

**Shrimati Indira Gandhi College**

**Nationally Accredited at 'A' Grade (3<sup>rd</sup> cycle) By NAAC  
Tiruchirappalli-2**

**HUMAN PHYSIOLOGY  
Subject Code : 16SCCBC2**

**Dr.T.Karpagam**

**Asst. Prof. Department of Biochemistry**

**I BSc BIOCHEMISTRY**

**Chemical Composition of Brain,  
Nervous Tissue And Energy  
Adaptation**

**II SEMESTER**

# Content

- 1. Chemical composition of the Nervous tissue**
- 2. Chemical composition of the Brain**
- 3. Energy Adaptation of Brain**

# Chemical composition of the Nervous Tissue

Nervous tissue is characterized by

- ❖ **high lipid and protein**
- ❖ **Complex lipids (e.g. phospholipids and sphingophospholipid) and**
- ❖ **unesterified cholesterol** are the most abundant lipids.

It does not contain

- ❖ **Saccharides.**

# Neurons.....

- ❖ Neurons synthesizes the longest fatty acids in the human body.
- ❖ Presence of **very long chain FA** is quite usual (often in the form of hydroxy acids).
- ❖ TAG – Triacyl Glycerol are missing.

## Role of Proteins....

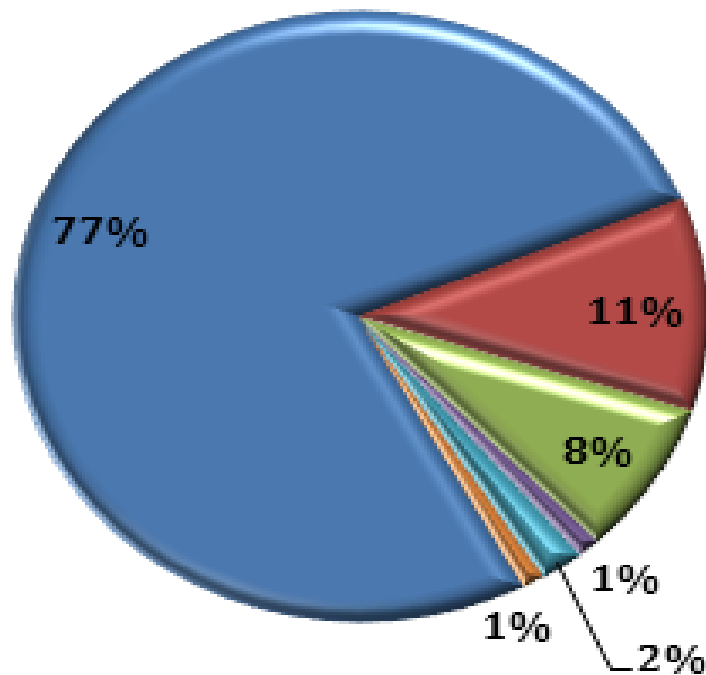
- ❖ Irreplaceable role as **channels, transporters, receptors** and neurotransmitters.
- ❖ The most important transporter -  **$\text{Na}^+/\text{K}^+$ -ATPase**,
- ❖ Responsible for maintenance of the **resting membrane potential**, at the cost of a **high energy consumption**.
- ❖ It takes up 70 % of the total energy expenditure.

# Myelin sheath of neurons are composed of

- ❖ lipids (**glycolipids, sphingomyelin** etc.)
- ❖ proteins (e.g. **myelin basic protein**)

# Composition of Brain

## Composition of the Average Human Brain



- Water
- Lipids (fats)
- Protein
- Carbohydrate
- Soluble Organic Substances
- Inorganic Salts



# Chemical Composition of the brain

- ❖ Water - 80 percent.
- ❖ Solids -20 percent.
- ❖ The water content of brain is little more than that of spinal cord.
- ❖ In brain, the grey matter where nerve cell bodies are present contains more water than the white matter where the nerve fibres are mainly found.

# Chemical Composition of the brain

- ❖ The solids - mainly composed of proteins, lipids, small amounts of organic extracts & inorganic salts.
- ❖ Proteins - 38 to 40 % of total solids.
- ❖ They include - globulins, nucleoproteins, albuminoid called neurokeratin.
- ❖ A fraction of the brain proteins remains combined with copper forming Caeruloplasmin.

# Chemical Composition of the brain

- ❖ Lipid -50 to 54 % of the total solids.
- ❖ The important lipids - phospholipids, cholesterol, cerebrosides, amino-lipids, and sulphur containing lipids.
- ❖ The principal inorganic salts – Potassium, Phosphate, Chloride, Sodium.
- ❖ Potassium is highly significant in the nerve impulse.

# Chemical Composition of the brain

- ❖ White matter, peripheral nerves contain more cerebrosides, free cholesterol, and sphingomyelin than grey matter.

## Pathology

- ❖ An increased deposition of copper is found in the brain tissue in Wilson's disease.
- ❖ The considerable increase in the concentration of sphingomyelin is found in Niemann-Pick disease.

# Energy metabolism of the CNS

- ❖ Brain constitutes only **2 % of the total body weight**
- ❖ But its **metabolic demands are extremely high.**
- ❖ It utilizes **20 % of the total oxygen and 20 % of the total glucose consumption.**
- ❖ The **glucose** is used to **maintain the membrane potential through  $\text{Na}^+/\text{K}^+$ -ATPase** and other processes involved in transport of ions across the membrane.

# Energy metabolism of the CNS

- ❖ Brain is the most **sensitive organ to oxygen or glucose deficit**.
- ❖ Shortage of oxygen causes **unconsciousness** within few tenths of seconds and
- ❖ **Damage to neurons becomes irreversible after about 5 minutes**.
- ❖ The rate of neuronal death depends on many factors, for example **temperature**.

# Energy metabolism of the CNS

- ❖ People with **hypothermia** have significantly **reduced cellular metabolism** and
- ❖ **Demands for oxygen and nutrients supply decrease** leading to a longer survival in their absence.
- ❖ Value of the respiratory quotient of brain is very close to 1.
- ❖ RQ, calculated as a proportion of **produced CO<sub>2</sub>** and **consumed O<sub>2</sub>** –  $RQ = VCO_2 / VO_2$ )
- ❖ Brain metabolism utilizes almost exclusively **saccharide sources, particularly** glucose.
- ❖ Its daily consumption is about **120 g**.

# Energy metabolism of the CNS

- ❖ Brain **does not utilize fatty acids.**
- ❖ Fatty acids Transported in bloodstream bound to the albumin, fatty acids are unable to cross the hemato-encephalic barrier.
- ❖ However, during a long-term starvation brain metabolism **adapts to the consumption of ketone bodies.**
- ❖ A full adaptation develops approximately within three weeks of starvation.
- ❖ After this period, the brain is able to **cover up to 50% of its energy expenditure from the oxidation of ketone bodies.**



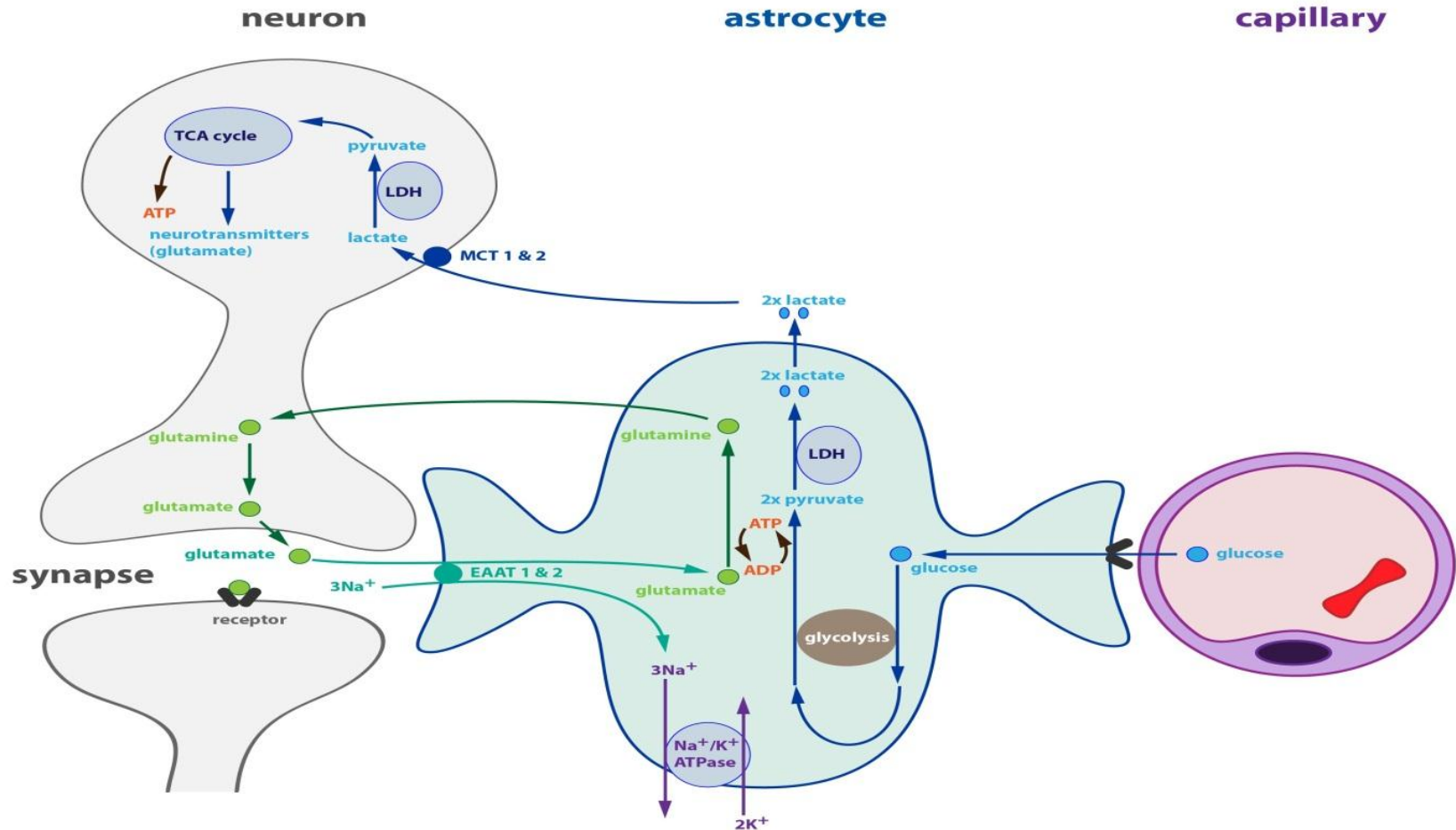
# The role of astrocytes

- ❖ **Glucose** is consumed mainly by **astrocytes**.
- ❖ Neurons themselves utilize other substrates: primarily **lactate** and **pyruvate**.
- ❖ These substances are produced and released into the extracellular space by astrocytes and followed by an absorption into neurons.
- ❖ **The production of a lactate in astrocyte is coupled with the activity of neuron.**

# The role of astrocytes

- ❖ Astrocytes play an important role in the **recycling of glutamate**-important excitatory neurotransmitter.
- ❖ **Glutamate from the synaptic cleft is transported into the astrocytes through symport with sodium cations.**
- ❖ Increased concentration of  $\text{Na}^+$  in astrocyte causes an **activation of  $\text{Na}^+/\text{K}^+$ -ATPase**, which restores the electrochemical gradient necessary for transport.
- ❖ Astrocytes **convert glutamate into glutamine** and return it back to the neuron to the further utilization.
- ❖ Both of the above-mentioned processes require **ATP**.

# The role of astrocytes



# Neuronal Activity

**When the activity of neuron is high**

It secretes a lot of glutamate into the synaptic cleft.

Increased transport of glutamate into the astrocyte

**Activates  $\text{Na}^+/\text{K}^+$ -ATPase**

Conversion of glutamate into glutamine.

This stimulates the glycolysis leading to an increase in glucose intake from blood and ATP Synthesis

# Neuronal Activity

**More lactate is produced**

**which is then utilized by neurons**

**Astrocytes contain small quantities of glycogen**

**Undergo an intense metabolism**

**Glycogen acts as a short-term energy reserve**

**Until the supply of glucose is increased**

# Energy metabolism of the CNS

- ❖ **Ammonia** is able to **freely cross the haemato-encephalic barrier**.
- ❖ If its **concentration in blood increases**
- ❖ (the upper physiological limit is around 50  $\mu\text{mol/l}$ )
- ❖ It significantly interferes with the brain metabolism.

# Energy metabolism of the CNS

- ❖ Excess of glutamate leads to a **disruption** in its **transport from synaptic cleft**
- ❖ called **excitotoxic neuronal damage** with an **impaired neurotransmission**.
- ❖ Excessive glutamate causes a **change in osmotic relationship** between the inner and outer environment.
- ❖ The resulting **influx of water** leads to **brain edema** (intracellular at first and later extracellular as well).

## Conditions that cause hyperammonemia...

- ❖ **An insufficient synthesis of urea due to the damage to liver function.**
- ❖ Quick/fulminant **liver failure** e.g. paracetamol poisoning - **liver encephalopathy**.
- ❖ They are caused by the toxicity of ammonia.
- ❖ Symptoms - confusion, disorientation, agitation, unconsciousness or coma.
- ❖ There are four grades of this encephalopathy (I-IV).



# Comparative Brain metabolism -

- ❖ Brain requirements and metabolism have different aspects as compared to other body parts.
- ❖ All vertebrates have a blood–brain barrier that allows metabolism inside the brain to operate differently from metabolism in other parts of the body.
- ❖ Glial cells play a major role in brain metabolism by controlling the chemical composition of the fluid that surrounds neurons, including levels of ions and nutrients.

## ENERGY CONSUMPTION .....

- ❖ Brain tissue consumes a large amount of energy in proportion to its volume,
- ❖ So large brains place severe metabolic demands on animals.
- ❖ The need to limit body weight in order,

## SUMMARY AND CONCLUSION

- ❖ Most of the brain's energy consumption goes into sustaining the electric charge (membrane potential) of neurons.
- ❖ Most vertebrate species devote between 2% and 8% of basal metabolism to the brain.
- ❖ In primates, however, the fraction is much higher—in humans it rises to 20–25%.

# SUMMARY AND CONCLUSION

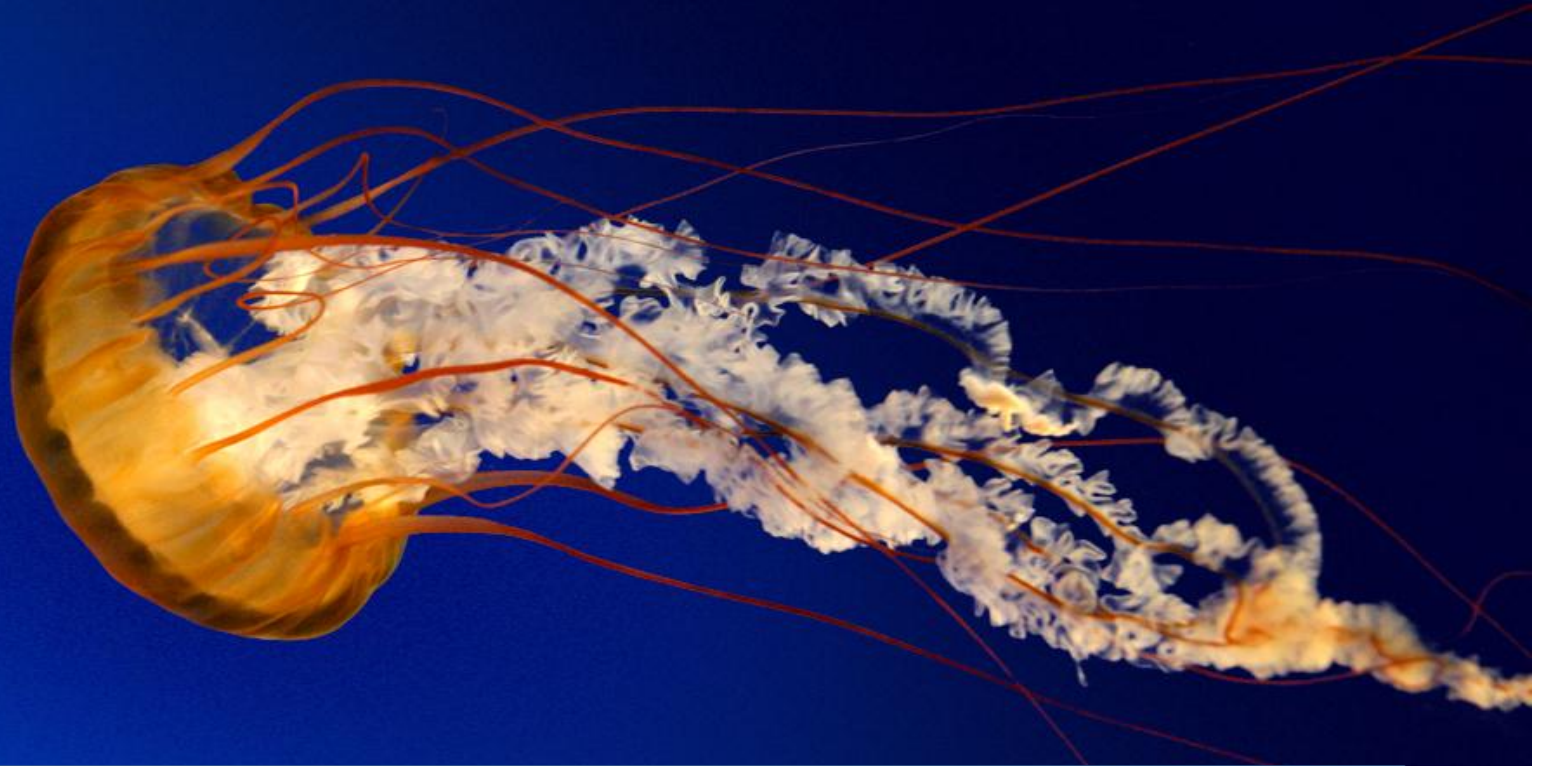
- ❖ The energy consumption of the brain does not vary greatly over time.
- ❖ Active regions of the cerebral cortex consume somewhat more energy than inactive regions.
- ❖ This forms the basis for the functional brain imaging methods PET, fMRI, and NIRS.

# SUMMARY AND CONCLUSION

- ❖ The brain typically gets most of its energy from oxygen-dependent metabolism of glucose (i.e., blood sugar),
- ❖ but ketones provide a major alternative source, together with contributions from medium chain fatty acids (octanoic and hexanoic acids), lactate, acetate, and possibly amino acids.

## Probable questions.....

1. Write the composition of Nervous Tissue.
2. What is the composition of Brain?
3. Write in detail about the metabolic adaptation of Brain?



**THANK YOU**