Question 1: Why do EEGs with relatively fast frequencies tend to have smaller amplitudes than EEGs with slower frequencies?

Answer: The amplitude of the EEG signal depends on the synchronization of the activity of the underlying neurons. If a group of cells are excited simultaneously, the tiny signals sum to generate one large surface signal. However, when each cell receives the same amount of excitation, but spread out in time, the summed signals are meager and irregular. In this case, the *number* of activated cells and the *total amount of excitation* has not changed; however, the timing of the activity has changed. Therefore, EEGs with relatively fast frequencies tend to have smaller amplitudes than EEGs with slower frequencies.

Question 2: The human cerebral cortex is very large and must be folded extensively to fit within the skull. What do the foldings of the cortical surface do to the brain signals that are recorded by an EEG electrode at the scalp?

Answer: For the most part, an EEG measures voltages generated by the currents that flow during synaptic excitation of the dendrites of many pyramidal neurons in the cerebral cortex. The signal must penetrate several layers of non-neural tissue, including the meninges, fluid, bones of the skull, and skin, to reach the electrodes. The population of cells deep within the folds of the cortical surface contributes very little to the recorded EEG, which measures activity only in the superficial layers of cortex close to the skull.

Question 3: Sleep seems to be a behavior of every species of mammal, bird, and reptile. Does this mean that sleep performs a function essential for the life of these higher vertebrates? If you do not think so, what might be an explanation for the abundance of sleep?

Answer: No single theory of the function of sleep is widely accepted, but the most reasonable ideas fall into two categories: theories of restoration and theories of adaptation. The theory of restoration states that we sleep in order to rest and recover, and to prepare to be awake again. The theory of adaptation states that we sleep to keep out of trouble, to hide from predators when we are most vulnerable or from other harmful features of the environment, or to conserve energy. Even animals that never rest, such as dolphins, give each hemisphere a nap: about 2 hours asleep on one side, then 1 hour awake on both sides, 2 hours asleep on the other side, and so on for 12 hours every night. Similarly, the blind Indus River dolphin uses microsleeps of 4-6 seconds in duration, adding up to 7 hours in a 24-hour day to rest its brain. This reinforces the importance of sleep but the reason for its importance remains unknown. And it is possible that sleep is simply a byproduct of some other vital process. Nonethless, rats deprived of sleep lose weight in spite of increased food intake, become weak, accumulate stomach ulcers and internal hemorrhages, and in severe cases even die. They are unable to regulate body temperature and metabolic needs.

Question 4: An EEG during REM sleep is very similar to an EEG when awake. How do the brain and body in REM sleep *differ* from the brain and body when awake?

Answer: Rapid eye movement sleep, or REM sleep, is a state where the whole body (except for the eye and respiratory muscles) is immobilized, and vivid, detailed illusions called dreams are conjured up. The oxygen consumption of the brain is higher in REM sleep than when the brain is awake and concentrating on difficult mathematical problems. Some areas, including primary visual cortex, are equally active in the two states. However, extrastriate cortical areas and portions of the limbic system are significantly more active during REM sleep.

Conversely, regions of the frontal lobes are noticeably less active during REM. Most of the body is incapable of moving during REM sleep, whereas the body can be moved normally when awake. The paralysis that occurs during REM sleep is almost a total loss of skeletal muscle tone. The muscles controlling eye movement, the tiny muscles of the inner ear, and the muscles of respiration are the exceptions, as these are strikingly active. During REM sleep, the same core brain systems that control the sleep processes of the forebrain actively inhibit the spinal motor neurons, preventing the descending motor activity from expressing itself as actual movement.

Question 5: What is a likely explanation for the brain's relative insensitivity to sensory input during REM sleep, compared to the waking state?

Answer: The control of REM sleep, as with the other functional brain states, derives from diffuse modulatory systems in the core of the brain stem, particularly the pons. The diffuse modulatory systems control the rhythmic behaviors of the thalamus, which in turn controls many EEG rhythms of the cerebral cortex; slow, sleep-related rhythms of the thalamus apparently block the flow of sensory information up into the cortex.

Question 6: The SCN receives direct input from the retina via the retinohypothalamic tract, and this is how light-dark cycles can entrain circadian rhythms. If the retinal axons were somehow disrupted, what would be the likely effect on a person's circadian rhythms of sleeping and waking?

Answer: Input from the retina to the suprachiasmatic nucleus (SCN) of the hypothalamus is essential and sufficient to entrain sleeping and waking cycles to night and day. When retinal axons are disrupted, and this essential input to the SCN is absent, the sleep-wake cycles cannot be entrained by light. Such an individual would be subject to a free-running clock, which would drift out of phase with the typical light or dark cycle because a free-running clock runs on a longer day than normal (25 hours in the short-term, 30-36 hours in the long-term). Such an individual would become sleepy during the day and wakeful at night, until the cycle drifted back into phase with the normal light or dark cycle.

Question 7: What differences would there be in the behavioral consequences of a free-running circadian clock versus no clock at all?

Answer: A free-running circadian clock still has certain alternating phases of sleep and wakefulness, and other behavioral and physiological cycles, such as body temperature, continue to alternate, although they may become desynchronized so that sleep-wake and body temperature cycle at their own pace, uncoupled. On the other hand, when the SCN is lesioned, circadian rhythms are abolished—the periodicity is lost. For example, squirrels and monkeys with no SCN have persistent high-frequency rhythms of both brain activity and temperature with no evidence of regular cycling.