Comparative physiology and pharmacology of sleep

Sleep stages in humans

Peter Achermann

Abteilung Chronobiologie und Schlafforschung
Institut für Pharmakologie und Toxikologie
Zentrum für Integrative Human Physiologie (ZIHP)
Zentrum für Neurowissenschaften Zürich (ZNZ)

BIO 333: HS 2012; 1. Oktober 2012

Learning objectives

At the end of the lecture you should be able to:

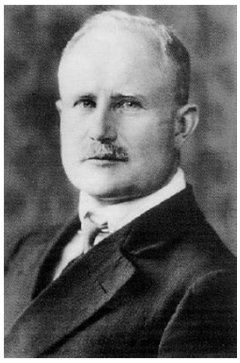
- provide a (electro-) physiological definition of sleep
- describe the human sleep stages and sleep structure

Definition of sleep

- Behavior
- Physiology

Sleep mainly defined by brain waves (EEG)

Hans Berger, first Human-EEG (1929)



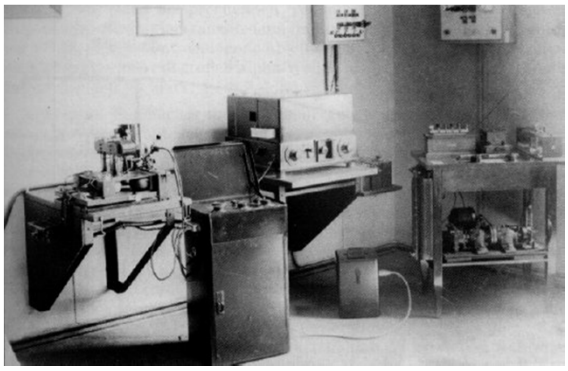
Über das Elektrenkephalogramm des Menschen.

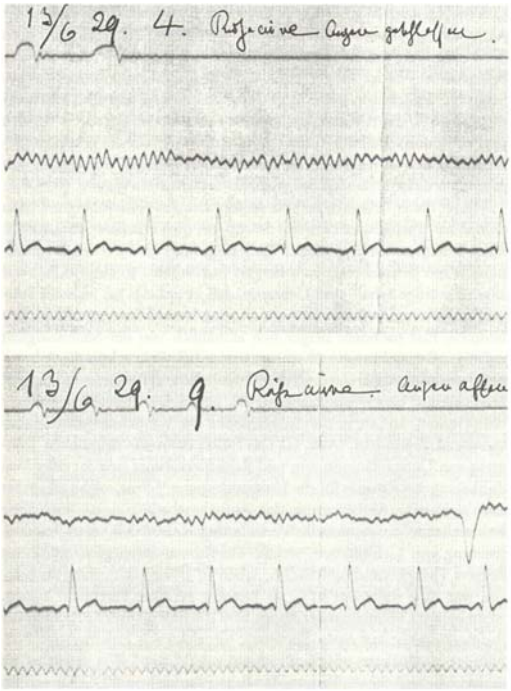
Von

Professor Dr. **Hans Berger**, Jena.

(Mit 17 Textabbildungen.)

(Eingegangen am 22. April 1929.)





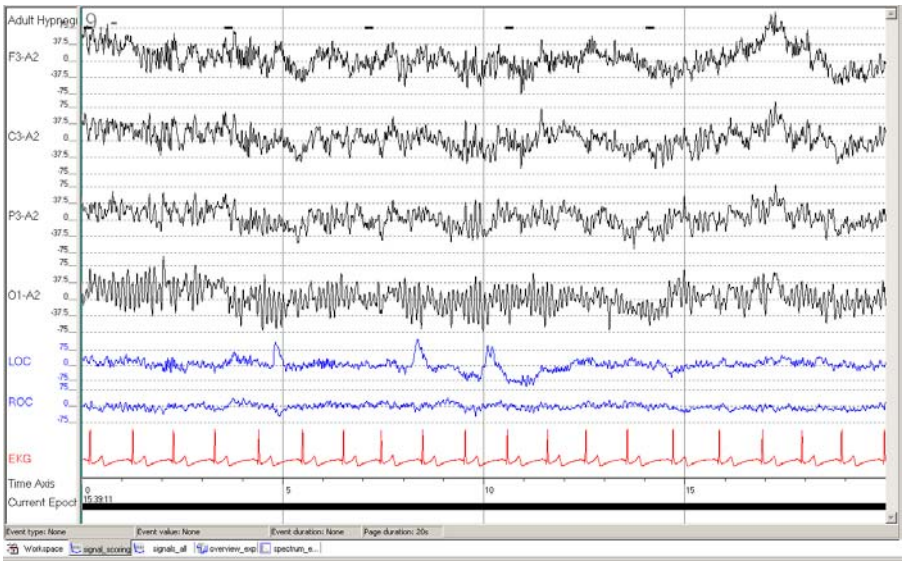
eyes closed

Alpha waves are blocked by opening of the eyes (experiment of Berger in 1929)

eyes open

Cornelius Borck (2005)
Hirnströme. Eine Kulturgeschichte der Elektroenzephalographie

Wake EEG – eyes closed

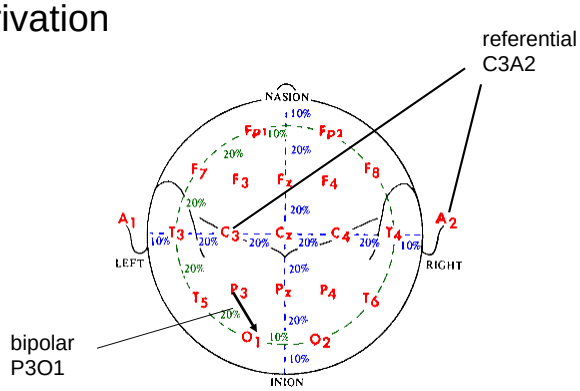


Electrode positions

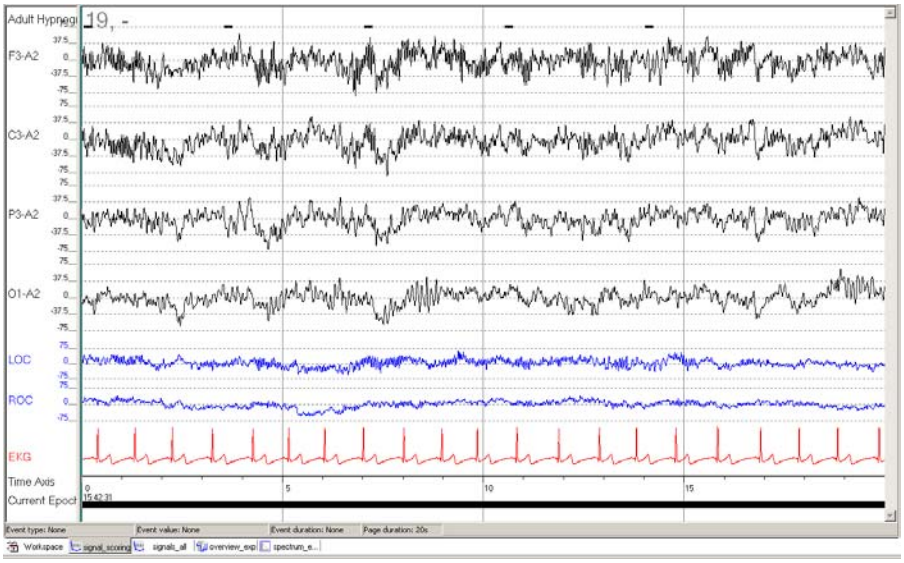
- potential difference ⇨ 2 electrodes
  - referential derivation
  - bipolar derivation

10-20 system

odd = left
even = right
z = „zero“



Wake EEG – eyes open



“Polysomnography”

Method to record physiological changes during sleep

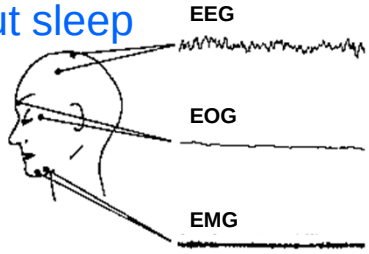
Definition of sleep

Many physiological changes occur during sleep:

- brain waves (EEG)
- muscle activity (EMG)
- eye movements (EOG)
- cardiac activity (EKG)
- body and brain temperature
- respiration

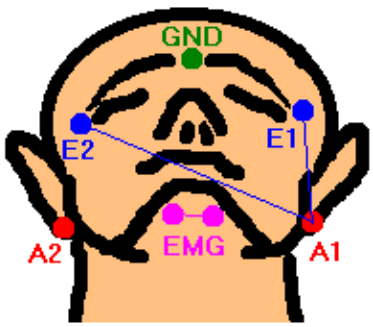
Electrophysiological recordings provide information about sleep

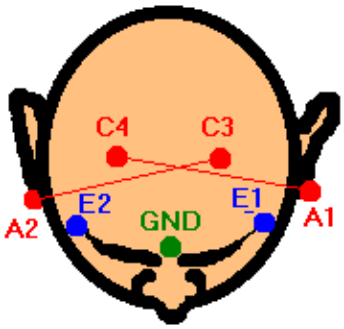
3 indicators define sleep

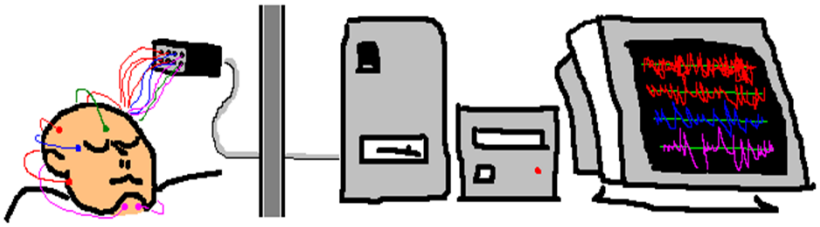


1. EEG **Electroencephalogram** (brain waves): small voltage changes measured between two metal plates fixed at the scalp. Origin: voltage changes in membranes of nerve cells (postsynaptic potentials). Signals (waves) are investigated for changes in frequency (Hz) and amplitude (µV)

Electrode configuration to record sleep



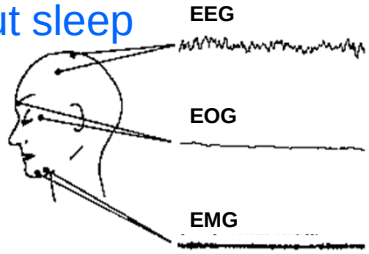




- EEG (Electroencephalogram)
- EMG (Electromyogram)
- EOG (Electrooculogram)

Electrophysiological recordings provide information about sleep

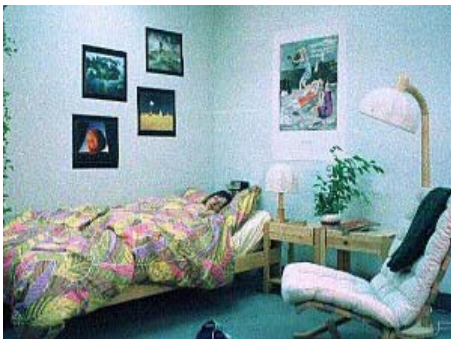
3 indicators define sleep

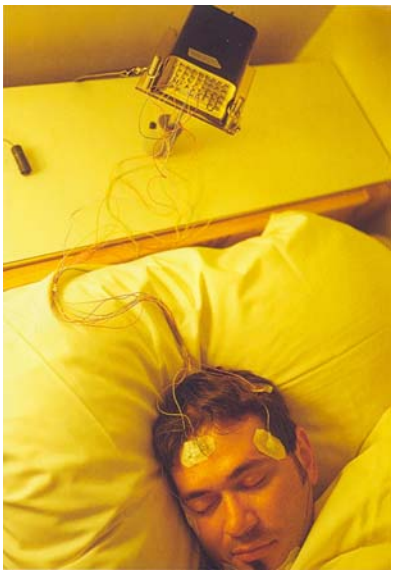


2. EOG **Electrooculogram** records eye movements. Eyeball is a dipole (retina negatively charched relativ to the cornea). Voltage changes occur due to rotation of the eyeball

3. EMG **Electromyogram** records electrical activity of the muscles

In the sleep lab

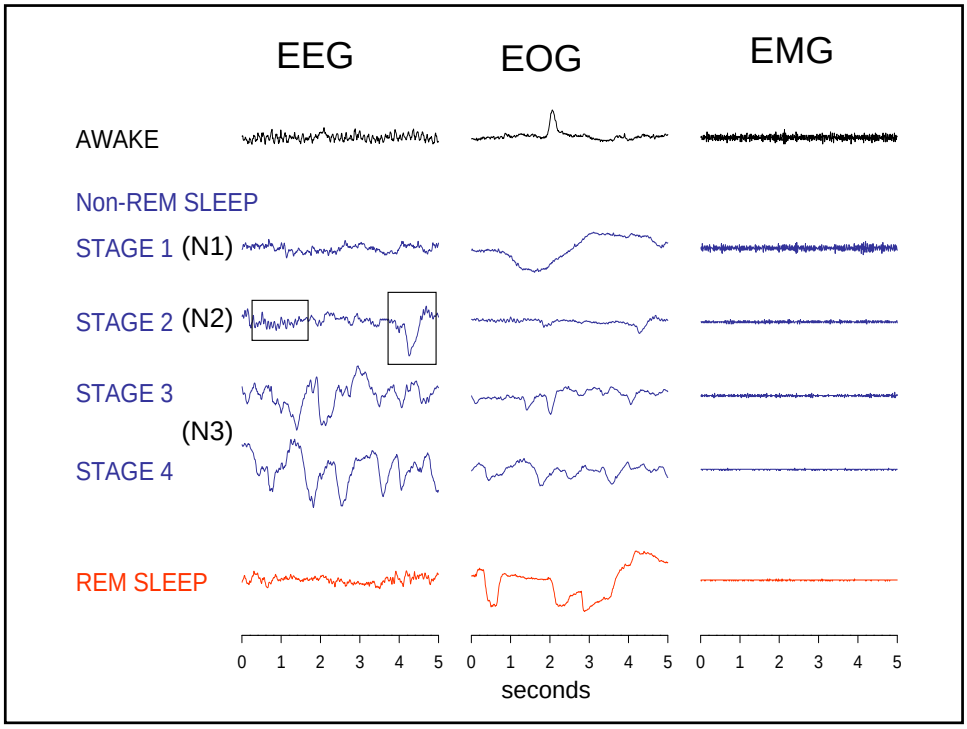




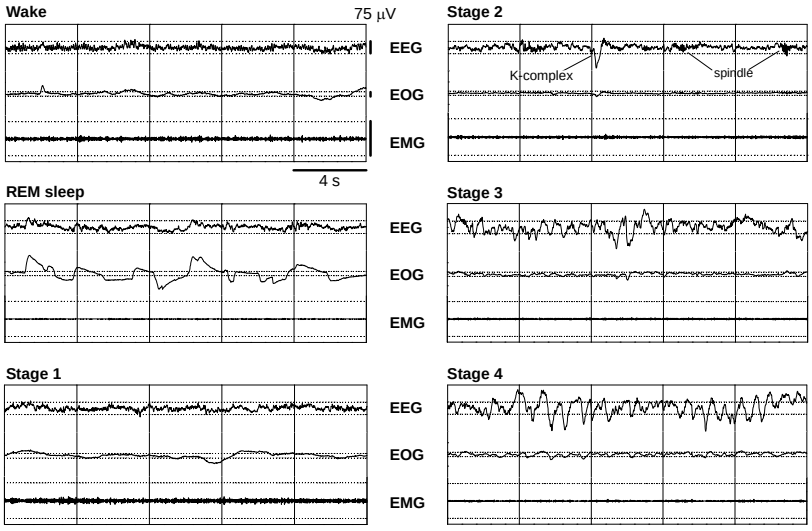
Manual with “standards” for the
definition of human sleep stages:

Rechtschaffen and Kales, 1968

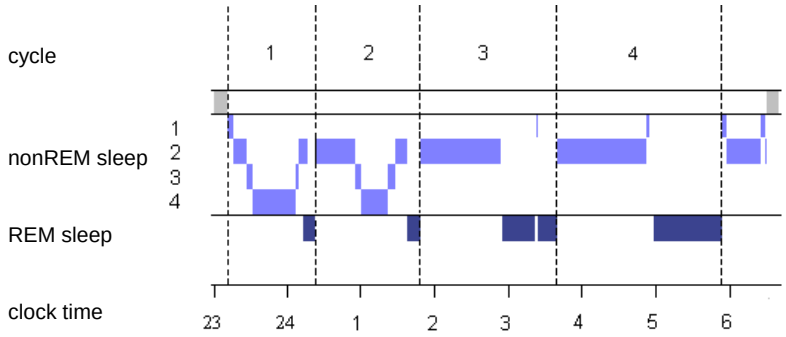
*The AASM manual for the scoring of sleep
and associated events:
Rules, terminology and technical specifications
2007*



Overview of human sleep stages



Sleep has a cyclic structure

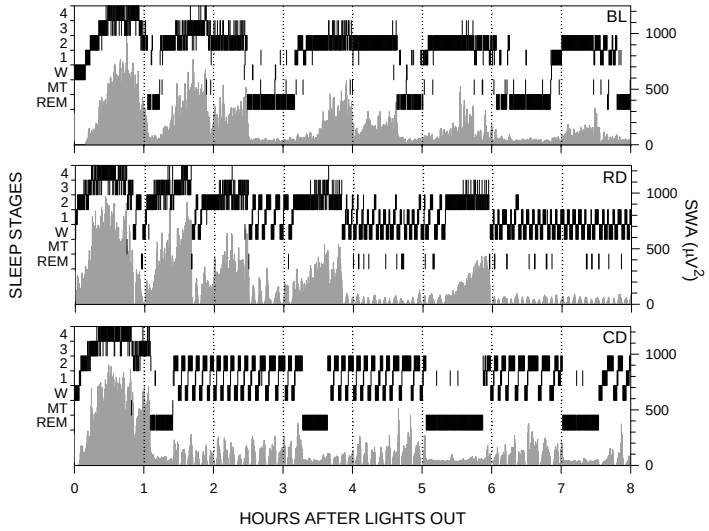


4 complete nonREM-REM sleep cycles (90 – 100 min)

NonREM sleep stages 3 und 4 (N3; deep sleep) predominant at the beginning of sleep

REM sleep episodes get longer in the course of a night

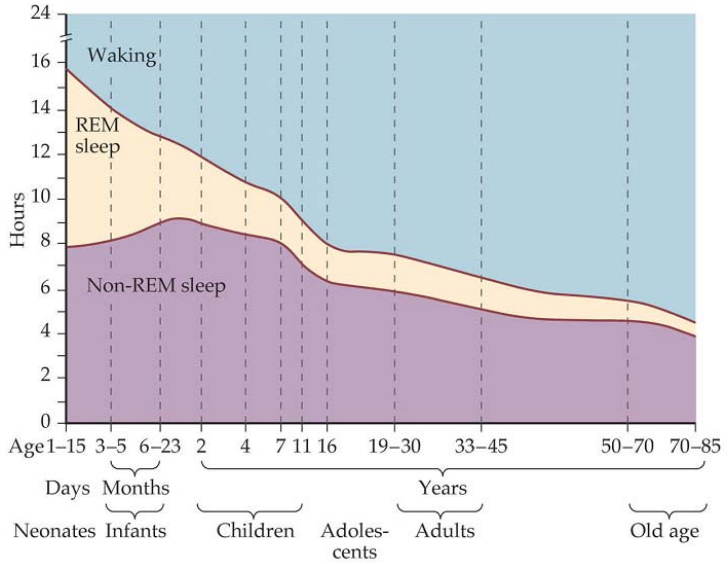
Selective REM sleep deprivation

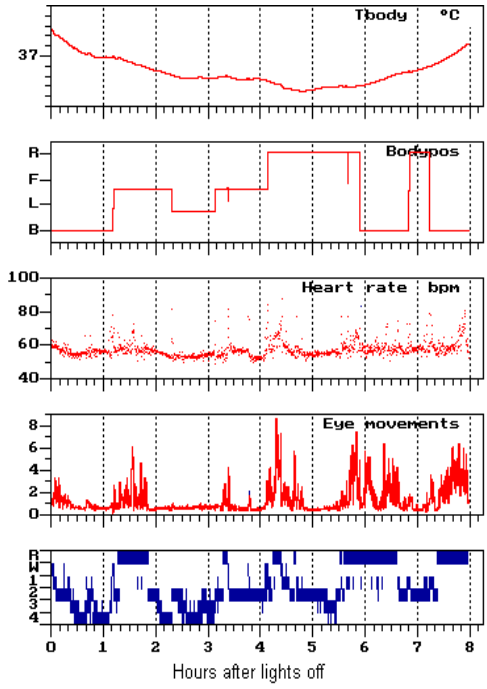


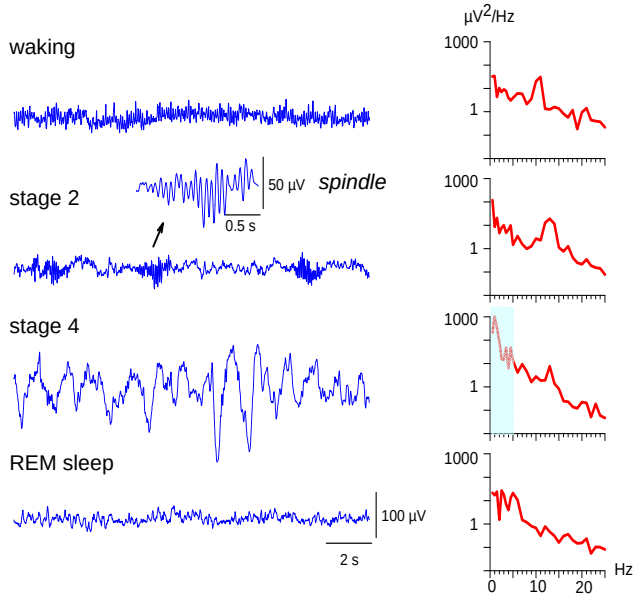
Endo et al., 1998

Sleep over Lifetime

from Roffwarg et al. (1966) Science 152: 604-619

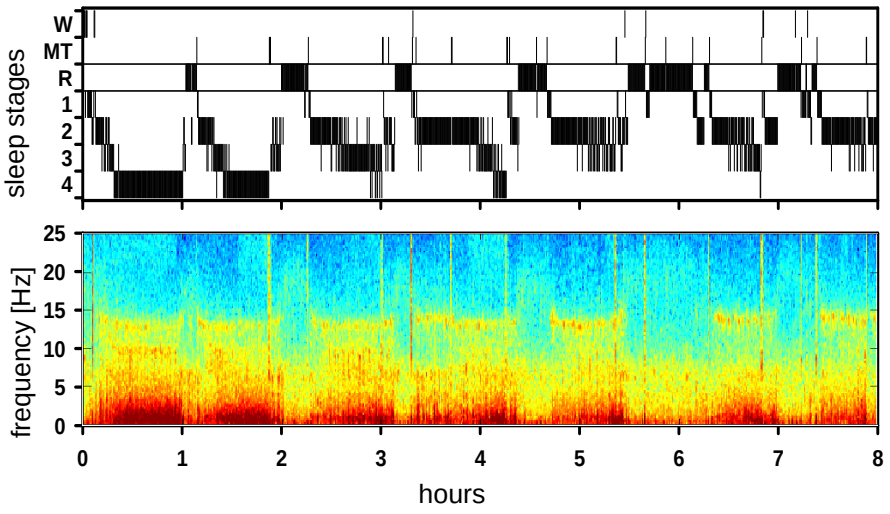


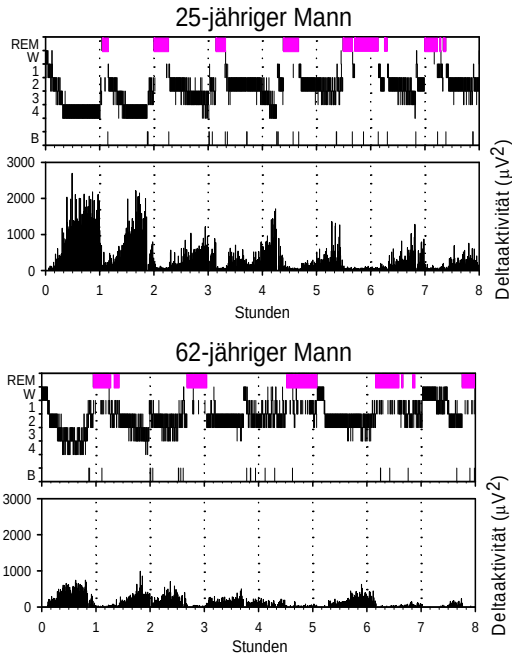




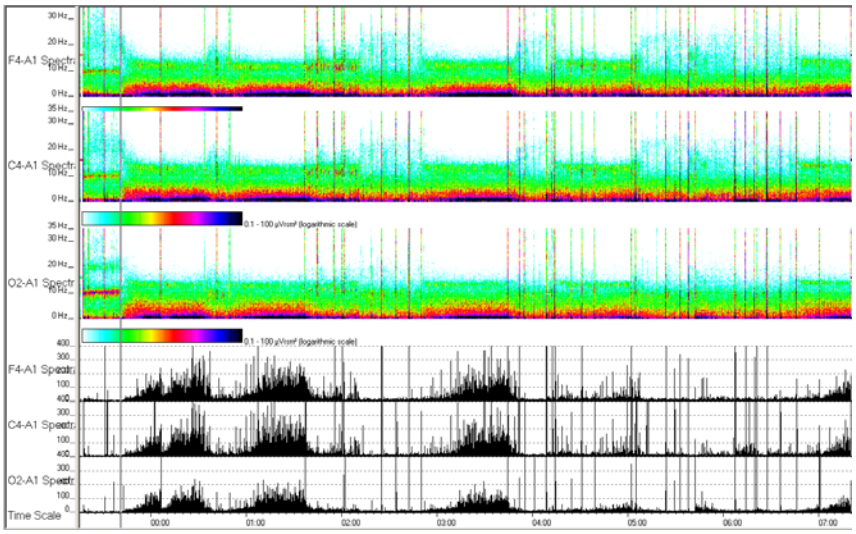
Aeschbach (1995)

Spectral analysis of sleep EEG





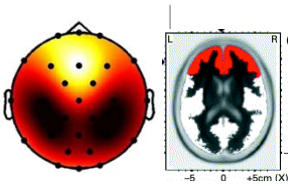
Alpha activity disappears at sleep onset

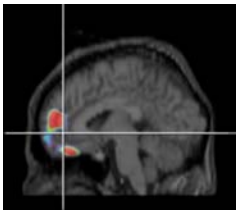


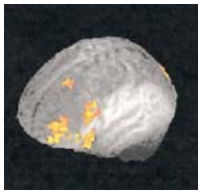
High-density EEG recording

(60 – 256 electrodes)

Brain imaging techniques







brain mapping / source localization

- EEG
- low spatial resolution
- high temporal resolution

PET

- ^{18}FDG or $H_2{}^{15}O$
- high spatial resolution
- low temporal resolution

fMRI

- BOLD signal
- high spatial resolution
- medium temporal resolution