# AP® BIOLOGY
# 2015 SCORING GUIDELINES

## Question 1

Many species have circadian rhythms that exhibit an approximately 24-hour cycle. Circadian rhythms are controlled by both genetics and environmental conditions, including light.

Researchers investigated the effect of light on mouse behavior by using a running wheel with a motion sensor to record activity on actograms, as shown in Figure 1.

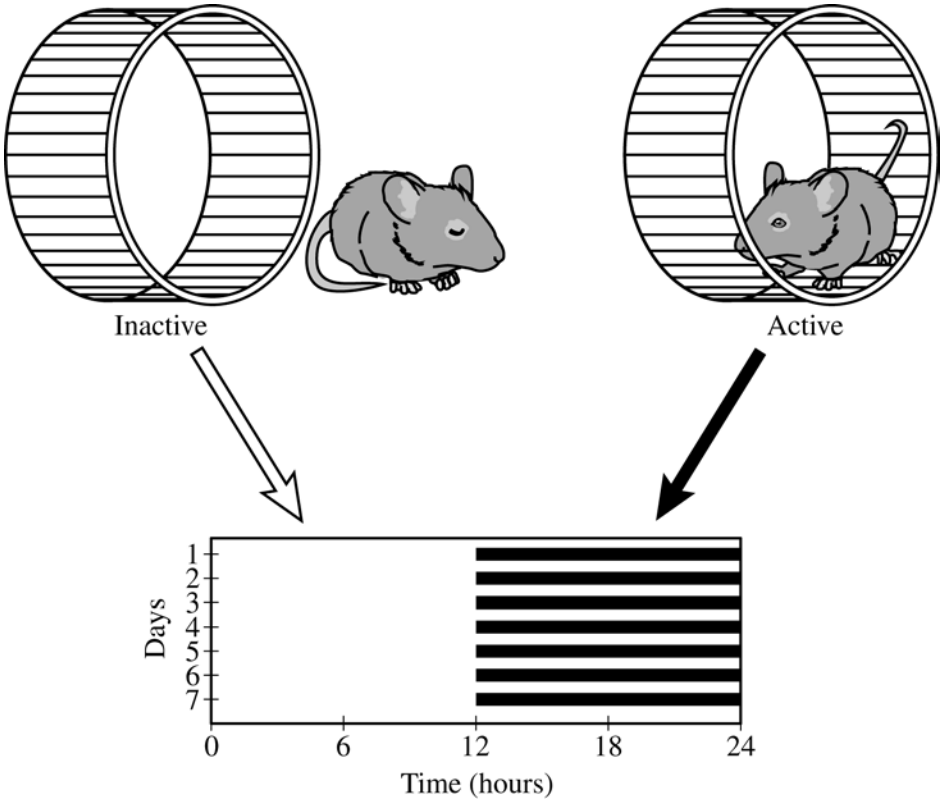


Figure 1. Strategy for recording mouse activity data. When a mouse is active on the running wheel, the activity is recorded as a dark horizontal line on an actogram. When the mouse is inactive, no dark line is recorded.

For the investigation, adult male mice were individually housed in cages in a soundproof room at 25°C. Each mouse was provided with adequate food, water, bedding material, and a running wheel. The mice were exposed to daily periods of 12 hours of light (L) and 12 hours of dark (D) (L12:D12) for 14 days, and their activity was continuously monitored. The activity data are shown in Figure 2.

**Question 1 (continued)**

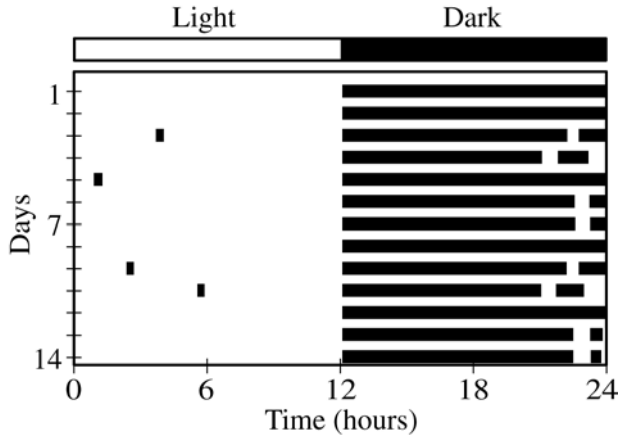


Figure 2. Actogram of mouse activity under L12:D12 conditions. Each row represents a 24-hour period, and the dark horizontal lines represent activity on the running wheel.

After 14 days in L12:D12, the mice were placed in continuous darkness (DD), and their activity on the running wheel was recorded as before. The activity data under DD conditions are shown in Figure 3.

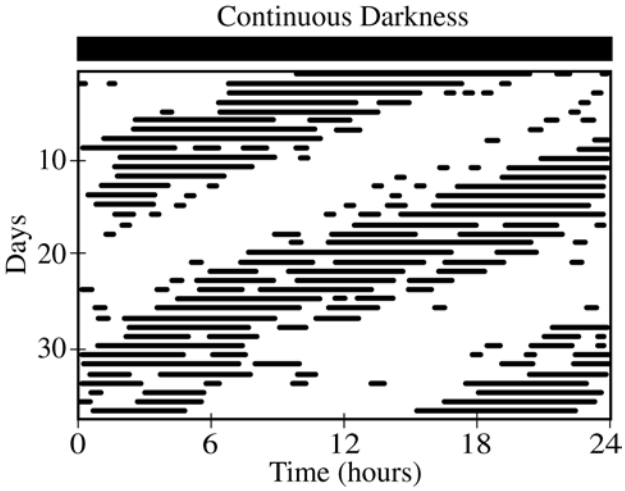


Figure 3. Actogram of mouse activity under DD conditions. Each row represents a 24-hour period, and the dark horizontal lines represent activity on the running wheel.

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## Question 1 (continued)

(a) The nervous system plays a role in coordinating the observed activity pattern of the mice in response to light-dark stimuli. **Describe** ONE role of each of the following anatomical structures in responding to light-dark stimuli.

- A photoreceptor in the retina of the eye
- The brain
- A motor neuron

| | **Descriptions (1 point per box; 3 points maximum)** |
|---|---|
| Photoreceptor | Detects light/dark stimulus and initiates/transmits signal |
| Brain | Integrates/processes/coordinates information |
| Motor neuron | Transmits signal from brain to an effector |

(b) Based on an analysis of the data in Figure 2, **describe** the activity pattern of the mice during the light and dark periods of the L12:D12 cycle.

**Description (1 point)**

- Active during dark phase AND inactive during light phase
- Active ONLY during the dark period
- Inactive ONLY during the light period

(c) The researchers claim that the genetically controlled circadian rhythm in the mice does not follow a 24-hour cycle. **Describe** ONE difference between the daily pattern of activity under L12:D12 conditions (Figure 2) and under DD conditions (Figure 3), and use the data to **support** the researchers' claim.

**Description (1 point)**

- Active period begins a little earlier each day
- Active/inactive period is shorter than 12 hours each day
- Daily circadian rhythm is less than 24 hours
- Pattern of activity shifts each day

**Support (1 point)**

- Without light, active/inactive periods are determined only by the genetically controlled circadian rhythm.
- If it were a 24-hour circadian rhythm, the pattern of activity in DD would be the same as the pattern of activity in L12:D12.

(d) To investigate the claim that exposure to light overrides the genetically controlled circadian rhythm, the researchers plan to repeat the experiment with mutant mice lacking a gene that controls the circadian rhythm. **Predict** the observed activity pattern of the mutant mice under L12:D12 conditions and under DD conditions that would support the claim that light overrides the genetically controlled circadian rhythm.

## Question 1 (continued)

| Conditions | **Predicted Activity Pattern (1 point per box; 2 points maximum**) |
|---|---|
| Mutant under L12:D12 | Normal rhythm/rhythm similar to wild-type mouse under L12:D12 (Figure 2) |
| Mutant under DD | • Random activity throughout the 24 hour period<br>• No pattern/rhythm<br>• Constantly active/constantly inactive |

(e) In nature, mice are potential prey for some predatory birds that hunt during the day. **Describe** TWO features of a model that represents how the predator-prey relationship between the birds and the mice may have resulted in the evolution of the observed activity pattern of the mice.

| | **Description (1 point per box; 2 points maximum)** |
|---|---|
| Selective Advantage | • Selection for individuals active at night<br>• Selection against individuals active during the day<br>• Day-active variants susceptible to predation<br>• Night-active variants able to avoid predation |
| Reproductive Success | • Mice selected for produce more offspring<br>• Mice selected against produce fewer offspring |

PAGE FOR ANSWERING QUESTION 1

a) The photoreceptor in the retina of the eye plays a role in sensing the light that is in the mouse's environment. It responds to the lack of light, and so when it is dark, the photoreceptor sends a signal to the brain indicating that it is dark. The brain receives the signal from the photoreceptor telling that it is dark, processes the signal, and then sends a signal to the appropriate neuron to act. In this case, it is the motor neuron. The motor neuron receives the signal from the brain to move, and in term causes the mouse to begin movement activity, such as using the running wheel.

b) During the dark periods, the mouse is almost constantly active, using the running wheel. During the light periods, the mouse rarely uses the running wheel.

c) Under L12:D12 conditions, the mouse is constantly active for 12 consecutive hours when it is dark, and then shows inactivity for the 12 hours that it is light. When looking at the mouse placed in DD conditions after 14 days of L12:D12 conditions, it first continues this same pattern of activity. However as the days increase, the mouse deviates from this pattern. By the 40th

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

day, the mouse now exhibits about 6 hours of activity, followed by roughly 9 hours of inactivity. This combines to a 15-hour cycle, differing from the 24-hour cycle in L12:D12 conditions. This shows that without the light stimulus, the mouse is genetically ~~program~~ set to a different cicardian ~~rhythm~~ rhythm cycle.

d) Lacking the genetically controlled cicardian rhythm, the mice will be active only when it is dark and inactive when exposed to light. Under L12:D12 conditions, the mice will be inactive for 12 hours during the light, and active for the following 12 hours during the dark. Under DD conditions, it will be constantly active as it is constantly dark. Eventually, the mice would probably die from exhaustion and overexertion.

e) The birds that prey on the mice hunt during the daytime, when there is light. If the mouse is active during this time, it will be more likely to be killed and eaten by the bird. This could have caused the mouse to be active only during the dark in order to avoid being preyed upon to survive, reproduce and pass on their fit genes to the next generation. The mice without the genes

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

for inactivity during light would have been killed by the birds, preventing them from passing their genes to the next generation. Over time, this has caused all or most mice to have this gene as it is the most favorable for survival. This is known as survival of the fittest or natural selection.

PAGE FOR ANSWERING QUESTION 1

a. As light enters the photoreceptor, neurons pass electrical signals to the brain. The brain then processes this information into sight, or in this case, perception of day and night. The motor neuron then receives signals from the brain.

b. The mouse remains inactive for the vast majority of the 12 hours of light, while they are active during the dark periods except for the occasional break.

c. The LD:DD cycle of activity is constant over all 14 days; active in dark, inactive in light. The DD cycle, however, is not constant over each day. The hours of activity shift over each 24 hour period. It appears to move over a ~20 day cycle with the mouse becoming more active in the earlier hours as the cycle progresses, this supports the researcher's claim.

d. The activity in the LD:DD should stay the same; while, the activity during the DD conditions should be random,

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1 B 2

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

since there would be no gene controlling the circadian rhythm, the mice will only rest when exhausted.

c. Mice that were inactive and stayed hidden during the day were more likely to survive and have offspring, having higher reproductive fitness, producing more mice that stayed inactive during the day. Mices that were active at night could also forage for more food without being attacked allowing them to also have an advantage over mice active during the day.

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PAGE FOR ANSWERING QUESTION 1

A) A photo receptor in the retina of the eye would be used to detect light levels and would send this information to the brain

The brain would send an impulse to the motor neurons based on light levels to start running on the wheel.

A motor neuron would receive an impulse from the brain to move muscle tissue based on the light levels detected by the retina

B) In the dark the mouse is very active on the running wheel. In the light the mouse is barely active on the running wheel.

C) In figure three the mouse seems to not have a set time to run on the wheel but in figure two all the wheel running is done in the dark. Figure three shows that the only reason

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

the mouse runs at the same time every day in figure two, is because it is nocturnal and is active at night.

D) The activity of these mutant mice would be random in L:12 D:12 along with DD.

E) The mice that would hide or be inactive during the day were less likely to be killed and more of them survived ~~like~~ and reproduced due to natural selection. Another feature is how mice run instinctively to survive and avoid attacks from predators.

# AP® BIOLOGY
# 2015 SCORING COMMENTARY

## Question 1

Question 1 was written to the following Learning Objectives in the AP® Biology Curriculum Framework: 1.25, 2.24, 2.36, 2.37, 2.39, 3.40, 3.44, 3.45, and 3.46.

### Overview

This question was based on a laboratory investigation of the effects of both environmental conditions and genetics on the activity pattern of mice. Students were presented with actograms representing the daily activity patterns of mice exposed to daily periods of 12-hours of light followed by 12 hours of dark (L12:D12) and of mice exposed to continuous darkness (DD). Students were asked to describe the role of a photoreceptor, the brain, and a motor neuron in the behavioral response of the mice to light-dark stimuli. Students were then asked to use the actogram to describe the activity pattern of the mice exposed to L12:D12 conditions. Students were then asked to compare the activity pattern of mice exposed to L12:D12 conditions with mice exposed to continuous darkness (DD), and to use the data to support a claim that the genetically controlled circadian rhythm does not follow a 24-hour period. Students were then asked to provide support for a claim that light can override the genetically controlled circadian rhythm by predicting the activity pattern of mice lacking a gene that controls the circadian rhythm under L12:D12 and DD conditions. Finally, students were asked to propose two features of a model representing how predation by birds may have resulted in the evolution of the observed activity pattern of the mice.

**Sample: 1A**
**Score: 10**

The response earned 1 point in part (a) for describing that the photoreceptor responds to the lack of light and sends a signal to the brain. The response earned 1 point for describing that the brain processes the signal. The response earned 1 point for describing that the motor neuron receives the signal from the brain and causes the mouse to begin movement.

The response earned 1 point in part (b) for describing that during the dark periods the mouse is almost constantly active and that during the light periods the mouse rarely uses the running wheel.

The response earned 1 point in part (c) for describing a difference in the activity pattern as showing an active and inactive period each shorter than 12 hours. The response earned 1 point for supporting the researchers' claim by stating that the 15-hour cycle differs from the 24-hour cycle in L12:D12 so without the light stimulus the mouse is genetically set to a different circadian rhythm cycle.

The response earned 1 point in part (d) for predicting that under L12:D12 conditions the mice will be inactive for 12 hours during the light and active during the dark. The response earned 1 point for predicting that under DD conditions the mice will be constantly active.

The response earned 1 point in part (e) for describing selection by stating that if the mouse is active during the light it will more likely be eaten. The response earned 1 point for describing reproductive success by stating that the mice without the genes for inactivity during a light period would have been killed by the birds preventing them from passing their genes to the next generation.

**Sample: 1B**
**Score: 8**

The response earned 1 point in part (a) for describing that as light enters the photoreceptor, neurons pass electrical signals to the brain. The response earned 1 point for describing that the brain then processes this information.

## Question 1 (continued)

The response earned 1 point in part (b) for describing that the mouse remains inactive for the vast majority of the 12 hours of light while they are active during the dark periods.

The response earned 1 point in part (c) for describing that under DD conditions the hours of activity shift over each 24 hour period.

The response earned 1 point in part (d) for predicting that under L12:D12 conditions the activity should stay the same. The response earned 1 point for predicting that the activity during the DD conditions should be random.

The response earned 1 point in part (e) for describing selection by stating that the mice that were inactive and stayed hidden during the day were more likely to survive. The response earned 1 point for describing that the surviving mice have higher reproductive fitness, producing more mice.

**Sample: 1C**
**Score: 6**

The response earned 1 point in part (a) for describing that the photoreceptor would be used to detect light levels and would send this information to the brain. The response earned 1 point for describing that the motor neuron would receive an impulse from the brain to move muscle tissue.

The response earned 1 point in part (b) for describing that in the dark the mouse is very active and in the light the mouse is barely active.

The response earned 1 point in part (d) for predicting that the activity of mutant mice under DD conditions would be random.

The response earned 1 point in part (e) for describing selection by stating that the mice that would hide or be inactive during the day were less likely to be killed. The response earned 1 point for describing reproductive success by stating more of the surviving mice reproduced.