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RHYTHMS OF BEHAVIOR

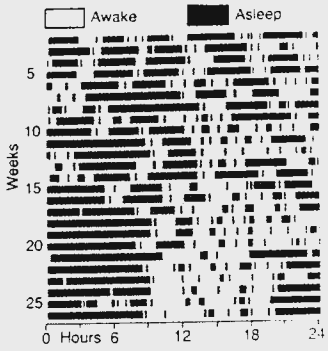
Types of rhythm. . . Responses to light levels. . . Control by the environment or an internal clock. . . Annual breeding cycles. . . Sleep. . . Hibernation. . .

ALL animals live in an environment in which some of the events affecting their lives are rhythmic. For example, animals may need to change their behavior at or before dawn, high tide, full moon, or the onset of warm spring weather. Behavior rhythms may result from responses to environmental rhythms or they may be a consequence of internal rhythms.

The term "rhythm" refers to a series of events repeated approximately regularly, but a truly regular rhythm, in which the events are separated by equal periods, is said to be a "periodicity." The period between events or wavelength of the rhythm can range from fractions of a second to years. The wingbeat rhythm of the smallest insects has a period of one-thousandth of a second while, for many eye-tracking, breathing, chewing or walking movements, the period is less than five seconds. Rhythms of feeding and digestion have wavelengths of minutes or hours, according to the size of the animal, while activities which depend on the state of the tide or the light level will have wavelengths of 12.5 and 24 hours respectively. Longer-wavelength rhythms include the reproductive cycles of female mammals and responses to the phases of the moon.

It is apparent from this wide range of behavioral rhythms that some are merely a consequence of control mechanisms but others serve a useful function for the animal, allowing it to cope with its environment. Species which can find food, avoid predators and generally maintain body state more effectively during daylight than during darkness obviously benefit from responding appropriately to different light levels and may operate most efficiently if they can predict the changes during the 24-hour period by means of an internal clock. The same argument would apply to responses to any other environmental rhythm, whether physical or resulting from the activities of other animals. Fishes in a school and birds in flocks may benefit from assuming a rhythm of locomotion which is precisely the same as that of their fellows and, if the main predator that might eat an animal comes near every two hours, then it is obviously advantageous to synchronize antipredator behavior with this rhythm. Horseflies and mosquitos may be able to bite mammals most effectively during the dawn and dusk periods. The activity peaks of parasites may be related to host behavior; for example, the human threadworm female often moves down the gut to the anal region to lay her eggs in the evening when the host is most likely to scratch and increase the chance that the eggs will be ingested. Avoiding predators may be more effective if the activity of the group is synchronized at a particular time of day. Newly fledged Brünnich's guillemots, for example, are vulnerable to attack by large gulls but most of the chicks leave their cliff nests within a very short time span so many can survive the depredations of the limited number of predators.

Breeding by large animals often occurs annually in temperate regions. It can be initiated by a particular day length. The interval between breeding seasons is not always one year in



▲ **Sleep patterns in a human baby.** Circadian (24 hour) cycles of sleep and wakefulness of human babies become established 16 weeks after birth.

► **Daily ritual**—Sugar gliders (*Petaurus breviceps*) settle down for their daytime sleep in a communal nest within a tree in the Australian woodlands. They are active at night.

▼ **Spawning frenzy.** Grunions (*Leuresthes tenuis*) of California respond to phases of the moon by coming to deposit eggs high on the beach during spring tides. The young develop well enough to be freed from the eggs by the next spring tide.

the tropics, however, for seabirds, such as some shearwaters and boobies, breed at intervals of eight to nine months. Breeding is annual in some invertebrates, such as the Palolo worm of the Atlantic and Pacific which gathers in vast numbers for fertilization during the neap tides of the last quarter moon in October and November.

During periods of adverse conditions in which finding food is difficult, or there is a high risk of predation or physiological damage, animals may reduce their activity and their metabolic rate. If the adverse period is the night, or the day for nocturnal animals, the usual behavioral response is sleep. Sleep is a prolonged period of inactivity with reduced responsiveness and a characteristic posture. The site chosen is usually appropriate for avoiding predators and the behavior often occurs with a circadian (approximately 24-hour) or tidal periodocity. Sleep may have no restorative function so it seems most likely that it has evolved as a means of minimizing predation risk and conserving energy. It does form part of the daily rhythm, however, and individuals may be harmed if that rhythm is disrupted by sleep deprivation.

Where sleep is associated with reduced metabolic rate and some lowering of body temperature, the word "torpor" is used. Torpor lasting for many days or months is called "hibernation" in winter conditions and "aestivation" in adverse summer conditions such as long dry periods in deserts. Torpor is the normal nocturnal state for cold-blooded animals in temperate regions, and the bumblebee buzzing to warm its body on a cold morning is a common sight. Bats and other small mammals as well as birds, such as hummingbirds, can become torpid overnight and hence save energy. Larger animals need too much energy to raise their body temperatures from low levels for overnight torpor to be worthwhile.

Before hibernating an animal must feed more to accumulate fat deposits as an energy store, select a suitable site and, often, build a nest. During hibernation, small mammals may lower their body temperature to a few degrees above ambient with seventy-fold energy savings, and may awaken on cold days. Mammals weighing 1 to 5kg (2 to 11lb), such as hedgehogs and marmots, do not awaken briefly because of the high energy cost and the long awakening time. A small bat can wake in half an hour but a marmot needs many hours. For a large mammal, such as a bear, the body temperature can be lowered by only 5°C (9°F), the metabolic rate reduced by only 50 percent and awakening is rapid so that this is scarcely hibernation.

Experiments with constant environmental conditions have shown that many of the periodicities found can be controlled by internal processes only. Recent studies of these have shown that the period can sometimes be lengthened by cooling the animal or by substituting the heavy isotope, deuterium, for normal hydrogen in the water so making the clock run slow. Evidence for the localization of pacemakers in the brain comes from studies in which removal of the pineal in sparrows, or the suprachiasmatic nucleus in rats, results in the loss of rhythms shown in constant conditions. DMB