EDO UNIVERSITY IYAMHO
Faculty of Basic Medical Sciences
Department of Biochemistry
BCH 414: BIOCHEMISTRY OF ORGANS AND TISSUES (3 Credits)

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Lectures: Wednesday, 3pm ï 4 pm, LT6, and Monday 2-4pm (LT)
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General overview of Course:

- Intracellular organization, structure and functions of specialized tissues ï liver, kidney, pancreas, testes, spleen, muscles, adipose tissue, elastin, collagen, brain, ear.
- Functional aspects of neural biochemistry: membrane potential and transport.
- Neurotransmitters and biogenic amines in the Brain.
- Constitution and function of blood, lymph and other fluids.
- Biochemistry of the eye and vision**.**

INTENDED LEARNING OUTCOMES

At the completion of this topic, students are expected to:

Å Know the Central Nervous system and its Composition.
Å Have knowledge of the structure of the Brain.
Å Know the important cells of the Brain.
Å Acquire knowledge on components of the Brain
Å Have knowledge on lobes of the Cerebrum

Assignments: We expect to have 3 homework assignments throughout the course in addition to a Mid-Term Test and a Final Exam. Term papers are to be given and submission made on the due date. Home works in the form of individual assignments, and group assignments are to be organized and structured as preparation for the midterm and final exam, and are meant to be a studying material for both exams.

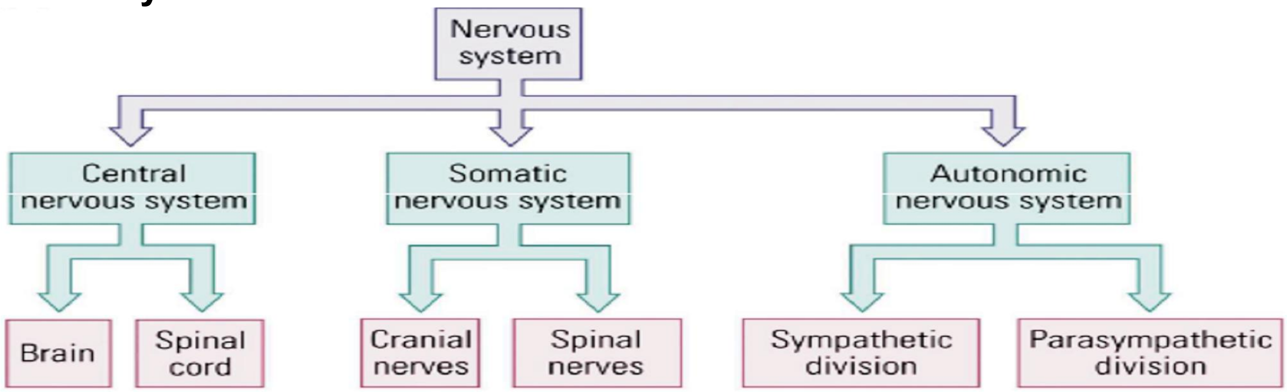
Grading: We will assign 10% of this class grade to home works, 10% for the student presentation, 10% for the mid-term test and 70% for the final exam. The Final exam is comprehensive.

Textbook: The recommended textbook for this class are as stated:

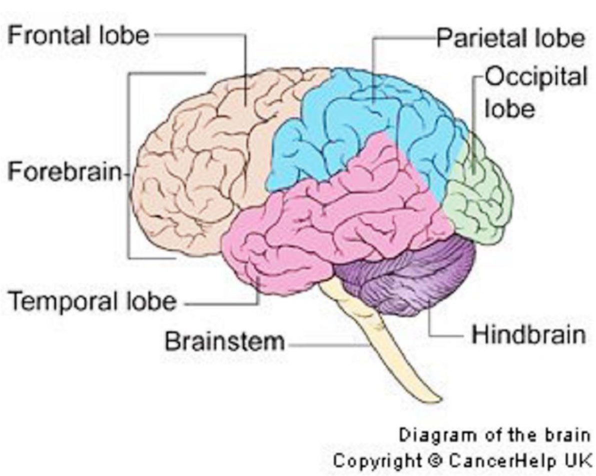
(i) Biochemistry by Lubert Stryer
(ii) Biochemistry by Voet and Voet
(iii) Lehninger, A. L. Principles of Biochemistry
(iv) Harper, H.A. Review of Physiological Chemistry
(v) Karlson P. Introduction to Modern Biochemistry.

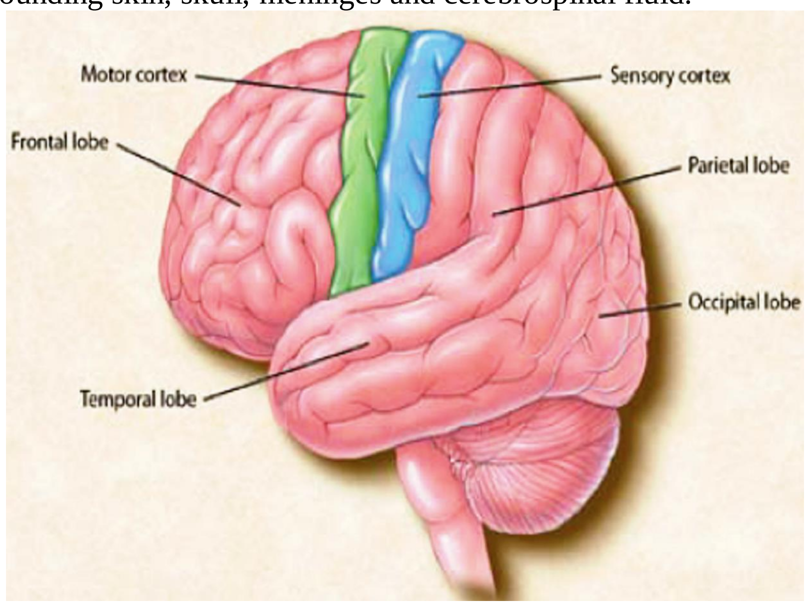
COMPOSITION AND FUNCTION OF BRAIN

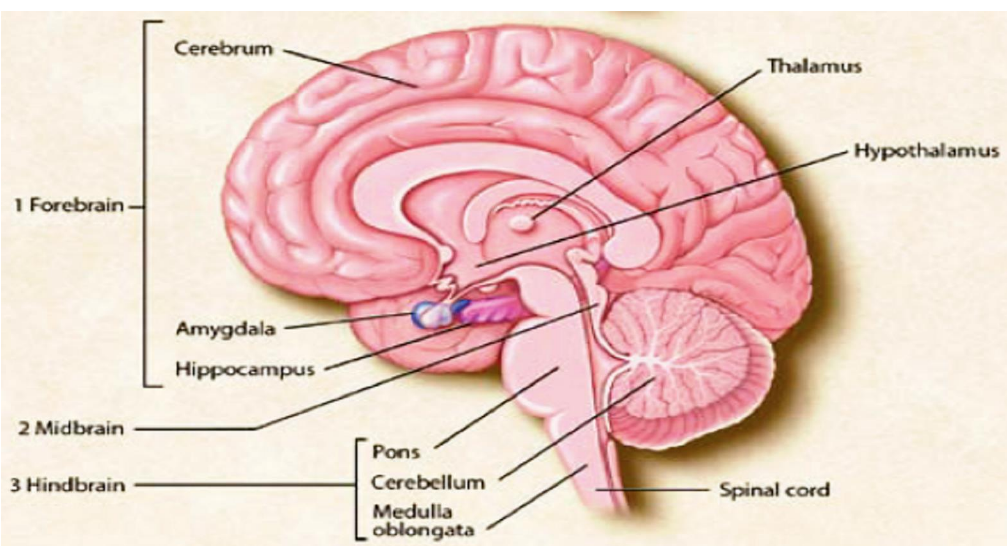
Anatomy of the head



The human *nervous system* consists of the *central nervous system* (CNS) and *peripheral nervous system* (PNS). The former consists of the brain and spinal cord, while the latter composes the nerves extending to and from the brain and spinal cord. The primary functions of the nervous system are to monitor, integrate (process) and respond to information inside and outside the body. The brain consists of soft, delicate, non-replaceable neural tissue. It is supported and protected by the surrounding skin, skull, meninges and cerebrospinal fluid.







THE BRAIN

The human brain is the centre of our nervous system. It is the most complex organ in our body and is responsible for everything we do - every thought we have, action we take, memory we have and feeling we experience.

At birth the brain weighs less than 400 g, but by the beginning of the second year of life it has more than doubled in weight to 900 g. The adult brain weighs between 1,250 and 1,450 g, and demonstrates a gender differential, since brains of males generally weigh more than those of females.

The brain is made up of fat, water, and protein. There are different kinds of brain cells. For our purposes, the two important cells are neurons, which are the cells that communicate via electro-chemical messages, and glia. Glia are brain cells that act as structural supports and little nurses, taking care of the neurons.

Glia cells provide a wide range of support functions to nerve cells, including surrounding the neurons and holding them in place, supplying nutrients and oxygen, forming a protective myelin sheath around neurons, destroying pathogens, removing dead nerve cells, and aiding in electrochemical signaling.

Each neuron is a self-contained functioning unit. The three basic parts of a neuron are the cell body, the dendrites, which receive incoming information, and the axon, which sends outgoing information.
A substance called myelin wraps around the axon to provide a form of insulation and acts as a superconductor. Myelin is a fatty, waxy substance that allows for optimal processing speed

The brain is packed with neurons, about 100 billion. When information is processed through the brain, neurons communicate with neighboring networks to create a symphony of thought. The more often certain networks are used, the more efficiently they may work. The more networks are working efficiently, the richer the neural networks may become.
The brain is made up of around 100 billion nerve cells - each one is connected to another 10,000. This means that, in total, we have around a thousand trillion connections in our brains. These are ultimately responsible for who we are. Our brains control the decisions we make, the way we learn, move, and how we feel.

What makes the human brain unique is its size. Our brains have a larger cerebral cortex, or cerebrum than any other animal. This enables us to have abilities such as complex language, problem solving and self-control.

The brain is protected by the thick bones of our skull and a protective and nourishing fluid called ócerebrospinal fluidô (CSF). It is separated from the rest of the bodyçs blood stream by the óblood-brain barrierô, which also serves to protect the brain.

THE CEREBRUM (ALSO KNOWN AS THE CEREBRAL CORTEX OR FOREBRAIN)

The cerebrum is the largest part of the brain. It is split in to two óhalvesô of roughly equal size called hemispheres. The two hemispheres, the left and right, are joined together by the corpus callosum. The right hemisphere controls the left side of the body and the left hemisphere controls the right side of the body. The cerebrum is further divided in to four lobes: frontal, parietal, occipital, and temporal, which have different functions.

The *cerebral cortex* constitutes a 2-4 mm thick *grey matter* surface layer and, because of its many convolutions, accounts for about 40% of total brain mass. It is responsible for conscious behaviour and contains three different functional areas: the *motor areas*, *sensory areas* and *association areas*. Located internally are the *white matter*, responsible for communication between cerebral areas and between the cerebral cortex and lower regions of the CNS, as well as the *basal nuclei* (or *basal ganglia*), involved in controlling muscular movement.

The covering over the hemispheres looks like a wrinkled blanket. These folds and undulations are called sulci (the grooves) and gyri (the bumps) and the covering is the cortex. The cortex is six layers thick and packed with nerve cells called neurons (a kind of brain cell). These neurons represent the grayish appearance of the cortex and are referred to as gray matter.

The frontal lobe
The frontal lobe located at the front of the brain. It has a huge role in what we do and who we are, and controls our personality, emotions, memory and behaviour. A higher function of the frontal lobe is helping us to think through the consequences of our actions and understanding social norms.

The frontal lobe also contains the Brocaøs area, which is associated with language production. If the Brocaøs area is damaged, it can lead to problems with communication. A tumour in the frontal lobe may cause changes in mood and personality and may also affect the senses of sight and smell.

That means the frontal lobes help people think in ways that include setting goals, delaying gratification, recognizing future consequences from current actions, overriding or suppressing inappropriate responses, recalling memories that are not task based, synthesizing information, and making sense of emotions. This area of the brain is the mecca of problem solving, critical thinking, and creativity. The frontal lobes reach full maturity somewhere in the second decade. This means that many of our students in a Kï 12 system are not operating with a fully matured brain. This does *not* mean that children from preschool through high school donøt use their frontal lobes for higher level thinking. What it does mean, however, is that the kinds of executive thinking we can depend on from adults are not always accessible to our students.

The parietal lobe
It is involved with spatial awareness (i.e. recognition of the distance between two objects) and navigation. It also helps us to respond to internal sensations.

The parietal lobes are located behind the frontal lobes and in front of the occipital lobes, across the top of the head. The parietal lobes help people integrate sensory information from their environment.

The parietal lobe consists of two areas: the ósensory cortexö, which receives information from our senses, such as touch, pain and pressure, and the ómotor cortexö, which helps control how we move our limbs and body in the space we are in. A tumour in the parietal lobe could impact on abilities such as finding oneøs way around, writing, speaking and understanding speech.

The temporal lobe
The temporal lobe is located at the middle, bottom part of the brain. It is a complex part of the brain, which is involved in many ôhigherô functions, such as intellect and behaviour.
The temporal lobe has a large role in auditory perception (i.e. the perception of sound) and is important in processing the meaning of speech.

It contains a structure called the öWernickeøs areaö, which is essential for understanding and forming speech. Damage to the Wenickeøs area, therefore, can result in problems with communication. As the temporal lobe is also involved in emotional memory, a tumour in this area may create a feeling of ódéjà vuô (a sense of having been somewhere or done something before).

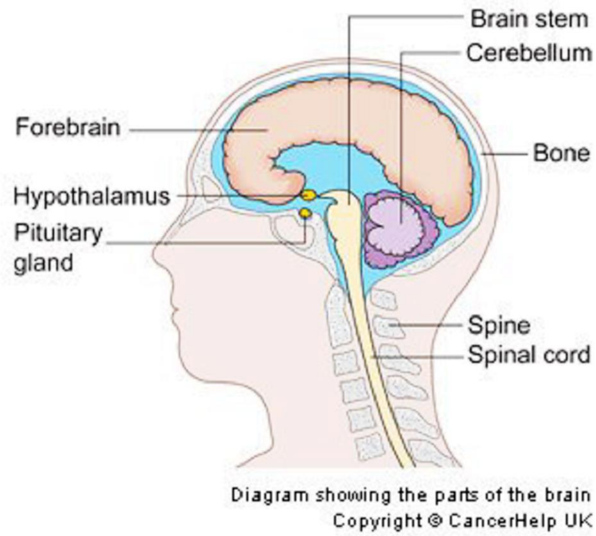
The temporal lobes are extraordinarily important with regard to language, auditory processing, and memory. With regard to language, the temporal lobes help us to verbalize language as well as comprehend it. In most people, the verbalization skills, comprehension, syntax, and processing of language are positioned in the left temporal lobe, while the ability to understand tone of voice, prosody, and vocal subtleties occurs in the right temporal lobe.

Certain kinds of memory are also a specialty of the temporal lobes. Episodic memory, the kind that enables someone to remember an event or ñepisodeò; declarative memory, the kind that enables someone to remember facts and figures; and the movement from short term to working memory are assisted by the temporal lobes. A structure called the hippocampus sits deep within the temporal lobes and plays a large role in short-term and working memory formation.

Occipital lobe
The occipital lobe is the smallest of the four lobes. Although it is located towards the very rear of the skull, it is still technically classed as part of the forebrain. The primary role of the occipital lobe is the control of vision. A tumour in the occipital lobe may lead to a loss of vision on one side.

The occipital lobes are the visual processing center of your brain and they enable you to see all the different shapes and colors in the world. Images and visuals are also stored as memories in the occipital lobe. The word occipital comes from the Latin words meaning ñback of the head,ò which is a way to remember the location of these lobes. They rest right under the occipital bone of the skull.

BRAIN STEM
The brain stem connects the cerebrum with the spinal cord. It controls many of the functions we would not usually think about, including breathing, swallowing, blood pressure and digestion.



The brain stem

The brain stem is similarly structured as the spinal cord: it consists of grey matter surrounded by white matter fibre tracts. Its major regions are the *midbrain*, *pons* and *medulla oblongata.* The midbrain, which surrounds the cerebral aqueduct, provides fibre pathways between higher and lower brain centres, contains visual and auditory reflex and subcortical motor centres. The pons is mainly a conduction region, but its nuclei also contribute to the regulation of respiration and cranial nerves. The medulla oblongata takes an important role as an autonomic reflex centre involved in maintaining body homeostasis. In particular, nuclei in the medulla regulate respiratory rhythm, heart rate, blood pressure and several cranial nerves. Moreover, it provides conduction pathways between the inferior spinal cord and higher brain centres.

Pons
The pons is part of the brain stem. It takes its name from the Latin word meaning óbridgeô. It links together, or acts as a bridge between, different parts of the brain. The pons helps to relay information from the medulla oblongata to higher parts of the brain. Childhood brain tumours in the brain stem usually originate in the pons.

Medulla oblongata: The medulla oblongata is also part of the brain stem and carries messages between the brain and the spinal cord. It is partly responsible for heart rate and lung functioning, and controls reflexes such as swallowing, coughing and the gag reflex.

The *medulla oblongata* contains tracts and reflex centers that are largely responsible for basic bodily functions such as respiration (e.g., breathing); cardiovascular function (e.g., heart rate, blood pressure);and other essential processes (e.g., vomiting). The medulla is the lowest lying structure of the brain and can best be thought of, in terms of structure and functioning, as an enlarged extension of the spinal cord.

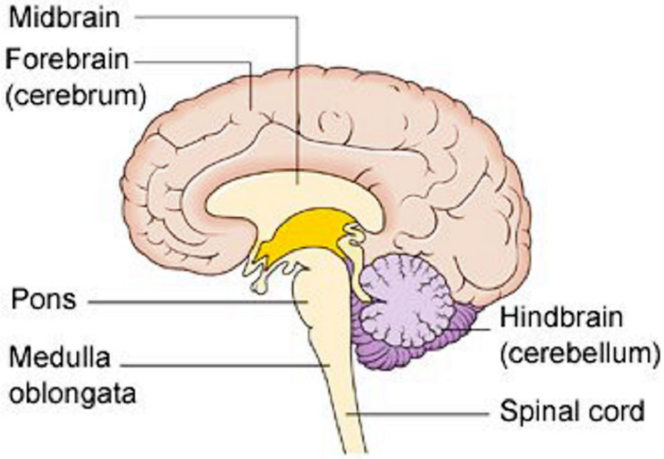


Diagram showing the brain stem which includes the medulla oblongata, the pons and the midbrain
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SPINAL CORD

The spinal cord consists of all the nerve fibres that pass down from the brain to the different parts of the body. It is filled with cerebrospinal fluid (CSF), which nourishes and protects it.

MENINGES

The meninges are a thin layer of tissue separating the brain from the skull. They are made of three sheets. Their function is to protect the brain.
The brain is surrounded by the meninges that protect and support it and the spinal cord. The outer layer is a tough, fibrous membrane, called *dura mater*.The inner layer is the softest one, which consists of two sheets, the *arachnoid mater* and the *pia mater*.

The main function of the meninges is to isolate the brain and the spinal cord from the surrounding bones. The meninges consist primarily of connective tissue, and they also form part of the walls of blood vessels and the sheaths of nerves as they enter the brain and as they emerge from the skull.

Folds of the meningeal layer form the *falx cerebri*, suspended vertically between the two cerebral hemispheres and the *tentorium cerebelli*, a shelf on which the posterior cerebra hemispheres are supported.

CEREBROSPINAL FLUID SPACES

The subarachnoid space, which separates the pia mater from the arachnoid, and the ventricles of the brain are filled with a colorless fluid (cerebrospinal fluid, or CSF), that provides nutrients for the brain and cushions the brain from mechanical shock. The cerebrospinal fluid is produced by the choroid plexus.
Since the subarachnoid space of the brain is directly continuous with that of spinal cord, the spinal cord is suspended in a tube of CSF

CEREBELLUM

The cerebellum is the second largest structure of the brain. It sits at the very back of the skull and plays a key role in our balance and co-ordination (which you may hear referred to as ‘motor control’ functions).
It is a processing center that is involved in coordination of balance, body positions, and the precision and timing of movements.

The *cerebellum*, which is located dorsal to the pons and medulla, accounts for about 11% of total brain mass. Like the cerebrum, it has a thin outer cortex of grey matter, internal white matter, and small, deeply situated, paired masses (nuclei) of grey matter. The cerebellum processes impulses received from the cerebral motor cortex, various brain stem nuclei and sensory receptors in order to appropriately control skeletal muscle contraction, thus giving smooth, coordinated movements.

In the back of the brain, tucked underneath the cortex, is the cerebellum. The cerebellum has striated tissue that looks more like muscle. It has more neurons than any other part of the brain, and it supports motor and mental dexterity. It influences our ability to balance and move, as well as different kinds of learning and memory. The cerebellum receives an enormous amount of information from other parts of the brain, and its ability to sort and process information from the cortex is as important as it is impressive.

The *cerebellum,* like the medulla, contains reflex centers for maintaining posture and advanced motor activities (e.g.,muscle contractions, limb movements).Two important functions of the cerebellum are of particular interest to criminologists. The first involves aiding the higher brain centers in establishing effective spatial orientation, which we will see has important implications on the cognitive processes of an individual.

The other key function of the cerebellum for our purposes is that it acts as a type of mediator or command center for a variety of sensory signals. More specifically, it integrates numerous forms of information from the eyes, ears, skin, and so on, and combines this knowledge with that of its spatial function and messages from the higher brain areas in order to produce the most effective motor response in a given situation.
Studies have shown that the cerebellum coordinates learning and helps coordinate finetuning of social tasks, and that structural changes in this brain region peak at age 18.

The malfunctioning of the cerebellum is perhaps best illustrated in humans when a large quantity of alcohol has been consumed. The effects of alcohol on the cerebellum are what cause the ñdrunken sailorò walk, often to the point of falling down. Other complications resulting from a poorly functioning cerebellum are dizziness/nausea (i.e., vertigo), slurred speech, loss of motor coordination, and tremors.

THE HYPOTHALAMUS

The Hypothalamus is an area of the brain whose primary function is the control of hormones, this is done by linking the nervous system to the endocrine system via the pituitary gland. Together, the hypothalamus and pituitary gland control the activity of most of the bodyôs other glands.

The hypothalamus regulates hormone levels by monitoring them; when a particular hormone drops to a level below where it should be, the hypothalamus signals to the pituitary gland that it should produce more. When the correct level is reached, the hypothalamus signals to the pituitary gland to stop.

The hypothalamus is located near the pituitary gland at the base of the brain, just above the brain stem.

DIENCEPHALON

The *diencephalon* is located centrally within the forebrain. It consists of the *thalamus*, *hypothalamus* and *epithalamus*, which together enclose the third ventricle. The thalamus acts as a grouping and relay station for sensory inputs ascending to the sensory cortex and association areas. It also mediates motor activities, cortical arousal and memories. The hypothalamus, by controlling the autonomic (involuntary) nervous system, is responsible for maintaining the bodyôs homeostatic balance. Moreover it forms a part of the *limbic system*, the ÷emotionalô brain. The epithalamus consists of the *pineal gland* and the CSF producing *choroid plexus*.

Blood is transported through the body via a continuous system of blood vessels. Arteries carry oxygenated blood away from the heart into capillaries supplying tissue cells. Veins collect the blood from the capillary

bed and carry it back to the heart. The main purpose of blood flow through body tissues is to deliver oxygen and nutrients to and waste from the cells, exchange gas in the lungs, absorb nutrients from the digestive tract, and help forming urine in the kidneys. All the circulation besides the heart and the pulmonary circulation is called the systemic circulation.

The cardiac output is about 5 l/min of blood for a resting adult. Blood flow to the brain is about 14% of this, or 700 ml/min.

STRUCTURE AND PATHOLOGIES OF THE NEONATAL BRAIN

The embryonic brain and spinal cord develop from the neural tube, which is formed by the fourth week of pregnancy. The brain grows immensely in both size and complexity during pregnancy and even soon after birth. Because a membranous skull restricts expansion, the forebrain is bent towards the brain stem, and the cerebral hemispheres almost completely envelop the diencephalon and midbrain. Moreover, the spatial restrictions cause the cerebral hemispheres to increase their surface area by becoming highly convoluted such that about two thirds of its surface are hidden in its folds. The skull bones of the foetus and neonate are soft and the sutures are not yet fused. Hence the skull is very flexible and deforms under light pressure.

Compared to the adult, neonates have a smaller head size (ca. 6-12 cm in diameter), thinner surface tissue, skull and CSF layers, lower scattering coefficients of grey and white matter (due to lesser myelination in the case of white matter), as well as a comparatively small mismatch between the two.

Arterial and venous haemoglobin saturation values for the foetus in utero are relatively low at 56 % and 18%, respectively, compared to about 97% and 67% for adults. This is because there is a gradient in oxygen concentration across the placenta which ensures diffusion of sufficient amounts of oxygen from maternal blood into the foetal bloodstream. A higher oxygen affinity of neonatal haemoglobin compensates for this. Over a period of about 6 months after delivery the neonatal haemoglobin is gradually substituted by the adult haemoglobin, which has a lower oxygen affinity.

Neurodevelopmental disorders in some *preterm* infants are due to either hypoxicischaemic damage to the periventricular white matter, or to intraventricular haemorrhage and its consequences. The period of highest risk is between 26 and 32 weeks of gestation.
In preterm infants the majority of haemorrhages occur into the ventricles and the surrounding white matter, the periventricular region. Hypoxic-ischaemic damage is caused by cerebral underperfusion, often combined with a global oxygen deficiency due to an impaired lung function. It also affects the periventricular white matter, which is thought to be a result of the following two effects:

- Increased vulnerability due to high metabolic demands at this phase of the brain development.
- The area is at a ‗watershed' of perfusion from the territories of the posterior and middle cerebral arteries.

Enduring neurodevelopmental disorders can lead to diminished neurological function in later life, and in particular spasticity, since motor fibres run through this region of the white matter. Given the potential of the premature infant's developing brain to repair some damage, spasticity is often restricted to stiff limbs and/or subtle learning disabilities.

Cerebral damage in the *mature* infant is most commonly a result of perinatal (‗birth') asphyxia, leading initially to cerebral oedema (resulting in compressed ventricles and flattening of the convolutions of the brain), and later to tissue necrosis (tissue death) and apoptosis (cell suicide). The subcortical white matter, basal ganglia, cerebellum and brainstem are the areas predominantly affected, frequently leading to learning disabilities or global developmental delay and cerebral palsy.

BIBLIOGRAPHY/FURTHER READINGS

(i) Biochemistry by Lubert Stryer

(ii) Biochemistry by Voet and Voet

(iii) Lehninger, A. L. Principles of Biochemistry

(iv) Harper, H.A. Review of Physiological Chemistry

(v) Karlson P. Introduction to Modern Biochemistry