THE EVOLUTION OF SLEEP

1. **Introduction**

All animal species (vertebrates and invertebrates) show consolidated periods of activity and inactivity

All show BRAC ultradian rhythm (incl. single-celled organisms)

But not all animals show true sleep (as defined by human/mammalian sleep)

Is this too homocentric a definition?

Some species show special needs that have affected their sleeping patterns

e.g. Cetaceans, ground roosting birds of prey

TST varies across mammal species, with no clear relationship between TST and other factors, with possible exception that predators/carnivores sleep longer than prey/herbivores (safety vs. dietary needs)

e.g. Donkey – 3 hours TST
Human - 8 hours
Guinea Pig – 9.5 hours
Rat – 12 hours
Rabbit – 14.5 hours
Cat – 14.8 hours
Opposum – 19.2 hours (marsupial)

2. Evolution of Sleep – **Some Background Information**

220-250 million years ago – most animals were the **advanced reptiles**

large terrestrial animals, may have had social groupings, may have shown cooperative hunting, may have had more complex brains

may have been capable of homeothermic regulation

gave rise to modern bird species

mammalian line would have also split off of a common ancestral reptilian form many years before this

first true mammals appeared **180 million years ago** (small insectivores)

2. **<u>Background Information (cont.)</u>**

Non-therian mammals (monotremes)

Egg-laying mammals (like their reptilian ancestors)

Sort of transitional mammals: had body hair, moneothermic, nursed young (had mammary glands)

Two species survive today: Duck-billed Platypus
Echnidna (anteater)

Therian Mammals (give birth to live young)

About 130 million years ago, this line split again

Marsupials – give birth to "fetal" young, which then carried by mother until more mature, attached to teat

Two living species: Kangaroos (only Australia), Opossum (No.Amer.)

Placental Mammals – give birth to live young, having been retained inside mother's body until mature, fed via placenta

So, the question is: What sort of sleep patterns do these transitional and true mammals show?

Duck-billed Platypus – sleeps 8 hours/24, has REM and NREM

Echidna – has NREM, but no REM

All therian mammals – have both REM and NREM, but with different patterns, timing, amounts of these sleep stages

What about earlier than mammals?
What about sleep in invertebrates?
What about sleep in fish, reptiles, and birds?

As usual**, It depends on your (operational) definition of what SLEEP is!**

3. **How to Define Sleep**

sleep is not rest
sleep is not torpor
sleep is not coma
sleep does not mean immobility
sleep does not mean lying down
sleep does not mean having closed eyes

Sleep is a) a lack of/decrease in awareness of environmental stimuli
b) the maintenance of core body temperature (in homeotherms)
c) relatively easily reversible (to wakefulness)
d) has distinct EEG patterns (different from wake)
e) has spontaneous occurrences with an endogenous periodicity (independent of other bodily needs and environmental cues)

note: researchers using non-humans (especially invertebrates) often use more **behavioral** definitions:
Inactivity
S is difficult to arouse (but can be aroused)
Stereotypic postures (often species-specific)
Predictable cycles
Rapid return to wake/activity once aroused
If *S* is prevented from "sleep", the *S* becomes more prone to inactivity

Thus, the most complex expression of what sleep is is found in the EEG wave changes seen in mammals (complex brains). However, more basic processes (such as behavioral changes) most likely also represent a kind of "sleep", even though no such EEG patterns have been (or are likely to be?) recorded.

So…what about those fish, lizards, birds and bees?

4. **Fish and Amphibians**

show periods of activity and inactivity, cyclic

show less response to environmental stimuli in "quiet" times, but are not unresponsive…so maybe are just "**resting**"

EEG data scare, but does not look much different from wake

5. **Reptiles**

EEG distinctly different from wake (low voltage, faster 11-13 cps)

High amplitude, sharp spikes, low frequency (6-8 cps)

Muscle relaxation

= **SWS**?

May show evidence of "**precursor REM**": clustered bursts of REMs,

Front paw twitches, occurs cyclicly ; no change in EEG

Recorded in Caimans, chameleons, other lizards, turtles

6**. Birds**

EEG has distinct sleep stages, including **SWS and brief bursts of paradoxical sleep** (10-15 second duration bursts)

Note: Would be see more paradoxical sleep if we recorded EEG is hatchlings?

Yes (hatchlings: 7.5% vs. adults: < 1%)

Same phenomenon seen in mammals: **all species of mammals have greater percentage of REM in fetus/neonate than in adults**

(kittens have 90% REM in 1-10 days post-natal; neonate rats >90% REM)

In paradoxical sleep in birds: see "alert" EEG, loss of muscle tone (note:

Foot tendons can lock foot in grip position while muscles relaxed)

Predatory birds have more paradoxical sleep than do prey birds

Why?

TST averages 7.75 hours/day

Unihemispheric sleep in roosting birds

"sleep" EEG in brain hemisphere contralateral to closed eye, wake EEG in brain hemisphere contralateral to open eye

note: **unihemispheric sleep seen also in Cetaceans**…Why?

7**. <u>Insects</u>**

Yes, insects “sleep”

Based more on behavioral criteria, no EEG recordings

In bees, wasps, flies, dragonflies, moths, butterflies, grasshoppers, *Drosophila*

If forced to remain active, show increased tendency to remain still

And “rest” time shows compensatory durations

If fed stimulants (e.g. caffeine) the “rest” time durations decrease initially, and then show compensatory increases in duration

If fed sedative-hypnotics (e.g. benadryl) the “rest” time durations increase

If prevent Drosophila from “sleep” for 14 days --- they die