What makes me tick...tock?

Circadian rhythms, genetics, and health

Lesson 1: What is a circadian rhythm?

I. Overview

In this introductory lesson to the unit, students conduct an in-class survey to learn about the circadian rhythms and biological clocks of their peers. Using this survey, students identify the owls and the larks in their classroom. In addition, students look at two different Sleepiness Scales as a whole class and interpret the sleep-wake cycles of two people, looking at their sleepiness scales. In addition, they write or draw what they currently know about circadian rhythms and generate questions related to what they would like to know or learn about biological rhythmicity. The students will confirm or refute their ideas based on knowledge gained through a variety of activities and readings in later lessons of the unit. At the end of the lesson, they learn about some concepts related to circadian rhythms as they watch a video about Michel Siffre, a French scientist who studied his own circadian rhythm.

Connections to the driving question

The driving question is introduced in Lesson 1. At the end of the lesson, students try to answer the driving question What makes me tick...tock? and What makes me sleep? by coming up with their own hypotheses to explain possible biological clocks. Students are asked to illustrate their theory with a drawing or by writing a short paragraph. Throughout the unit, as students learn new information to answer the driving question, they will refer back to their hypotheses to confirm, readjust or reject them.

II. Standards/Benchmarks

National Education Science Standards

Content Standard A: Abilities necessary to do scientific inquiry

- Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and conceptual understanding of scientific investigations (9-12 A: 1/1).

Content Standard C: The Behavior of Organisms

- Organisms have behavioral responses to internal changes and to external stimuli. Responses to external stimuli can result from interactions with the organism's own species and others, as well as environmental changes; these responses either can be innate or learned. The broad patterns of behavior exhibited by animals have evolved to ensure reproductive success. Animals often
live in unpredictable environments, and so their behavior must be flexible enough to deal with uncertainty and change (9-12 C: 6/2).

- Behavioral biology has implications for humans, as it provides links to psychology, sociology, and anthropology (9-12 C: 6/4).

**Benchmarks for Science Literacy**

**The Nature of Science: Scientific Inquiry**

- Investigations are conducted for different reasons, including exploring new phenomena, to check on previous results, to test how well a theory predicts, and to compare theories. 1B/H1
- Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available). 1B/H2

### III. Learning Objectives

<table>
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<tr>
<th>Learning Objectives</th>
<th>Assessment Criteria</th>
<th>Location in Lesson</th>
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<tr>
<td>Explain that circadian rhythms are not the same in every one, and that it is very likely that their sleep-wake cycle is different from their parents’ or peers’ sleep-wake cycle.</td>
<td>Students’ survey questions reflect the main characteristics of owls and larks. Depending on the number of survey “points,” the students accurately identify their classmates as owls, larks, or “hummingbirds.”</td>
<td>Activities 1 and 2</td>
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<tr>
<td>Plot data on a diagram (sleepiness scale) and interpret a sleepiness scale.</td>
<td>Students correctly identify the time of day on the x-axis (12 am to 12 am) and note that the higher number on the y-axis, up to 10, indicates a higher level of sleepiness. They also draw accurate sleepiness scales based on their own sleepiness.</td>
<td>Activity 2</td>
</tr>
<tr>
<td>Describe key circadian rhythm terms: lark, owl, hummingbird, circadian, zeitgeiber, diurnal, nocturnal.</td>
<td>Students’ descriptions include: <strong>Lark</strong> (colloquial): those most active early in the day <strong>Owl</strong> (colloquial): those most active in the evening or late at night <strong>Hummingbird</strong> (colloquial): those adaptable to several different day-night cycles <strong>Circadian</strong>: being, having, characterized by, or occurring in approximately 24-hour periods or</td>
<td>Activity 3</td>
</tr>
</tbody>
</table>
cycles (as of biological activity or function) (Merriam-Webster)

**Zeitgeber**: (from the German, literally “time giver”) an environmental agent or event (as the occurrence of light or dark) that provides the stimulus setting or resetting a biological clock of an organism (Merriam-Webster); examples include light/dark cycle (primary), temperature, social interactions, chemical manipulation and nutritional intake

**Dirunal**: active during day

**Nocturnal**: active at night

| Describe that other animals, besides humans, have circadian rhythms. | Owls, larks, and hummingbirds all have an internal clock. Some animals are active at night, such as bats, opossums, and raccoons, among others. Some are active during the day, such as squirrels, some types of birds. | Activity 3 |
| Describe the importance of the Michel Siffre experiment. | Students’ descriptions highlight that the Siffre experiment showed scientists that humans have a longer than 24 hour day circadian rhythm when no exogenous cues (zeitgeibers) are in affect. | Activity 4 |
| Describe what an “actogram” is and how it can be read. | An actogram is a graph that plots time on the x-axis and activity level on the y-axis. The higher the peak, the more active the organism. | Activity 5 |
| Describe the circadian rhythm of a mouse under a variety of light/dark conditions. | Descriptions include that in the 12:12 L/D cycle, the mouse is active during the dark and not active during the light. Under constant darkness, the mouse experiences a shift, where he sleeps progressively earlier, but still maintains a high level of activity. In constant light, his activity levels are lower and he falls asleep progressively later. In the pulse, the mouse will fall asleep when the light turns on for ~12 hours and then wake up for its night time activity. | Activity 5 |
IV. Adaptations/Accommodations
Depending on the class size and availability of resources, the Sleepiness Scale image can be either handed out to students or projected using PowerPoint or an overhead projector. Depending on the class size, the question generating activity can be done as a whole-class discussion or in groups, pairs or individually. If there is no access to the Internet, students can read an interview with Michel Siffre from Cabinet magazine. This is available as a PDF in the lesson materials (“U3_L1_Supplement_Caveman.pdf”) or at the following URL: http://www.cabinetmagazine.org/issues/30/foer.php

V. Timeframe for activity

Opening of Lesson
• Introduction to the lesson (Q &A) – 5 minutes

Main Part of Lesson

Day 1
• Activity 1: Find the Owls and the Larks in your classroom! – 20 minutes
• Activity 2: How sleepy are you?: Put it on Sleepiness Scale – 20 minutes

Day 2
• Activity 3: Discussion of The Lark vs. The Owl: How Do You Get Your Zzzs? Reading – 5 minutes
• Activity 4: “Sleep and Circadian Rhythms” video and discussion – 15 minutes
• Activity 5: Introduction to Actograms and Circadian Rhythm Terms – 15 minutes
• Extension Activity: Mouse Actogram Analysis – 15-20 minutes

Conclusion of Lesson
• Wrap-Up Discussion and Connection to Lesson 2 – 10 minutes

VI. Advance prep and materials

Activity 1: Find the owls and the larks in the classroom!

Materials:
• A copy of Owl and Lark images (U3_L1_Images_OwlLark.pdf)
• Paper and pencil
• Copies of the survey template and guidelines (U3_L1_StudentSheet_OwlLarkSurvey.docx)
• A copy of L1_StudentSheet_OwlLarkSurvey_SAMPLE.docx for reference.

Preparation:
• Hand out copies of the survey template and guidelines to the students.
Activity 2: How sleepy are you? Put it on the Sleepiness Scale!

Materials:
- Sleepiness Scale Graphs of two people (an owl and a lark)
  
  U3_L1_Presentation_SleepinessScales.pptx
- A projector to reflect the PowerPoint to the classroom, or an overhead projector
- Copies of Sleepiness Scale templates to be handed out to students
  
  U3_L1_StudentSheet_SleepinessScale.docx

Preparation:
- Make certain that the Sleepiness Scales of two people can be projected on the board using an overhead projector.
- Hand out copies of the Sleepiness Scale templates to students to plot their sleepiness data.

Activity 3: Discussion of The Lark vs. The Owl: How Do You Get Your Zzzs?

Materials:
- The Lark vs. The Owl: How Do You Get Your Zzzs? reading
  
  (U3_L1_Reading_TheLarkVsTheOwl.docx)

Preparation:
- Pass the reading out before beginning discussion. This is to be completed as homework before Activities 4, 5, and 6.

Activity 4: “Sleep and Circadian Rhythms” video

Materials:
- Computer with projector
- Internet access

Preparation:
- Connect a computer to the classroom projector
- Access the video at the following URL (Video # 13):
  
  http://www.learner.org/vod/vod_window.html?pid=1581
- Maximize the video window by clicking on the box in the lower right corner

Activity 5: Introduction to Actograms and Circadian Rhythm Terms

Materials:
- Circadian Basics Powerpoint presentation (U3_L1_Presentation_CircBasics.pdf)
- Student supplement packet (U3_L1_Homework_IntroductionCircadianTerminology.docx)

Preparation:
• Distribute students’ homework that will be used as a discussion guide at the conclusion of the lesson

Extension Activity: Mouse Actogram Analysis

Materials:
• Computers with Internet Access
• Access to the Mouse Actogram on Project NEURON website, http://www.neuron.illinois.edu/game/mouse-actogram-game
• Student Sheet to complete Mouse Actogram analysis,
  U3_L1_MouseActogram_ExplorationGuide.docx

Preparation:
• Distribute student materials
• Print out Answer Key for the Exploration Guide,
  U3_L1_MouseActogram_ExplorationGuide_ANSWERS.docx

Homework and Assessments
• Sleepiness Scales (U3_L1_StudentSheet_SleepinessScale.docx)
• Owl vs. Lark Reading before Activity 3 (U3_L1_Reading_TheLarkVsTheOwl.docx)
• Mouse Actogram Exploration Guide (U3_L1_MouseActogram_ExplorationGuide.docx)
• Reading and questions that introduce circadian rhythm terminology
  (U3_L1_Homework_IntroductionCircadianTerminology.docx)
• Reading on Model Organisms (U3_L1_Reading_ModelOrganisms.docx)

VII. Resources and References
For more information on the Michel Siffre experiment, the file U3_L1_Supplement_Caveman.pdf provides an interview with Michel Siffre with more specific questions related to his experience in the cave.
VIII. Lesson Implementation

Day 1

Opening of Lesson:
Start the lesson by asking students:

- How many of you are feeling very sleepy now?
- How many of you had to use an alarm clock to wake up this morning?
- How many of you didn’t need to use an alarm clock and were able to get up on time without any assistance to get up for school?

Use these questions and others to get the students’ thinking about the topic of sleep-wake cycles. After they answer these questions, put up the pictures of an owl and a lark (refer to U3_L1_Images_OwlLark.pdf) and tell students that some people are considered owls and some are larks in their sleep patterns. Ask the students:

- Why are these birds used to describe groups of people with different sleep patterns?
- Would you classify yourself as an owl or a lark? Why?

Main Part of Lesson

Activity 1: Find the Owls and the Larks in the classroom!

Explain to the students that in order to find the late sleepers and the early risers in class (the owls and larks), they need to develop questions that can be used to create a survey.

Hand out U3_L1_StudentSheet_OwlLarkSurvey.docx document to students. Tell students to work in small groups and develop 5 questions to identify who are the owls and larks in the classroom. Tell them that as they develop the survey questions as well as interpret their peers’ answers, they should use the guidelines listed in the first page.

Through this activity, students begin to develop a better understanding of what they might be—a lark or owl. Using the descriptions of the “owls” and the “larks” as guidelines, students may develop questions similar to these:

- When do you go to bed during the week? What time do you wake up? Do you need an alarm clock to wake up?
- When do you go to bed on the weekend? When do you get up? Do you get up with or without an alarm clock?
- Do you go to bed early on Sunday? Do you find it easy to wake up on Monday mornings?
- How many hours of sleep do you get on the weekend compared to during the week?
- What are your parents’ sleep habits like? Do they go to bed early (or earlier than you)? When do they wake up? How many hours of sleep do they get?
• Do you have a younger sister or a brother (between ages 0–12)? How many hours of sleep do they get?
• Do you find it easier to get up in the summer or in winter?

**Teacher Pedagogical Knowledge**
Students can either come up with questions in groups or this can be a whole-class activity where the questions they come up with can be written on the board. Refer to *L1_StudentSheet_OwlLarkSurvey_SAMPLE.docx*, which gives ideas as to how students should use the template and interpret the results.

After students develop 5 questions as a group, each student in the group will ask these questions to 3 peers. Based on their answers and the description of an “owl” and a “lark” in the guidelines, they will decide whether that person is more like an “owl” or a “lark”. When all of the students finish conducting their surveys, ask them to report their results to the whole class and write the number of “larks” and the number of “owls” in the classroom on the whiteboard. In order to guide them as they discuss the results of the survey, ask them questions similar to these:

- Are there more larks than owls in the classroom?
- Why do you think the majority of you are owls?
- What do you think your parents are? Owls or larks? Why?
- How do you think it may be helpful to know whether you are an owl or a lark?

**Teacher Content Knowledge**
At the end of the whole-class discussion, if some students have almost equal “owl” and “lark” scores, and have difficulty deciding which category they belong to, introduce the concept of being a “hummingbird”. Hummingbirds are in the middle and they may be ready for action both early in the morning and late at night. Some hummingbirds are more larkish, and others, more owlish. For instance, a hummingbird could wake up at dawn for camping or other occasions and stay up later than usual bedtime to complete an assignment.

**Activity 2: How sleepy are you? Put it on the Sleepiness Scale!**
After students discuss the results of the class survey, tell them that another way to identify whether a person is more like a lark or an owl is by using Sleepiness Scales. Our alertness and activity levels change significantly throughout the day. Information about the time of the day when we feel most alert versus when we feel sleepy may guide us in arranging our schedules. Tell students that the sleepiness scale can also help them identify whether a person is more like a “lark” or an “owl”. Using PowerPoint or an
overhead projector, display the sleepiness scales of two people with different sleep-wake cycles, one a typical “owl” and the other a “lark” (Refer to L1_Presentation_SleepinessScales powerpoint). By only looking at these two different sleepiness scales, have students try to read them to interpret the sleep-wake cycles of these two people. Ask the students the following questions:

- Which person is a “lark” and which one is an “owl”?
- Which person is more likely to work till late hours?
- Which person is more likely to pull all-nighters before an exam?
- Which person is more likely to enjoy exercising in the mornings?
- For each of them, what is the best time to take exams?
- What times are likely to be nap times for these people?
- What other information do their Sleepiness Scales tell us?

When interpreting the Sleepiness Scale, the x-axis shows the Sleepiness Scores. The bigger the sleepiness score, the sleepier a person is. A score of 10/10 would indicate deep sleep, while a score of 2/10 would indicate a very good level of alertness. The y-axis of the Sleepiness Scale indicates the 24 hours of the day.

Scientific Practices: Planning and Carrying Out an Investigation

Before students start plotting their sleepiness on the Sleepiness Scale, have a whole class discussion about what is data and what constitutes as data. Many students may have the misconception that data corresponds to facts or factual knowledge. At this point, explain to students that data, whether quantitative or qualitative, can be measurements or a collection of observations of a set of variables. In this case, sleepiness is a variable, and how sleepy they may feel at a given time is a piece of data. You may ask the following questions to start a discussion:

- What is data? What constitutes as data?
- Give some examples of data?
- Does data always correspond to facts? Can anything count as data?
- What are some different types of data?
- Why is it important to collect data?

The legend for the sleepiness score on the Sleepiness Scale is not provided. At this point, you may have a discussion about operational definition in research. An operational definition refers to how the characteristics of a concept can be defined, including identification and classification. Have a discussion with students about coming to a consensus about the operational definition of sleepiness score or how to interpret the sleepiness scores. For instance, you may decide that 10 corresponds to very deep sleep, and the range for “sleep” is 7–10, while the range for feeling very sleepy during
Next, distribute Sleepiness Scale Templates (U3_L1_StudentSheet_SleepinessScale.docx). Similar to Taylor and Tom’s Sleepiness Scales (which have been displayed to the students using Powerpoint or overhead projector), ask students to plot on the Sleepiness Scale how sleepy they feel on a typical weekday. After they plot their sleepiness data on a typical day weekday on the Sleepiness Scale, ask them the following questions:

- Looking at your Sleepiness Scale, are you a lark or an owl?
- Is your survey result consistent with your Sleepiness Scale? How?
- What times are the ideal times for you to take a test, why?
- What times are you more likely to take a nap?
- What times are ideal for you to do challenging physical work? What other information does your sleepiness scale tell you?

After students plot their data on the Sleepiness Scale and report their results, tell them that their typical weekday Sleepiness Scales might be very different from their typical weekend Sleepiness Scales. In addition, their sleepiness scales might seem quite different on different weekdays. Therefore, ask them to plot their sleepiness scales for Mondays, Thursdays and Saturdays for two weeks (or until the end of this unit). In addition, ask them to create the Sleepiness Scales of another family member (a parent or a younger sibling) on these same days of the week. Explain that they will use and interpret their sleepiness data that they collect at the end of the two-week period (in Lesson 6).

**Scientific Practices: Analyzing and Interpreting Data**

By collecting data over an extended period of time, students will gain a better understanding of their own circadian rhythms and how these rhythms show individual differences. This extended data collection will show students that despite some individual differences, age and profession are also important factors that may impact one’s circadian rhythms, as they will see that their parents will likely show similar circadian rhythms as their peers’ parents.

By collecting first hand data on themselves and family members, students will more likely make meaning from the activity. As students gather information about their sleepiness and alertness levels throughout the day and on different days of the week, they will be more conscious about how much sleep they get every day and what times of the day are ideal for doing challenging tasks.
At the end of this activity, hand out the homework reading, The Lark vs. The Owl: How do you get your Zzzs? \(U3_11\_Reading\_TheLarkVsTheOwl.docx\). Explain to the students that this reading will introduce them to certain terms used to describe “sleepiness” such as circadian rhythm and zeitgeber.

Tomorrow, the students will discuss what they have learned from the article so they should prepare themselves by paying careful attention to the ideas discussed in the reading.

**Day 2**

**Activity 3: Discussion of The Lark vs. The Owl: How Do You Get Your Zzzs?**

Begin this activity by having the students reflect briefly on the reading they completed as homework from Day 1, *The Lark vs. The Owl: How Do You Get Your Zzzs*. Ask the class about the language used in the reading.

- What were the different terms used in the reading to describe different aspects of circadian rhythms?

Students should pull several key terms from the reading, as they do, write them on the board to keep track. If students struggle to identify a key term, guiding questions can be asked to help point them in the right direction. Terms include:

- **Lark** (colloquial): those most active early in the day
  - **Owl** (colloquial): those most active in the evening or late at night
  - **Hummingbird** (colloquial): those adaptable to several different day-night cycles
  - **Circadian**: being, having, characterized by, or occurring in approximately 24-hour periods or cycles (as of biological activity or function) (Merriam-Webster)
  - **Zeitgeber**: (from the German, literally “time giver”) an environmental agent or event (as the occurrence of light or dark) that provides the stimulus setting or resetting a biological clock of an organism (Merriam-Webster); examples include light/dark cycle (primary), temperature, social interactions, chemical manipulation and nutritional intake

Leave these terms on the board during the next activity, return to them after the video to add/discuss further.

To wrap up the discussion, have the students think back to the poem in the reading. Ask the students:

- Why was the author (Plautus) so upset about the use of sundials?
  - Have the class hypothesize briefly on what they think might happen to someone if he/she had no way to keep track of time. No clocks, no sun, no alarms...

Use this as the bridge to the next activity, beginning with the video of French cave explorer Michel Siffre.

**Activity 4: “Sleep and Circadian Rhythms” Video**
Tell students that “sleep scientists” have also had various theories and questions regarding sleep and they have developed various methods to test their theories about sleep. Tell them that they are going to watch a sleep scientist and his 2-month experiment on sleep, and continue with showing of the Annenberg Media video about Michel Siffre’s 2-month experiment in a Texas cave.

After students watch the video about Michel Siffre’s experiment, ask the following questions:

- How was his sleep-wake cycle? How different was it from yours?
- How do you know when it is time to sleep?
  - Other than the clock and other extraneous factors, ask further questions to get them give examples of endogenous factors.
- How did Michel know when it was time to sleep?
- How did Michel’s day begin to grow longer than 24 hours? Is that possible? Why don’t we experience the same effect?
- What do you think happened to Michel’s sleep-wake cycle after he started outside the cave?
- What cues, or zeitgebers (refer to board if needed), was Siffre able to remove through his cave experiment?
- What zeitgebers can’t be removed by living in a cave?
- Would you still be a lark or an owl inside the cave?

**Activity 5: Introduction to Actograms and Circadian Rhythm Terms**

Introduce another circadian rhythm research tool, the actogram, by projecting the first slide of the “Circadian Basics” Powerpoint found as the U3_L1_Presentation_CircBasics.pdf file.

Tell the students to look at the top graph. Ask them how they interpret it. Specifically, what do the rising and falling activity levels in the mice suggest?

- The activity levels of the two mice are generally elevated when it is dark outside. This suggests that mice are nocturnal.

Have the students look at the bottom graph of the chaffinches (a species of small bird). How does this differ from the graph of the mice?

- Chaffinches exhibit significantly higher activity during the day, with practically no activity at night. This makes them diurnal.

Hand out the students’ homework, Introduction to Circadian Rhythm Terminology, U3_L1_Homework_IntroductionCircadianTerminology.docx. Using the first page of the reading as a guide, begin a discussion about basic circadian concepts:

- Based on the sleepiness scales generated in class, are humans diurnal or nocturnal?
  - Naturally diurnal, though modern life sees humans maintaining erratic schedules that aren’t strictly diurnal or nocturnal. Point out that this is particularly true of high school and college students!
• What is the name for animals that are most active at dawn and dusk? Can you give examples of such animals?
  o Crepuscular. Examples include dogs, cats and fruit flies.
• How would you characterize Siffre’s day-night activity patterns while he was in the cave? Was he diurnal? Nocturnal? Crepuscular?
  o None of these.
• So was Siffre’s sleep pattern erratic and unpatterned?
  o No. In the absence of strong zeitgebers, such as the sun, animals experience a phenomenon called “free running,” in which their circadian rhythms match their bodies’ inner, or endogenous rhythms. Explain that this is what happened to Michel Siffre in the cave, and that his daily activity closely matched those seen in the third graph, which is called an actogram.

Next, show the second slide of the “Circadian Basics” powerpoint. This image is the same one found on page 2 of their Circadian Rhythm Terminology homework. Tell the students that the black portions of the graph represent activity over a 24-hour period; the blue portions represent night, while yellow portions represent day. Each row in an actogram represents a 24-hour day. Many humans and other animals isolated from critical zeitgebers actually revert to an approximately 25-hour daily cycle, while other animals possess endogenous rhythms with a period less than 24 hours. This is why the onset of activity on successive days seems to shift in this actogram.

Ask the students:
• Which of the other three graphs most closely corresponds to normal human circadian rhythms? How is this graph not quite representative of human daily activity? What sort of animal might it describe?
  o The top one, labeled “Entrainment.” Explain that animals, including humans, are normally entrained, or synchronized, to the day-night cycle created by the sun. The top graph suggests that the animal whose rhythms are being modeled is nocturnal, as it is most active during the night. This is not normally the case with humans. Additionally, this animal is active approximately 12 hours each day. Humans are usually active about 16 hours a day, receiving on average 8 hours of sleep. This actogram could model a mouse or rat, for example.

Ask the students if they can make sense of what the “Phase Shift” actogram might represent. Explain to the students that a circadian phase shift occurs when the activity cycle of an animal is either naturally or artificially moved up or back by a few hours.
• For example, if the sun rose at 5 AM instead of 7 AM, most animals would experience a forward phase shift of two hours. This actogram indicates that the animal at hand started its activity cycle during light hours on Day 1. By Day 3, its activity cycle had been shifted backward to begin at the start of the dark cycle (presumably by artificial entrainment).
Ask students what the bottom graph, labeled “Lesion,” might represent. What does it suggest about the animal’s activity pattern?

- Its activity pattern is unpredictable. This is because it has a lesion, an injury or abnormality, in the part of the brain which functions as the “control center” for circadian rhythms. In mammals, this is called the suprachiasmatic nucleus (SCN), found in an important region of the brain known as the hypothalamus. In fruit flies, the ventral lateral neurons (LNvs) are thought to be primarily responsible for circadian regulation.

Finally, introduce the terms “subjective day” and “subjective night”. Explain that when Siffre was active in the cave, this was, by definition, his subjective day, regardless of whether or not it was actually day or night outside. Siffre slept during his subjective night. Unlike actual day and night, which depend on the times at which the sun rises and sets, an animal’s subjective day and night can vary when its rhythms are phase-shifted or exposed to free running (the latter was the case with Siffre). They depend only on the animal’s endogenous rhythms, regardless of whether these are in sync with the actual day-night cycle.

**Extension Activity: Mouse Actogram Analysis**
After introducing the actogram in Activity 5, the Mouse Actogram Analysis can provide more in-depth instruction on the actogram as well as a useful assessment tool for students. Upload the Mouse Actogram applet found at [http://www.neuron.illinois.edu/game/mouse-actogram-game](http://www.neuron.illinois.edu/game/mouse-actogram-game) and hand out the Exploration Guide for the students, *U3_L1_MouseActogram_ExplorationGuide.docx*.

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<th>Teacher Pedagogical Content Knowledge</th>
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<td>In this activity, students will measure the daily rhythms of mice and they will observe the changes in their circadian rhythms by changing the light/dark cycle. There are 4 main light/dark conditions to be observed in this activity:</td>
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<td>• 12:12 Light/Dark: The mice experience 12 hours of dark and 12 hours of light in a 24 hour day cycle.</td>
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<tr>
<td>• Constant Darkness: The mice experience 24 hours of dark with no light.</td>
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<tr>
<td>• Constant Light: The mice experience 24 hours of light with no darkness.</td>
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<td>• Pulse (Phase Response Experiment): The mice experience darkness for 24 hours except for 1-hour pulse of light.</td>
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The students will observe how the mice’s activity levels change due to the changes in exposure to light. Encourage the students to discuss how the different conditions affect the mice’s activity levels, and how scientists use this tool to study circadian rhythms.

Ask students to observe the circadian rhythm of the mouse in these different light conditions either using individual computers or on a projected computer. If students do this activity individually, students
will need to save one actogram (by clicking “Save” button as the actograms are being plotted on the right hand side) for each of these light conditions. When students are done with all of these conditions, ask them the following questions:

- What did you observe in 12:12 LD condition? Which times of the day was the mouse more active?
- The mice were active when it was dark. What does it imply about the mice? Are they nocturnal animals or diurnal?
- What was their circadian rhythm like under full-light condition? Given that the mice are nocturnal; did they not do any activity when there was constant light?
- Compare the Full Dark and Full Light conditions. What kind of changes did you observe about the mouse’s circadian rhythm?
- How did the circadian rhythm of the mice change under the pulse condition? What happened when you changed the time of the day when the light was introduced?
- How do you compare the constant darkness and full light conditions?
- What does this activity imply about the role of external factors (light, in this case) on circadian rhythms?

This activity can be done as a whole discussion. If it is done this way, have students take notes about the different actograms following each light-dark condition so that they can make reference back to their “data” during the final discussion.

**Teacher Pedagogical Content Knowledge**

Instead of using a whole-class discussion, the Mouse Actogram Exploration Guide can be used as an assessment tool for students. After an initial discussion on how to analyze an actogram, the students can answer the questions from the Mouse Actogram Exploration Guide in groups or individually, depending on the technology available.

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**Conclusion of Lesson**

As a final discussion, and bridge to Lesson 2 NetLogo Fly Experiments, have a class discussion about the role of Siffre’s experiment and current circadian research. Ask the students:

- How do the sleepiness scales and actograms compare? Which ones would be more useful in human research? What about animal research?
- What did Siffre’s experiment add to the collective knowledge of the scientific community?
  - Michel Siffre’s time in the cave provided important information to scientists studying circadian rhythms. Specifically, how the lack of zeitgeibers can alter a human’s internal clock.
• Why don’t more people live in caves now to help us learn more about circadian rhythms? What could be some ethical reasons to prevent this?
• How can we replicate the Siffre experiment without using humans? What types of models could we use?

With these questions, inform the students that in the next lesson, they will work with fruit flies to answer some of the questions they have about circadian rhythms, how environment and genetics can affect the sleep/wake cycle. Hand out the homework reading, “Model Organisms used in Neuroscience Research” for students to complete before Lesson 2.

Assessment
In this lesson, there are a variety of opportunities for teachers to assess students informally based on group and whole-class discussions. For more formal and formative assessments, the Sleepiness Scales and Mouse Actogram Exploration Guide provide information on students’ comprehension of the two tools used to track circadian rhythm activity in both humans and other organisms. Additionally, the two homework readings, The Owl vs. The Lark and Circadian Rhythm Terminology, contain guided reading questions to evaluate students’ comprehension of the text.