Structure and function of human brain - its relationship to early childhood development

Impressive and rapid developments in science have provided compelling evidence to bring about a paradigm shift in policy to accelerate the reduction of early childhood mortality, bring about improvement in nutritional status and transformation. Amongst the numerous strides made, the developments in the science of brain development during the last five decades has been very impressive. Attention during the first 1000 days (foetal life and the first 730 days after birth) can have life long impact. The results are even more rewarding if stress, neglect and trauma during this stage of human development are attended to through improved quality of care and provision of equitable services.

These impressive developments have helped the leaders of the world to agree on the goals for sustainable development to be achieved by 2030 (1). India is a signatory to SDGs. Eleven of the 17 SDGs have included targets that relate directly to early childhood development (ECD). The importance of ECD in reaching the sustainable development goals has been highlighted in another communication in SWACH website.

In this brief, key features of structure and functions of different parts of the brain have been highlighted to stress the importance of providing care during the critical and sensitive periods of human brain development.

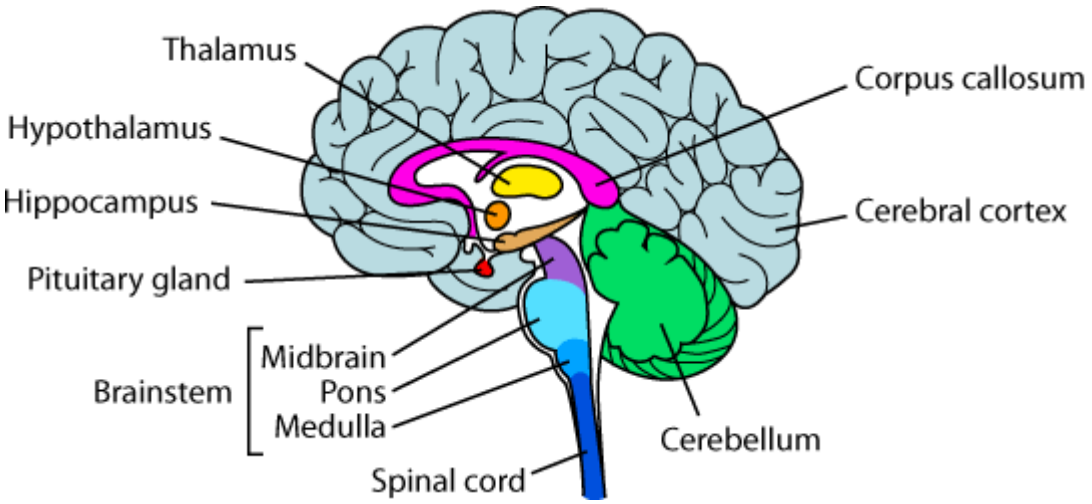
Amazing facts about human brain

1. The weight of an adult brain is about 1400 grams. A 2 year old infant's brain is about 80% of that of an adult (2) but brain reaches its maturity at around 25 years age.
2. Brain comprises of about 60% of fat (much higher than rest of the body) and about 25% cholesterol (reference 3,4).
3. Total weight of the brain is only about 2-3% of the body but it consumes upto 20% of the energy and oxygen (5)
4. The brain is richly supplied with blood - about 400 miles (6)
5. Human brain is soft like a gelatin and it is very fragile (7)
6. Our brains have an estimated 86 billion brain cells (8) and each cell is connected by about 40,000 synapses with a lot of variation in the number of synapses (9)
7. All brain cells are not alike, there are about 10,000 different types of cells in the brain (10)
8. Information moves at a speed of above 250 mph which is faster than the speed of cars in fastest race- formula 1 (11). The brain generates electricity between 15-25 watts (12).
9. More than 100, 000 chemical reactions take place every second (13)
10. Brain storage and processing capacity is limitless (14)
11. A blood brain barrier protects us from the ill effects of toxins though this is not a perfect barrier (15)
12. The human brain survives starvation for long but when pushed beyond limits can cannibalize itself (16)

Adult brain is about 1400 grams in weight representing only 2-5% of the body weight. In contrast, the brain at birth is about 25% of the body weight and at 1 year some 80% of the brain has already developed (in weight) while the body weight is only about 8-10% of the adult weight. This means growth of the brain is very rapid from conception upto 2 years age. As the brain develops, different parts of the brain develop according to the various needs of the body functions to serve different critical functions and at the same time prepare for transformation to become a productive healthy adult. The various parts of the brain work together in complete harmony for localization of different functions and at the same time function in a highly co ordinated fashion.

Basic structure and functions of the brain – critical parts of the brain and what they do

Brain structure in this brief has been arranged according to the sequence of key functions of the body starting at the time of birth. Brain is soft gelatin like, it is quite fragile. It is protected by a bony structure- the skull. Between the skull and the brain is the meninges and cerebro spinal fluid (CSF).



Source: Structure of the brain Parts of the Brain | ASU - Ask A Biologist
https://askabiologist.asu.edu/parts-of-the-brain

Brainstem: The brainstem besides other parts comprises of **Medulla**, **Pons**, and the **Midbrain**. The brainstem is situated below the cerebellum. It is the connection between brain and the spinal cord. Brain stem controls involuntary muscles that control and stabilize heart beat. It helps keep us alive by controlling breathing, blood circulation, blood pressure and digestion etc.

Hypothalamus: is the area of the human brain that serves the function of a thermostat. When one gets hot, hypothalamus sends signals to the skin to sweat. If one gets cold it makes the person shiver and gain body heat. The development and functioning of this thermostat as well as other parts of the brain responsible for temperature control occurs in a few days after being born. This can be slower or less efficient in pre mature and low birth weight babies. Besides temperature control, it is also the control

center for thirst, hunger and release of important hormones at different times of the day and night (temperature control, thirst, hunger, circadian rhythm)

Pituitary gland: This gland is about the size of a pea. It controls our body growth - when and how fast we grow. Therefore it is important in early childhood and adolescence. It uses hormones that control sugar and water, circulation, digestion and body metabolism through hormonal control.

Thalamus: this critical part of the brain functions like a switch and relay station that helps to transfer information received from different parts of the body to cerebral cortex. The information is processed and sent back to thalamus for sending the signals to the body for action. Besides the body, thalamus also acts like a switch for different parts of the brain. The critically important functions of sleep and consciousness are also controlled by thalamus (sleep, consciousness, sensory and motor integration)

Hippocampus: is situated deep inside the brain. It is responsible for creating and storing memory and helps the brain recall the events that have occurred varying from the last few minutes upto a very long time (creating and storing memory)

Cerebral cortex: This is the wrinkled part of brain that resembles the inside of the shell of a walnut. It is the largest part of the brain and it does all the thinking that humans do in their life. All intellectual functions, control of muscles and sensations is under the control of this executive part of the brain. There are two halves of the brain. These two halves act in perfect coordination and unison (thought, sensory and motor function)

Cerebellum: This part is located at the back of the brain. It is mainly responsible for movements and also helps to maintain body balance (movement and balance)

Corpus callosum: This is important part of the brain that connects the right and the left hemisphere of the brain (connects and coordinates the two halves of the brain)

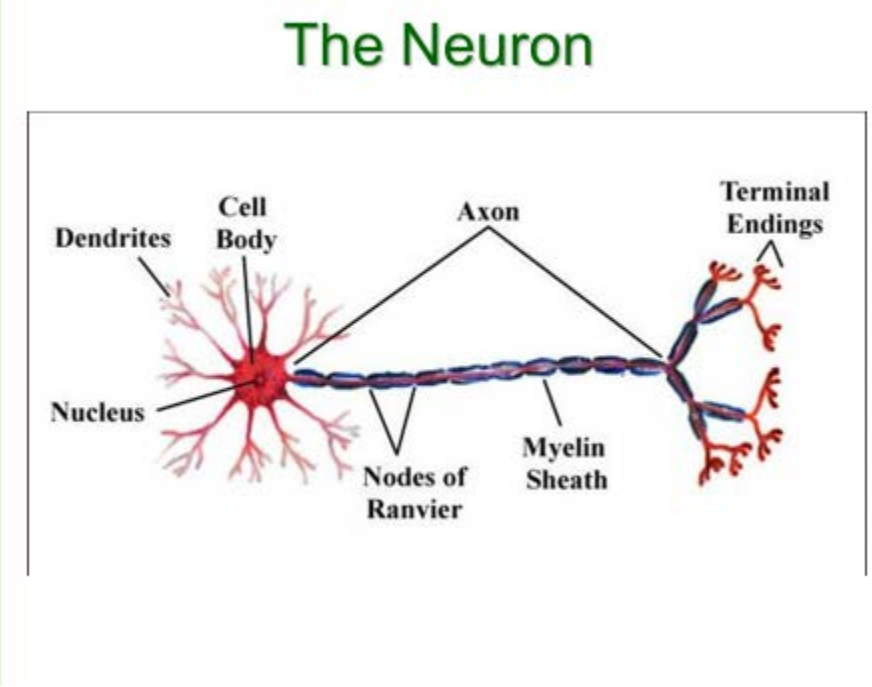
Spinal cord: This is a long structure extending from the hind brain all the way from neck upto the coccyx. All the way, it is protected by bony structure called the vertebral bones- the back bone (moving motor and sensory messages from the brain to the rest of the body and back).

Besides above vital structures, there are numerous structures and functions of the human brain for very efficient use of the five senses vision, hearing, smell, touch and taste. These function through the use of five sense organs. Their structure and function as well as development is described in another communication.

Different cell types and their functions in the brain

Neuron

The basic structure of the brain is the neuron. The brain is made of about 100 billion neurons. Each neuron comprises of (a) dendrites which are like branches of a tree and these receive signals from other neurons (b) cell body is the central hub of the neuron. It processes, and integrates all the information received from the other neurons (c) axons are fiber like structure that transmits all information and (d) axon terminals that are end points and at this point electrical information and chemical transmission helps to pass it to other axon terminal to be shared and transmitted to other axons and neurons. There is no physical contact with other axon terminals. The gap between two neurons is called the synaptic cleft. The transmission of signals does not occur electrically but it gets mediated through neuro transmitters. This neuro transmitter converts the message into an electrical signal which is then transmitted to another neuron. The axons are of variable size (from very little- like breadth of a thread to several feet). The latter extends from the spinal cord to the feet. The axon is surrounded by axon sheath which comprises of myelin. Myelination is progressive after being born and it contributes to greater efficiency of functioning of the central nervous system.



Source: How Does the Brain Develop? www.mccc.edu/~jenningh/.../HowDoestheBrainDevelop.pp (Accessed October2016)

Glial cells

In the human brain and the spinal cord the neurons are outnumbered greatly by glial cells that provide support and other vital functions for the neurons. These glial cells serve to keep the neurons insulated to facilitate the transmission of signals in an efficient manner, provide nutrition to the neurons and

prevent various toxins to damage the neurons. This function is served by blood brain barrier. The glial cells produce fatty material called the myelin that helps to insulate the neurons.
White matter of the brain is substantial and it comprises of dendrites, axons and glial cells.

Synapses, synaptic connections and neurotransmission

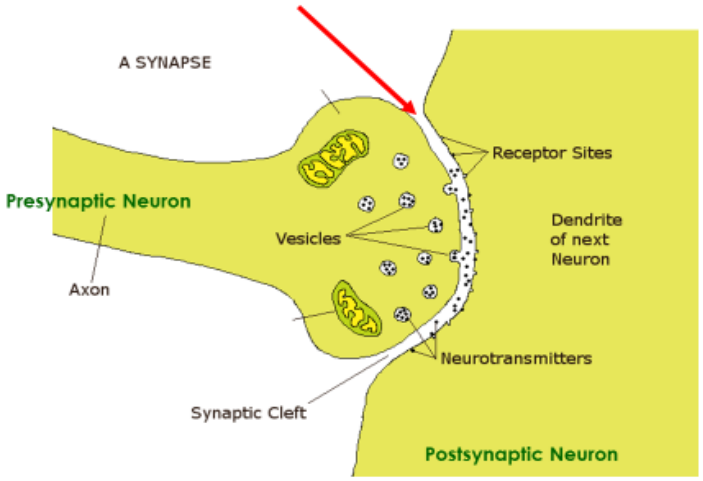
In the human brain there are humongous numbers of synapses and synaptic connections (trillions and more) that transact business with the power greater than a super human computer that is beyond imagination. This is done very efficiently through neurotransmitters.

In the nervous system synapses transmit electrical or chemical signal to a neuron. There can also be a non-neuronal communication for e.g. motor cell. This communication is to a junction. Synapses are stabilized through synaptic adhesion molecules (SAMs). Synapses are critical to the functioning of neurons in the brain. There are pre synaptic sites and post synaptic sites that are separated from each other. The pre synaptic sites connect to the axons while the post synaptic sites are connected to the dendrites. This is the key to neuro transmission. Broadly there are chemical synapses and electrical synapses.

In a chemical synapse electrical activity is converted at the pre synaptic location into chemical activity at the post synaptic location. The neuro transmitter can also initiate an electrical activity that may excite or inhibit post synaptic neuron.

In an electrical synapse, the pre and post synaptic cell membranes are connected by special channels called gap junctions or synaptic clefts that are capable of transmitting electrical current across synapses. This is useful in rapid transmission of the signals. Synapses are associated with memory - a very important function of the human brain. This results from repeated use and is called long term potentiation.

Neurotransmitters and their functions
Electrical impulses in the brain travel at a very rapid speed upto maximum of about 250 miles per hour (though it is variable) and comes to the synaptic bud which is located at the end of the axon. For the signal to pass to another neuron there is release of chemicals called neurotransmitters at the synaptic cleft. This activates receptors on the receiving dendrites of the receiving neuron.



Source: How Does the Brain Develop?
www.mccc.edu/~jenningh/.../HowDoestheBrainDevelop.pp (Accessed October2106)

There are many neuro transmitter chemicals in the human brain. The nature and effect of the neuro transmitter is variable depending on and guided by the receptors that the receiving neuron has. It also depends on the network of the brain in which the neuro transmitter is acting. Neuro transmitters serve different functions that are specific. Consequently different neuro transmitters are concentrated in different parts of the brain. This is guided by the specific function to be performed.

A special note should be made of two neuro transmitters. These are glutamate and gamma-aminobutyric acid (GABA). These two neuro transmitters do not originate from a specific hub of the neurons. They are universal in brain structure. Glutamate is an excitatory neuro transmitter. Through its release, it brings the neuron closer to the firing of an action potential. In contrast to glutamate, GABA is an inhibitory neuro transmitter. Its release inhibits the receiving neuron to be able to fire an action potential.

Besides glutamate and GABA that perform excitatory and inhibitory functions, there are several other neurotransmitters that are found in the brain and are released from specific hubs of neurons to perform different functions that are specific. The operation of neurotransmitters is quite complex four principal neurotransmitters and their role is articulated below to provide a basic understanding. It is interesting that most of these neuro transmitters are located in the brain stem. This emphasizes the critical functions of the brain stem. A more detailed exposition on neuro transmitters is beyond the scope of this communication.

- Acetylcholine is concentrated in neurons that are situated in the brainstem (which is the lowest part of the brain), and in the forebrain. Acetyl choline is involved in processes related to attention and arousal. There is an additional important function of acetyl choline. It is found at

the junction of neurons and muscles. The reason for this is their critical role in executing movements.

- Dopamine is a very important neuro transmitter. It is mainly found in two areas in the midbrain that are the origins of two pathways: (1) critical for movement and (2) important for motivation. This is also called the desire pathway.

- Another important neuro transmitter is noradrenalin. This is released from neurons that originate deep within the brainstem. This is critical to the learning processes in the brain. It is involved in the flight and fight responses. This neuro transmitter is linked with conditions like depression and mania.

- Serotonin is a very important neuro transmitter. It is released from the neurons that are located in the brain stem. It is responsible for critical functions like (1) control of pain and feeling of pain (2) sleep wake cycle (3) mood control and (4) temperature control.

The basic structure of brain and its functions helps to better understand the development of its various parts during the rapid development that occurs maximally during fetal life and the first 2 years of life. The development continues into adolescent age when there is another spurt. Brain development continues beyond adolescence. Though the development of brain is an ongoing process, special care and attention is needed during the critical and sensitive phases of brain development. These aspects are described in another communication.

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