University of Zurich

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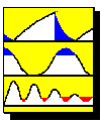
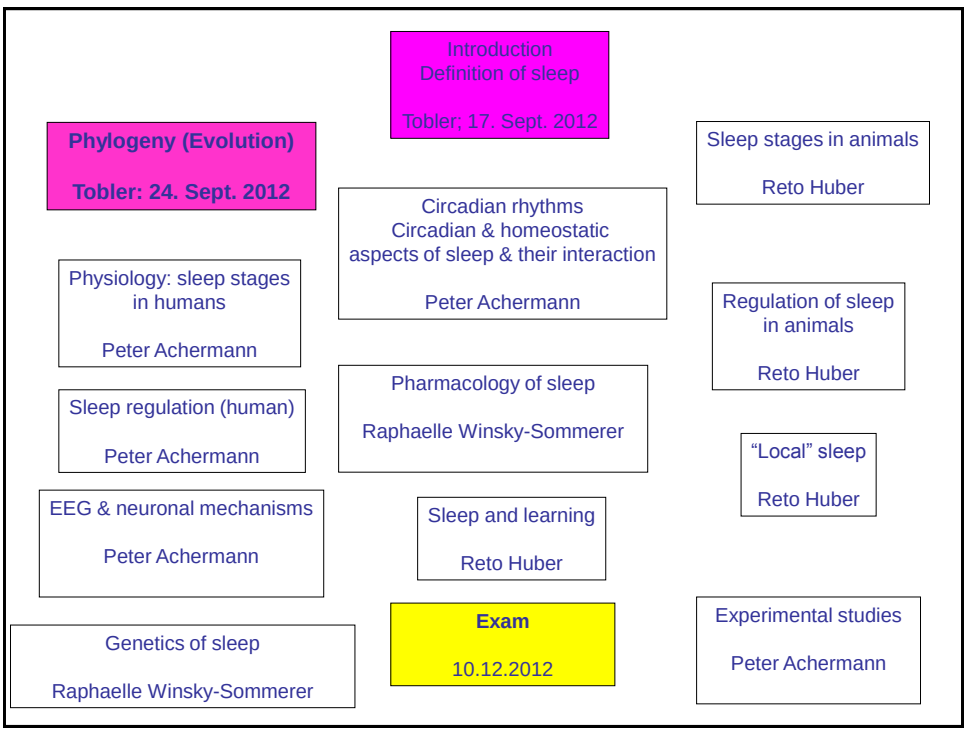


Phylogeny (Evolution) of sleep

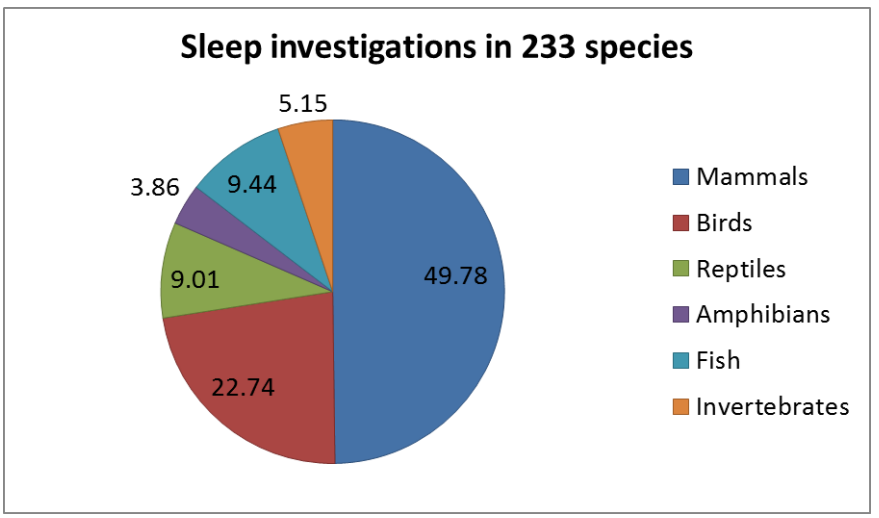
Irene Tobler

BIO 333: HS 2012; September 24, 2012



Trace the *phylogenetic origins* of sleep

"Sleep is universal"



Tobler, March 2012

1. Trace the *phylogenetic origins* of mammalian sleep

common ancestor →

- monotremes
- marsupials
- placental mammals
- birds
- reptiles
- amphibians
- fish

Monotremes: „Key species“ in evolution

basal position before the Theria (Marsupials & Eutheria)

1. Short-beaked Echidna (anteater)

Tachyglossus aculeatus

1972: no REM sleep !

but another story surfaced in 1996….

Allison & McTwyver, 1972

The Journal of Neuroscience, May 15, 1996, 16(10):3500–3506

Siegel et al, J Neurosci. 1996

The Echidna *Tachyglossus aculeatus* Combines REM and Non-REM Aspects in a Single Sleep State: Implications for the Evolution of Sleep

J. M. Siegel,[1] P. R. Manger,[2] R. Nienhuis,[1] H. M. Fahringer,[1] and J. D. Pettigrew[2]

[1]*VAMC Sepulveda and UCLA School of Medicine, Neurobiology Research, Sepulveda, California 91343, and* [2]*Vision, Touch and Hearing Research Centre, University of Queensland, Brisbane, Australia*

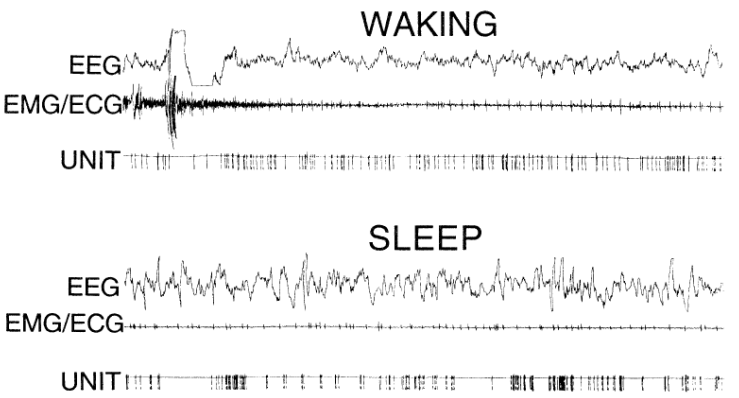


Figure 3. Unit discharge of a representative neuron recorded in the nucleus reticularis pontis oralis of the echidna during waking and sleep. Note irregularity of neuronal discharge during sleep. EEG, EMG–ECG (electromyogram–electrocardiogram) unit, pulse output of window discriminator triggered by neuron. Duration of recordings is 30 sec.

Monotremes: „Key species“ in evolution

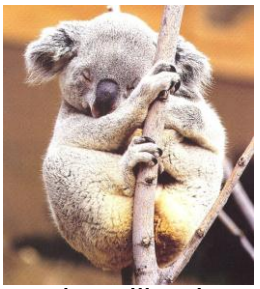
60% of TST is REM sleep

7-8 h REM sleep per 24 h

2. Duck-billed Platypus

Ornithorhynchus anatinus

Siegel et al, Neurosci. 1999



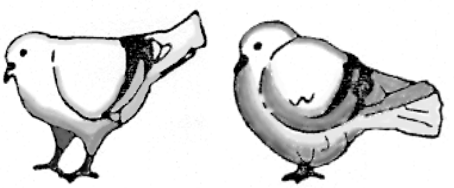
Koala, still unknown

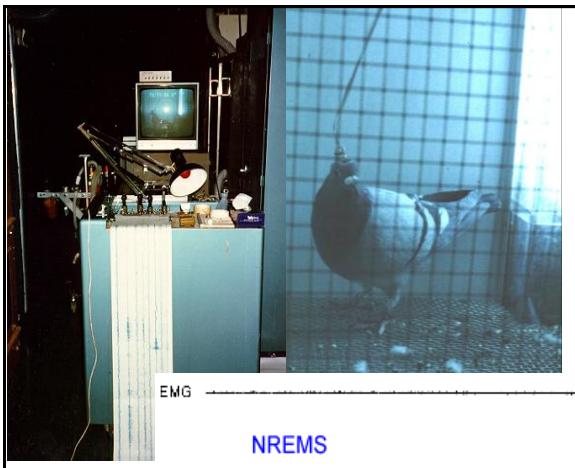
Marsupialia:
Sleep was recorded in:
Kangaroo, Opossum

No special features
except for rel. large amounts
of REM sleep

Opossum (6.6 h REM sleep/day)

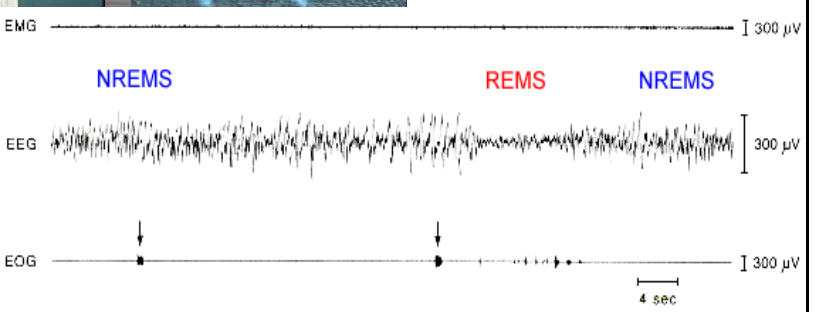
sleep behavior is evident in birds





Simultaneous observation and polysomnography: birds have NREMS and REMS

REMS epochs are short

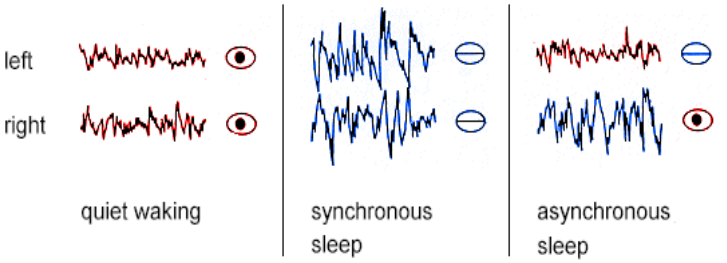


Tobler & Borbély, J Comp Physiol 1988

Short unilateral eye-openings correlate with a waking EEG pattern in the contralateral hemisphere

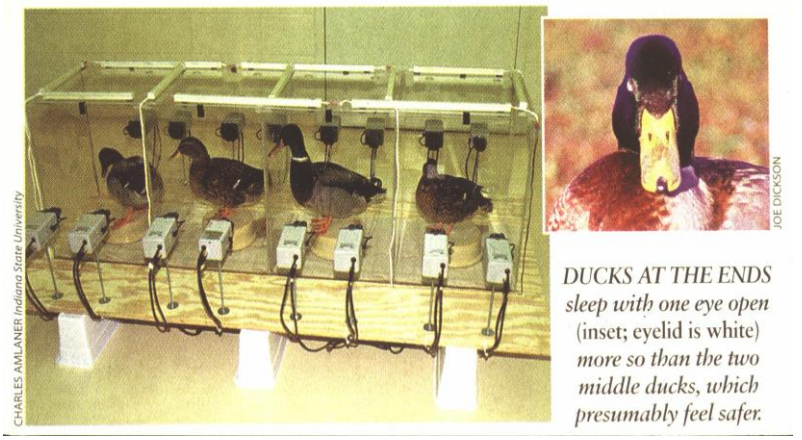
"blinking"

Seagulls



Amlaner & Ball, 1994

Functional significance of unilateral eye closure



DUCKS AT THE ENDS sleep with one eye open (inset; eyelid is white) more so than the two middle ducks, which presumably feel safer.

Amlaner et al, 2001

Rattenborg et al, Behav Brain Res 1999

Migration is still unresolved

PLOS Biol 2004

Migratory Sleeplessness in the White-Crowned Sparrow *(Zonotrichia leucophrys gambelii)*

Niels C. Rattenborg[1], Bruce H. Mandt[1], William H. Obermeyer[1], Peter J. Winsauer[2], Reto Huber[1], Martin Wikelski[3], Ruth M. Benca[1*]

ARDEA 2002

DO MIGRATORY BIRDS NEED A NAP AFTER A LONG NON-STOP FLIGHT?

REGINE SCHWILCH[1], THEUNIS PIERSMA[2], NOEL M. A. HOLMGREN[3] & LUKAS JENNI[1]

Bar-tailed godwits

Extreme endurance flights by land birds crossing the Pacific Ocean

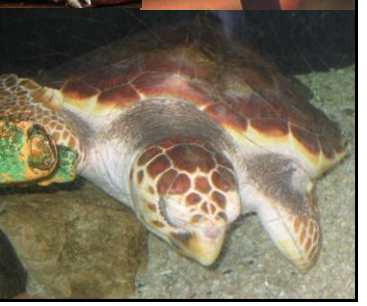
Gill et al, Proc R Soc B 2009

Four living orders of the class reptiles

- Lizards and snakes (*Squamata*)
- Turtles and tortoises (*Chelonia*)
- Alligators, caimans, crocodiles & gharials (*Crocodilia*)
- Tuatara (*Rhynchocephalia or Sphenodontia*)

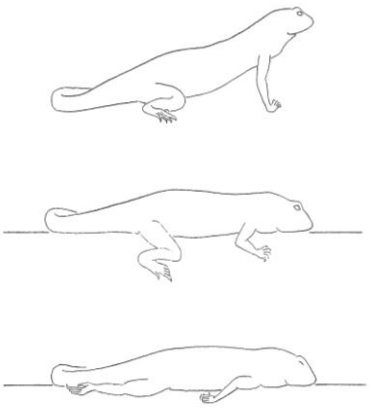
Capacity to remain in quiet waking

prey stimuli
temperature



Lizards:

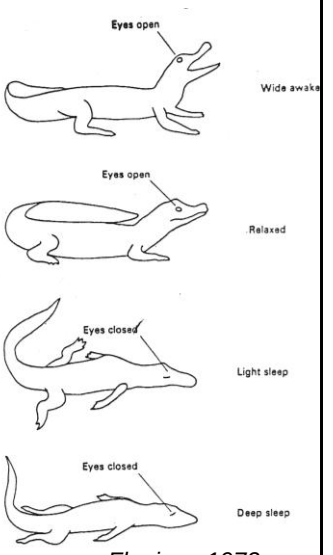
Desert iguana (Dipsosaurus dorsalis)



Huntley AC 1979

Crocodiles:

Caiman



Flanigan 1973

Chameleon behavior:

Specific sleeping site

“Sleep posture”

No movement (quiescence)

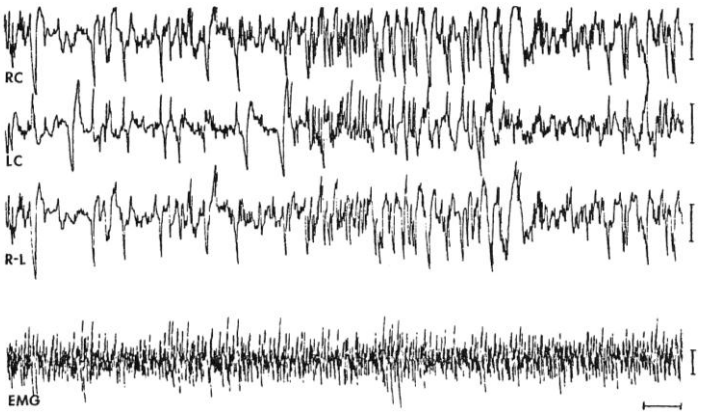
Change of color

No EEG/EMG/EOG recordings

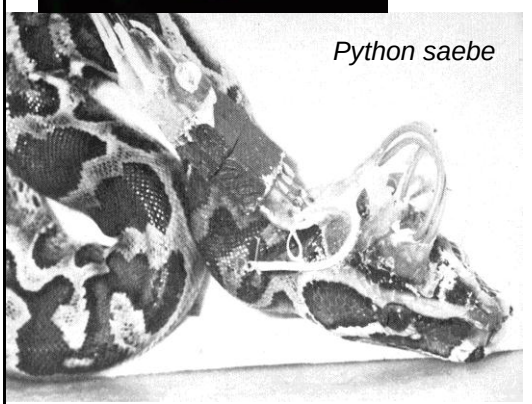
Eye movements visible

Typical example of reptilian EEG and EMG traces during active waking

Iguana (*Dipsosaurus dorsalis)*



Huntley 1979



Python saebe

Peyrethon J & Peyrethon D, *1968*

pit viper (*Agkistrodon)*

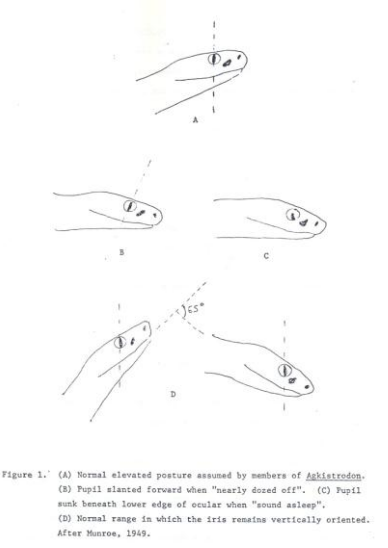


Figure 1. (A) Normal elevated posture assumed by members of Agkistrodon. (B) Pupil slanted forward when "nearly dozed off". (C) Pupil sunk beneath lower edge of ocular when "sound asleep". (D) Normal range in which the iris remains vertically oriented. After Munroe, 1949.

Munroe, 1949 in William K Hayes, 1984

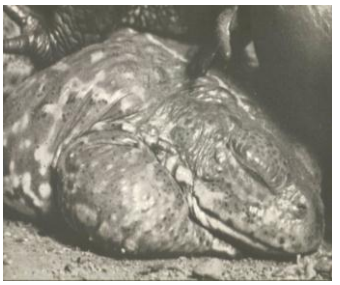
Polysomnogragraphy in reptiles

Clear EEG differences between waking and sleep behavior

EEG spike-like activity, correlates of slow waves in mammals?

No obvious REM sleep

Amphibians



bullfrog

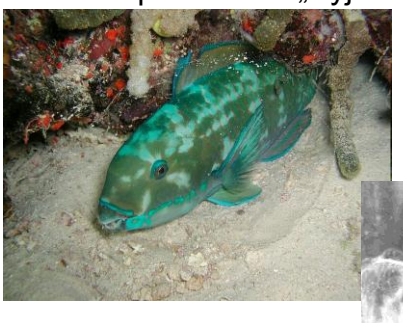
No conclusions possible

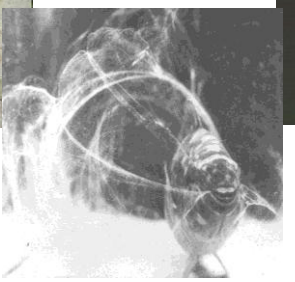
treefrog

Manifold manifestations of behavioral sleep in Teleosts

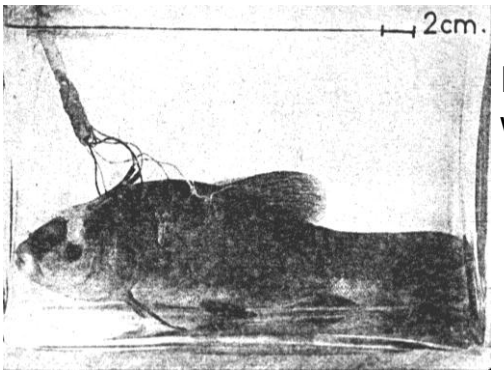
"sleep swimming"

Rainbow parrotfish : „Pyjama“





Boxfish: Guinea fowl puffer



Tench (*Tinca-tinca)*

Polysomnography was inconclusive

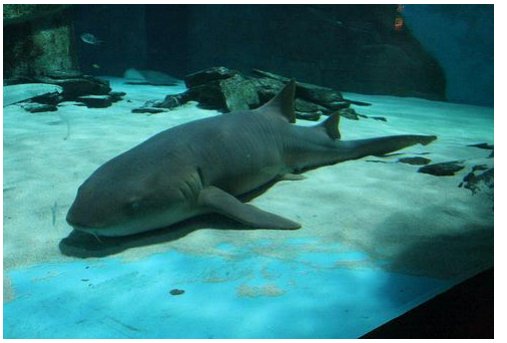
Peyrethon, 1968

Zebrafish (*Danio rerio)*

Many aspects of sleep are documented..… genetics

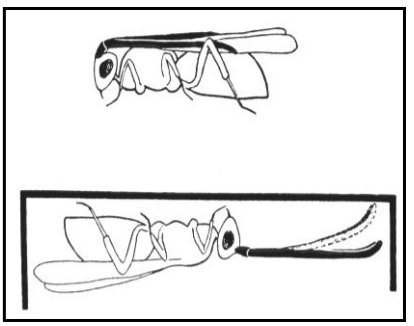
Yokogawa et al, PLOS Biol 2007

Fish: *Chondrichthyes*



1. Can sleep be defined in invertebrates ?
2. Can invertebrates be used as „less complex models“ to investigate sleep ?

Wasp (*Habrobracon*)



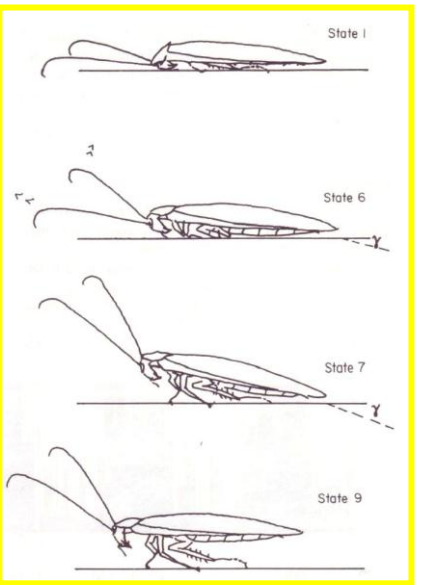
Schulze, 1924

Cockroach (*Leucophea maderae*)

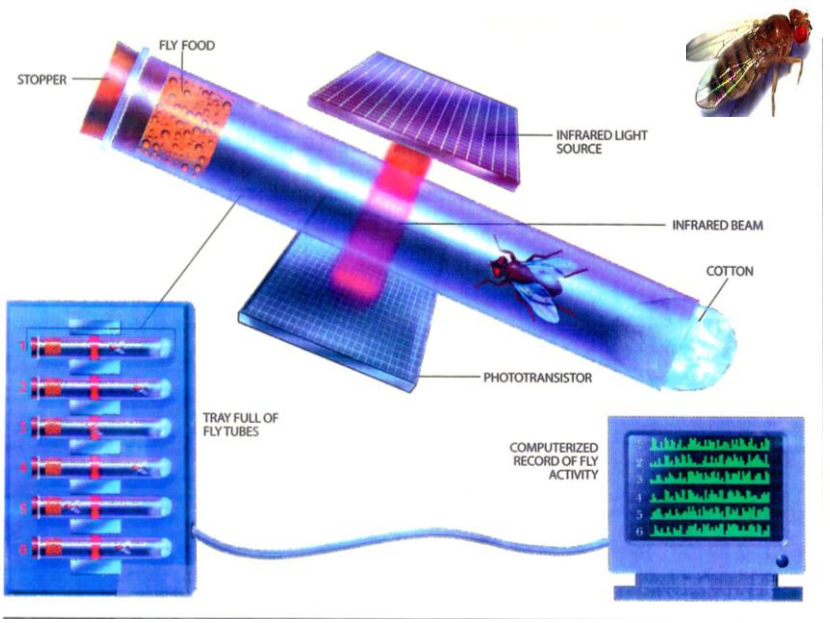
Tobler 1983; Tobler et al, 1984

Behavioral states

Posture and arousal



Tobler & Neuner-Jehle, JSR 1992

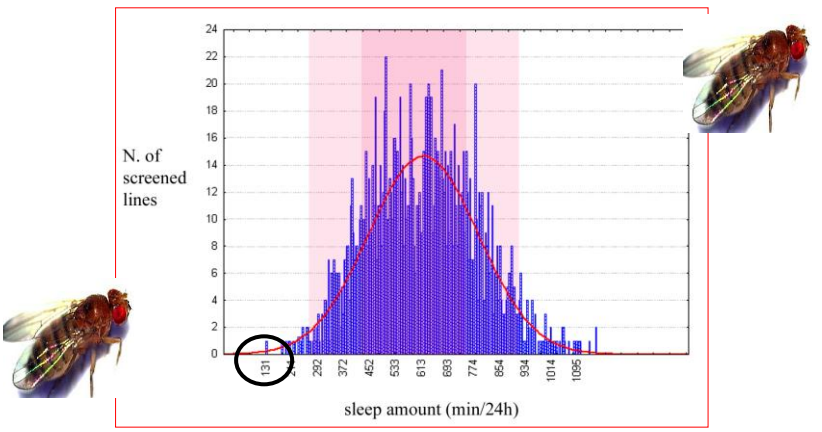


by Cynthia Turner

Definition of sleep in Drosophila

	Mammals	Drosophila
behavioral sleep	√	√
elevated arousal threshold	√	√
circadian rhythm	√	√
sleep homeostasis duration	√	√
sleep homeostasis intensity	√	√
reduced performance after sleep deprivation	√	√

Sleep duration in Drosophila: mutants with short and long sleep (screening of > 9000 mutants)



Pave the way to investigate genetics of sleep

Cirelli, Bioassays 2003
Cirelli et al, Nature 2005

Reizen et al, Nature 2008

Lethargus is a *Caenorhabditis elegans* sleep-like state

David M. Raizen[1,2], John E. Zimmerman[1], Matthew H. Maycock[1], Uyen D. Ta[1,2], Young-jai You[3], Meera V. Sundaram[3] & Allan I. Pack[1,4]

Activity recording in *C. elegans* & their response to rest deprivation