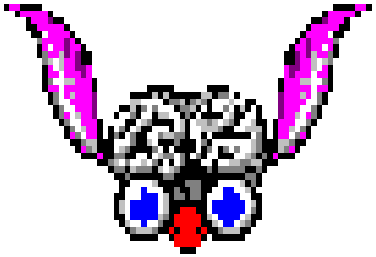
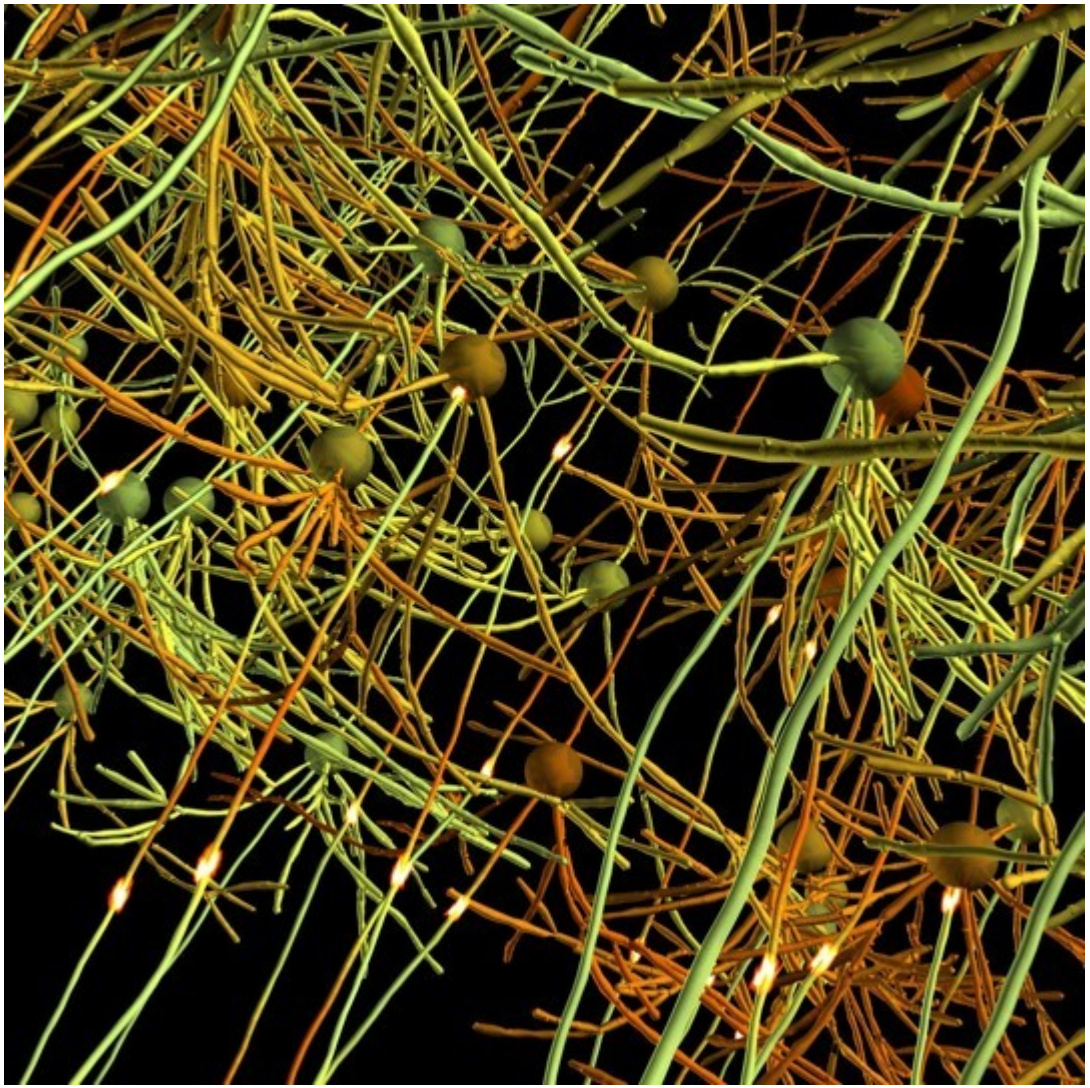
CEREBRAL CORTEX

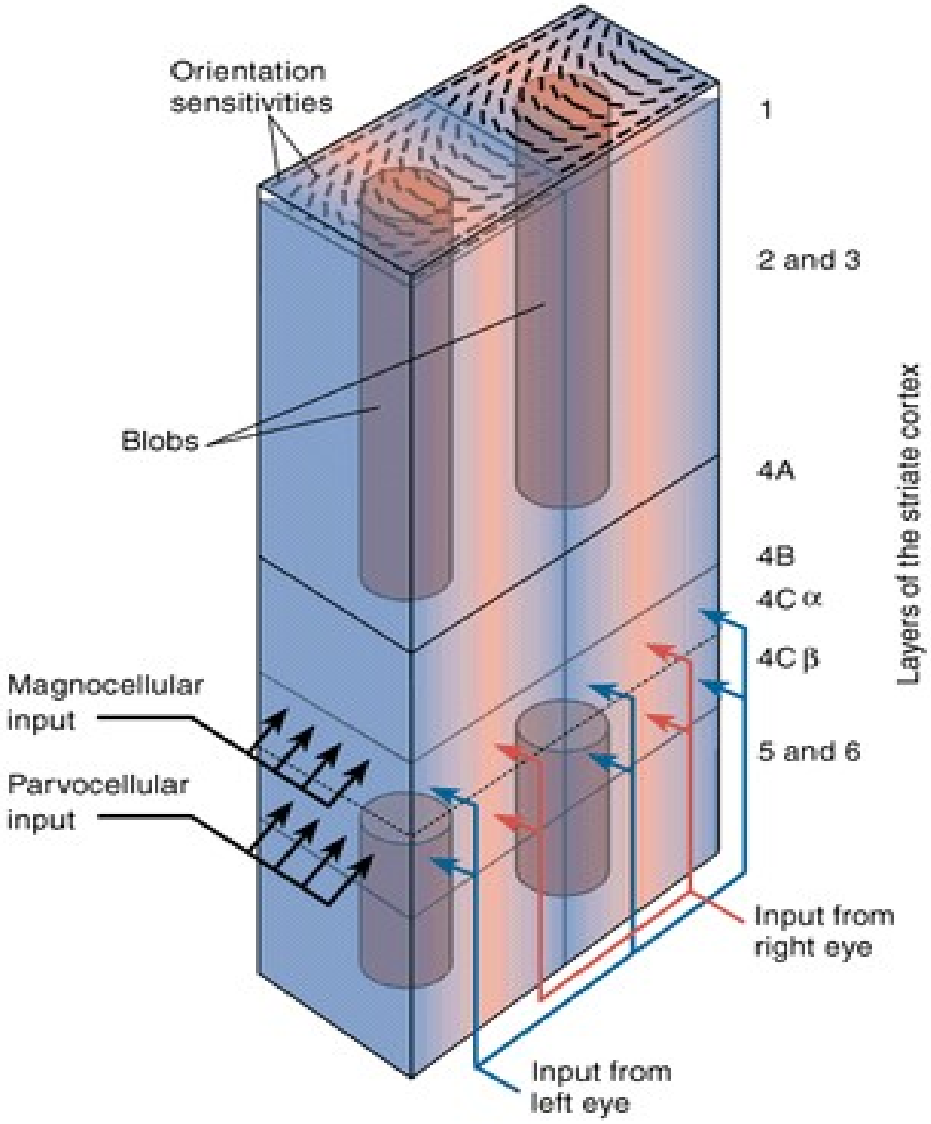




CEREBRAL CORTEX AND HIGHER NEURAL FUNCTIONS

The activity of the nervous system can be divided into:

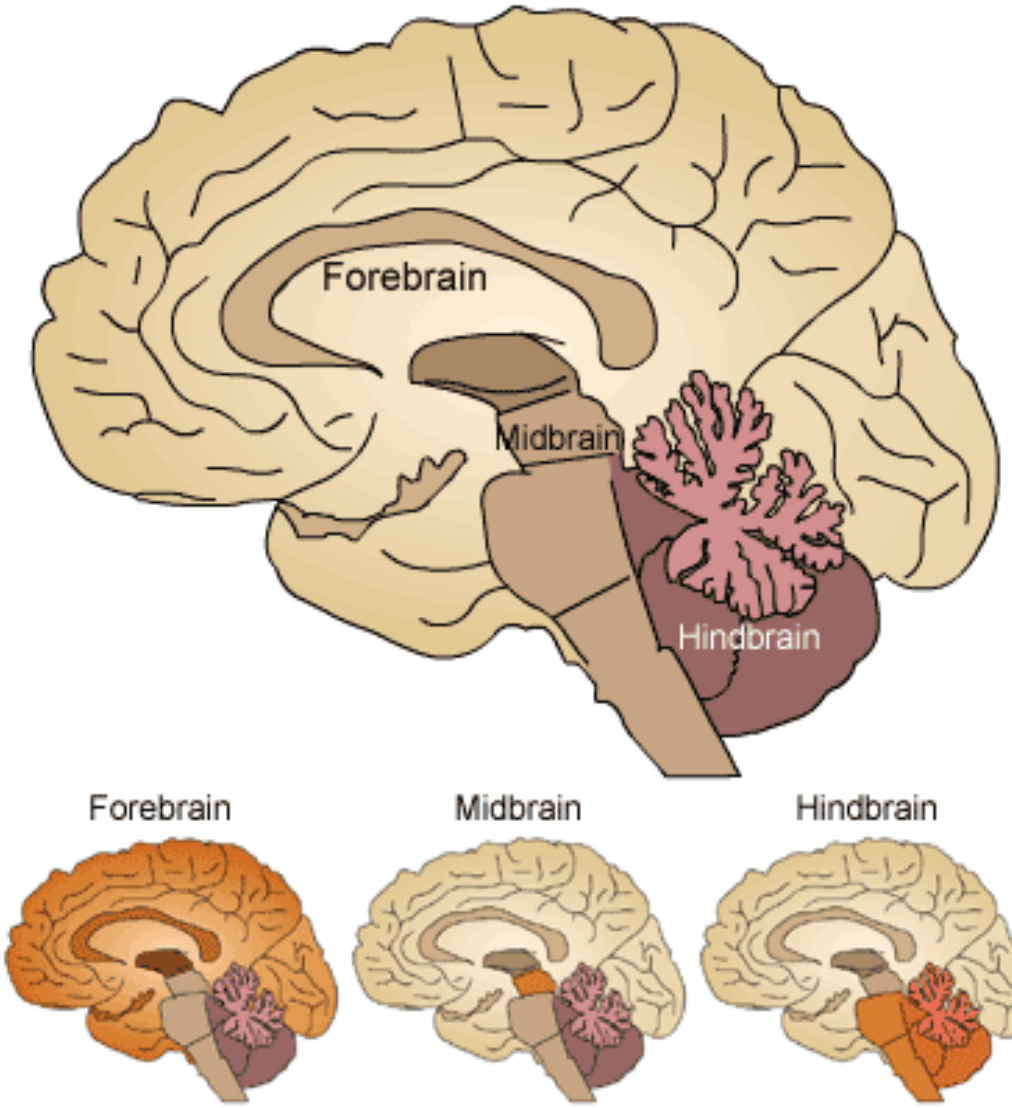
- **routine work of intercellular communication;**
- **special or higher functions.**



CEREBRAL CORTEX

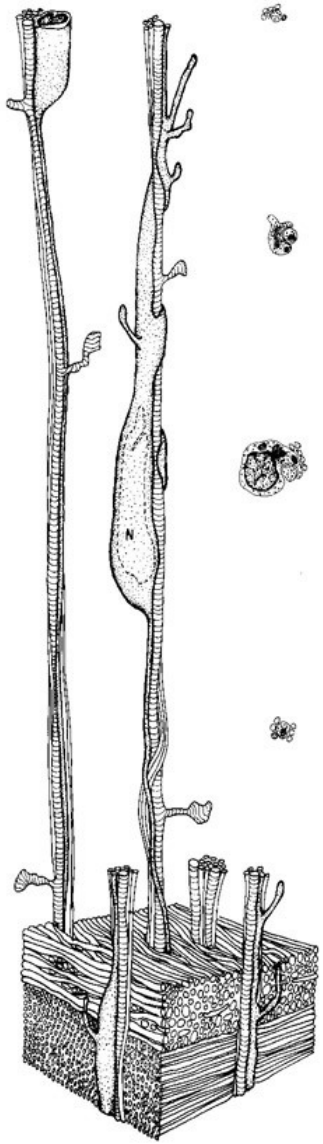
Cerebral hemispheres are the most important structures of the CNS and are also of most importance for higher functions.

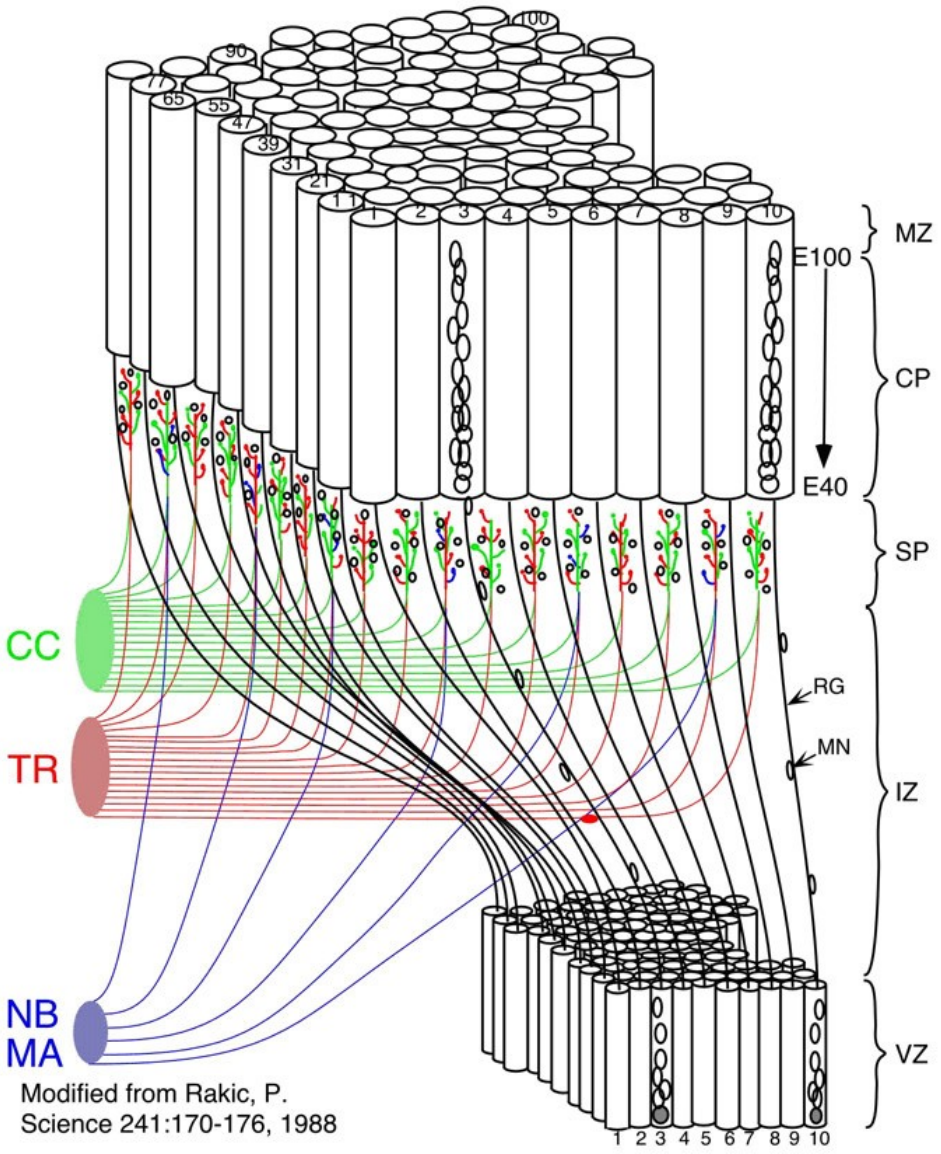
Figure AB-7: Forebrain / Midbrain / Hindbrain



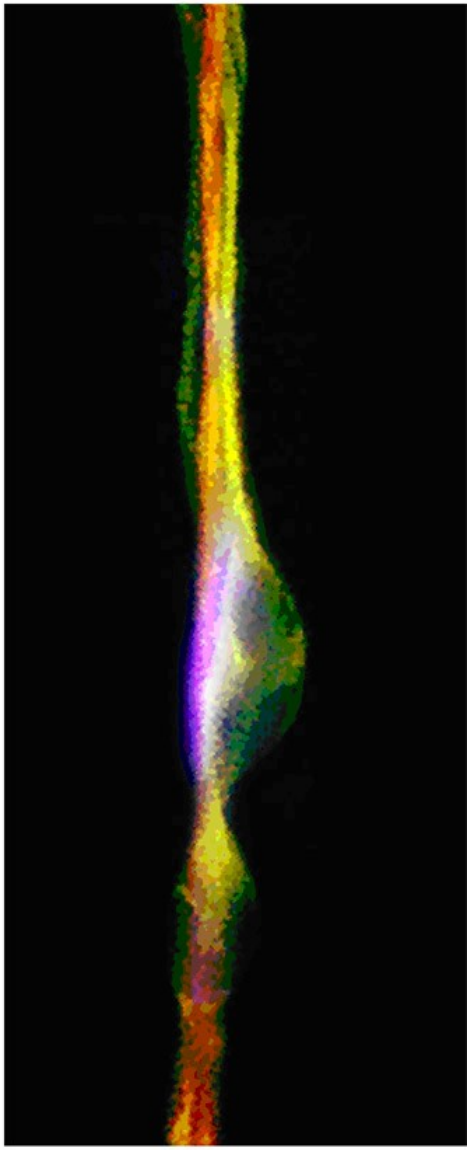
CEREBRAL CORTEX

- The outer surface of each hemisphere is called cerebral cortex, which has the cell bodies of the neurons. It is about 2 to 5 mm thick.
- The cerebral cortex is highly convoluted structure consisting of many elevation separated by depressions.
- These elevations are called gyri and the depressions are called sulci.





Modified from Rakic, P.
Science 241:170-176, 1988



LAYERS OF THE CEREBRAL CORTEX

The cells of the neocortex are arranged in six layers, from superficial to deep they are as follows:

1. MOLECULAR OR PLEXIFORM LAYER

   This layer contains mainly the dendritic processes, axon terminals and the synapses. It also has the horizontal cells of Cajal.

2. OUTER GRANULAR LAYER

   This layer contains the granule cells along with some small pyramidal cells.

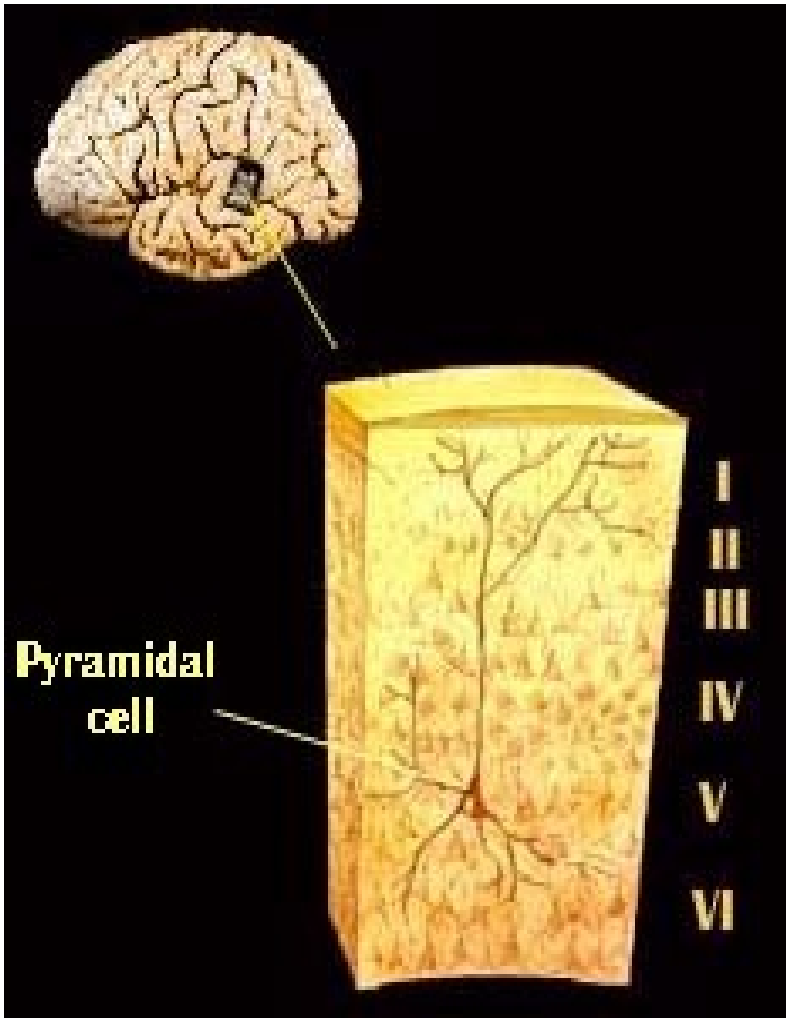
LAYERS OF THE CEREBRAL CORTEX

3. **OUTER PYRAMIDAL CELL LAYER**

   It is formed of small pyramidal cells mainly and has some stellate cells. The pyramidal cells situated superficially are smaller and are of medium size in the deeper part.

4. **INNER GRANULAR LAYER**

   It contains plenty of granule cells and some medium sized pyramidal cells. It's deeper part contains the outer band composed of transverse fibres. Most of the incoming fibres synapse here.



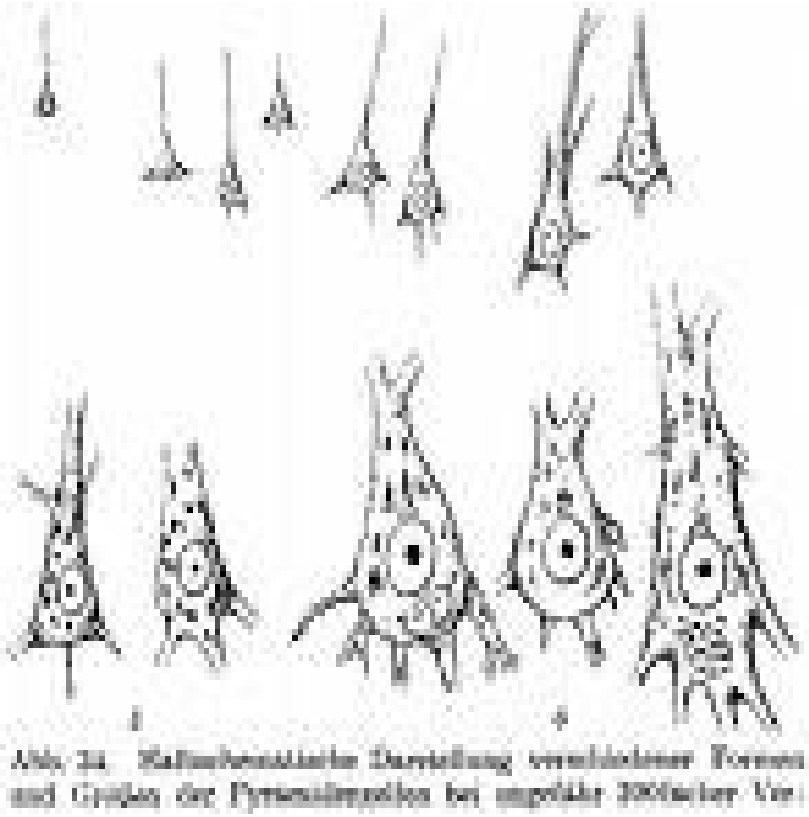
Layers of the Cerebral Cortex

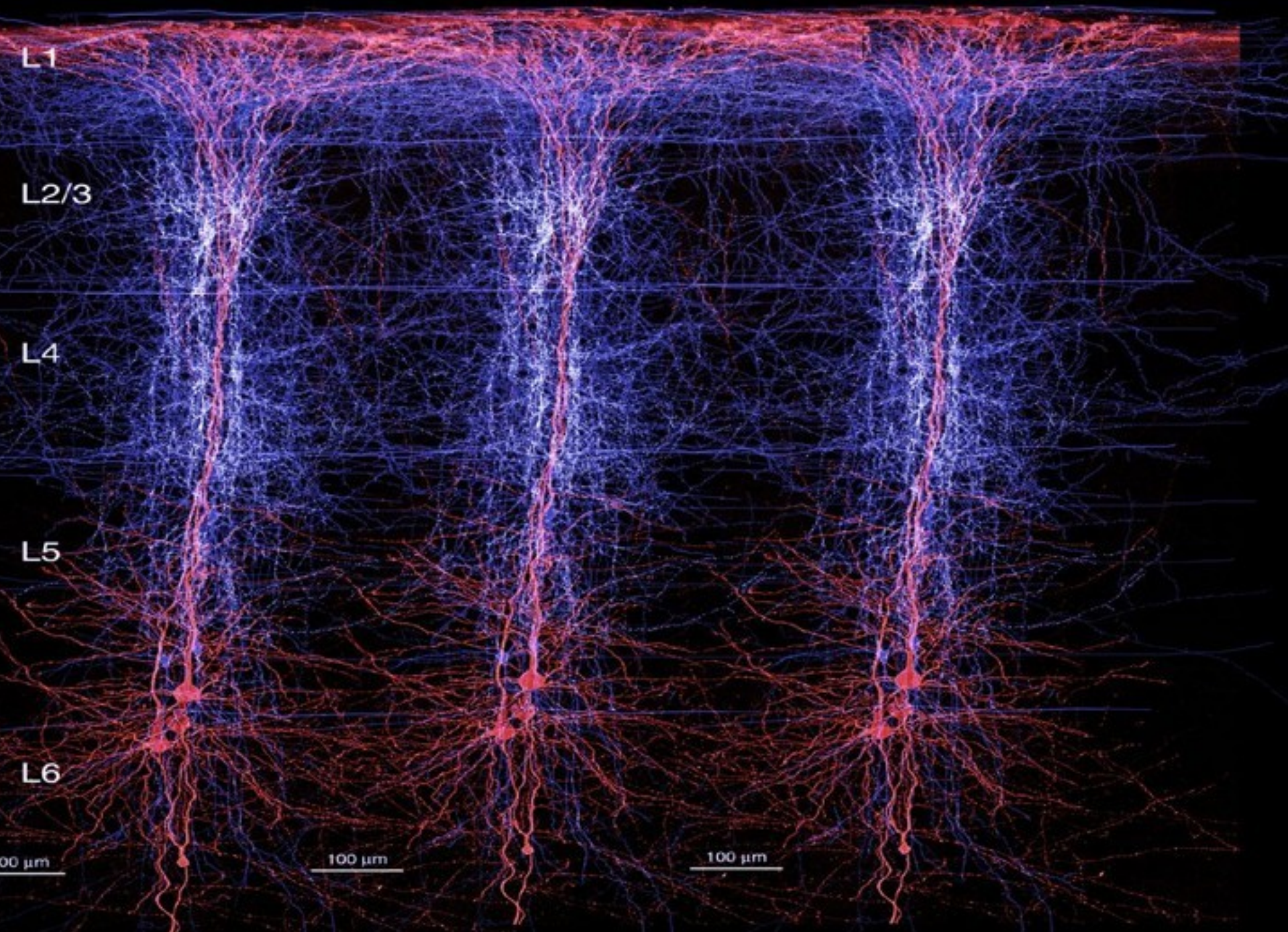
5. INNER PYRAMIDAL LAYER

This layer contains medium sized pyramidal cells superficially and the larger ones in the deeper part. (These large cells include the giant pyramidal cells of Betz in the precentral gyrus). In its outer part is the inner band formed of transverse fibres. This layer provides the outgoing fibres of the cortex.

6. FUSIFORM CELL LAYER

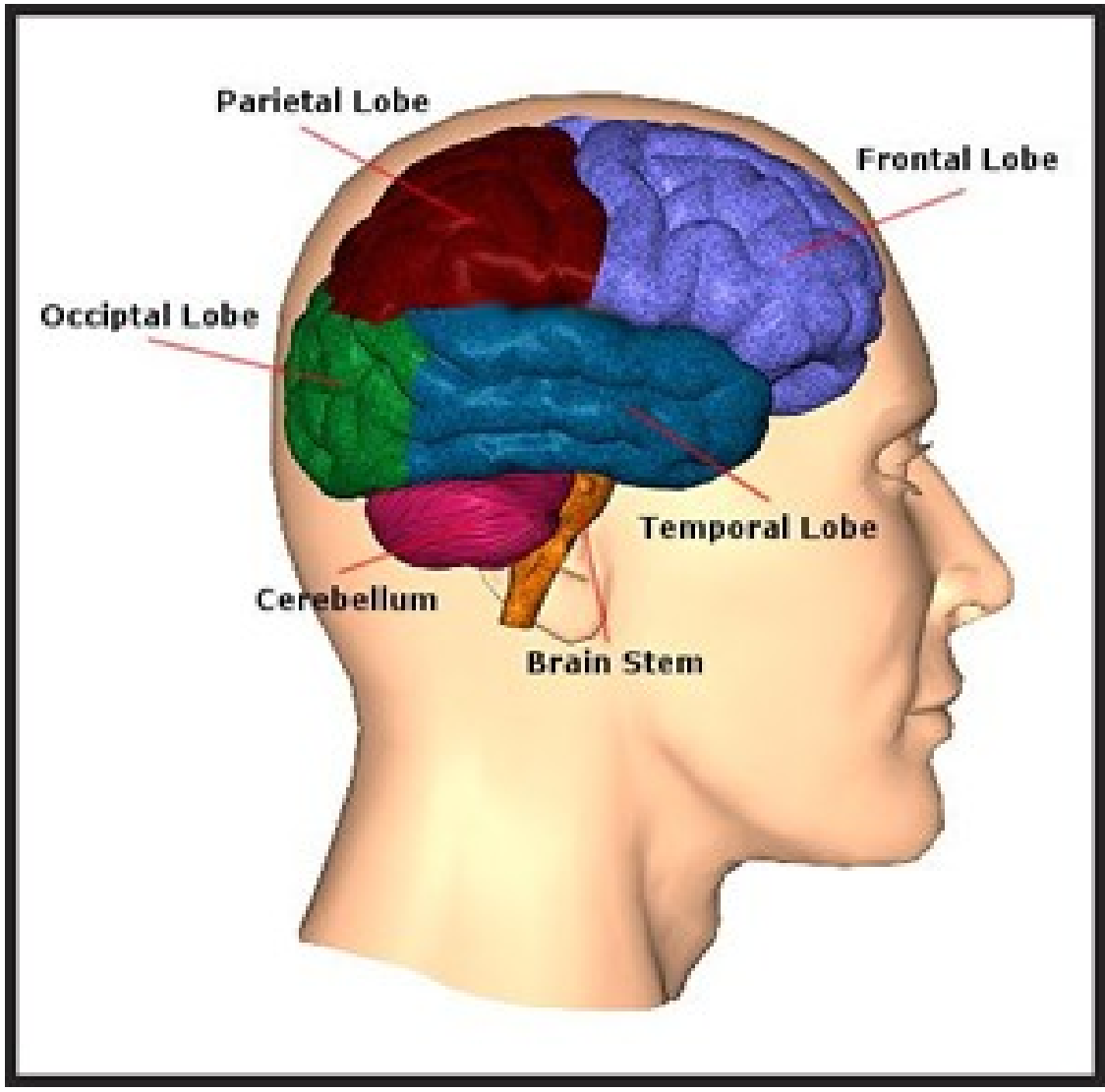
This layer is formed of fusiform multipolar cells and also by the cells of Mortinotti. This layer gives rise to corticofugal fibres to the thalamus.




L1
L2/3
L4
L5
L6
100 µm
100 µm

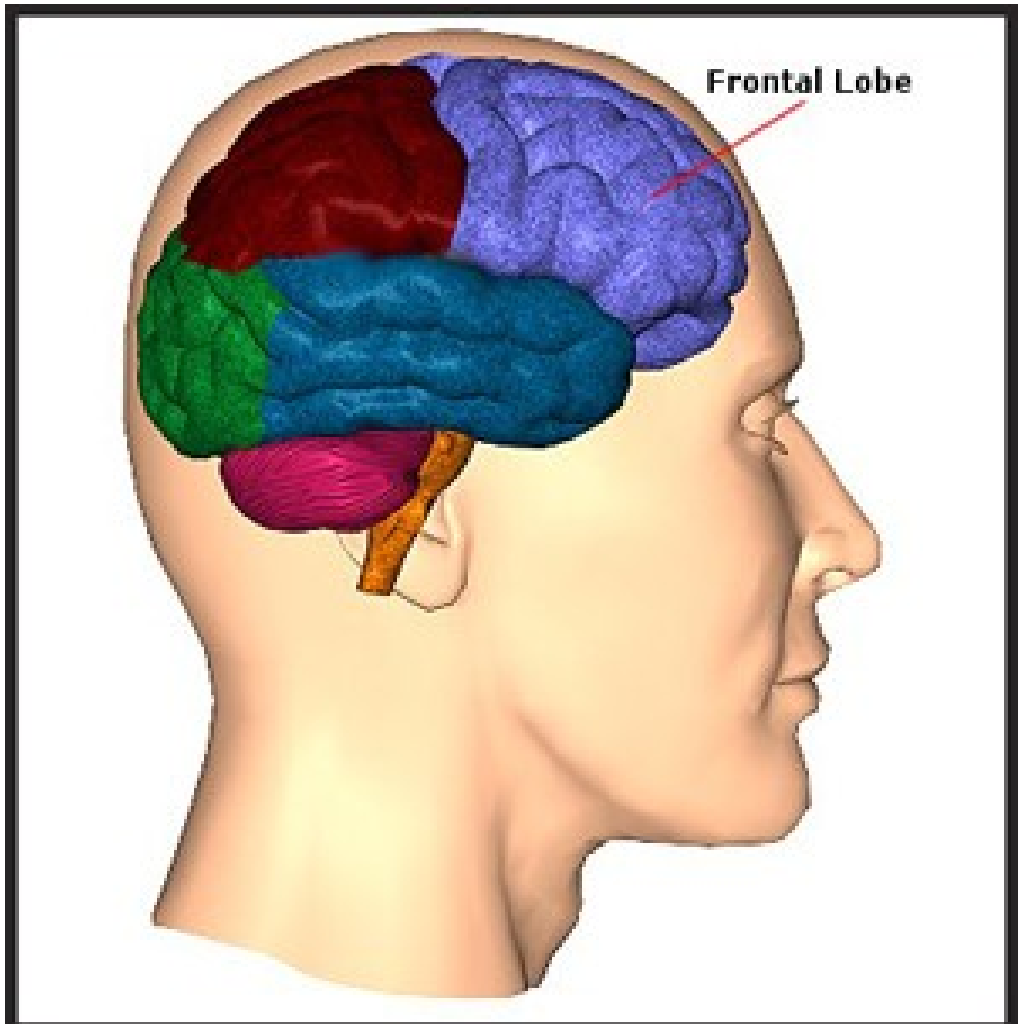
CEREBRAL CORTEX LOBES

- Cerebral cortex is divided into different lobes.
- Names of these lobes are according to the overlying bones of the skull.



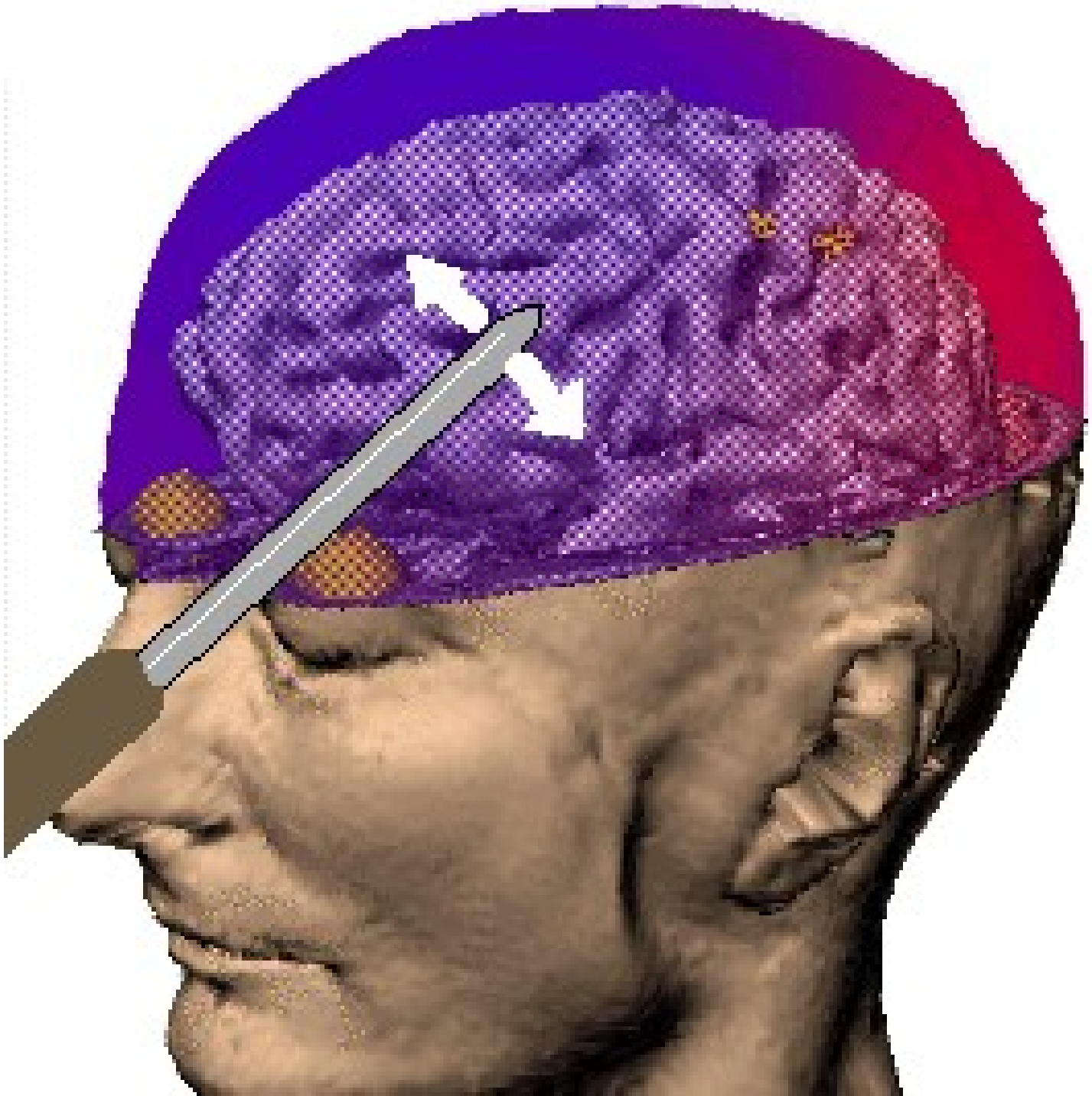
FRONTAL LOBE

- **Frontal lobe is associated with the motor system and the functions of the related portions, i.e., motor, premotor and supplementary motor areas, and the motor speech area.**
- **The rest of the frontal lobe, lying in front of the above areas, is called prefrontal lobe. It is the newest part of the cerebral cortex.**



LESION IN PREFRONTAL LOBE

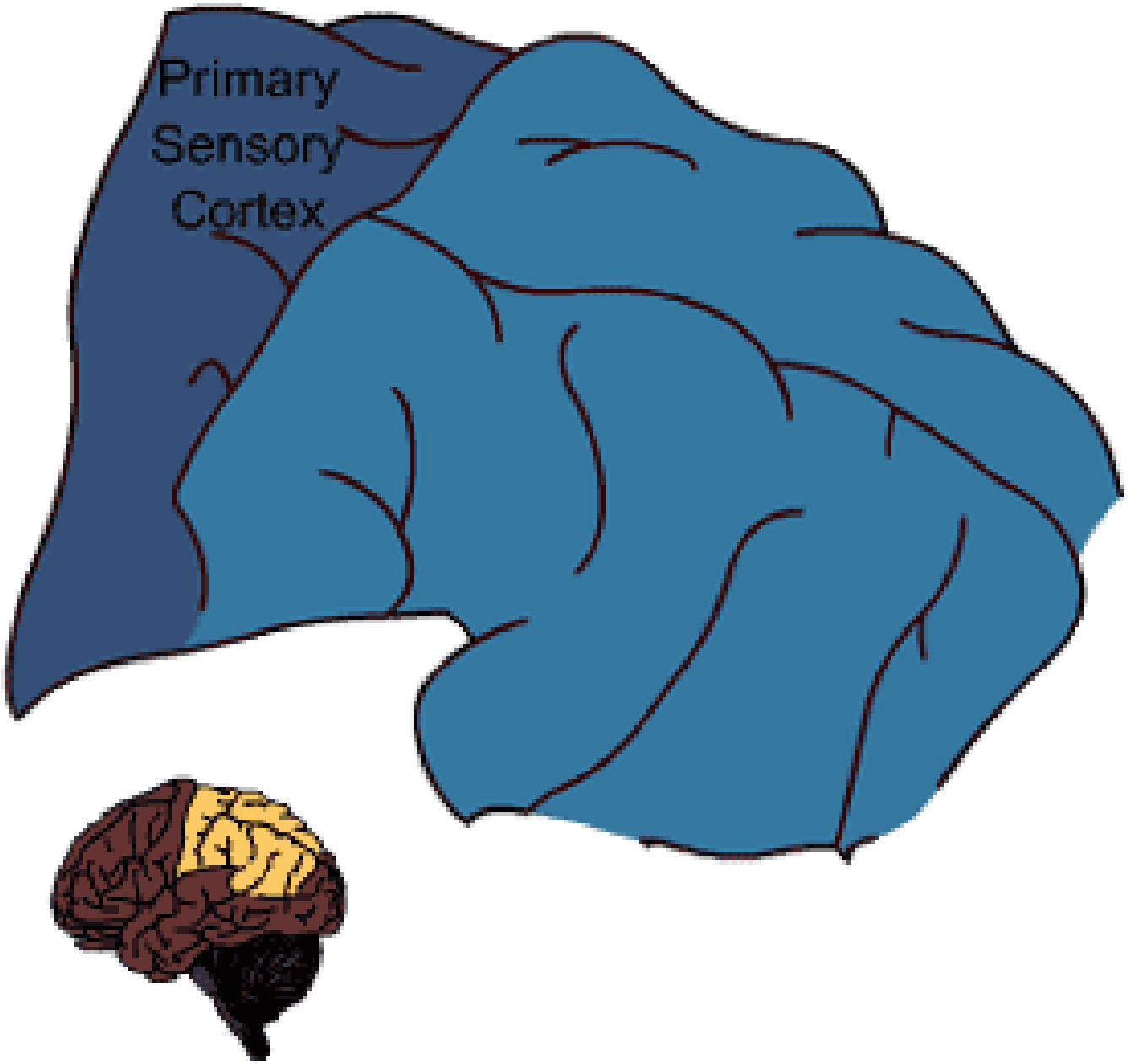
- **Lesion in prefrontal lobe leads to a group of symptoms which together are called *frontal lobe syndrome*.**
- **The symptoms are:**
  - **1) inability to perform two works at a time;**
  - **2) inability to follow the proper sequence to achieve a task (e.g., cooking which requires sequential steps);**
  - **3) lack of initiative;**
  - **4) inability to store a programme;**
  - **5) incontinence;**
  - **6) anosmia;**
  - **7) impairment of moral sense;**
  - **8) impairment of social sense;**
  - **9) failure to realise the gravity of a situation.**
- **Thus, the prefrontal lobe is responsible for personality, social behaviour, ability to analyse a situation, restraint.**



PARIETAL LOBE

- It occupies a central position in the cortex with audio, visual, motor and the somoto-sensory area around it.
- Thus it is involved in coordination of functions. It is reciprocally connected to the thalamus and is the highest area for sensory motor association.
- In the dominant hemisphere it is responsible for language function, planned movements.
- On the nondominant side its function is constructional skill, spatial orientation. The center for taste sensation is also situated here.

Figure AB-13: Parietal Lobe



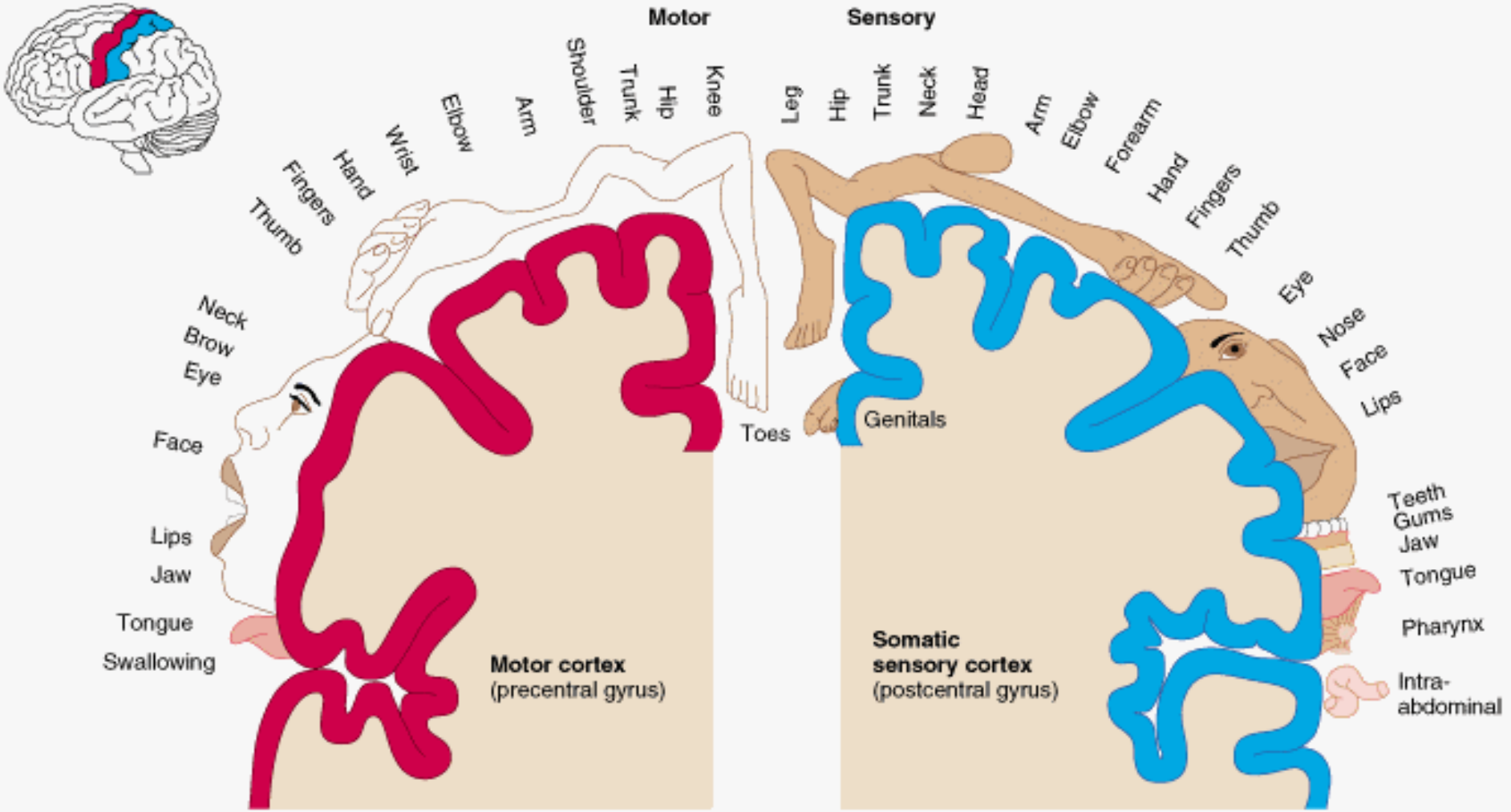
LESION OF PARIETAL LOBE

- Lesion of parietal lobe produces various features:

  a) Agnosia. It means inability to recognise the import of sensory impression.

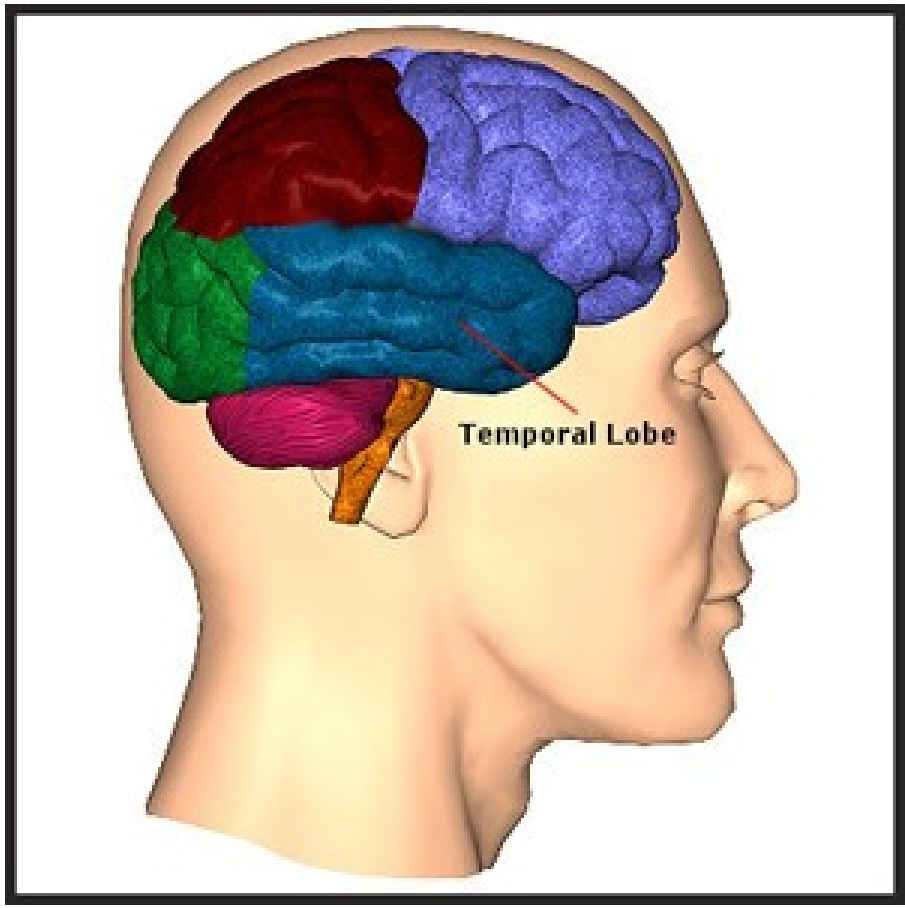
  b) Apraxia. It means impairment of the ability to use correct sequence of a movement or work.

  c) Aphasia. It means disorder of speech due to central reason.
- Defect in parietal lobe also leads to inability to understand the meaning of written (visual) and spoken (auditory) words.



TEMPORAL LOBE

- It is responsible for perception and interpretation of sounds heard and thus related to speech and language function. It is also involved in olfaction and in equilibrium.
- On the non-dominant side it is the seat of musical skill and centre for appreciation of music.
- The medial part of this lobe is included in the limbic system.



LESION OF THE TEMPORAL LOBE

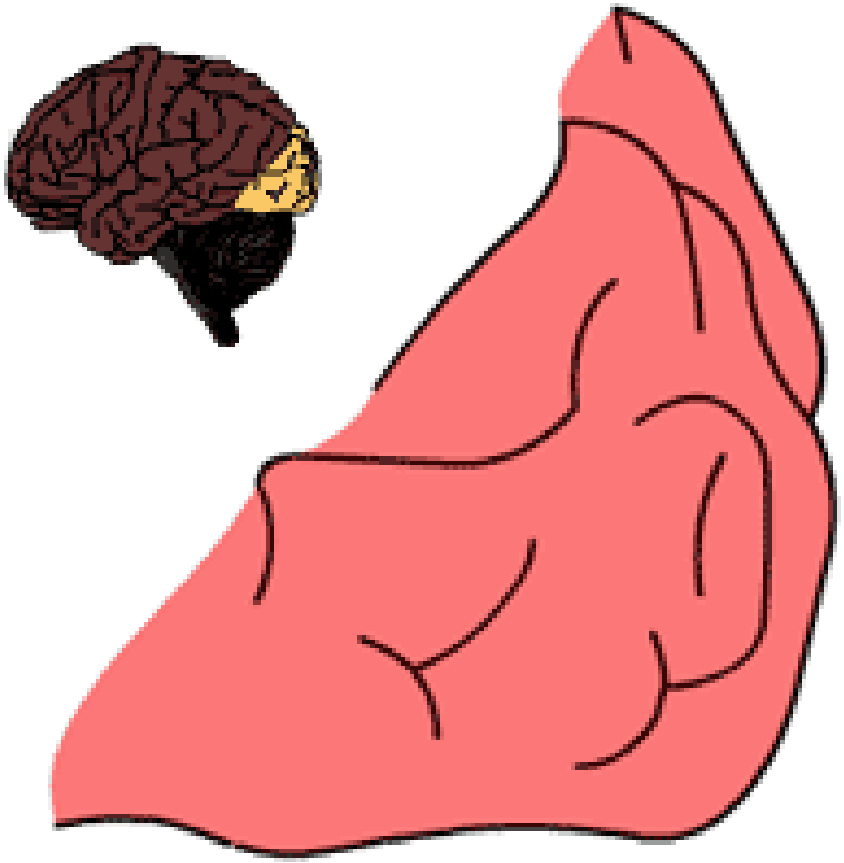
- **Lesion of the temporal lobe leads to abnormalities like poor memory, loss of musical skill, speech disorder, auditory disturbances, psychomotor seizure (a type of epilepsy), hallucinations, dreamy state.**

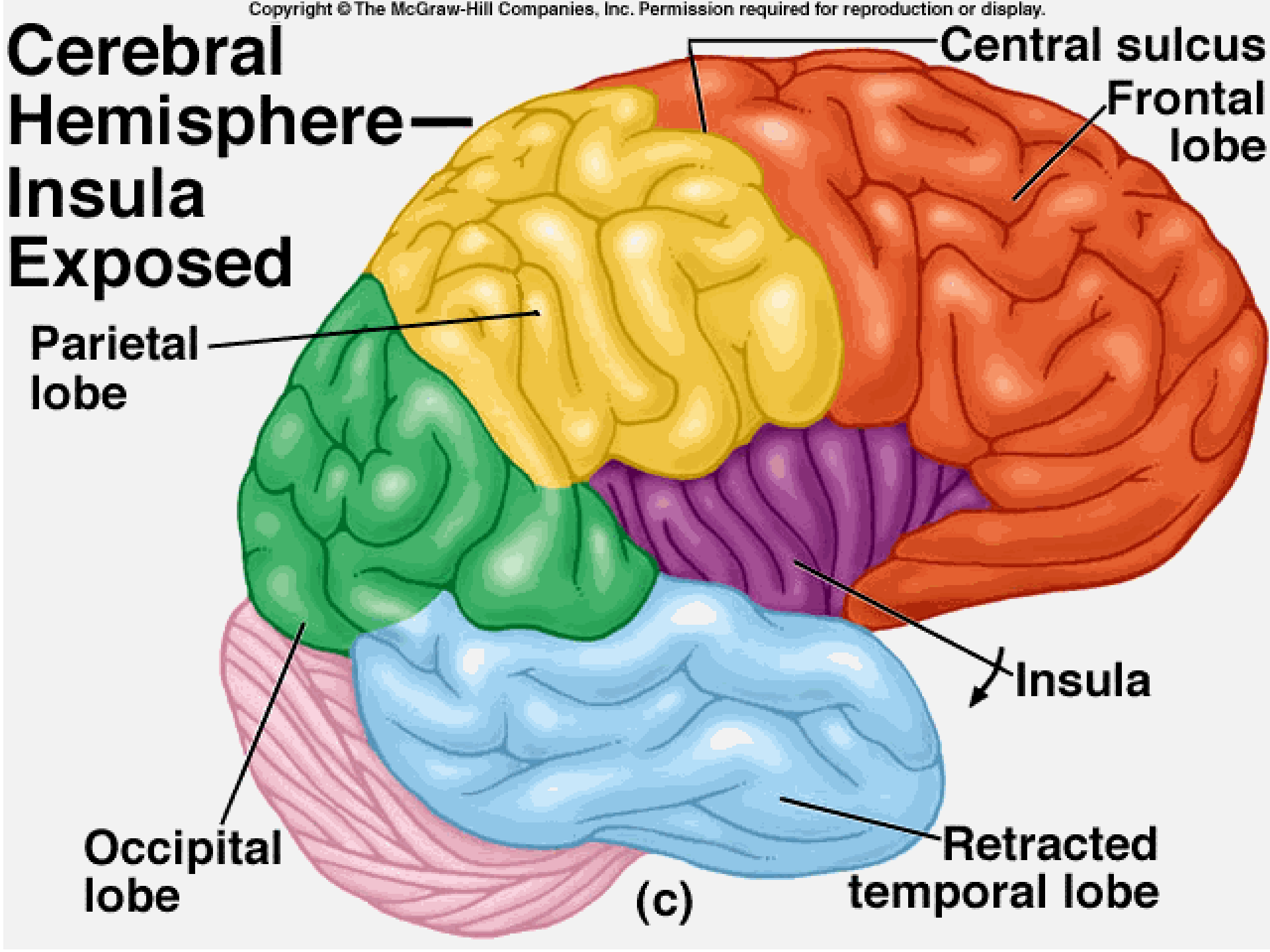
Figure AB-14: Temporal Lobe

OCCIPITAL LOBE

- **It receives and recognises visual information including colour, feature, movement, and everything of what we see and perceive.**
- **It is also involved in eye movements for fixation of gaze and in some occular reflexes.**
- **Accommodation for near vision is also a function of this lobe.**
- **Lesion of occipital cortex leads to various types of visual abnormalities.**

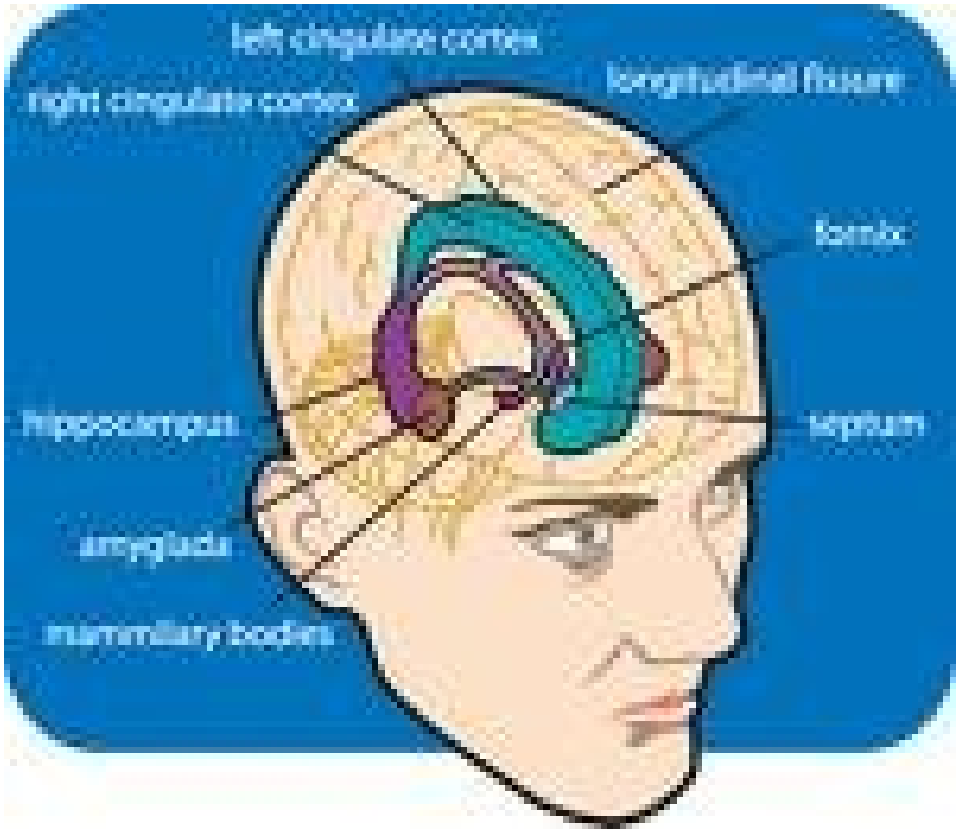
Figure AB-15: Occipital Lobe





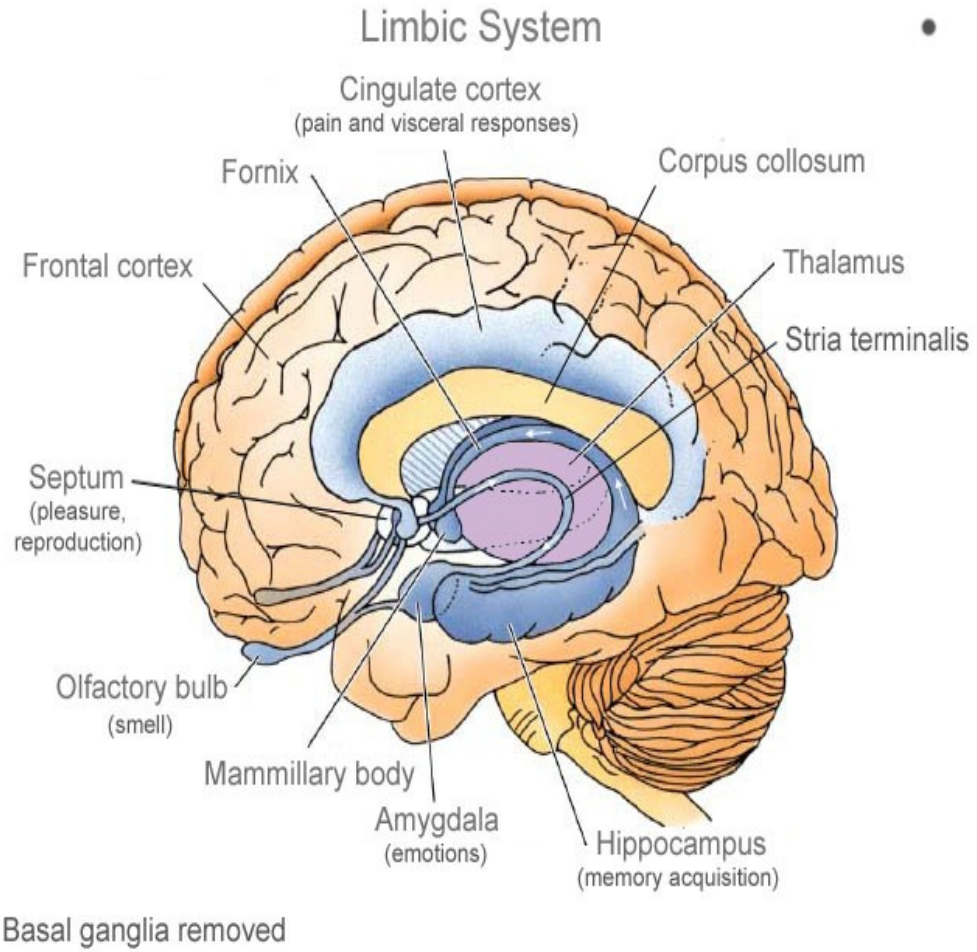
LIMBIC LOBE

- **The limbic system is the modern name of the part of the brain, which is the seat of emotion.**
- **As the motor system is the apparatus for expression of the motor programmes of the brain, similarly the limbic system is responsible for outward expression of the "internal state".**

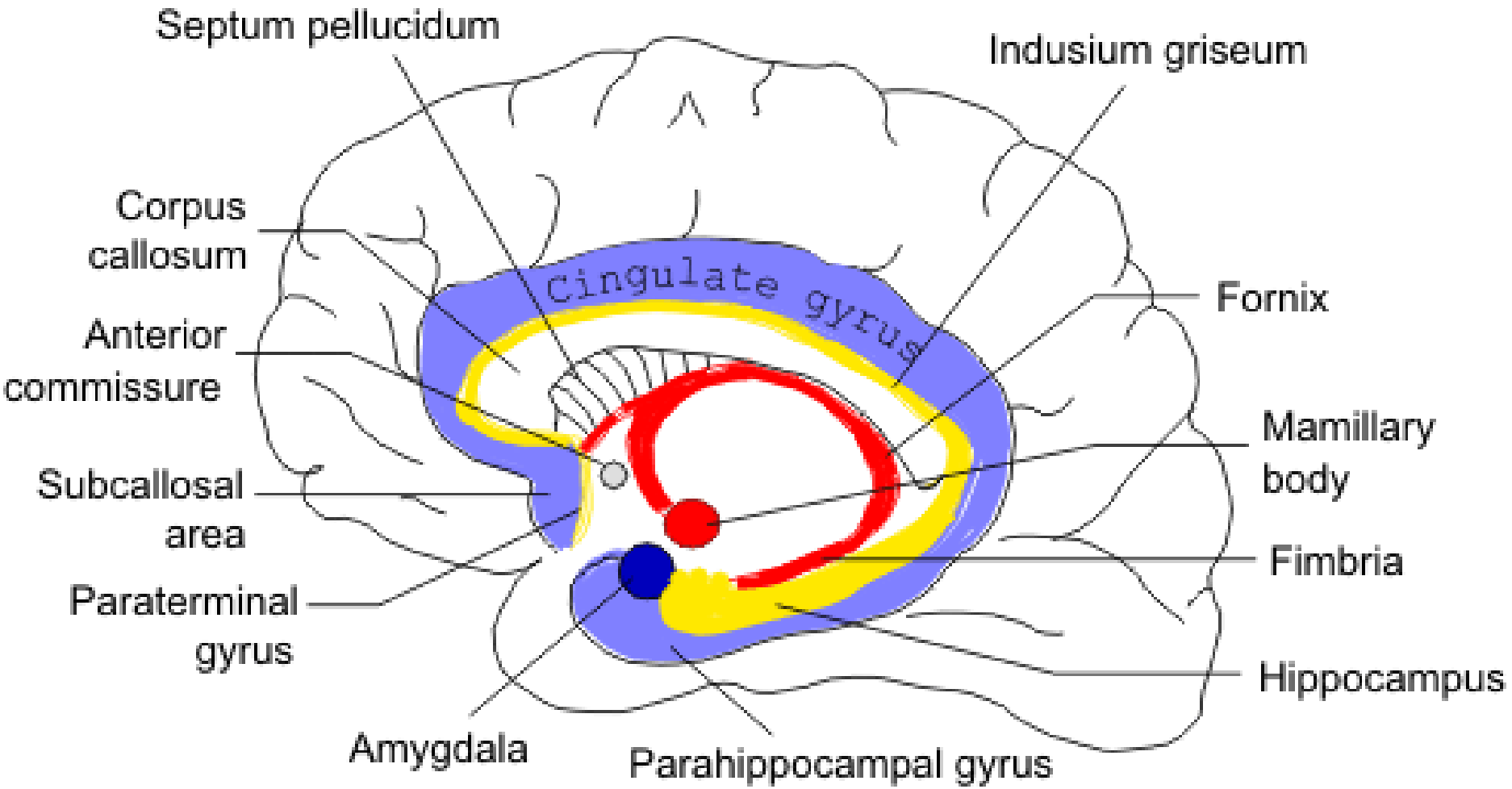


LIMBIC LOBE

- **The limbic system is composed of cortical and subcortical structures present around the hylus of the cerebral hemispheres where they join with the brain stem.**
- **There are many connections between the limbic system with cortical and subcortical structures.**

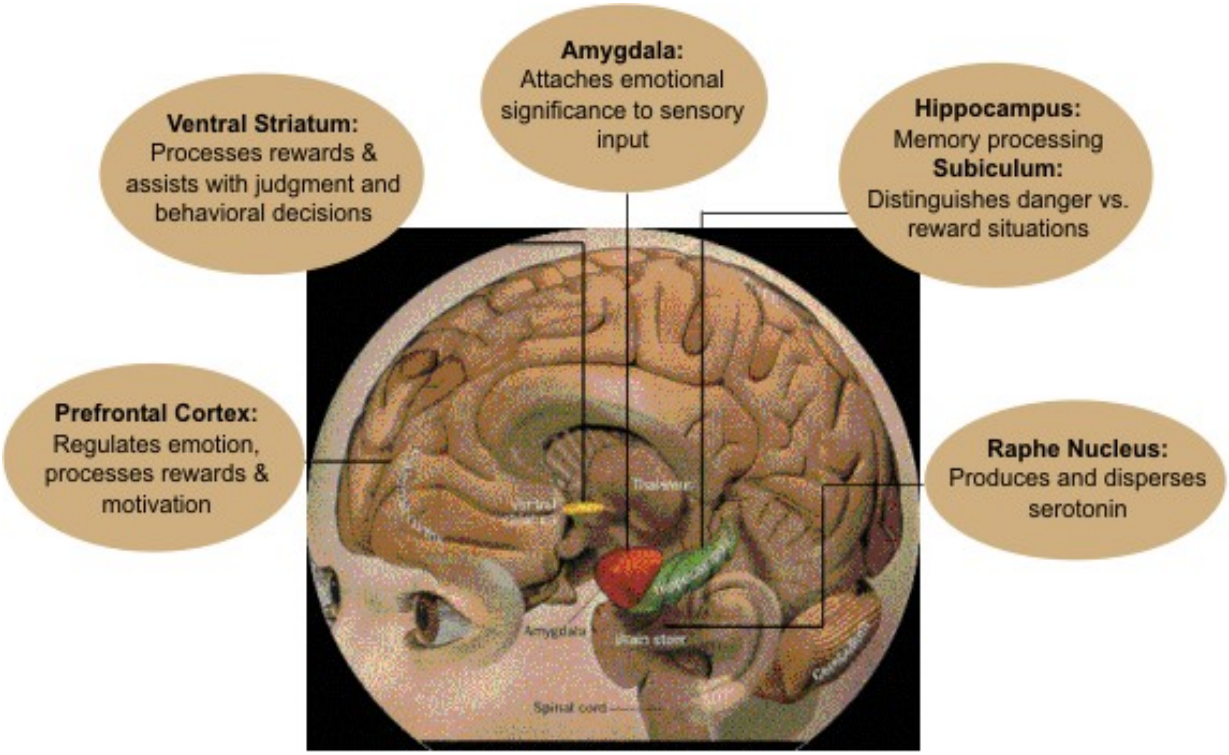


The Limbic System



FUNCTION OF LIMBIC SYSTEM

- Emotion
- Motivation
- Autonomic manifestation
- Memory
- Olfaction
- Fear
- Rage and placid reactions
- Behaviour like feeding, drinking, sexual, maternal.



The Bipolar Brain

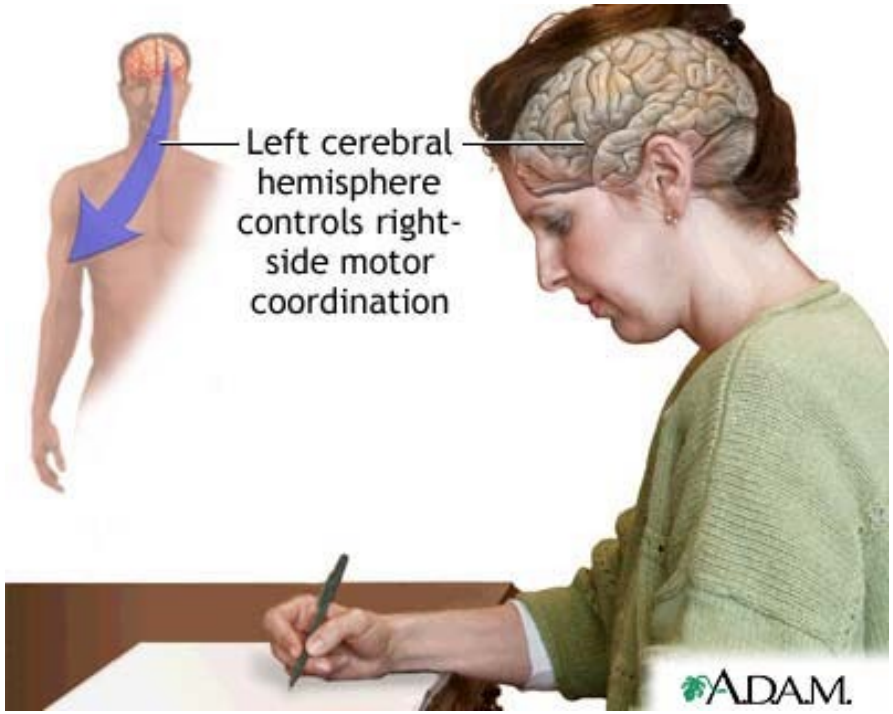
DOMINANT HEMISPHERE

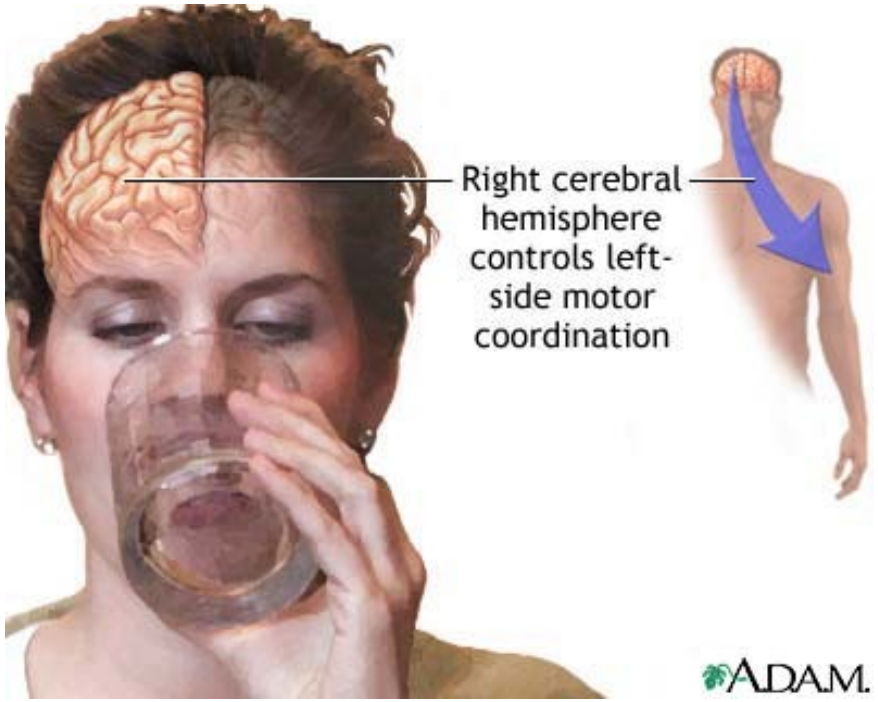
- Though the cerebral hemispheres are alike they have some functional difference in all individuals.
- Most of the human beings are right handed as in them the right side of the body shows dominance in all functions.
- The right side is under the control of left hemisphere (because both the motor and sensory pathways cross).
- Hence the left hemisphere is called dominant hemisphere in right handed persons (also called categorical hemisphere).

DOMINANT HEMISPHERE

- This phenomenon is called cerebral dominance.
- The other hemisphere is called non-dominant hemisphere.
- In the dominant hemisphere there is the centers for speech and language function. This is taken as the most important determinant of cerebral dominance.
- Many of the motor and sensory areas are also more developed in the dominant side and these areas are connected to both sides of the brain.

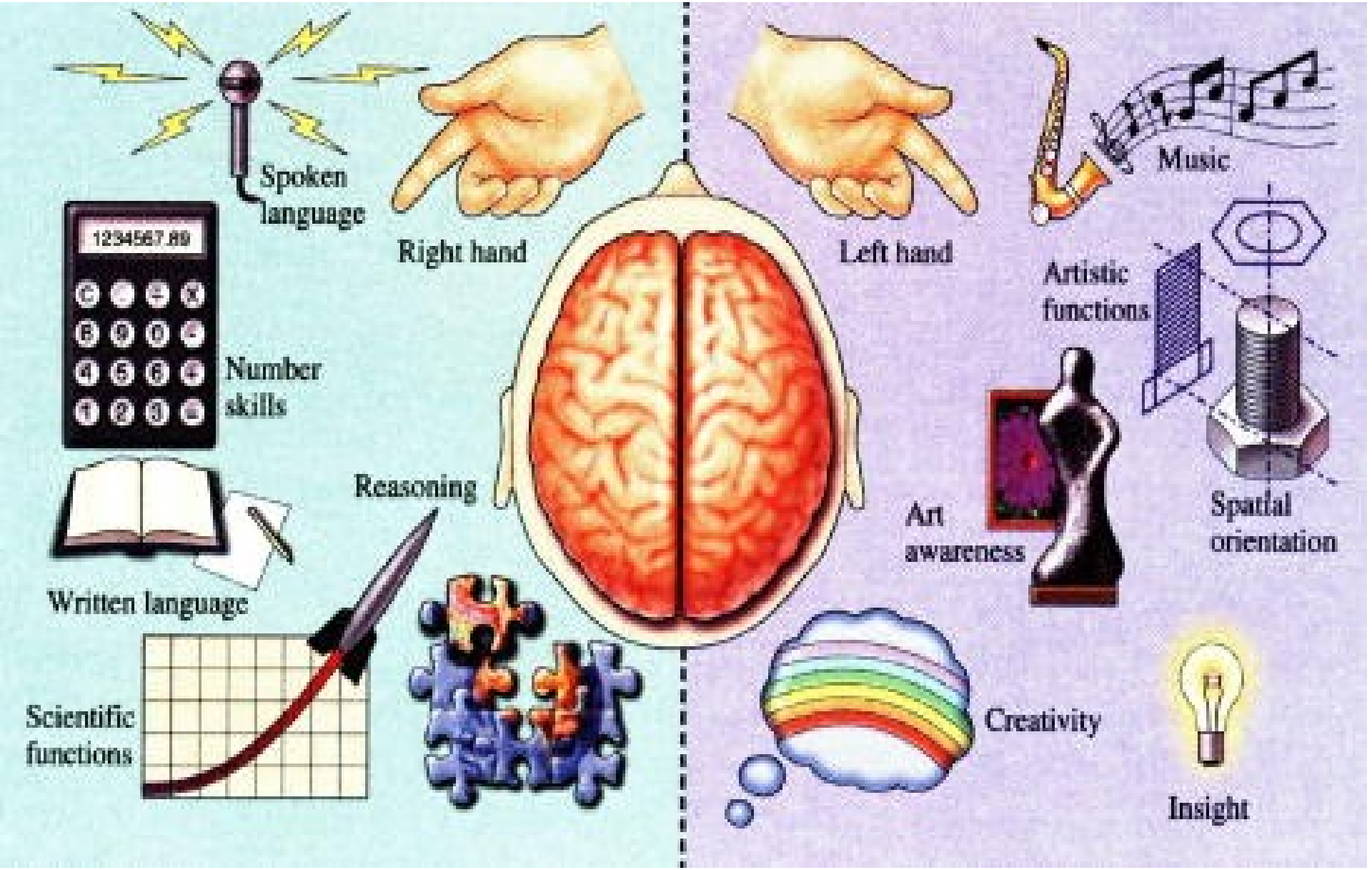
DOMINANT HEMISPHERE





DOMINANT HEMISPHERE

- **The right or the non-dominant hemisphere is also specialised in some functions, which are not present in the left, e.g., musical skill, appreciation of music.**
- **In about 90% of the right handed people the left hemisphere is dominant and in rest 10%, the right hemisphere is dominant but in most of the latter group, the speech centre remains in the left hemisphere.**


Spoken language
Right hand
Left hand
Music
Artistic functions
Number skills
Reasoning
Art awareness
Spatial orientation
Written language
Scientific functions
Creativity
Insight

ESTIMATING THE FUNCTIONS OF DOMINANT HEMISPHERE

1. A man was asked whether he has any close-relatives who is a left-hander or who can work with both the hands (all the works, e. g. writing)—ambidextrous. If he has any left-handed relatives mark it with the letter “L”, if an ambidextrous use the letter “A” and if all are right-handed use the letter “R”.

ESTIMATING THE FUNCTIONS OF DOMINANT HEMISPHERE

2. He was also asked which hand he prefers to do the domestic works like- kicking the ball, hold the instruments, wind up the watches, brush the teeth, light up the matches, etc. If he prefers the left-hand we mark it with the letter “L”, and if right-hand we mark the letter “R”, if there is no preference for any hands in particular, we use the letter “A”.

ESTIMATING THE FUNCTIONS OF DOMINANT HEMISPHERE

3. If you are meeting a person, observe which hand he uses for gesticulation, observe on which hand (dorsal side) you can see the veins more protruding, also observe the direction of his hairs' growth – either towards the left or to the right. If there is the predominance of the left-side you mark it with the letter "L", and if right-side you mark the letter "R", if no predominance can be seen in particular, use the letter "A".

ESTIMATING THE FUNCTIONS OF DOMINANT HEMISPHERE

4. Measure the strength of his hand with the dynamometer thrice in both the hands and get the average value for each hand, if the value differs by 2 kg mark the letter “A”, if the difference is more than 2 kg on the right – use the letter “R”, if on the left – use the letter “L”.

ESTIMATING THE FUNCTIONS OF DOMINANT HEMISPHERE

5. Make him to stand up and straighten his hands downwards and measure the length of his hand from the acromial process of the scapula to the tip of the middle finger. If the difference in length is less than 0.2 cm mark it with the letter “A”, if it is more than 0.2 cm on the right, use the letter “R”, if on the left use the letter “L”.

ESTIMATING THE FUNCTIONS OF DOMINANT HEMISPHERE

6. Measure the width of the thumb's nail (at its center) with a micrometer or a scale. If there is no difference, mark it with the letter "A", if the width on the right thumb is more than the left, use the letter "R", if it is more on the left, use the letter "L".

ESTIMATING THE FUNCTIONS OF DOMINANT HEMISPHERE

7. Tell a man to screw and unscrew a rifle (move the rifle and not the screw) with each hand for 5 times and measure the time, if the time difference is less than 30 seconds, use the letter “A”, if the difference is more on the right, use the letter “R”, if it is more on the left, use the letter “L”.

ESTIMATING THE FUNCTIONS OF DOMINANT HEMISPHERE

8. Tell a man to draw some geometrical figures - triangle, square, circle, etc with both the hands at the same time by closing both the eyes. Compare the figures, if the figures drawn by the right hand is more better, mark it with the letter “R”, if the figures drawn by the left hand is more better mark it with the letter “L”, if the quality is somewhat the same, use the letter “A”.

ESTIMATING THE FUNCTIONS OF DOMINANT HEMISPHERE

9. a) Tell a man to clasp his fingers together, if the right thumb is placed at the first position, mark it with “R”, if the left was at the first position, use the letter “L”.

   b) Tell a man to cross his hands together, if the right hand is placed over the left, use the letter “R”, if the left is over the right, use the letter “L”.

   c) If he gets “R” in both the tests, mark it with the “R”. If he gets “L” in both the tests, mark it with the “L”. If he gets one “R” and one “L”, mark it with the “A”.

ESTIMATING THE FUNCTIONS OF DOMINANT HEMISPHERE

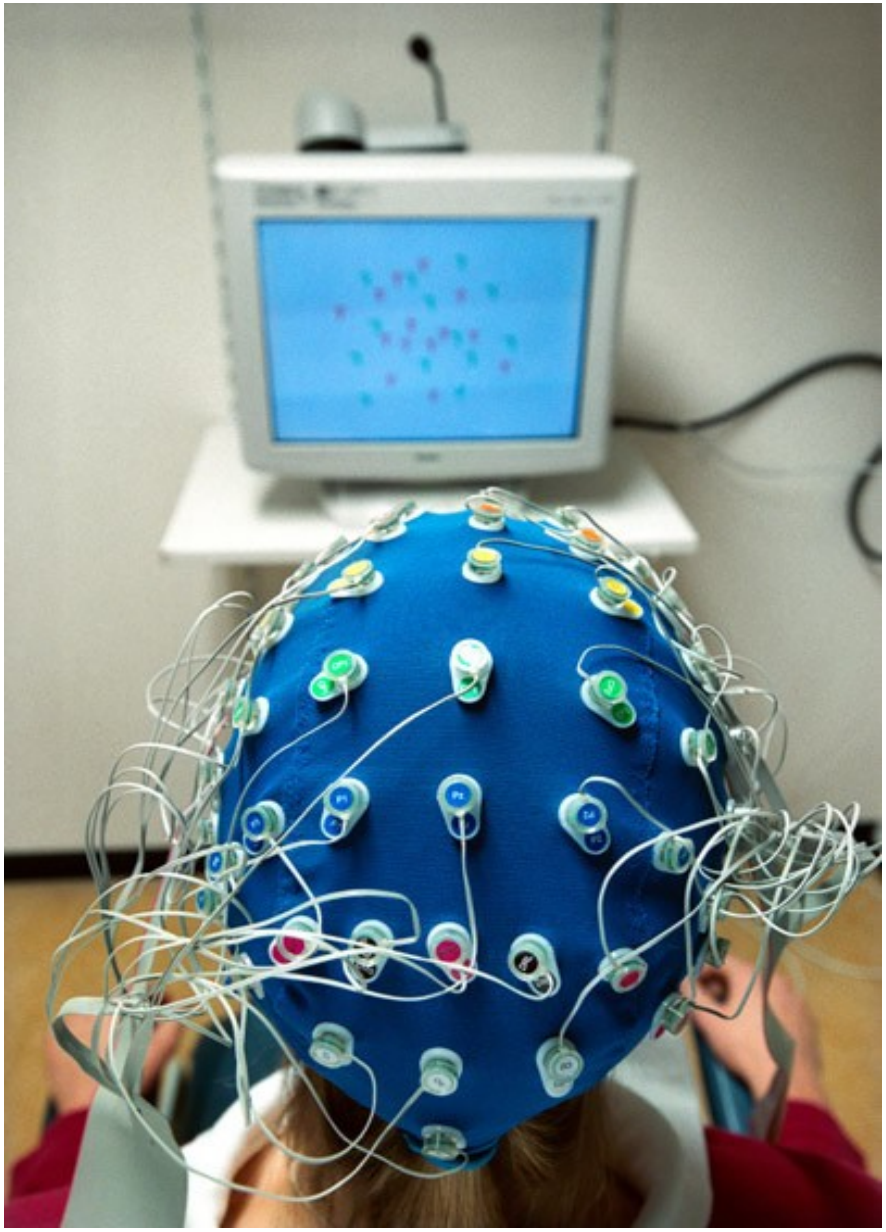
10. Tell a man to draw a circle (target) of diameter 20 cm, tell him to put dots in it (approximately at the center) by both the hands separately, by closing his eyes in the vertical plane. If the dots are kept at a distance of 5 cm from the center – towards the right then mark “R”, towards the left, then “L”.

ELECTRICAL ACTIVITIES OF THE CEREBRAL CORTEX

- **Electroencephalogram is the recording of the spontaneous electrical activities of the cerebral cortex. It was first recorded and introduced by Hans Berger in 1929.**
- **EEG is recorded by placing electrodes over scalp. If electrodes are placed on cortical surface then it is called electrocorticogram.**
- **EEG helps in diagnosis of diseases, epilepsy in particular. It shows four types of waves: alfa-, beta-, delta- and teta-, which show gradual decreasing frequencies.**
- **In awake and alert individuals frequency of EEG waves is higher but the EEG frequency decreases in condition of mental rest, during sleep, in young individuals and in disease.**

Source of EEG

- **The dendritic tree of the cerebral cortex pyramidal cells receive their own axon collaterals along with the axons of the interneurons and various incoming fibres.**
- **These incoming impulses and the electrical activities in the soma of the pyramidal cells form a dipole. Electrical field of this dipole is recorded in EEG through surface electrodes.**



Waves of EEG

The waves seen in EEG are of different frequencies and amplitudes.

Alfa-wave:

- **These are regular 8 to 13 Hz (Hertz, i.e., cycles per second) waves of about 50 μV amplitude (recall, the amplitude of AP is about 100 mV).**
- **These are found in awake individuals when the eyes are closed but mind is wandering, i.e., neither asleep nor undertaking any mental work (thinking).**
- **These waves can be recorded from various parts of brain (e.g., occipital, occipitoparietal).**

Alfa-block

- If the person, whose EEG is showing a waves, opens his eyes or undertake some mental calculations, the EEG waves changes from the regular a-waves into a rapid, low voltage irregular wave.
- This type of disappearance of the waves by a stimulus is called alfa-block. This is also called desynchronisation (or EEG arousal).

Beta-wave

- These are regular 14 to 30 Hz waves of 5 to 10 μV amplitude.
- These are found in the recordings from frontal and parietal regions in a normal alert individual.
- Beta-waves are also found during mental tension and generalized activation of CNS.

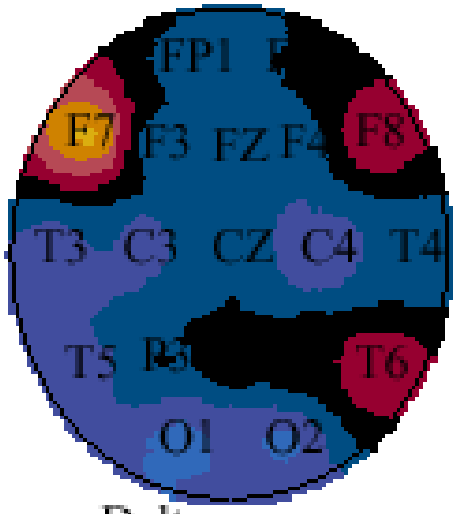
Teta-wave

These are 4 to 7 Hz waves of about 10 μV amplitude and can be recorded from parietal and temporal regions.

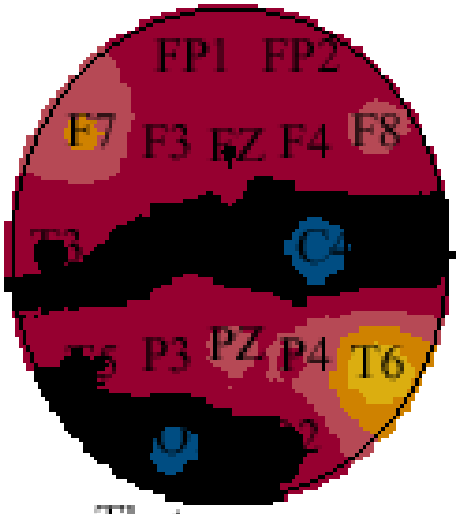
It is also found normally in children.

Delta-wave

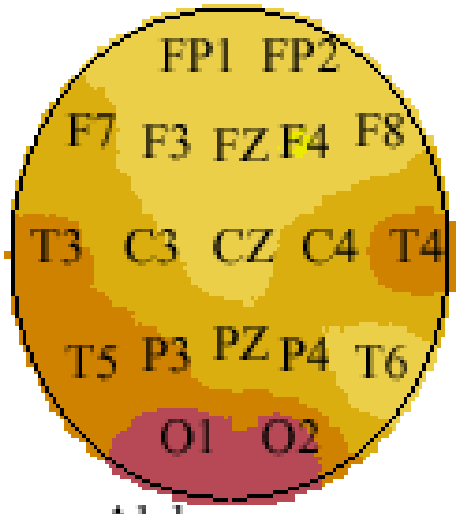
- These are high amplitude (20 to 200 μV) slow (1 to 3 Hz) waves found during sleep, after over breathing.
- Intracranial tumors frequently produce delta-waves.
- It is also found in a cortex with low activity without any external stimulation.



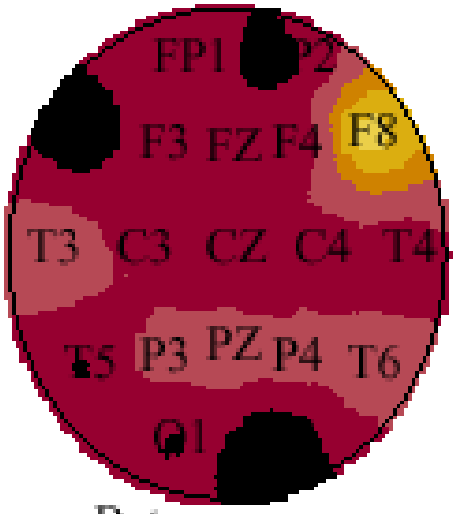
Delta



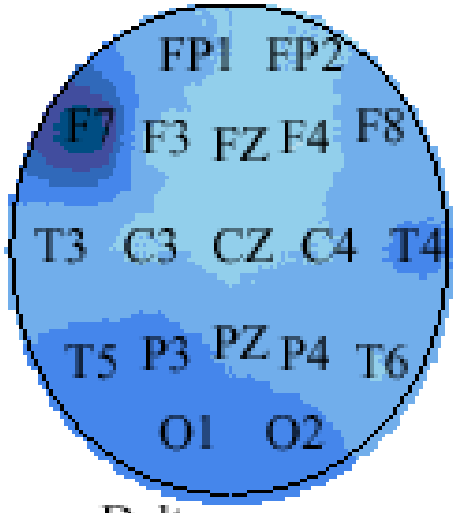
Theta



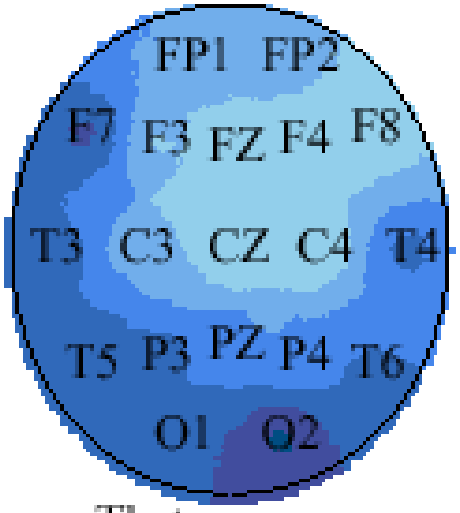
Alpha



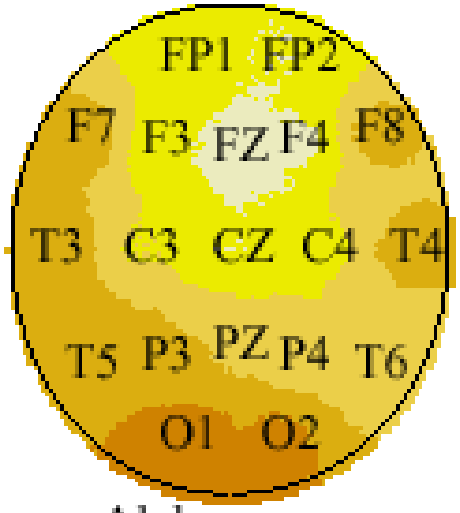
Beta



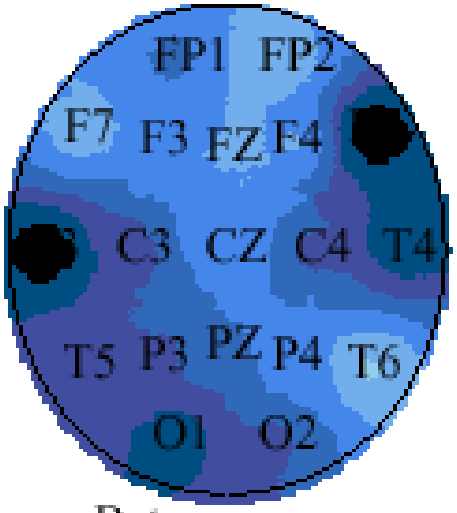
Delta



Theta



Alpha



Beta

Variations in the EEG

1) Sleep-wake cycle shows maximum variations in EEG waves. The high frequency irregular waves of awake condition gradually change to slow but larger waves with sleep.

2) The fast activities in the infants gradually changes to reach the adults pattern.

Variations in the EEG

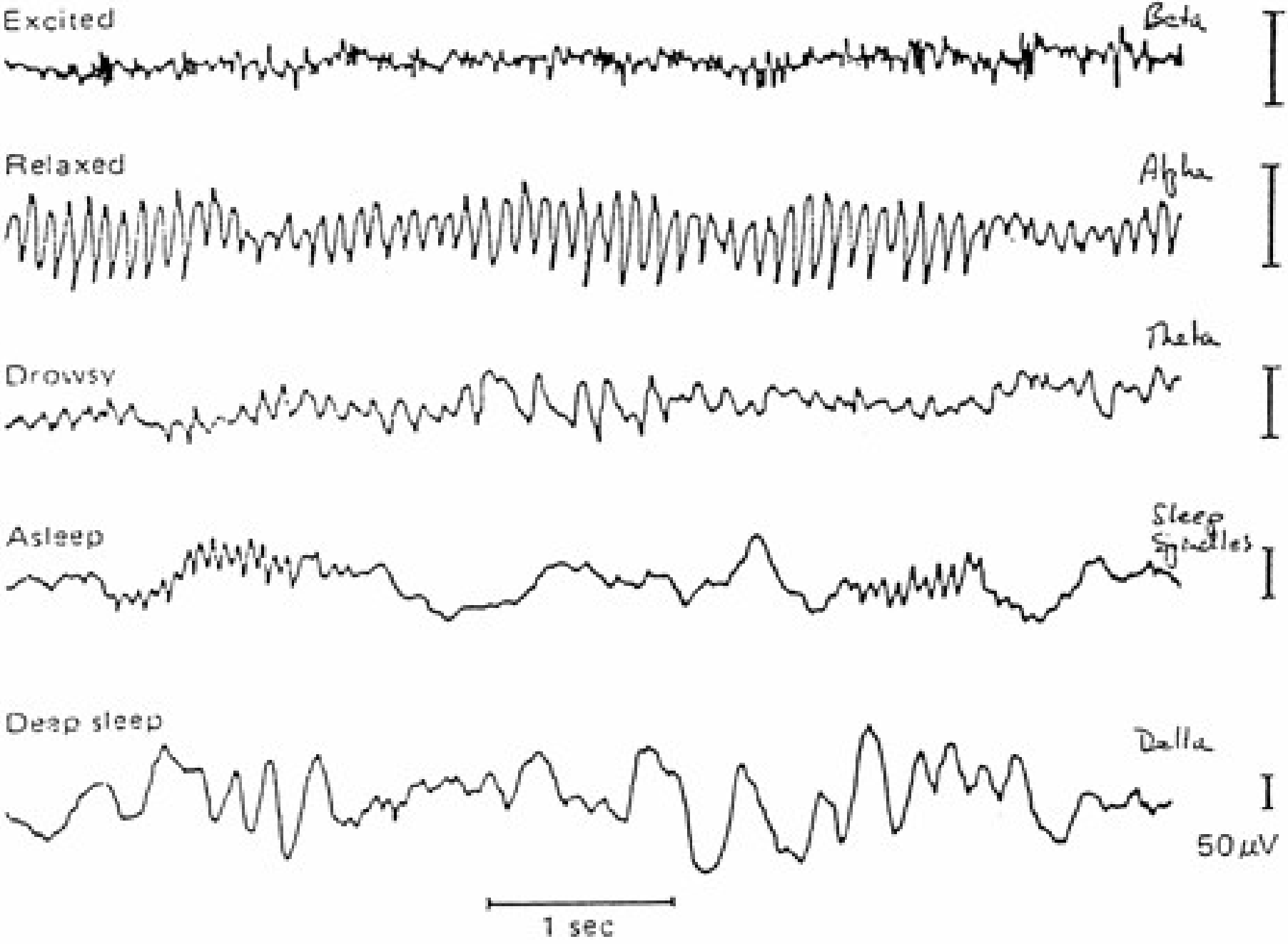
3) Hyperventilation also leads to changes in EEG. It helps to unmask any abnormal rhythm present, hence used in routine EEG. Increased CO_2 also changes the EEG.

4) In hypoglycaemia the EEG becomes of low frequency so also in hypothermia.

Variations in the EEG

5) Certain hormonal changes also affect EEG pattern e.g., hyposecretion of glucocorticoids decreases the frequency of a rhythm and increased secretion increases the frequency.

6) Different diseases give charateristic EEG changes e.g., in epilepsy.


Excited
Beta
Relaxed
Alpha
Drowsy
Theta
Asleep
Sleep Spindles
Deep sleep
Delta
50 μV
1 sec

Sleep fundamentals

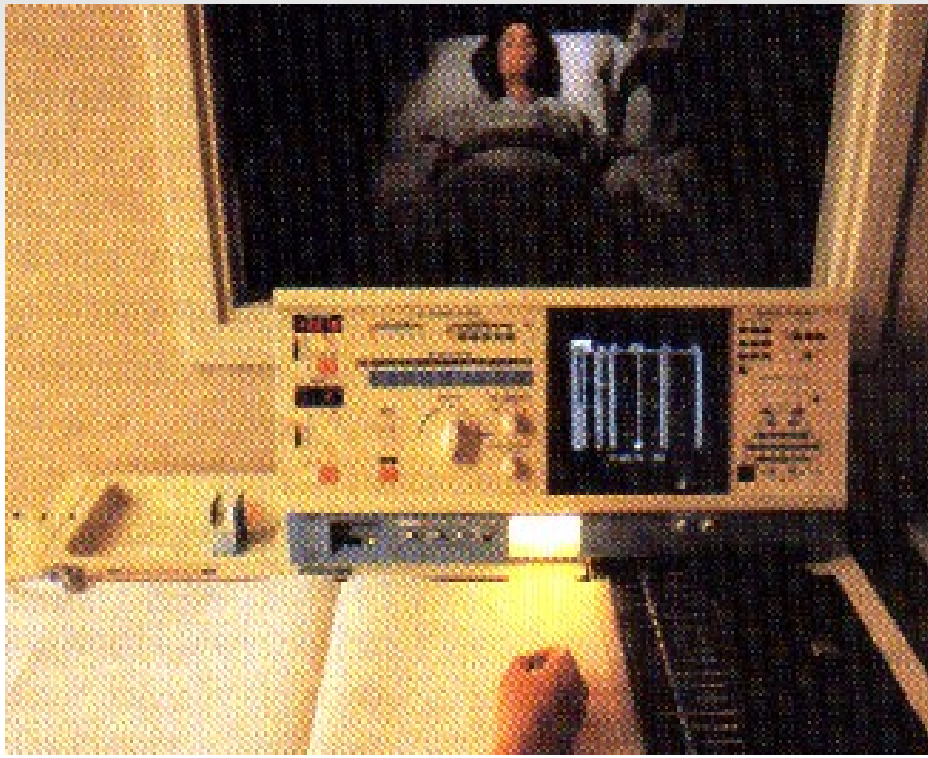
- **Sleep is a readily reversible state of reduced responsiveness to and interaction with the environment**
- **Fundamental behavioural states:**
  - **awake**
  - **non-REM sleep**
  - **REM sleep**

CIRCADIAN RHYTHM

- Any rhythmic change that continues at close to a 24-hour cycle in the absence of 24-hour cues
  - **body temperature**
  - **cortisol secretion**
  - **sleep and wakefulness**
- In the absence of time cues, the cycle period will become somewhat longer than 24 hours

Electroencephalogram (EEG)

- Electrodes placed on the scalp provide a gross record of the electrical activity of the brain
- EEG recordings are a rough index of psychological states during awake and sleep



EEG Waves of Wakefulness

- Awake, but non-attentive – large, regular alpha-waves.
- Awake and attentive – low amplitude, fast, irregular beta-waves.

Getting to sleep

- Decrease in body temperature
- Built-up of prostaglandines
- Increased adenosine levels
- Increased GABA release

Non-REM sleep

- Reduced muscle tension throughout body
- Minimal movement (body capable of movement, but brain rarely commands to)
- Low temperature and energy consumption
- Heart rate, respiration and kidney function slow down
- Increased digestive process

Non-REM sleep

- Brain is resting – energy use and general neuron firing rates at lowest point of day
- Cortex neurons oscillating at high synch - sensory information cannot reach cortex
- Detailed, entertaining dreams rare

“An idling brain in a movable body”

W.Dement

Non-REM sleep stages

- Stage 1 – transitional sleep (lightest stage)
  - EEG α-rhythms less regular
  - eyes make slow rolling movements
    - duration few minutes
- Stage 2 – slightly deeper
  - occasional sleep spindles
  - K-complex observed
  - eye movements almost stop
    - duration 5-15 minutes

Non-REM sleep stages

- **Stage 3**

  - large amplitude slow δ-rhythms

  - no eye or body movements

- **Stage 4** (deepest stage)

  - large 2 Hz and slower rhythms

  - duration 20-40 minutes

REM sleep

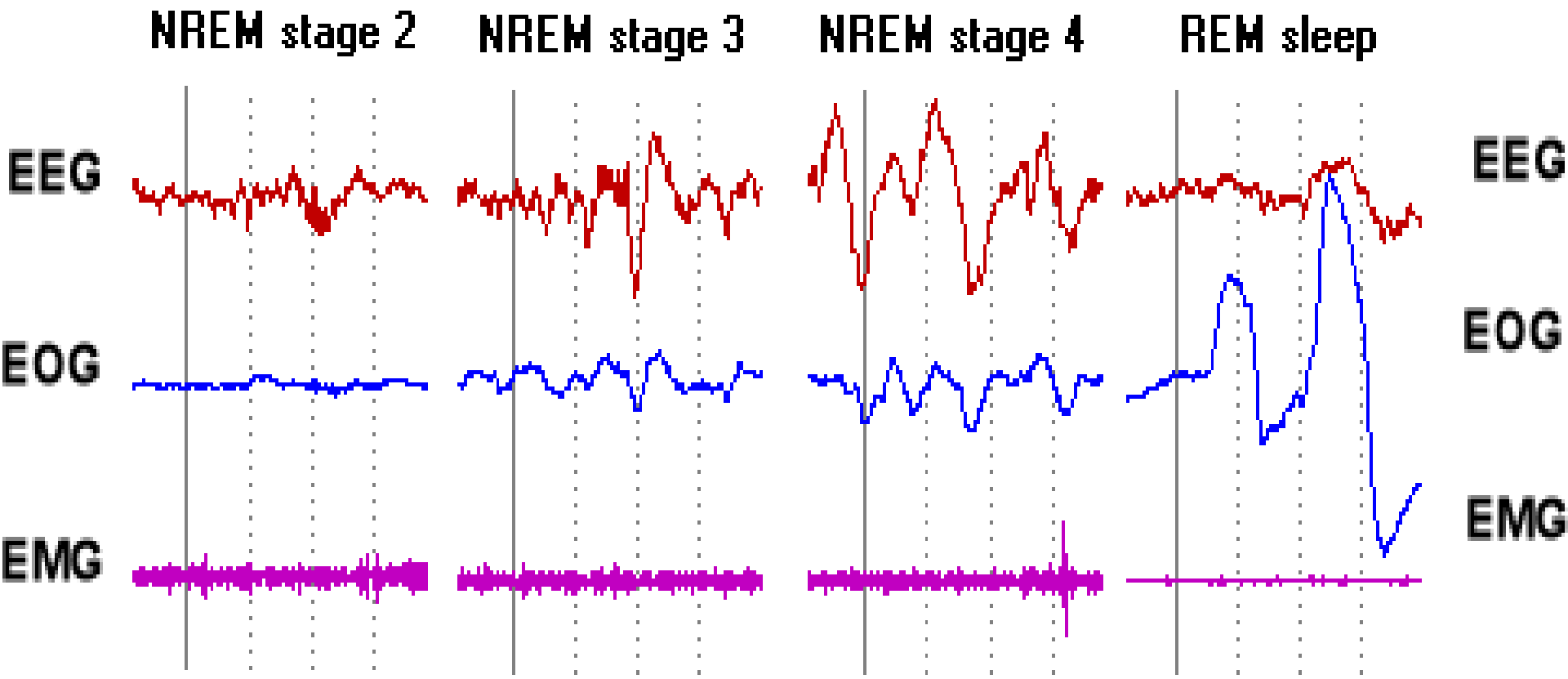
- Dreaming period
- EEG almost indistinguishable from that of an active brain i.e. fast, low voltage fluctuations
- High oxygen consumption
- Increased and irregular heart and respiration rates

- **Muscle atonia**
  - exception: muscles controlling eye movements and tiny muscles in inner ear
  - respiratory muscles barely operate
  - eyes occasionally dart rapidly back and forth
- **Body temperature drops**
- **Sexual arousal**

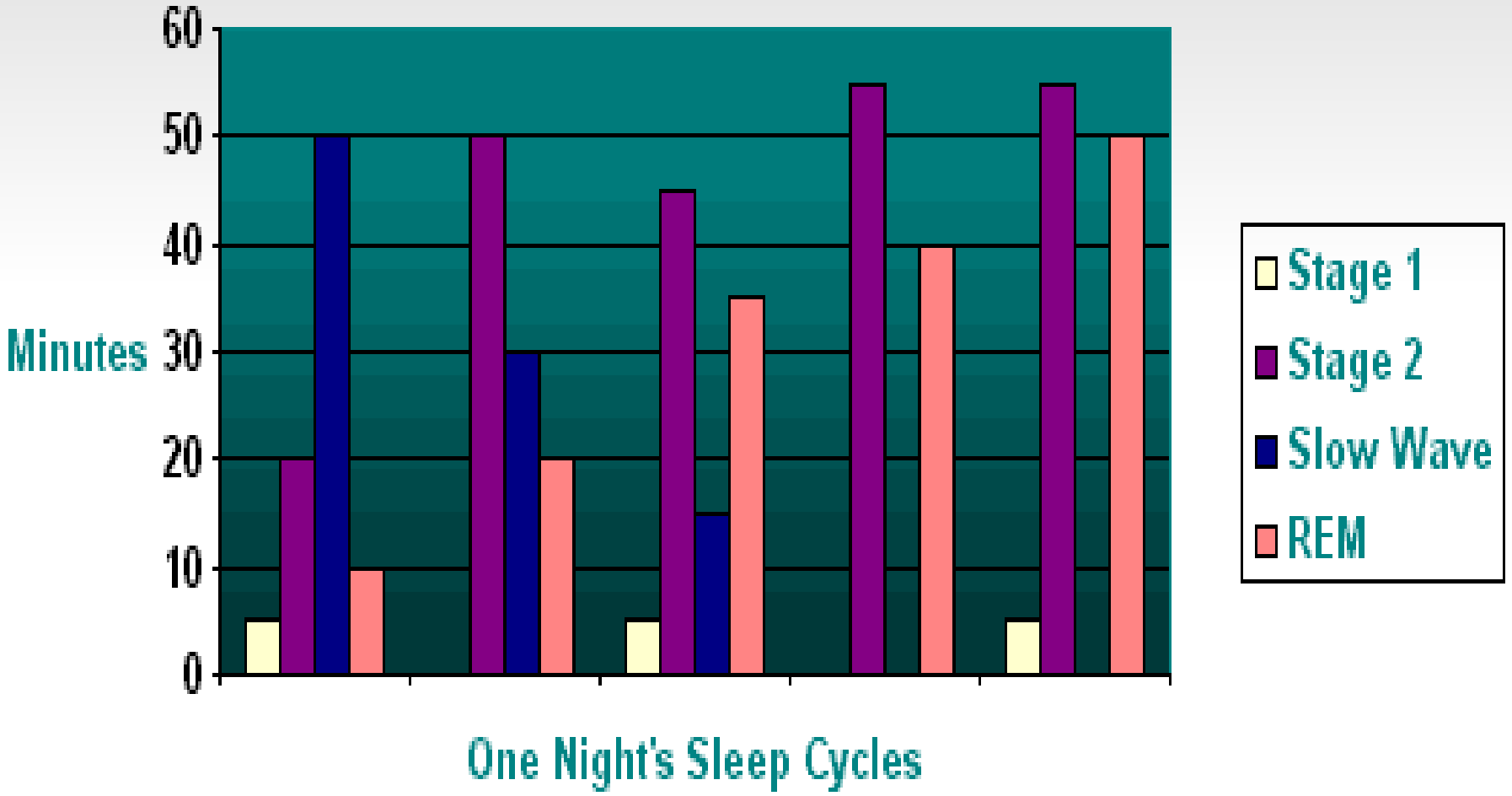
"An active, hallucinating brain in a paralysed body"

W. Dement

EEG, EOG and EMG during different sleep stages



Sleep cycle


60
50
40
30
20
10
0
Minutes
Stage 1
Stage 2
Slow Wave
REM
One Night's Sleep Cycles

Why do we sleep?

- **Restoration:** we sleep to

  - rest, recover and prepare to be awake (but no physiological process restored or essential substance made or harmful toxin destroyed during sleep has been identified so far)
- **Adaptation:** we sleep to

  - keep ourselves out of trouble

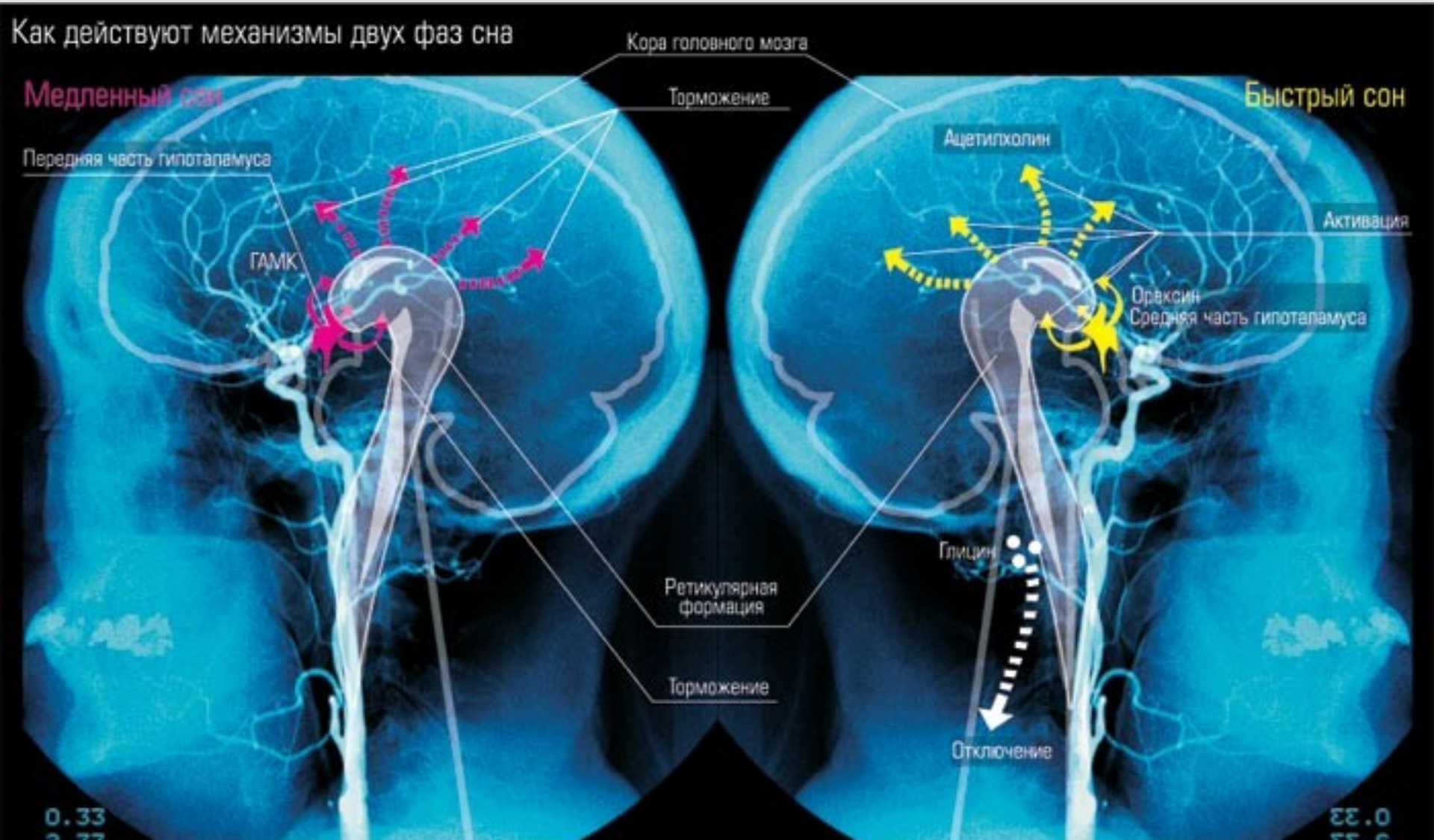
  - hide from predators when we are most vulnerable

  - conserve energy

Brain Mechanisms Controlling Sleep

- Sleep is promoted by a complex set of neural and chemical mechanisms
- Daily rhythm of sleep and arousal
  - suprachiasmatic nucleus of the hypothalamus
  - pineal gland's secretion of melatonin
- Slow-wave sleep
  - raphe nuclei of the medulla and pons and the secretion of serotonin
- REM sleep
  - neurons of the pons

Brain Transections Reveal Sleep Mechanisms



Individual Differences in Sleep Drive

- **Some individuals need more and some less than the typical 8 hours per night.**
- **Nonsomniacs – sleep far less than most, but do not feel tired during the day.**
- **Insomniacs – has a normal desire for sleep, but is unable to and feels tired during the day.**

SLEEP DEPRIVATION

- **Has little effect on performance of tasks requiring physical skill or intellectual judgment.**
- **Hurts performance on simple, boring tasks more than challenging ones.**
- **Most reliable effect is sleepiness itself.**

Sleep disorders

- **Dyssomnias:**
  - Restless Legs Syndrome
  - Periodic limb movements
  - Sleep-related eating disorder
  - Insomnia & Hypersomnia
  - Sleep apnea
- **Parasomnias:**
  - REM behaviour disorder
  - Sleep terrors
  - Sleepwalking (somnambulism)
  - Rhythmic movement disorder

Narcolepsy

- Unwanted sleep attacks. Symptoms:
  - excessive daytime sleepiness
  - cataplexy (sudden muscular paralysis while conscious)
  - sleep paralysis (similar loss of muscle control during transition between sleeping & waking)
  - hypnagogic hallucinations
  - automatic behaviour

Genetic component

No known cure, only symptom relief

DREAMS

Everyone dreams several times a night
(every night of our lives)

- **true dream – vivid, detailed dreams consisting of sensory and motor sensations experienced during REM**
- **sleep thought – lacks vivid sensory and motor sensations, is more similar to daytime thinking, and occurs during slow-wave sleep**

ANCIENT CULTURES

dreams were window to higher world, source of info and guidance, power or enlightenment, alternative realities, prophetic visions, sexual fantasies

Sigmund Freud

dreams were disguised wish-fulfilment; unconscious way of expressing our sexual and aggressive fantasies which are forbidden while we are awake

Hobson and McCarley
"**ACTIVATION – SYNTHESIS**" - theory
(reject Freudian psychological interpretation)

Dreams are associations and memories of the cerebral cortex elicited by random discharges of the pons during REM

Alternative view – dreams originate partly from external stimuli, but mostly from brain's own motivations, memories and arousal

Dreams and REM Sleep

- What are true dreams for?
- Although research has yet to answer this question, a prevalent view today is that dreams don’t serve any purpose at all, but are side effects of REM
  - to exercise groups of neurons during sleep
  - some are in perceptual and motor areas
- REM occurs in other mammals and to a much greater extent in fetuses and infants than adults

- REM (and perhaps dreams) have important role in memory. REM sleep may help consolidate memories
- REM deprivation can impair ability to learn a variety of tasks, but no scientific evidence for sleep-learning
- Means by which brain gets rid of unnecessary or wrong info obtained while awake – reverse learning

Lucid Dreaming

- Dreaming while knowing that are you dreaming
- Usually begins in midst of dream when dreamer realises that it is a dream. Triggered by noticing some impossible or unlikely occurrence
- High-level and low-level lucidity

Why have lucid dreams?

- Adventure and fantasy
- Overcoming nightmares
- Rehearsal
- Creativity and problem solving
- Healing
- Transcendence

  (everybody can learn to have lucid dreams)

Thank You For Your Attention!