Allison + van Twyer (1970)

# )F SLEEP

For most of us, sleep is a seemingly empty void except for an occasional remembered dream and a rested feeling after a night of slumber. This subjective impression is only partly correct. Each night, four or five times at intervals of about 90 minutes, the quiet repose of human sleep is interrupted by a curious set of physiological and mental events: A dream begins and develops its own inner logic. The dream narrative does not flash through the mind almost instantaneously, as was once commonly thought, but proceeds in "real time" with a duration about as long as the events would actually require. During the dream, the nervous system and bodily functions are very different from those of the preceding, nondreaming sleep. Heart rate and respiration become irregular, and the eyes move as if following the dream events. Muscular twitches of the hands or limbs occur, but otherwise the dreamer is still.

"Dreaming" sleep is not confined to *Homo sapiens*; based on laboratory studies, it is clearly present in many lower animals such as monkeys, cats, dogs, and rats. For these animals, however, we use a more cautious term—paradoxical sleep—to describe their apparent dream-sleep.

The concept of sleep, viewed in terms of both humans and lower animals, raises a number of important questions: If animals exhibit the symptoms of dream-sleep, do they actually dream? In what sort of animal did this type of sleep first arise, and for what reason? Is dreaming, and all the physiological changes that accompany it, a necessary biological event or, as Freud suggested, simply a means for satisfying psychological needs?

Through studies conducted by many investigators during the past fifteen years, we can provide tentative answers to these questions. Of the numerous species of living animals, the sleeping states of less than three dozen mammals and even fewer nonmammals have been studied in the laboratory. Still, enough is known to indicate the broad outlines of a story that takes us back almost 200 million years, to the time when mammals first appeared on earth. Lacking the opportunity to go back in time to observe the first mammals, we, and other investigators, have studied the sleep of certain living mammals that approximate critical stages of mammalian evolution in order to determine how these first mammals slept—and perchance dreamed.

How do we decide when an animal is sleeping? At first, this probably sounds like no problem at all: simply look at the animal and observe whether it is active or lying quietly, whether the eyes are open or closed. What would we say, however, in the case of a horse or cow, which seldom closes its eyes, or a fish or snake, which cannot? Humans as well as some other mammals have also been known to sleep with one or both eyes partially open.

Thus, casual techniques of observation are often not an objective means of telling when an animal is awake or asleep. Instead we use the electroencephalograph, or EEG machine, an electronic instrument used in hospitals to record the electrical activity of the brain. It consists of several very sensitive amplifiers that magnify the extremely small voltages generated by brain nerve cells. In humans these signals are detected by electrodes attached to the scalp, and the brain activity is recorded by an ink-writing pen on a moving paper chart. In animals brain activity can be recorded in the same manner, and with certain modifications of the machine, other physiological processes—such as breathing, heartbeat, and muscle activity—can also be recorded. To measure these physiological events, the animal is anesthetized and fine wires are placed in various regions of its brain and body. When the animal has recovered from the implantation, the electrodes are connected by cable to the EEG machine, which then records the changes that occur during waking and sleep. After implantation the animals are normal and do not appear to notice the electrodes or cables.

Typical EEG recordings during a cat's waking and sleep states appear on page 59. The tracings on the left were made while the animal was sitting quietly. Small electrical charges generated by the movement of the eyes were recorded by electrodes placed around the eyes. In the example shown there are two eye movements about four seconds apart. The electrical activity from the cerebral cortex, or gray matter, shows many small, fast fluctuations. (The cortex is nonexistent in reptiles. Increasingly prominent in higher mammals, it is believed to underlie complex mental functions.) The next tracing was taken from the hippocampus, an area deep within the brain involved with memory, whose electrical emanations accurately reflect changes in arousal. When the animal is alert and exploring its surroundings, nerve cells in the hippocampus tend to discharge electrical impulses in synchrony at the rate of several bursts per second, giving the record a rhythmic, wavelike appearance. Several such waves can be seen in the left-hand portion of the tracing. The third tracing shows electrical activity recorded from the neck muscles. During the waking state these are constantly active to support the head, resulting in large, rapid fluctuations recorded as a thick, ragged line.

When the cat goes to sleep (middle section), muscle tone is reduced but still present. Large eye movements cease, although there may be occasional slow, rolling movements. The activity of the brain is now markedly different. Large, slow waves, indicating the synchronous activity of many nerve cells, are recorded both in the cerebral cortex and the hippocampus, hence the name slow-wave sleep.

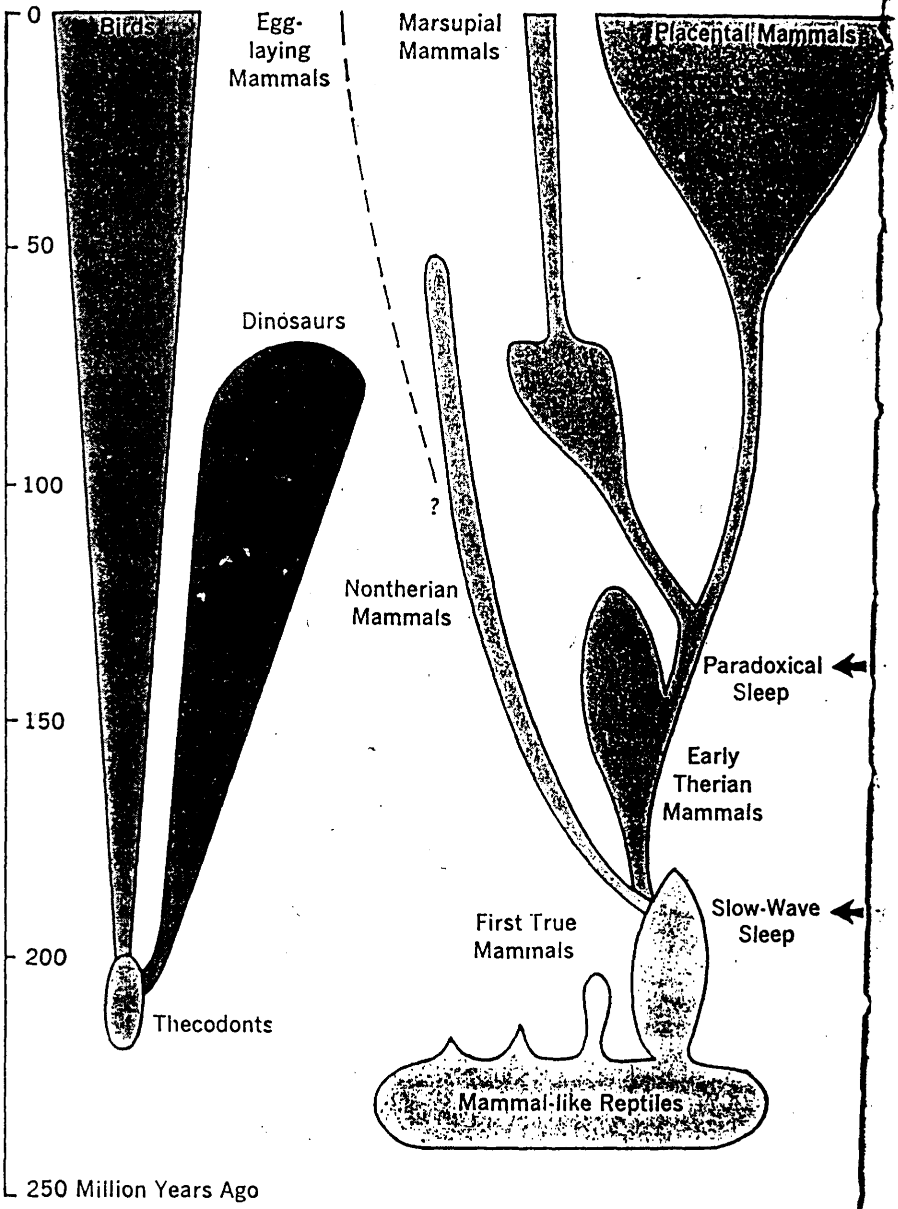
After several minutes of slow-wave sleep, the cat then passes fairly rapidly—the transition takes only a few seconds—into paradoxical sleep. Now a number of physiological events occur. Many of these—such as twitching and eye movements—are visible to an observer. Others can only be seen with the aid of the EEG machine. Eye movements, either singly or in bursts, appear and continue sporadically during the paradoxical sleep episode. The eye movements occur more often and are jerkier than during waking. Electrical activity of the brain is similar to that during waking. Indeed, the hippocampus waves are even more rhythmic than when the animal is very alert. All these signs indicate an alert waking brain, but clearly the animal is not awake, for now muscle tone has disappeared completely; the cat is limp and difficult to arouse. It is this discrepancy between what appears to be a waking brain and a deeply sleeping body that led Michel Jouvet of the University of Lyons, France, to coin the term paradoxical sleep. This state has also been called rapid eye movement, or REM, sleep. But since this phase of sleep occurs also in animals that rarely or never move their eyes we prefer the term paradoxical sleep.

In mammals these EEG signs of sleep are very clear, but in submammalian forms such as amphibians and reptiles, EEG recordings may not be adequate to define sleeping and waking periods because the animals have relatively undeveloped brains. In the lower animals, behavioral criteria are also necessary; sleep is defined as a period when the animal is quiet and less responsive to stimulation.

We begin our analysis of the evolution of sleep with the bullfrog and salamander, lowly amphibians that mark the point of transition from sea-dwelling to land-dwelling vertebrates. Both EEG and behavioral criteria indicate that they almost certainly do not sleep. Instead they alternate between periods of quiet and active wakefulness.

In reptiles, which evolved from amphibians, the presence of sleep is not clear-cut. Conflicting results have been reported by different investigators. As in amphibians, there are periods during which the animal is quiet and immobile but still essentially awake. If reptiles sleep at all, they have only the rudiments of sleep as compared to mammals.

During cold weather both amphibians and reptiles retreat to secluded places where they remain completely inactive until warm weather resumes. These periods of torpidity also occur in some familiar mammals such as bears.



Interestingly, both stages of sleep —slow-wave and paradoxical—are found in birds. In chicks and pigeons, small amounts of paradoxical sleep can be observed and a clear stage of slow-wave sleep is evident.

With some variation from animal to animal and from species to species, both kinds of sleep have been found in all higher mammals studied in the laboratory. So far, the list includes, in addition to humans of all ages, the chimpanzee and several other primates, various rodents, hedgehogs, bats, sheep, and goats—even the pilot whale. Visual observation of elephants at the Boston Zoo suggests that they too have paradoxical sleep. Since paradoxical sleep is present in animals as different in size as mice and elephants, and as different in life styles as bats and goats, it is probably safe to say that all higher animals have both slow-wave and paradoxical sleep. Given that sleep is probably not present in reptiles, but clearly present in mammals and birds, at what stage of mammalian evolution did sleep arise?

The diagram above summarizes

This phylogenetic tree summarizes the evolution of some reptile groups and their descendants. In the mammalian branch, slow-wave sleep apparently had evolved by the time noted by the first arrow. Paradoxical sleep arose some time after, but probably no later than the time indicated by the second arrow.

the probable evolution of mammals as it is presently understood by paleontologists. About 220 million years ago the most abundant land vertebrates were a diverse group of advanced reptiles, which had in some respects almost reached the mammalian level of development. The first true mammals, small creatures resembling shrews in appearance—and perhaps in behavior—descended from one of these reptilian groups about 180 million years ago.

All the later mammals probably derived from early mammals similar to this shrewlike creature. One group of descendants, the therians, eventually gave rise to the two main kinds of living mammals, the marsupials and the placentals. A second group, the nontherians, became extinct many millions of years ago with the exception of two that still survive, the platypus and the echidna. These remarkable animals are now found only in Australia and nearby islands, where they have survived because these geographically isolated islands were until recently inhabited only by relatively docile marsupials. Placental mammals tend to displace less cunning and aggressive neighbors.

The living nontherians—platypus and echidna—are hairy, maintain a constant body temperature, and nurse the young. They are therefore unquestionably mammals, even though they have retained a number of reptilian features, the most striking of which is that the young are hatched from eggs. These two egg-laying mammals seem to have changed little (except perhaps in external appearance) since they first evolved. They provide the opportunity to study sleep as it appeared in the first mammals.

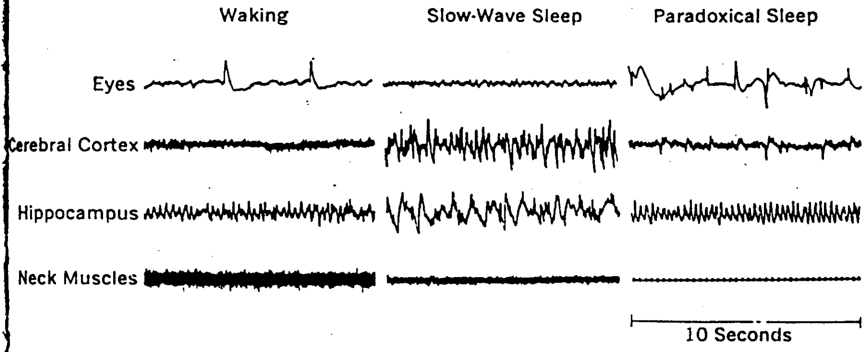
The platypus is difficult, if not impossible, to keep in captivity. The echidna, however, adapts readily to laboratory conditions. We obtained several echidnas through the cooperation of Mervyn Griffiths of the Commonwealth Scientific and Industrial Research Organization in Canberra and were able to study their sleep habits in detail. We found that this animal sleeps a great deal, up to twelve hours a day, and that its sleep is all slow-wave. We have not detected a single episode of paradoxical sleep. Instead the EEG reveals quiet periods that in many ways resemble the resting periods of reptiles. Because paradoxical sleep had been seen in all other mammals studied, we had expected to find it in the echidna as well.

It is possible that we were not able to see paradoxical sleep because its physiological and nervous system manifestations are radically different in primitive mammals. To test this possibility we studied sleep in another primitive mammal, the opossum. This marsupial, which has been called a living fossil, appears to have changed little since it first evolved. Just as the echidna gives us the best picture of earliest nontherian mammals, the opossum gives the best picture of early therian life. As it turns out, both slow-wave and paradoxical sleep are present in the opossum and are entirely similar to these states in placental mammals. The opossum revealed that paradoxical sleep is much the same in any mammal in which it is present at all, no matter how primitive the creature.

With this finding we then checked the hypothesis that paradoxical sleep is absent in the echidna because the animal is highly specialized in its life style, and not because it is primitive. To test this possibility we needed a placental mammal specialized, like the echidna, as a digging animal that spends considerable time underground and consequently has poor vision. We decided that the common mole would provide the best comparison. Even more adapted to life underground than the echidna, and like other animals that live in darkness, the mole's visual system has degenerated. The mole should therefore serve admirably as an "advanced echidna."

Moles, we found, are perfectly normal mammalian sleepers. Their slow-wave and paradoxical sleep, as measured by the EEG, are typical of that seen in other placental mammals and in the opossum. Like humans, moles sleep about eight hours a day; about one-fourth of this is paradoxical sleep. Furthermore, the electrical activity of their brain during sleep is similar to that of man.

These findings indicate that the lack of paradoxical sleep in the echidna is probably due to its primi-



These electrical recordings, made from a cat in its waking state and during two states of sleep, show that the pattern of activity in each state is clearly different. Recordings taken from other animals during the same states would look very similar.

## THE DREAM WATCHER'S GUIDE

Although episodes of "dreaming," or paradoxical, sleep can be determined most accurately in the laboratory, it can also be seen in animals found around the house, such as dogs, cats—and children. Indeed, its signs are so clear that, in retrospect, it is surprising that this kind of sleep was discovered less than twenty years ago.

In cats and dogs, watch for this sequence of events: When the animal first goes to sleep, "nondreaming," or slow-wave, sleep always occurs first. Respiration is fairly regular and slow. Bodily movements are infrequent and the animal is still and quiet. After a period of ten to twenty minutes the first paradoxical sleep period begins. Now the eyes can be seen moving under the eyelids, which may be partially open. Breathing is irregular: rapid, shallow breaths alternating with periods of breath holding. The ears and whiskers twitch, often accompanied by facial twitches and grimaces. The paws may twitch, occasionally in synchrony as if the animal were trying to run.

In children the signs of paradoxical sleep are much the same except that facial movements often include sucking movements. In babies a paradoxical sleep episode may directly follow feeding.

The frequency of paradoxical sleep varies according to body size, from about every nine minutes in the mouse, to fifty minutes in the monkey or child, to ninety minutes in adult humans.

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tive mammalian status, not to its particular way of life. We can judge by the echidna then that slow-wave sleep was present in the first true mammals, and thus had probably evolved in its present form about 180 million years ago.

Since paradoxical sleep is virtually identical in the marsupials and placentals it was probably present in their common ancestor among the early therian group. It is unlikely that paradoxical sleep evolved independently in both groups at some later time. If this reasoning is correct, paradoxical sleep probably evolved in its full-blown mammalian form about 130 million years ago, or as much as 50 million years after the development of slow-wave sleep.

This evolutionary history of sleep is somewhat speculative, since we are inferring from living animals events that took place in the distant past. There are, however, two types of investigation that could lend further credence to the sequential development of sleep—from nonsleep to slow-wave to slow-wave plus paradoxical sleep. One study would involve platypus research. If we found only slow-wave sleep in this animal, which came upon earth at about the same time as the echidna, it would support the hypothesis that paradoxical sleep evolved at a later stage of evolution. Because it appears impossible to study the platypus in the laboratory, tiny devices would have to be implanted under its skin to transmit EEG information to distant receivers, as is done with astronauts. The advantage of telemetry, as this method is called, is that the animal is free to live in its natural habitat.

In principle, a second way of testing the idea that slow-wave sleep and paradoxical sleep arose sequentially is to look at different birds that approximate critical stages of avian evolution. So far as can be determined from the scanty fossil record of birds, all living forms are relatively recent. There appear to be no really primitive forms comparable to the echidna and opossum. However, the appearance of both phases of sleep in birds does show that, just as birds and mammals independently evolved a four-chambered heart from the three-chambered variety of their reptile ancestors, both phases of sleep evolved independently at least twice (in birds and in mammals) in the course of vertebrate evolution. There may have been transitional avian species, therefore, which displayed slow-wave, but not paradoxical sleep.

What do these findings tell us about the biological role of sleep? The descendants of reptiles—the mammals and the birds—have two things in common: they both sleep, and they both maintain constant body temperatures despite changes in environmental temperature. The ability of mammals and birds to be active at any temperature is a distinct advantage over the reptiles, which become sluggish in cool weather. A disadvantage of this mechanism, though, is that a great deal of food is required to keep the bird or mammal body warm; it would be advantageous to turn down the body's "thermostat" when the stomach is full or danger is not imminent.

A clear example of this benefit of lowered body temperatures during sleep is provided by comparing shrews and bats. Both are small mammals. When active, their metabolic rates are very high. The shrew is a nervous little creature that scurries around almost constantly in search of food and that does not exhibit clear periods of sleep. Under ideal laboratory conditions or in its natural habitat both phases of sleep are very likely present, but observation under seminatural laboratory conditions indicates that the shrew is an animal that can, and probably does, get by with little sleep. In contrast, bats sleep up to twenty hours per day, and during sleep their metabolic rate drops considerably. The life-span of the short-tailed shrew is about two years, whereas bats of the same size live up to eighteen years. Thus the bat's ability to "turn himself off" apparently results in a ninefold gain in life-span. In most animals metabolic rate during sleep does not decrease as dramatically as it does in the bat, but nevertheless it seems clear that the ability to sleep, and thereby conserve energy, can prolong life.

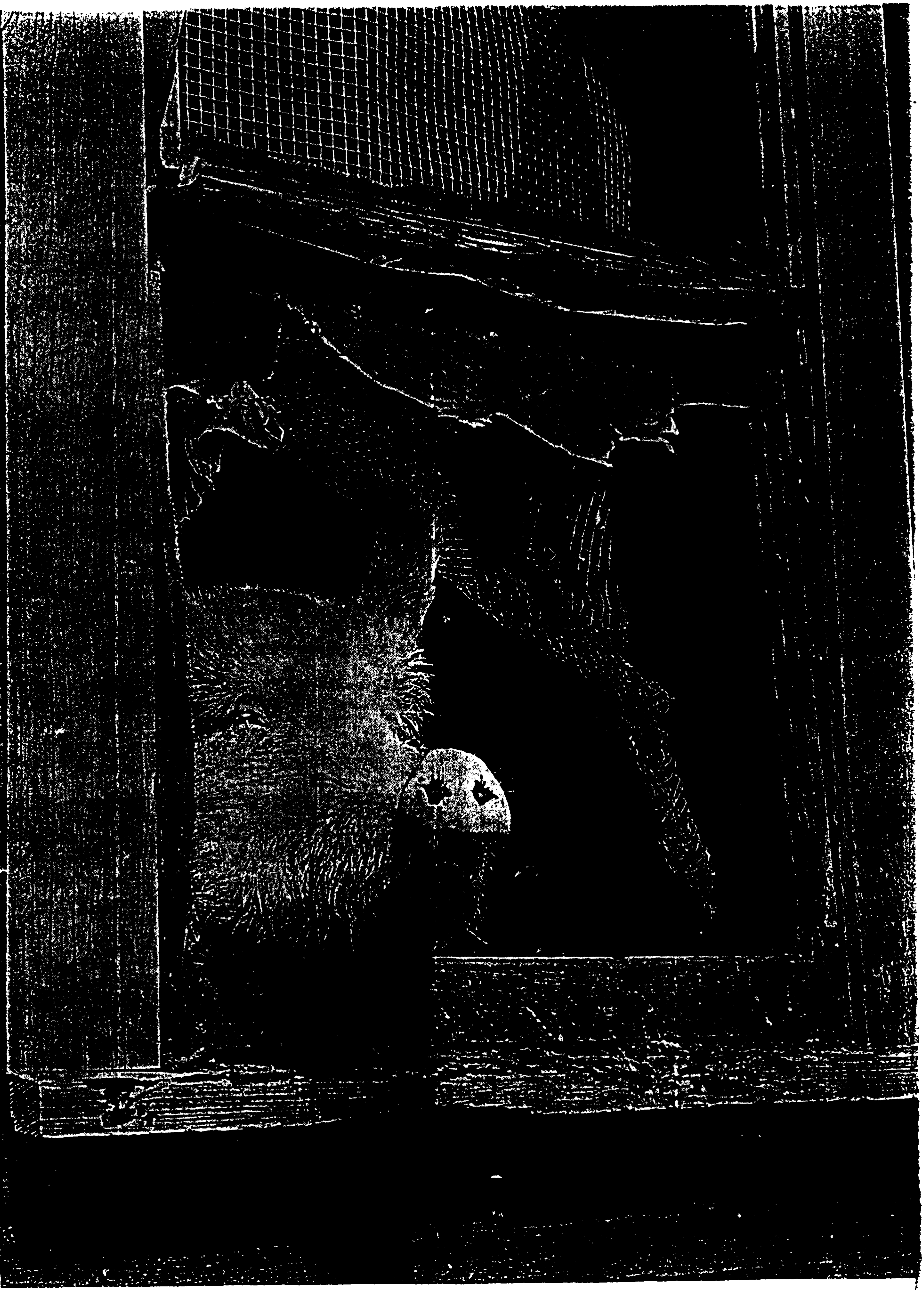
The daily temperature cycle (and therefore the underlying metabolism) is independent of sleep; therefore subjects deprived of sleep still have lower temperatures at those times that would correspond to normal sleep.

Specifically, we suspect that slow-wave sleep serves this function. It alone is present in the echidna, and it accounts for nearly all the sleep of birds, yet these animals maintain a constant body temperature as do marsupial and placental mammals. Paradoxical sleep in contrast is a time of heightened metabolic and nervous system activity. Slow-wave sleep may have evolved parallel with temperature regulation, as an active mechanism in the brain for periodically "forcing" mammals and birds—with their generally high body temperatures—to conserve energy. In amphibians and reptiles, whose body temperatures can drop to low levels, this active brain mechanism does not appear to be present.

For man, sleep is a recurring and persistent need. Attempts to stay awake for prolonged periods can have disastrous consequences, both psychological and physiological. Not every mammal, however, must bow to the demands of eight hours sleep per day. Certain of them, notably the hoofed animals, have evolved the ability to do without much sleep. In

| ANIMAL | BEHAVIOR AND HABITAT | SLEEP |
|---|---|---|
| | "Good Sleepers" | |
| Mole | Carnivore, active day or night. Lives below ground in an extensive network of burrows. | Sleeps 8 hours per day in lab with almost no adaptation. 24% paradoxical sleep. |
| Ground squirrel | Herbivore, hibernates, prey. Lives in extensive burrows of its own making. | Deep sleeper, about 14 hours a day in lab. 25% paradoxical sleep. |
| Cat | Predator. Only the domestic cat has been studied. | Deep sleeper, readily sleeps about 14 hours a day in lab. 27% paradoxical sleep. |
| Macaque | Omnivore, strong fighter. Sleeps in tops of tall trees. | After short adaptation sleeps 8 hours a day, 15-20% paradoxical sleep. |
| Chimpanzee | Omnivore, most similar to man. Lives in tropical rain forests and shelters in tree nests at night. | After relatively short adaptation, sleeps 11 hours a day. 19% paradoxical sleep. |
| Man | Omnivore. Has mastered defense from other species and the elements. Chief predator is man. Inhabits all ecological ranges. | Deep sleeper. After short adaptation sleeps 8 hours in lab. 24% paradoxical sleep. |
| | "Poor Sleepers" | |
| Guinea pig | Herbivore; nervous, hyperactive, excitable; prey. Lives in burrows, which it excavates or borrows, in rocky areas, savannas, swamps, and at edges of forests. | After long adaptation will sleep 12 hours per day. 5% paradoxical sleep. |
| Rabbit | Herbivore, prey. Some strains are extremely nervous and easily excited. Usually lives in grass nests on the surface or occasionally in burrows. | Difficult to adapt; sleep is seen only after several months in lab with some strains. Up to 15% paradoxical sleep when well adapted. |
| Sheep | Herbivore; nervous, excitable; prey. Lives in grasslands. (Study includes only domestic species.) | Requires long adaptation. About 4% paradoxical sleep. |
| Goat | Herbivore, excitable, prey. Lives in grasslands or mountains. (Only domestic species studied.) | After two months adaptation will enter paradoxical sleep, but only rarely. |
| Donkey | Herbivore, excitable, prey. Lives in grasslands. (Only domestic species studied.) | After several months in lab will sleep about 4 hours a day, but paradoxical sleep apparently not seen. |
| Baboon | Omnivore. Strong fighter but subject to predation. Lives at edges of forests, in savannas and rocky areas. Sleeps in tops of scrub trees where it is easily visible. | Enters paradoxical sleep phase after extended adaptation. 4-9% paradoxical sleep. |

Animals that have been studied in the laboratory can be divided into "good sleepers" and "poor sleepers." Good sleepers are either predatory or have secure sleeping places included in their way of life. Poor sleepers tend to be animals subject to predation at all hours; they sleep less and experience less paradoxical sleep.



these animals sleep is seen only under very carefully controlled laboratory conditions and then only after extended periods of adaptation.

There are several factors that determine how much a particular species needs to sleep, but perhaps the clearest is the predator-prey relationship. Predators such as men, cats, and dogs are good sleepers, whereas the animals most subject to predation at any time of the day, the hoofed mammals, are generally very light sleepers. Browsing animals—such as sheep, goats, and donkeys—were derived from wild species that were continually exposed to predators. These animals are poor sleepers and only rarely enter the paradoxical sleep phase. Only under the most carefully controlled conditions will they sleep in the laboratory. (This is also true of the rabbit, chinchilla, and guinea pig.) Folklore holds that domesticated ungulates do not sleep at all. When questioned, those familiar with various farmyard species usually cannot recall having seen one of them lying down with eyes closed, obviously asleep. It is probable, although lack of exact knowledge of their habits makes it impossible to say with any certainty, that most poor sleepers are surface-dwelling mammals that, because of their habitat or size, cannot retreat to well-protected dens or burrows to sleep.

Good sleepers, however, are not always predators. As examples, consider the 13-lined ground squirrel and the hamster, which live mainly on vegetation yet are good sleepers. These animals are not predatory but are themselves subject to predation. They are not surface-dwellers, however, and thus need not constantly monitor their surroundings. The ground squirrel or hamster snugly enclosed in its burrow can afford the luxury of deep sleep. Another example of a deep-sleeping nonpredator is the macaque monkey of Asia, a species studied in the laboratory. This primate is able to afford the luxury of deep sleep because his environmental surroundings allow it. He sleeps in treetops that have dense foliage at the crown. Nocturnal predators are rare. He is light in weight, nimble and small, and can climb to high places that his chief enemies cannot reach. The macaque is a relatively deep sleeper with high percentages of paradoxical sleep. In contrast, the African baboon, although a savage and bold fighter, is insecure while sleeping. At night, his chief enemy, the leopard—a skillful climber—is most active, and the baboon must seek the tops of the tallest trees available. Cover is poor in the scrubby trees of the savanna environment, and he is usually quite visible, silhouetted against the night sky. As a result, the baboon is a fitful sleeper and rarely enters the paradoxical sleep phase.

We believe, therefore, that the essential difference between good sleepers and poor sleepers depends on the security of the animal's sleeping arrangements and not solely upon his food-getting status. Examination of the list of animals studied in the laboratory indicates that secure sleepers tend to have large amounts of paradoxical sleep. Thus it appears that deep sleep and high percentages of paradoxical sleep go hand in hand with a safe sleeping arrangement. Returning to our comparison of shrews and bats, we propose that the bat can afford to sleep deeply because its security during sleep is assured, suspended as it is from the ceiling of a cave or attic. The shrew, primarily a surface-dweller, must be much more circumspect about the duration and depth of its sleep.

The importance of security for deep sleep has also been suggested by H. Hediger, a zoologist who has observed animals in their natural habitat. He notes that the antelope probably never sleeps whereas the Indian sloth bear, a fighter so competent that even the tiger avoids him, sleeps deeply.

What biological function is served by paradoxical sleep? Clearly evident in man, the most advanced mammal (while absent in the echidna, a primitive mammal), this form of sleep does not appear to be a vestigial remnant of our prehistory.

Apparently, paradoxical sleep is not simply a mechanism to provide dreaming. It occurs in situations in which the possibility of dreaming is remote. Cats that have had most of the brain removed, except for the vital respiratory and cardiac centers in the medulla, still have paradoxical sleep. Similarly, human beings with diseases that essentially disconnect the cerebral cortex and higher centers of the brain nevertheless have periods of paradoxical sleep. In both these situations it seems unlikely that dreaming could occur. Thus, it seems that dreaming does not necessarily occur during paradoxical sleep. It is interesting that these results also suggest that dreaming does not cause paradoxical sleep, but, if anything, is caused by it. Perhaps an increase in heart rate and rapid shallow breathing evoke emotional dreams, rather than the other way around.

One of the most striking and unexpected findings of sleep research is that newborn mammals, whether they are humans, cats, or rats, have much more paradoxical sleep than adults. The human newborn, for example, spends about 50 percent of his sleep in the paradoxical phase, while adults spend about 24 percent. (Premature infants spend an even larger percentage of their sleep in this state.) These studies suggest that at earlier stages of prenatal development, all sleep may be paradoxical.

These findings have prompted a plausible theory for the biological significance of this form of sleep. The rapidly developing fetal nervous system presumably needs a great deal of excitation to build in the neural circuitry necessary for the development of integrated behavior patterns. Because paradoxical sleep is a time of intense central nervous system activity, it may provide a period of nerve "exercise," the stimulation coming from within the brain instead of from the environment. In the course of maturation less internally generated brain stimulation is necessary because sensory stimulation is now available from the environment; the amount of paradoxical sleep, therefore, declines.

Other findings seem to lend support to this hypothesis. At birth, poor sleepers such as the guinea pig and lamb have less paradoxical sleep than more secure sleepers such as man and the cat. The former, however, are born at an advanced level of nervous system maturation. Shortly after birth they can walk, and their sensory systems are functional, unlike man and the cat who are born completely helpless. Presumably, since the sensory systems are well developed they need less internally generated stimulation and spend less time in paradoxical sleep. Similarly, the young of the hoofed mammals must quickly develop a responsiveness to their environment; the rapid maturation of the brains in such species and their small amounts of sleep are both adaptive responses to the same environmental pressures.

An intriguing theory of the biological role of paradoxical sleep was suggested by Frederic Snyder of the National Institute of Mental Health. His view is that this "third state of existence," as he calls it, serves to periodically arouse the sleeping animal so that he can inspect his environment for danger. In times of danger, animals (or men, for that matter) tend to sleep fitfully, in short bursts, and may awaken during a paradoxical sleep episode. This would explain why the insecure sleepers such as sheep, or guinea pigs get so little paradoxical sleep.

The advantage of such a "sentinel" mechanism is obvious: the animal is assured that his sleep will not be unduly prolonged; possibly forever in the case of the rabbit that does not see the approaching hawk. Furthermore, an animal aroused from paradoxical sleep is alert and reactive, ready for fight or flight, whereas awakened from slow-wave sleep he is disoriented for a few seconds. In addition, several kinds of evidence indicate that humans or cats can discriminate meaningful stimuli better during paradoxical sleep than during slow-wave sleep. Not only might paradoxical sleep serve to awaken the animal in danger, but he would awake ready to react in an integrated manner.

As far as can be determined with laboratory techniques, paradoxical sleep is similar in all mammals that exhibit it—from the opossum, a prototypal therian, to man, presumably the most advanced mammal. How similar, however, is the mental activity that might accompany the physiological signs of dreaming in animals and man? Is it possible, for example, for animals to experience visual imagery and other sensations during paradoxical sleep?

These are difficult questions to answer. We already know that paradoxical sleep can occur even when the possibility of any complex mental activity is highly unlikely. If we cannot automatically assume that dreaming occurs in humans during paradoxical sleep, we must certainly be cautious in making such an assumption about animals. Furthermore, to what extent can we ascribe human kinds of subjective experiences to an animal? Many scientists believe this is a futile, hazardous, even heretical undertaking. Darwin, on the contrary, insisted that mind, or consciousness, was a biological phenomenon that evolved from lower forms in much the same way as did anatomical characteristics. He pointed out that emotional expressions indicating particular "states of mind" were obvious in all animal forms. He went so far as to say, "even insects express anger, terror, jealousy, and love by their stridulations."

While it is difficult to attribute such complex emotions to so simple a beast as a cricket, it is reasonable to suppose that visual, auditory, and tactile imagery occurs in mammals. Most scientists have no particular qualms about attributing subjective states such as pain, hunger, and fear to animals. Yet an animal's outward manifestations of these states are not nearly so clear, not nearly so similar to the human manifestations of these states, as are the animal's signs of dreaming. We agree with the view stated many years ago by Julian Huxley:

"It is also both scientifically legitimate and operationally necessary to ascribe mind, in the sense of subjective awareness, to higher animals. This is obvious as regards the anthropoid apes: they not only possess very similar bodies and sense-organs to ours, but also manifest similar behavior, with a quite similar range of emotional expression, as anybody can see in the zoo; a range of curiosity, anger, alertness, affection, jealousy, fear, pain and pleasure. It is equally legitimate and necessary for other mammals, although the similarities are not so close. We just cannot really understand or properly interpret the behavior of elephants or dogs or cats or porpoises unless we do so to some extent in mental terms. This is not anthropomorphism: it is merely an extension of the principles of comparative study that have been so fruitful in comparative anatomy, comparative physiology, comparative cytology and other biological fields."

If one is willing to admit that it is possible to infer dreaming in animals, then several lines of evidence indicate that it actually does occur. Recall that muscle tone in the cat is completely suppressed during paradoxical sleep. If the brain center that produces this suppression is not functioning, however, a bizarre pattern of events takes place during the cat's paradoxical sleep. Although completely asleep, the cat will display behavior almost identical to that during the waking state. It will rise, walk about, attack invisible enemies, stalk an imaginary prey, or sit quietly and follow an unseen object with its eyes for periods of several minutes—all while deeply asleep! It is difficult for an observer to deny that some sort of imagery is present in the cat brain at these times.

In another experiment that suggests dream life in animals, monkeys were trained to press a lever when they saw patterned stimuli flashed on a screen before them. Later, during sleep, they were seen to press the lever as if they were hallucinating or dreaming of the stimuli acquired during the waking state. Techniques such as this bypass the problem that animals cannot give us spoken reports of their dream life.

We are willing to conclude that imagery occurs during paradoxical sleep in animals. To the extent that they are capable of mental life during waking it is equally plausible to grant them the power of dreaming during sleep. And what do they dream about? Anyone who owns a dog has witnessed the trembling, jerking, abortive running movements, the grimacing and whimpering that periodically occur during sleep. A dream of a rabbit chase? Why not? Freud thought that dreams are often wish fulfillments. In *The Interpretation of Dreams* he wrote: "I do not myself know what animals dream of. But a proverb, to which my attention was drawn by one of my students, does claim to know. 'What,' asks the proverb, 'do geese dream of?' and it replies: 'Of maize!' The whole theory that dreams are wish fulfillments is contained in these two phrases." Perhaps cats dream of the perfect mouse, and moles of big juicy earthworms. We like to think so.