Biology 104

Circadian Rhythms

Objectives:

1. Learn about circadian rhythms in human physiology.
2. Practice gathering data on an extended basis.
3. Practice making and interpreting graphs.

Introduction:

All eukaryotic organisms studied, and some cyanobacteria, show rhythms in behavior, biochemistry, and/or physiology that repeat around once a day. These are called circadian rhythms, from the Latin *circa dies*, meaning "about a day." In nature, these rhythms synchronize to the rhythm of day and night, and they help the organism to adapt to that dramatic and important cycle in the organisms environment. In higher animals, the most obvious rhythm is the cycle of sleep and wakefulness. However animals also show rhythms in the levels of hormones in the blood, in body temperature, in heart function, and so on. Plants show rhythms in photosynthetic ability, and some fold their leaves at night. Fungi exhibit rhythms in the production of reproductive structures. Protozoa and cyanobacteria have rhythms in cellular uptake of nutrients.

How do we know, you might wonder, that these are truly rhythms and not just responses to sunlight and darkness? Your own experience might demonstrate that the rhythms must be real. In the winter people may wake before sunrise, and become sleepy before sunset. Rigorous demonstration of the reality of these rhythms comes from laboratory experiments in which organisms are kept in constant darkness or constant light, with no clues of the passing of the days. The first report of a circadian rhythm was in the 1700s when deMairan found that plants kept in continual darkness still moved their leaves up and down each day. Plants in constant darkness also prepare each day for photosynthesis, even though no photosynthesis can take place. Animals in constant darkness sleep and wake on a daily schedule. Even the common bread mold in constant darkness produces reproductive spores once each day.

Humans have these rhythms also. While few volunteers are willing to live for days in constant darkness, researchers have found volunteers willing to live for days in special rooms set up in caves with no clocks, no daily paper, no contact with the outside world and no other clues of the passing of time (these volunteers have mostly been graduate students writing their dissertations). Under these conditions people still wake up and become sleepy, and have rhythms in temperature and hormone levels approximately 24 hours long.

Why are these rhythms important? Consider that physical examinations are generally given early in the morning, and blood pressure usually shows a low point in its rhythm early in the morning. It's possible to have high blood pressure and look normal at every physical examination. Consider also the all too common practice in industry, transportation and the military of having people work in the wee hours of the morning for some weeks, and then to abruptly switch them to a more normal daytime shift. Their internal rhythms do not shift so quickly, so for days their peak times of concentration may come when they are trying to sleep, and their periods of inefficiency may come when they are running heavy machinery, piloting airplanes, or engaging in combat. A commercial passenger jet bound for Los Angeles once flew right past the city and was about a hundred miles out to sea when air traffic control was able to awaken the cockpit crew over the radio. Turns out the entire crew had recently changed shifts and found their bodies wanted to sleep when they were supposed to be flying a plane. Or simply consider the more mundane practice of flying business people halfway around the world where, for days, their body rhythms will disagree with local day and night. Having your rhythms out of synch with the world certainly reduces your performance, and some feel it may produce stress that weakens the immune system and leads to wear on the body's organs.

In this laboratory exercise you will measure certain parameters of your own physiology at various times of the day for several days. You will graph this data to verify that your body is actually varying rhythmically, and you will consider some possible factors that may be affecting your rhythms. Obviously, this is not a well-controlled experiment, since you will not be locked in a cave, but will be exposed to daily cycles of sunlight and darkness as well as to other environmental clues to the passage of time. In addition, you may engage in behaviors that affect your rhythms, such as not getting enough sleep before a test, or drinking caffeine-containing beverages.

Methods:
On your own
You will need an oral thermometer, and a watch or other timepiece that is accurate to seconds. If you have or can borrow a blood pressure cuff you may also monitor blood pressure.

Several times a day, take a few minutes to measure your pulse and body temperature and record these. If you have a blood pressure cuff also measure and record your systolic and diastolic pressure. Also make an estimation of time. To do this, get out your watch and at some convenient point (when the second hand hits 12, maybe?) turn the watch away from you and begin counting off seconds to yourself. After 120 seconds stop and check your watch to see how accurate you were. If you counted too slow record how many seconds slow you were as a negative number; if too fast record how many seconds fast you were as a positive number. (Note: do not make these measurements immediately after a hot bath or shower, physical exercise, or sexual activity since all of these will temporarily shift the measurements.)

Record these measurements and the time of day you made them. Each day also record the time of day you went to bed and the time you got up.

Nighttime measurements will be hard to come by. At the least, make measurements immediately before going to bed and immediately after arising. If you should awaken during the night (to use the bathroom for example), make measurements before returning to bed. Of course, if you are very dedicated you could set your alarm to wake you several times during the night to make measurements…

Continue the recording for at least a week.

In Class
Graph your measurements against time for the entire week. On the x-axis (time axis) mark the periods when you were asleep.

Do you see daily rhythms in your graphs? Which measurements had clear rhythms?

The acrophase of a rhythm is defined as the time when it reaches a peak value, for example, highest body temperature. For each rhythm, approximately when, as a time of day, does the acrophase occur? You will want to look at all the data for all days, and possibly average the days.

For each rhythm when does the acrophase occur relative to your sleep times? For example, right after arising, or about 6 hours before bedtime.

Some things that can alter rhythms or even make them go wild include missing sleep to study or party, drinking too much alcohol, excessive worry, drinking excess caffeine, or radically changing your bedtime. Do you see any evidence of these factors in your data? Explain.

Compare your graphs and acrophases to those of other people in your group. What differences do you see between people?

Applying what you've learned

Think of some factor that might cause rhythms to go out of synch. Jet lag, or changes in work shifts, are possible examples. Others might be the factors mentioned above. Make a list of several.

Suppose we had the time and resources to test these factors for their ability to cause rhythms to go out of synch. Pick one factor from your list and design an experiment to determine its effect on rhythms. Be sure to address the following in your plan:

- How many volunteers will you need?
- What rhythm(s) will you measure?
- How and for how long will you determine normal rhythms?
- Which factor from your list are you testing and how will you expose your volunteers to that factor.
- How will you monitor rhythms after the treatment?
- What other factors will you try to keep constant and how will you do this?
- What do you hypothesize you will see?