

**Sample: 1A**

**Score: 9**

The response earned the maximum of 6 points in part (a). One point was earned for correctly identifying the cell cycle stages in correct order and combining the synthetic events with the mitotic events. The response earned another point for correctly identifying S phase as the phase in which DNA is replicated. The remaining four points were earned for correctly describing the events of the remaining stages of mitosis. The student could have earned more points in this section, but the 6-point maximum had already been reached.

In part (b) the response earned 1 point for correctly identifying microtubules as spindle fiber components. No point was earned for the description of actin filaments because they are incorrectly identified as spindle apparatus components. No point was earned for the description of motor proteins because it is too vague.

In part (c) the response earned 2 points. One point was earned for the correct presentation of the concept of cell cycle checkpoints and for providing an example of a substrate-specific checkpoint. Another point was earned for discussing how cancer cells escape this checkpoint regulation because they lose anchorage dependency.

**Sample: 1B**

**Score: 6**

In part (a) the response earned 1 point for correctly identifying the cell cycle stages in correct order, although most of the answer specifies only the mitotic cycle. Another point was earned for correctly specifying interphase as the phase in which DNA is replicated. The response earned 3 points for describing the events of the remaining phases of mitosis. (The response does not adequately distinguish telophase and cytokinesis, so only 1 point was awarded for that portion of the response.)

No points were earned in part (b). No adequate or correct descriptions are given in this section.

In part (c) 1 point was earned for linking contact inhibition and the escape of cancer cells from this inhibition. No points were earned for the incomplete description of checkpoints as regulatory control periods of the cycle, along with a vague description of contact inhibition.

**Sample: 1C**

**Score: 3**

In part (a) the response earned 1 point for correctly listing the phases of the mitotic cycle in correct order. One point was earned for describing metaphase as the stage at which chromosomes “line up at the 50-yard line.” The response earned 1 more point for the description of chromatid separation at anaphase. No other statements are correct or sufficiently precise to earn points.

No points were earned in part (b) because the statement that motor proteins “aid in energy” is too vague.

No points were earned in part (c) because no correct or precise statements are given in this section, nor is an example of a substrate-specific checkpoint presented.