AP Bio FRQ Fridays

2015 #1
Circadian Rhythm and Evolution

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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.

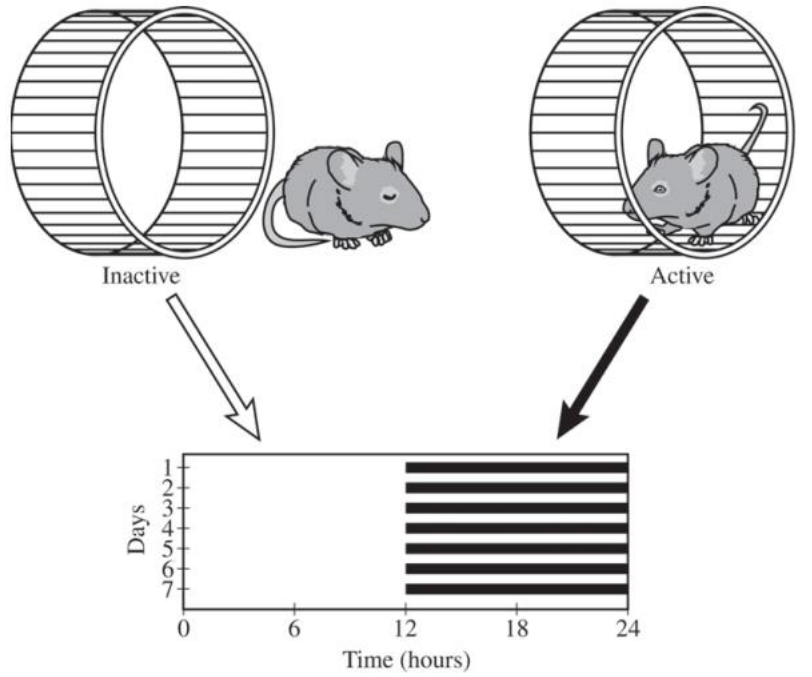

Figure 1. Strategy for recording mouse activity data. When a mouse is active on the running wheel, the activity is recorded as a dark horizontal line on an actogram. When the mouse is inactive, no dark line is recorded.

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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.

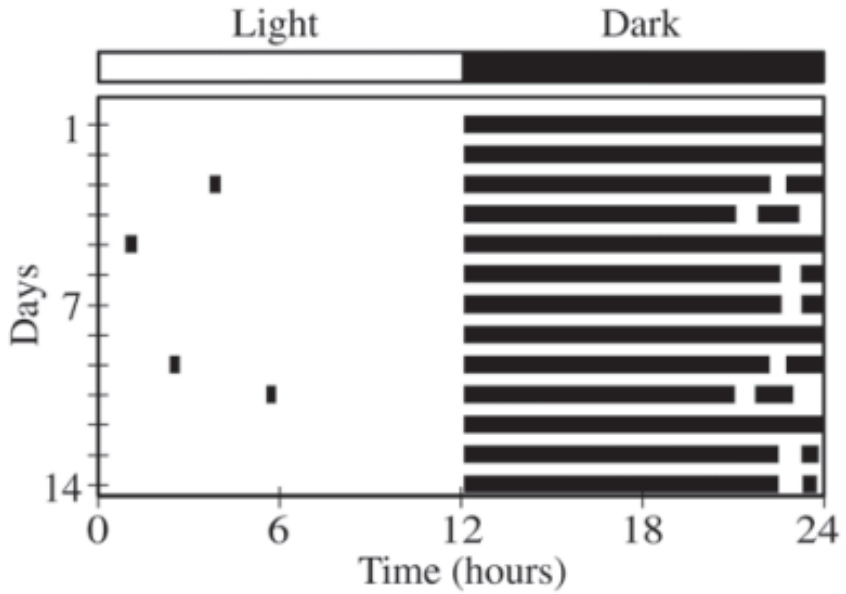

Figure 2. Actogram of mouse activity under L12:D12 conditions. Each row represents a 24-hour period, and the dark horizontal lines represent activity on the running wheel.

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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.

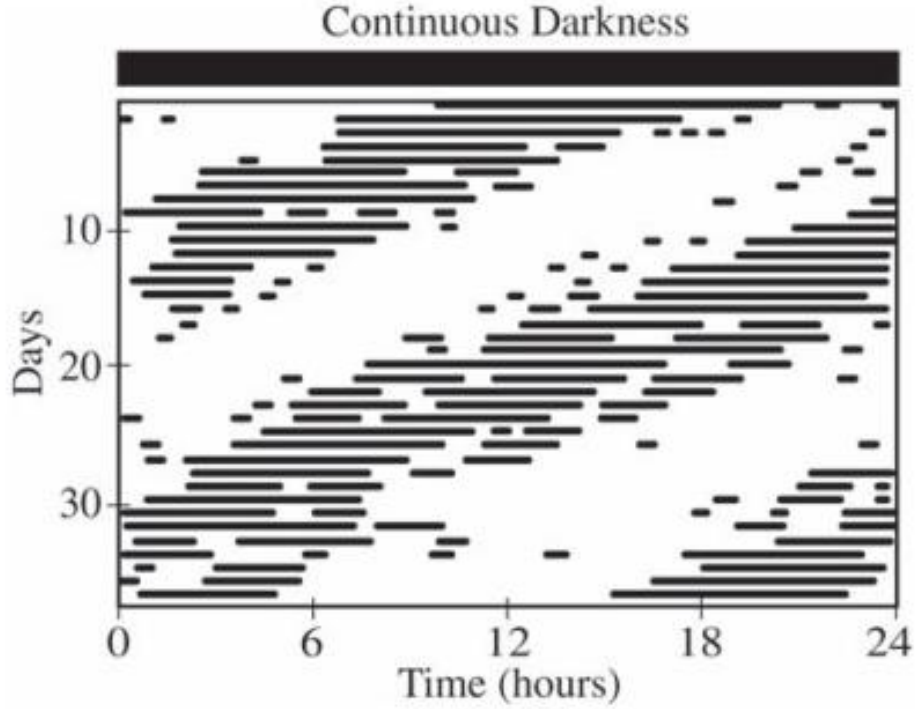

Figure 3. Actogram of mouse activity under DD conditions. Each row represents a 24-hour period, and the dark horizontal lines represent activity on the running wheel.

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(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

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	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

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.

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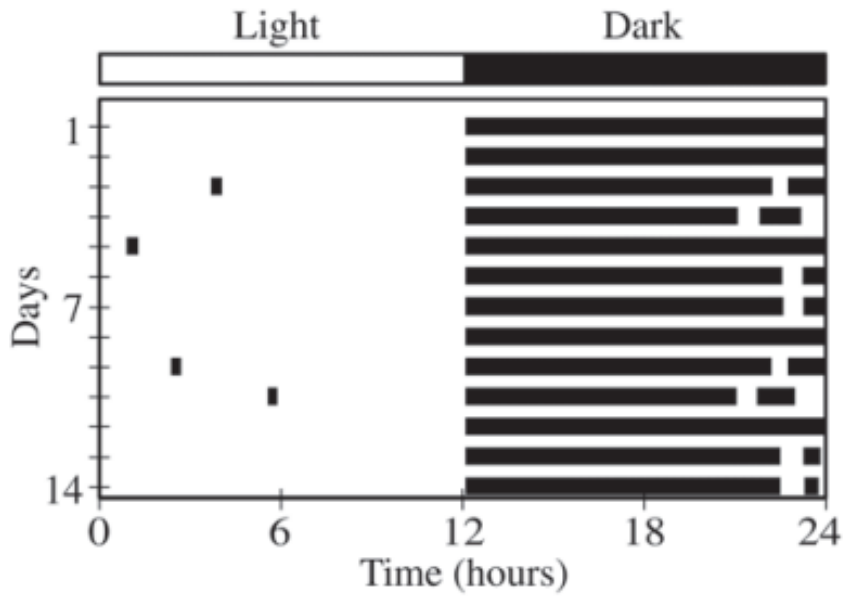
(b) Based on an analysis of the data in Figure 2, **describe** the activity pattern of the mice during the light and dark periods of the L12:D12 cycle.



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(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

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.

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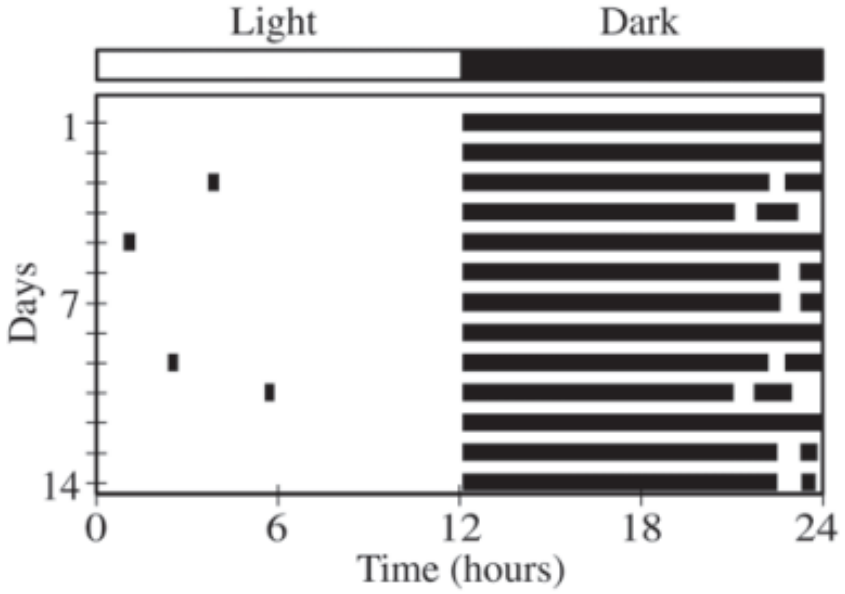
(c) The researchers claim that the genetically controlled circadian rhythm in the mice does not follow a 24-hour cycle. **Describe** ONE difference between the daily pattern of activity under L12:D12 conditions (Figure 2) and under DD conditions (Figure 3), and use the data to **support** the researchers'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



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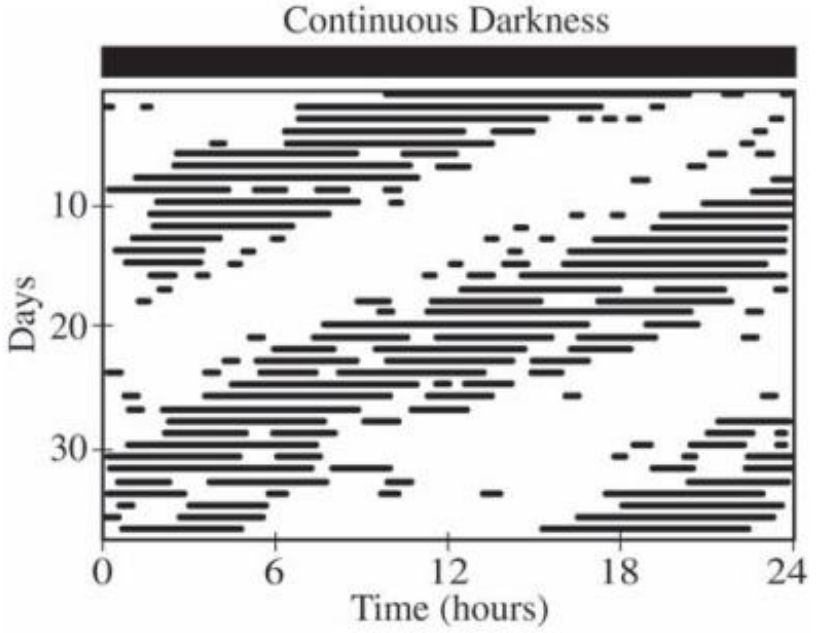

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Description (1 point)

- 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.

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- 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.

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 ~~mice~~ mouse placed in DD conditions after 14 days of L12:D12 conditions, it first continues this same pattern of ~~rest~~ activity. However as ~~the~~ the days increase, the mouse deviates from this pattern. By the ~~30th~~ 40th

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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 circardian ~~rhythm~~ rhythm cycle.

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(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.

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 • No pattern/rhythm • Constantly active/constantly inactive

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Mutant under DD	• Random activity throughout the 24 hour period • No pattern/rhythm • Constantly active/constantly inactive

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.

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(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 • Selection against individuals active during the day • Day-active variants susceptible to predation • Night-active variants able to avoid predation
Reproductive Success	• Mice selected for produce more offspring • Mice selected against produce fewer offspring

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Reproductive Success	• Mice selected for produce more offspring • Mice selected against produce fewer offspring

e) The birds that prey on the mice hunt during the daytime, when theve 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

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	Description (1 point per box; 2 points maximum)
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for inactivity during light would have been killed by the birds, preventing them from passing their genes to the next generation. Overtime, 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.