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PHYSIOLOGY

Prep Manual for Undergraduates

Vijaya D Joshi
Sadhana Joshi-Mendhurwar

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PHYSIOLOGY

Fourth Edition

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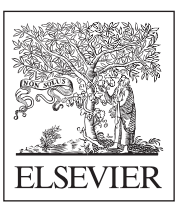

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Dedicated
to
Dr DV Joshi

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Foreword

It gives me great pleasure in writing the foreword for this book. Physiology is one of the basic medical sciences which needs to be thoroughly studied by medical students for proper understanding of the clinical subjects, particularly pathology, pharmacology and medicine. This subject is so vast that students often find it difficult to revise it adequately from large textbooks before examinations. There has been a long felt need for a book which is concise and covers the subject in a format that provides quick revision and easy comprehension.

It is my belief that Dr Vijaya Joshi's book in the present form should meet the requirements of the students fully, both for theory and viva-voce examinations. All the topics are comprehensively covered in a simplified way. The author has made an attempt to systematically analyse and present the relevant data in question and answer form. Another strength of the book is the large number of excellent line drawings that should assist in comprehending the subject with ease. The students will therefore find it very helpful in revising the subject quickly and facing the examinations with confidence.

This book will also be useful for dental, paramedical, physiotherapy, homeopathy and ayurvedic students.

A lot of meticulous work seems to have gone into preparing this book for which Dr Vijaya Joshi deserves all praise.

I wish this book all success.

Dr PB Patil
Minister of Energy and Irrigation
Govt. of Maharashtra and
President, Terna Public Charitable Trust

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Preface to the Fourth Edition

It gives me great pleasure to write the Fourth Edition. To make the book more reader-friendly and better suited to students certain modifications have been done in this edition, *viz.*

- In each chapter, titles and subtitles are given so that students can easily know how to write long and short questions.
- Certain answers are modified; few diagrams and tables are added.
- Diagrams are colored.

Hope the students will appreciate the changes made in this new edition. Any suggestions from them will be highly appreciated.

Dr (Smt) Vijaya D Joshi

Dr (Smt) Sadhana Joshi - Mendhurwar

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Preface to the First Edition

The curriculum of physiology for the medical students is very vast and the time available for its study is comparatively short. Students have to prepare for theory as well as viva-voce examinations. In viva examination, the students have to answer several questions within a short time and the answers must be precise and correct to secure good marks. With my experience as an examiner over the years, I have noticed that many students find it difficult to answer the theory paper properly and complete it within the stipulated time. All this has prompted me to write this manual in concise form to facilitate preparation of the students both for viva and theory examinations. I would, however, like to emphasize that it is not intended as a textbook on physiology but a supplement for revision purposes.

The book is divided into fourteen chapters and covers all important topics. The important points in each topic are reviewed. Each topic is described in the form of questions and answers. The book is written in a simple and easy to understand language. Wherever possible the information is given in the form of tables and flowcharts. It is well illustrated.

I feel that, at the time of examination, the students will be able to revise the subject quickly with the help of this manual. It would also be useful for postgraduate entrance examinations.

I do hope the students will appreciate this book as a resource for securing good marks in the examination. Any suggestions, comments from the readers will be highly appreciated.

I am very much thankful to Dr PB Patil (President, Terna Public Charitable Trust) and Dr (Smt) CP Patil for giving me permission to write this book. I wish to express my sincere gratitude to (Smt) Sushma R Apte and Mr RP Apte for their valuable help in preparing the manuscript.

I am grateful to B.I. Churchill Livingstone for their valuable suggestions, supplying the line drawings and publishing this book in a professional manner.

Dr (Smt) Vijaya D Joshi

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CHAPTER 1

The Cell and General Physiology

CELL AND CELL ORGANELLES

What is a cell?

Cell is a basic living unit of the body.

What is protoplasm?

The different substances that make up the cell are collectively called protoplasm. Protoplasm is mainly composed of water, electrolytes, proteins, lipids and carbohydrates.

Name different cytoplasmic organelles.

Each cell is enveloped by a cell membrane. Fluid inside the cell is termed cytoplasm. Cytoplasm contains minute and large dispersed particles and organelles. The clear fluid portion of cytoplasm in which organelles are suspended is termed 'cytosol.'

Cytoplasmic organelles are:

- Granular and smooth endoplasmic reticulum.
- Golgi apparatus.
- Lysosomes.
- Peroxisomes.
- Mitochondria.
- Secretory vesicles.
- Nucleus with nuclear membrane.
- Filament and tubular structures of cell, e.g. cilium, flagellum, centrioles and mitotic spindles of mitosing cell (Fig. 1.1).

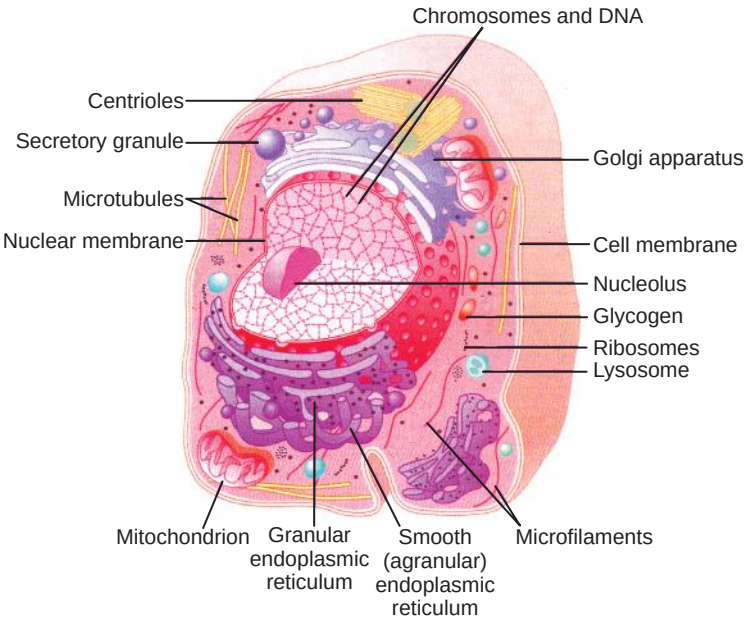

Fig. 1.1 Structure of typical cell.

Describe the structure of cell membrane.

The cell membrane measures 75 nm in thickness. It is composed mainly of lipids, proteins and carbohydrates.

1. ***Lipids.*** Basic structure of a membrane is a lipid bilayer (2 molecules thick), which is continuous over the entire cell surface. This lipid bilayer is composed of phospholipid and cholesterol. Each lipid molecule has one hydrophilic part which is soluble in water and other hydrophobic part which is soluble in lipid. In phospholipid molecule phosphate part is hydrophilic and fatty acid radicals are hydrophobic. In cholesterol molecule hydroxyl radical is hydrophilic and steroid nucleus is hydrophobic.

Because hydrophobic portions of both these molecules are repelled by water, they have a natural tendency to line up, occupying the centre of the membrane. Hydrophilic portions project to two surfaces (inside and outside of the cell).

The membrane lipid bilayer is the major barrier to usual water soluble substances (e.g. urea, glucose, ions). Fat soluble substances such as alcohol, CO_2, O_2 can easily penetrate through lipid bilayer.

2. ***Proteins.*** Proteins of the membrane are of two types:

- Integral proteins.
- Peripheral proteins.

Integral proteins. At intervals, lipid bilayer is replaced by globular proteins known as integral proteins. They act as channels (pores) for passage of water soluble substances.

Integral proteins have selective properties causing preferential diffusion of certain substances more than others. Some integral proteins act as carriers allowing active transport of certain substances. Some integral proteins act as enzymes.

Peripheral proteins. They are present mostly on the inside surface of the membrane, attached to integral proteins. They act as enzymes.

3. ***Carbohydrates.*** Carbohydrates are mainly present in combination with lipid (as glycolipids) or in combination with proteins (as glycoproteins). Some integral proteins are glycoproteins and about one-tenth lipid molecules are glycolipids.

Other important carbohydrate compounds are proteoglycans which are mainly carbohydrate substances bound together by small protein cores. They form a loose carbohydrate coat which covers the entire surface of the cell. This coat is termed glycocalyx.

The functions of carbohydrate moieties are as follows:

- Because of their negative charges they give cell an overall negative surface that repels other negative objects.
- Glycocalyx causes attachment of cells to each other.
- Many carbohydrates act as receptor substances for binding hormones like insulin.
- Some carbohydrates enter into immune reactions.

What are the functions of cell membrane?

1. Acts as a selective barrier allowing some molecules to cross, excluding others. Thus it regulates the passage of substances in and out of the cell and hence separates two aqueous compartments of dissimilar compositions.
2. Plays important role in receiving chemical signals from other cells by detecting the chemical messenger arriving at the cell surface.
3. Links adjacent cells together.
4. Provides sites for attachment of protein filaments associated with generation and transmission of force to the cell surface.

What is the function of mitochondria?

Mitochondria are 'power houses' of the cell. Almost all oxidative reactions occur inside the mitochondria and energy that is released is used to form high energy compound termed ATP (adenosine triphosphate). This ATP is stored in the mitochondria and is made available for supplying energy for different functions of the cell.

What is agranular/smooth endoplasmic reticulum?

Part of endoplasmic reticulum has no attached ribosomes. This is called agranular or smooth endoplasmic reticulum. It functions in synthesis of lipid substances and in many enzymatic processes of cell.

What are the functions of endoplasmic reticulum?

1. Transports substances from one part of the cell to the other.
2. Granular endoplasmic reticulum (with ribosomes) is involved in packaging of proteins that are secreted by the cell.
3. Smooth endoplasmic reticulum (without ribosomes) is the site of lipid synthesis.
4. Smooth endoplasmic reticulum contains enzymes controlling glycogen breakdown.
5. Smooth endoplasmic reticulum also contains enzymes capable for detoxifying substances that are damaging to the cell.

What are ribosomes? What is their main function?

Ribosomes are small granular structures attached to endoplasmic reticulum. They are composed of ribonucleic acid (RNA) and proteins.

They do the function of protein synthesis.

What are the functions of Golgi apparatus?

1. Site for concentration of proteins and polysaccharides.
2. Sorts out the different types of proteins received from endoplasmic reticulum into vesicles which are delivered to the various parts of the cell. Vesicles delivered to plasma membrane release their protein contents outside the cell. They are known as secretory vesicles.
3. Site for completion of synthesis of carbohydrate moiety of glycoproteins which are major components of ground substance in the interstitial spaces.

What is the role of centriole in the cell?

Initiates the process of cell division.

What is the role played by lysosomes?

Lysosomes are a highly specialized intracellular digestive system. They contain about 50 different hydrolytic enzymes. They breakdown bacteria and debris from dead tissue cells that have been taken into the cell. They play important role in various specialized cells that make up defence system of the body.

What is the role played by peroxisomes?

Peroxisomes contain oxidases. They destroy certain products formed from oxygen, notably hydrogen peroxide that can be toxic to the cell.

What are the functions of nucleus in the cell?

1. The nucleus is the main control centre of the cell. It controls the rate of different chemical reactions occurring in the cell.
2. Responsible for transmission and expression of genetic information.

What is chromatin?

Chromatin is a network of threads present in the nucleus. It is composed of DNA and proteins.

What are chromosomes? What is their function?

Chromosomes are fine thread-like structures formed from chromatin at the time of cell division. They store genetic information and pass it over from cell to cell each time when a cell divides.

What is the number of chromosomes in somatic cells of human beings?

There are 46 (23 pairs) chromosomes in the cell. Out of these 44 (22 pairs) are somatic chromosomes and 2 (1 pair) sex chromosomes.

What are filaments or tubules?

The fibrillar proteins of the cell are organised into filaments or tubules. These originate as precursor protein molecules synthesized by ribosomes in cytoplasm. The precursor molecules then polymerize to form filaments.

What are microtubules?

Main function of microtubules is to act as a cytoskeleton to provide rigid physical structures for some parts of cells.

A specific type of shift filament composed of polymerized tubulin molecules is used to construct strong tubular structures called microtubules.

MOVEMENTS OBSERVED IN HUMAN CELL

What types of movements are observed in human cells?

Different types of movements observed in human cells are:

1. ***Muscle contraction.*** Different muscle cells, e.g. skeletal, cardiac and smooth muscles contract and cause important movements.

2. ***Amoeboid movement.*** It is movement of entire cell in relation to its surroundings. It is seen in white blood cells, tissue macrophages, microphages, fibroblasts during repair, etc.

These movements are initiated by chemotaxis, i.e. by appearance of certain chemical substances in blood. There can be positive and negative chemotaxis which causes movement towards or away from areas respectively.

3. ***Ciliary movement.*** It is whisp-like movement of cilia. It occurs on inside surface of respiratory airways and on inside surface of fallopian tubes.

Flagellum of a human sperm is quite similar to cilium but is much longer and moves in quasi sinusoidal waves instead of whisp-like motion.

CELL DIVISION

What are the types of cell division?

Cell division is of two types:

(a) Mitosis
(b) Meiotic

In mitosis number of chromosomes in two daughter cells remains the same as that of a parent cell (i.e. diploid cells are formed).

In meiotic division, number chromosomes is halved (becomes half) and haploid cells are formed.

CELL DEATH

What is apoptosis?

It is a process of programmed cell death in which body cells die and get phagocytosed (absorbed) under genetic control.

Significance:

- It is responsible for removal of inappropriate clones of immune cells.
- Important in degeneration and regeneration of neurons within central nervous system and for formation of synapse.
- Is responsible for cyclical shedding of endometrium at the time of menstruation.

Abnormal apoptosis is seen in cancers, autoimmune diseases, etc.

What is a tissue?

Collection of cells having same structure and function is termed tissue.

HOMEOSTASIS

What is 'milieu interieur'?

Cells live in the environment of extracellular fluid and this extracellular fluid is called 'milieu interieur'.

Define homeostasis.

Homeostasis means maintenance of static or constant conditions in the internal environment of cells.

Explain the role of various systems of the body in homeostasis.

Homeostasis, i.e. maintenance of constant conditions in the internal environment (extracellular fluid) is very essential for normal functioning of various cells.

The following factors must be maintained for homeostasis:

- pH
- Temperature

- Electrolyte concentrations
- Supply of nutrients
- Supply of O_2
- Hormone levels
- Metabolic end products
- Water content.

Almost all systems of the body are involved in maintenance of internal environment.

1. ***Circulatory system.*** Nutrients and O_2 from extracellular fluid are constantly utilized by the cells. Waste products from the cell constantly diffuse from cells to the extracellular fluid. This changes the composition of extracellular fluid. For maintaining constancy in this fluid, the body has circulatory system which causes constant flow of blood to various tissues. In tissues, blood passes through capillaries which are thin walled and can cause exchange of materials very easily. There is diffusion of nutrients and O_2 from blood to interstitial fluid and the waste products in the opposite direction. Also there is a constant exchange of fluid from blood and extracellular fluid. Small amount of protein-free plasma comes out of capillaries at the arterial end and almost equal quantity is absorbed at the venous end. Thus circulatory system causes circulation of blood to different tissues and allows constant exchange of materials between blood and the interstitial fluid.

2. ***Respiratory system.*** Blood is also circulated to lungs. It picks up O_2 in the alveoli needed for the cell. CO_2 from blood diffuses out in alveoli of lungs for excretion.

3. ***Gastrointestinal tract.*** Large amount of blood is pumped by the heart to the wall of gastrointestinal tract. Here different digested materials such as amino acids, fatty acids, glucose, etc. are absorbed from lumens of the gastrointestinal tract into the blood. Thus nutrients required for cells are obtained. All the substances which are absorbed may not be utilized by the cells. The absorbed substances first pass to the liver which changes the chemical compositions of some of them and make them utilizable by the tissue cells. Liver can also store the excess materials for future use.

4. ***Musculoskeletal system.*** This allows the person to move to appropriate places either for obtaining food, water or for protection against adverse surroundings.

5. ***Kidneys.*** Water and water soluble waste products are selected from the blood and are excreted by kidneys in urine. Kidneys assist in the maintenance of water balance, electrolyte balance with the help of endocrine system. Kidneys also help in regulation of pH of the extracellular fluid.

6. ***Hormonal system (Endocrine glands).*** Each endocrine gland secretes hormone or hormones, which are transported to all the parts of the body in the extracellular fluid. Hormones regulate metabolic functions of different body cells, e.g. insulin controls glucose metabolism. Adrenocortical hormones control levels of different ions and protein metabolism. Parathyroid hormone controls calcium level of extracellular fluid and also the bone metabolism.

7. ***Nervous system.*** It is composed of the sensory portion, the central nervous system (CNS) which is the integrator, and the motor portion.

Sensory portion receives information from the surroundings, e.g. eyes give visual image of the surrounding area, ears hear the sounds.