Competency Based Questions and Answers in Physiology

for First MBBS Professional Examination

Compiled and designed as per CBME Guidelines | Competency Based Undergraduate Curriculum for the Indian Medical Graduate

- 50 Long Essays
- 244 Short Essays
- 255 Short Notes
- 621 MCQs

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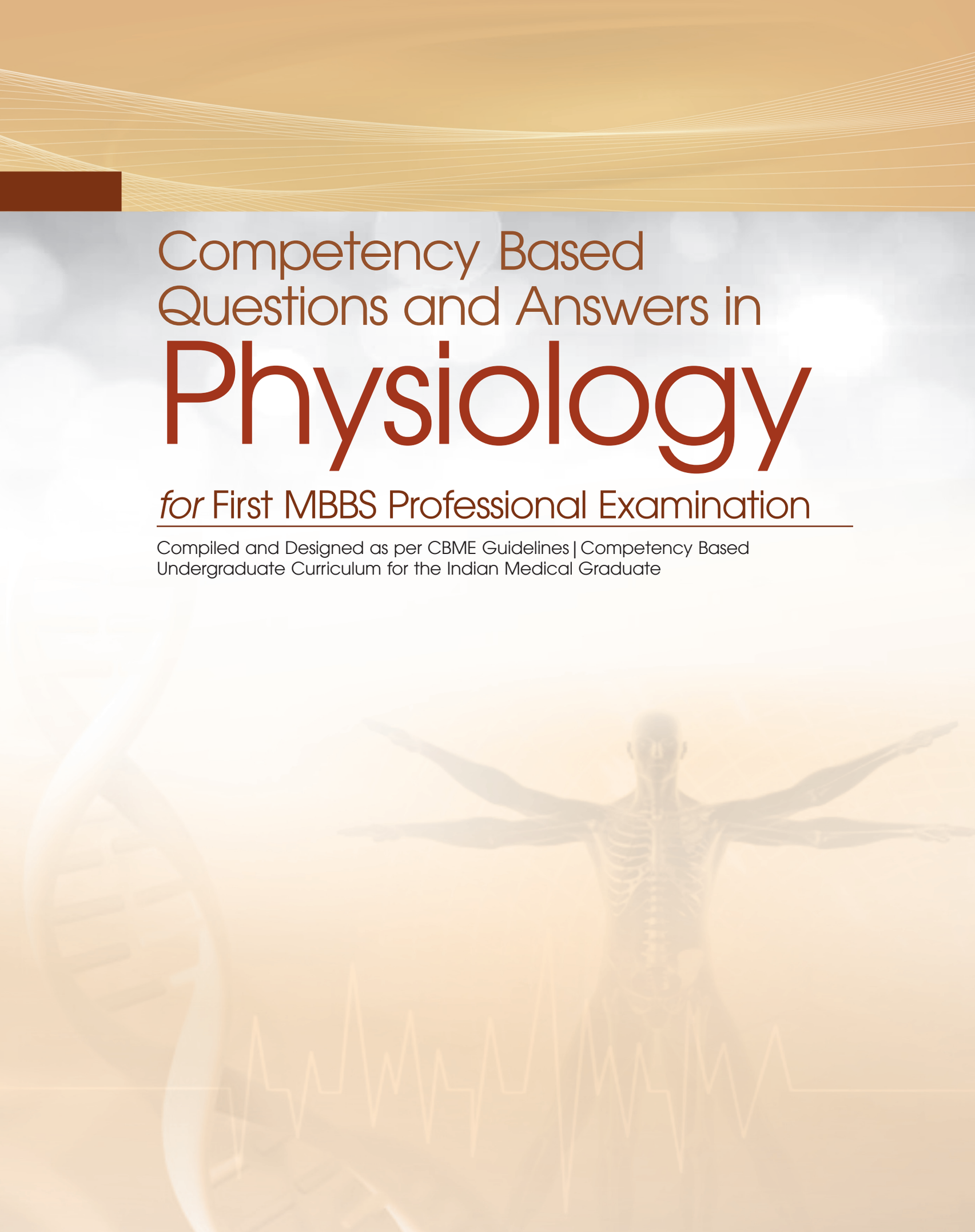

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Sushrutha Academy
Bengaluru

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Preface

"Assessment drives learning"

The purpose of assessment is not just to assess learning but also assist learning. The new CBME curriculum proposed by the Medical Council of India (MCI) calls for an outcome-based teaching-learning approach and transition from just acquisition of knowledge to application and practice of knowledge. Assessments need to be designed to suit the newer teaching-learning methods and to assess if the required competency has been achieved or not.

The purpose of bringing out this book is to introduce the I MBBS students to the new format of questions that is most likely to be asked during the internal assessment and the university examination and also equip them to face these exams without fear. Students can use this book for self-assessment of learning, preparing for internal assessment and university examination.

The book has been compiled by group of teachers who have undergone MCI recognized training in revised basic medical education technologies and advanced course in medical education. The questions in this book have been arranged according to competencies as listed in the MCI curriculum document. Various types of questions including structured long essays, modified essays, short answers, and multiple choice questions are added. These questions have been framed according to the guidelines set by the MCI with appropriate use of verbs at each level of Bloom's taxonomy of cognitive domain. The questions not only assess recall but also higher levels of learning.

We would like to acknowledge all the people who are involved in the preparation of this book especially Shri SK Jain (Chairman), Shri Varun Jain (Managing Director), Shri YN Arjuna (Vice President—Publishing, Editorial and Publicity), Ms Ritu Chawla (GM Production), and Ms Jassi, and of CBS for their all-time support and bringing out this book in record short time.

We hereby wish all the readers of the book all the best in their endeavors.

Happy reading!

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Details of the Number of Questions and MCQs Included as per the Competency

S. No.	*Competency No.*	*Competency details*	*Long essays*	*Short essays*	*Short answers*	*MCQs*
		1. General Physiology				
1.	PY 1.1	Describe the structure and functions of a mammalian cell	—	—	03	5
2.	PY 1.2	Describe and discuss the principles of homeostasis	—	02	02	3
3.	PY 1.3	Describe intercellular communication	—	01	01	3
4.	PY 1.4	Describe apoptosis-programmed cell death	—	01	05	1
5.	PY 1.5	Describe and discuss transport mechanisms across cell membranes	—	01	—	6
6.	PY 1.6	Describe the fluid compartments of the body, its ionic composition and measurements	—	01	—	4
7.	PY 1.7	Describe the concept of pH and buffer systems in the body	—	02	—	1
8.	PY 1.8	Describe and discuss the molecular basis of resting membrane potential and action potential in excitable tissue	—	02	01	2
9.	PY 1.9	Demonstrate the ability to describe and discuss the methods used to demonstrate the functions of the cells and its products, its communications and their applications in clinical care and research.	—	01	—	1
		2. Haematology				
10.	PY 2.1	Describe the composition and functions of blood components	—	01	—	1
11.	PY 2.2	Discuss the origin, forms, variations and functions of plasma proteins	—	02	02	2
12	PY 2.3	Describe and discuss the synthesis and functions of haemoglobin and explain its breakdown. Describe variants of haemoglobin	—	—	02	3
13	PY 2.4	Describe RBC formation (erythropoiesis and its regulation) and its functions	02	—	—	1
14	PY 2.5	Describe different types of anaemias and jaundice	01	02	—	2
15	PY 2.6	Describe WBC formation (granulopoiesis) and its regulation	—	01	02	5
16	PY 2.7	Describe the formation of platelets, functions and variations.	—	02	—	3
17	PY 2.8	Describe the physiological basis of hemostasis and anticoagulants. Describe bleeding and clotting disorders (hemophilia, purpura)	02	05	02	4
18	PY 2.9	Describe different blood groups and discuss the clinical importance of blood grouping, blood banking and transfusion	—	04	—	1

S. No.	Competency No.	Competency details	Long essays	Short essays	Short answers	MCQs
19	PY 2.10	Define and classify different types of immunity. Describe the development of immunity and its regulation	—	05	02	1
20	PY 2.11	Estimate Hb, RBC, TLC, RBC indices, DLC, blood groups, BT/CT	—	07	—	2
21	PY 2.12	Describe test for ESR, osmotic fragility, hematocrit. Note the findings and interpret the test results, etc.	—	03	—	2
22	PY 2.13	Describe steps for reticulocyte and platelet count.	—	—	03	2
		3. Nerve and Muscle Physiology				
23	PY 3.1	Describe the structure and functions of a neuron and neuroglia; discuss nerve growth factor and other growth factors/cytokines	—	03	—	5
24	PY 3.2	Describe the types, functions and properties of nerve fibers	02	08	06	7
25	PY 3.3	Describe the degeneration and regeneration in peripheral nerves	01	02	04	5
26	PY 3.4	Describe the structure of neuromuscular junction and transmission of impulses	01	03	01	5
27	PY 3.5	Discuss the action of neuromuscular blocking agents	—	01	02	5
28	PY 3.6	Describe the pathophysiology of myasthenia gravis	—	02	01	5
29	PY 3.7	Describe the different types of muscle fibres and their structure	—	03	02	5
30	PY 3.8	Describe action potential and its properties in different muscle types (skeletal and smooth)	01	10	13	5
31	PY 3.9	Describe the molecular basis of muscle contraction in skeletal and in smooth muscles	02	08	03	5
32	PY 3.10	Describe the mode of muscle contraction (isometric and isotonic)	—	02	02	5
33	PY 3.11	Explain energy source and muscle metabolism	—	03	03	5
34	PY 3.12	Explain the gradation of muscular activity	—	—	02	4
35	PY 3.13	Describe muscular dystrophy: Myopathies	—	02	01	5
36	PY 3.14	Perform ergography	—	02	—	5
37	PY 3.15	Demonstrate effect of mild, moderate and severe exercise and record changes in cardiorespiratory parameters	—	01	—	5
38	PY 3.16	Demonstrate Harvard step test and describe the impact on induced physiologic parameters in a simulated environment	—	01	—	4
39	PY 3.17	Describe strength–duration curve	—	—	01	5
40	PY 3.18	Observe with computer assisted learning (i) Amphibian nerve–muscle experiments (ii) Amphibian cardiac experiments	—	—	—	6

S. No.	Competency No.	Competency details	Long essays	Short essays	Short answers	MCQs
		4. Gastrointestinal Physiology				
41	PY 4.1	Describe the structure and functions of digestive system	—	—	02	5
42	PY 4.2	Describe the composition, mechanism of secretion, functions, and regulation of saliva, gastric, pancreatic, intestinal juices and bile secretion	—	07	01	9
43	PY 4.3	Describe GIT movements, regulation and functions. Describe defecation reflex. Explain role of dietary fibre.	01	03	05	6
44	PY 4.4	Describe the physiology of digestion and absorption of nutrients	01	01	01	6
45	PY 4.5	Describe the source of GIT hormones, their regulation and functions	—	02	02	5
46	PY 4.6	Describe the gut–brain axis	—	—	02	5
47	PY 4.7	Describe and discuss the structure and functions of liver and gall bladder	—	02	02	5
48	PY 4.8	Describe and discuss gastric function tests, pancreatic exocrine function tests and liver function tests	—	—	03	5
49	PY 4.9	Discuss the physiology aspects of: Peptic ulcer, gastro-oesophageal reflux disease, vomiting, diarrhoea, constipation, adynamic ileus, Hirschsprung's disease	—	—	06	5
50	PY 4.10	Demonstrate the correct clinical examination of the abdomen in a normal volunteer or simulated environment	—	—	—	5
		5. Cardiovascular Physiology (CVS)				
51	PY 5.1	Describe the functional anatomy of heart including chambers, sounds; and pacemaker tissue and conducting system.	—	02	01	5
52	PY 5.2	Describe the properties of cardiac muscle including its morphology, electrical, mechanical and metabolic functions	—	04	01	5
53	PY 5.3	Discuss the events occurring during the cardiac cycle	01	02	01	5
54	PY 5.4	Describe generation, conduction of cardiac impulse	—	01	—	5
55	PY 5.5	Describe the physiology of electrocardiogram (ECG), its applications and the cardiac axis	—	01	01	5
56	PY 5.6	Describe abnormal ECG, arrhythmias, heart block and myocardial infarction	—	04	04	6
57	PY 5.7	Describe and discuss haemodynamics of circulatory system	—	01	02	5
58	PY 5.8	Describe and discuss local and systemic cardiovascular regulatory mechanisms	01	02	—	5
59	PY 5.9	Describe the factors affecting heart rate, regulation of cardiac output and blood pressure	—	04	06	5

S. No.	Competency No.	Competency details	Long essays	Short essays	Short answers	MCQs
60	PY 5.10	Describe and discuss regional circulation including microcirculation, lymphatic circulation, coronary, cerebral, capillary, skin, foetal, pulmonary and splanchnic circulation	—	05	—	5
61	PY 5.11	Describe the pathophysiology of shock, syncope and heart failure	01	—	01	5
62	PY 5.12	Record blood pressure and pulse at rest and in different grades of exercise and postures in a volunteer or simulated environment	02	01	—	—
63	PY 5.13	Record and interpret normal ECG in a volunteer or simulated environment	—	—	01	—
64	PY 5.14	Observe cardiovascular autonomic function tests in a volunteer or simulated environment	—	01	—	—
65	PY 5.15	Demonstrate the correct clinical examination of the cardiovascular system in a normal volunteer or simulated environment	—	01	—	—
66	PY 5.16	Record arterial pulse tracing using finger plethysmography in a volunteer or simulated environment.	—	02	—	—
		6. Respiratory Physiology				
67	PY 6.1	Describe the functional anatomy of respiratory tract	—	01	02	5
68	PY 6.2	Describe the mechanics of normal respiration, pressure changes during ventilation, lung volume and capacities, alveolar surface tension, compliance, airway resistance, ventilation, V/P ratio, diffusion capacity of lungs	06	07	03	7
69	PY 6.3	Describe and discuss the transport of respiratory gases: Oxygen and carbon dioxide	—	03	02	6
70	PY 6.4	Describe and discuss the physiology of high altitude and deep-sea diving	—	01	—	5
71	PY 6.5	Describe and discuss the principles of artificial respiration, oxygen therapy, acclimatization, and decompression sickness.	—	—	01	4
72	PY 6.6	Describe and discuss the pathophysiology of dyspnea, hypoxia, cyanosis, asphyxia; drowning, periodic breathing	—	02	03	5
73	PY 6.7	Describe and discuss lung function tests and their clinical significance	—	—	01	3
74	PY 6.8	Demonstrate the correct technique to perform and interpret spirometry	—	—	02	—
75	PY 6.9	Demonstrate the correct clinical examination of the respiratory system in a normal volunteer or simulated environment	—	01	—	—
76	PY 6.10	Demonstrate the correct technique to perform measurement of peak expiratory flow rate in a normal volunteer or simulated environment	—	01	—	—

S. No.	Competency No.	Competency details	Long essays	Short essays	Short answers	MCQs
		7. Renal Physiology				
77	PY 7.1	Describe structure and functions of kidney	—	02	01	20
78	PY 7.2	Describe the structure and functions of juxta-glomerular apparatus and role of renin-angiotensin system	02	01	02	
79	PY 7.3	Describe the mechanism of urine formation involving processes of filtration, tubular reabsorption and secretion; concentration and diluting mechanism.	01	04	03	
80	PY 7.4	Describe and discuss the significance and implication of renal clearance	—	—	01	5
81	PY 7.5	Describe the renal regulation of fluid and electrolytes and acid–base balance	—	02	—	8
82	PY 7.6	Describe the innervations of urinary bladder, physiology of micturition and its abnormalities	—	02	03	4
83	PY 7.7	Describe artificial kidney, dialysis and renal transplantation	—	—	02	2
84	PY 7.8	Describe and discuss renal function tests	—	01	—	3
85	PY 7.9	Describe cystometry and discuss the normal cystometrogram	—	01	—	2
		8. Endocrine Physiology				
86	PY 8.1	Describe the physiology of bone and calcium metabolism	01	01	—	5
87	PY 8.2	Describe the synthesis, secretion, transport, physiological actions, regulation and effect of altered (hypo and hyper) secretion of pituitary gland, thyroid gland, parathyroid gland, adrenal gland, pancreas and hypothalamus	07	08	12	19
88	PY 8.3	Describe the physiology of thymus and pineal gland	—	—	03	2
89	PY 8.4	Describe function tests: Thyroid gland; adrenal cortex, adrenal medulla and pancreas	—	—	03	10
90	PY 8.5	Describe the metabolic and endocrine consequences of obesity and metabolic syndrome, stress response. Outline the psychiatry component pertaining to metabolic syndrome.	—	—	04	
91	PY 8.6	Describe and differentiate the mechanism of action of steroid, protein and amine hormones	—	—	03	4
		9. Reproductive Physiology				
92	PY 9.1	Describe and discuss sex determination, sex differentiation and their abnormities and outline psychiatry and practical implication of sex determination.	—	—	05	7

S. No.	Competency No.	Competency details	Long essays	Short essays	Short answers	MCQs
93	PY 9.2	Describe and discuss puberty: Onset, progression, stages; early and delayed puberty and outline adolescent clinical and psychological association.	—	01	03	5
94	PY 9.3	Describe male reproductive system: Functions of testis and control of spermatogenesis and factors modifying it and outline its association with psychiatric illness	—	01	04	6
95	PY 9.4	Describe female reproductive system: (a) Functions of ovary and its control; (b) Menstrual cycle—hormonal, uterine and ovarian changes	01	01	02	7
96	PY 9.5	Describe and discuss the physiological effects of sex hormones		01	01	5
97	PY 9.6	Enumerate the contraceptive methods for male and female. Discuss their advantages and disadvantages	—	02	03	5
98	PY 9.7	Describe and discuss the effects of removal of gonads on physiological functions	—	—	02	4
99	PY 9.8	Describe and discuss the physiology of pregnancy, parturition and lactation and outline the psychology and psychiatry—disorders associated with it.	—	04	02	6
100	PY 9.9	Interpret a normal semen analysis report including (a) sperm count, (b) sperm morphology and (c) sperm motility, as per WHO guidelines and discuss the results	—	—	03	5
101	PY 9.10	Discuss the physiological basis of various pregnancy tests	—	—	01	5
102	PY 9.11	Discuss the hormonal changes and their effects during perimenopause and menopause	—	01	01	5
103	PY 9.12	Discuss the common causes of infertility in a couple and role of IVF in managing a case of infertility.	—	02	01	5
		10. Neurophysiology				
104	PY 10.1	Describe and discuss the organization of nervous system	—	01	04	6
105	PY 10.2	Describe and discuss the functions and properties of synapse, reflex, receptors	—	05	03	10
106	PY 10.3	Describe and discuss somatic sensations and sensory tracts.	01	06	02	7
107	PY 10.4	Describe and discuss motor tracts, mechanism of maintenance of tone, control of body movements, posture, and equilibrium and vestibular apparatus	02	08	04	11
108	PY 10.5	Describe and discuss structure and functions of reticular activating system, autonomic nervous system (ANS)	—	01	02	5

S. No.	Competency No.	Competency details	Long essays	Short essays	Short answers	MCQs
109	PY 10.6	Describe and discuss spinal cord, its functions, lesion and sensory disturbances	01	—	01	6
110	PY 10.7	Describe and discuss functions of cerebral cortex, basal ganglia, thalamus, hypothalamus, cerebellum and limbic system and their abnormalities	05	03	06	9
111	PY 10.8	Describe and discuss behavioral and EEG characteristics during sleep and mechanism responsible for its production	—	02	01	6
112	PY 10.9	Describe and discuss the physiological basis of memory, learning and speech	—	04	04	6
113	PY 10.10	Describe and discuss chemical transmission in the nervous system. (Outline the psychiatry element.)	—	01	—	5
114	PY 10.11	Demonstrate the correct clinical examination of the nervous system: Higher functions, sensory system, motor system, reflexes, cranial nerves in a normal volunteer or simulated environment	—	—	01	—
114	PY 10.12	Identify normal EEG forms	—	01	—	—
115	PY 10.13	Describe and discuss perception of smell and taste sensation	01	03	—	5
116	PY 10.14	Describe and discuss pathophysiology of altered smell and taste sensation	—	—	02	2
117	PY 10.15	Describe and discuss functional anatomy of ear and auditory pathways and physiology of hearing	01	04	03	5
118	PY 10.16	Describe and discuss pathophysiology of deafness. Describe hearing tests	—	02	02	5
119	PY 10.17	Describe and discuss functional anatomy of eye, physiology of image formation, physiology of vision including colour vision, refractive errors, colour blindness, physiology of pupil and light reflex	—	07	08	9
120	PY 10.18	Describe and discuss the physiological basis of lesion in visual pathway	01	—	—	3
121	PY 10.19	Describe and discuss auditory and visual evoke potentials	—	—	01	5
122	PY 10.20	Demonstrate (i) testing of visual acuity, colour and field of vision, (ii) hearing, (iii) testing for smell, and (iv) taste sensation in volunteer/simulated environment	—	—	01	—
		11. Integrated Physiology				
123	PY 11.1	Describe and discuss mechanism of temperature regulation	—	01	02	5
124	PY 11.2	Describe and discuss adaptation to altered temperature (heat and cold)	—	01	—	5
125	PY 11.3	Describe and discuss mechanism of fever, cold injuries, and heat stroke	—	—	03	6

S. No.	Competency No.	Competency details	Long essays	Short essays	Short answers	MCQs
126	PY 11.4	Describe and discuss cardiorespiratory and metabolic adjustments during exercise; physical training effects	—	—	03	5
127	PY 11.5	Describe and discuss physiological consequences of sedentary lifestyle	—	02	03	6
128	PY 11.6	Describe physiology of infancy	—	—	01	5
129	PY 11.7	Describe and discuss physiology of aging; free radicals and antioxidants			03	6
130	PY 11.8	Discuss and compare cardiorespiratory changes (isometric and isotonic) with that in the resting state and under different environmental conditions (heat and cold)	01	01	01	5
131	PY 11.9	Interpret growth charts	—	—	02	5
132	PY 11.10	Interpret anthropometric assessment of infants	—	—	01	5
133	PY 11.11	Discuss the concept, criteria for diagnosis of Brain death and its implications	—	—	01	5
134	PY 11.12	Discuss the physiological effects of meditation	—	—	01	5
135	PY 11.13	Obtain history and perform general examination in the volunteer/simulated environment.	—	—	01	5
136	PY 11.14	Demonstrate basic life support in a simulated environment	—	—	01	6
		Total Content	**50**	**244**	**255**	**621**

Chapter 1

General Physiology

1.1 DESCRIBE THE STRUCTURE AND FUNCTIONS OF A MAMMALIAN CELL

SHORT ANSWERS

1. Write the functions of plasma membrane.

- It is a protective membrane that encloses cell body
- It is also called cell membrane or plasmalemma.

Functions

1. **Protective function:** The cell membrane protects the cell organelles and cytoplasm from external substances by forming a mechanical barrier.
2. **Permeability:** Since the plasma membrane is selectively permeable to some substances and impermeable to others.
3. **Exchange of gases:** Oxygen and carbon dioxide can diffuse into and out of the cell through cell membrane as they are soluble in the cell membrane.
4. **Absorption:** Some substances are absorbed through cell membrane, especially nutrients.
5. **Excretion:** Some unwanted excretory wastes are thrown out of the cell through plasma membrane.
6. **Maintenance of shape and size of cell:** It prevents water accumulation and maintains cell size through NAK ATPase channels.

2. Which organelle is called suicide bag of the cell? What type of enzymes does it contain? And what is its function?

Organelle

- Lysosome is called the suicide bag of the cell.
- These are membrane bound vesicles within the cytoplasm of a cell.

Enzymes

1. **Amylases:** They digest carbohydrates
2. **Proteases:** They digest proteins
3. **Lipases:** They digest lipids
4. **Nucleases:** They digest nucleic acids

Functions

1. Degradation of macromolecules that have been engulfed by phagocytosis, pinocytosis or endocytosis.
2. Degradation of damages organelles is carried out by lysosome by formation of autophagolysosome.
3. Removal of excreted products is done by lysosomes.
4. Some lysosomes have been found to have secretory function. Examples are perforin and granzymes which can destroy microbes, serotonin by mast cells carry out allergic response and melanin secretion from melanocytes.

3. What are the peculiarities of mitochondrial DNA?

Mitochondria

- Are called powerhouse of the cell
- It has an outer membrane which encloses the cytosol

- The inner membrane is thrown into numerous folds which have 5 enzymes required for Krebs cycle.

Mitochondrial DNA

- The matrix of the mitochondria houses the DNA.
- Most of the DNA is packed within the nucleus. But a small portion is enclosed within the mitochondria.
- It is around 16,500 Da in mass.
- It is inherited from the mother as only nucleus of the sperm takes part in zygote formation and other cell organelles are derived from the egg.
- This DNA is responsible for production of enzymes that takes part in respiratory cycle and specific for cells having mitochondria.
- Due to its small size and ease to isolate, it has been a target for genome sequencing projects.
- It lacks introns as against DNA in the nucleus.
- Also, it has the ability of translation using a single t-RNA sequence.

1.2 DESCRIBE AND DISCUSS THE PRINCIPLES OF HOMEOSTASIS

SHORT ESSAYS

1. Explain the different feedback mechanisms operating to maintain homeostasis with examples.

- Homeostasis is a phenomenon of maintenance of constant internal environment.

Feedback Mechanisms

- Any change in pattern of any system activates sensors
- These signals reach a control centre.
- The effectors bring about the necessary change by causing the required action.

1. Negative Feedback Mechanism

- A change in homeostasis causes to inhibit the natural activity to bring the change under control
- Example: Thyroid hormone regulation

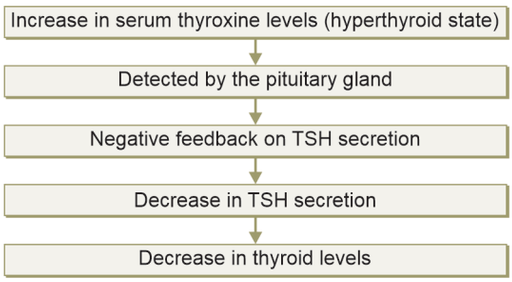


Fig. 1.1

- The same holds good for FSH regulation also.
- Another example of negative feedback is water regulation.

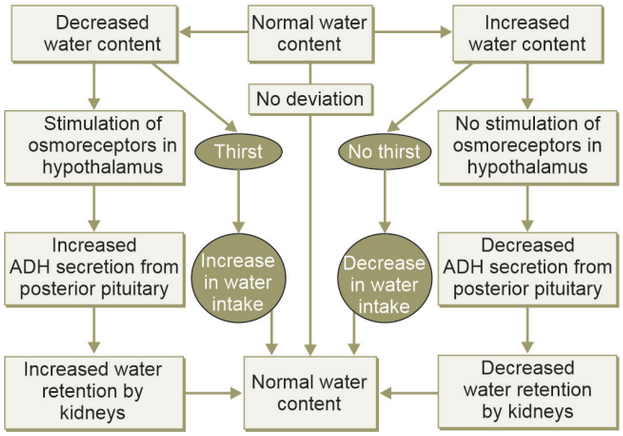


Fig. 1.2

2. Positive Feedback Mechanism

- In this type of feedback, there is increase in the activity in the same direction.
- Examples are blood clotting, labor, milk ejection reflex.

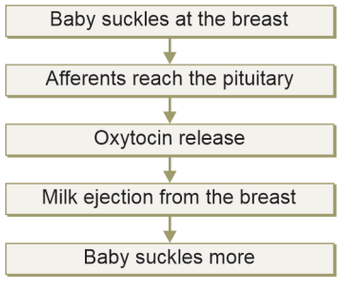


Fig. 1.3

2. What is milieu intérieur? What are the mechanisms which help in maintaining fluid osmolality?

Milieu Intérieur

- Milieu intérieur literally means internal environment.
- Claude Bernard, a scientist in the 19th century explained that multicellular organisms live in a perfectly organized and coordinated environment—which he called milieu intérieur.
- It is the extracellular fluid which house various types of cells and contains many nutrients, ions and various other structures required for sustenance of cells.
- It is further divided as blood and interstitial fluid.

Homeostasis in Maintaining Fluid Osmolarity

1. ADH Mechanism

- Hypothalamus plays an important role in detecting osmolarity of blood through osmoreceptors.
- Osmoreceptors sense a variation-decrease or an increase in osmolarity in the blood.

Increase in blood osmolarity

- May be due to water loss or due to inadequate solutes in blood
- When the osmolarity is increased, thirst increases and the osmoreceptors are stimulated.
- Thirst causes the person to drink more water
- This causes stimulation of posterior pituitary to secrete antidiuretic hormone.

- ADH acts on the distal convoluted tubule to absorb more water through increased formation of aquaporin channels and increases water reabsorption.
- This causes dilution of ECF and decreases in osmolarity.

Decrease in blood osmolarity

- May be due to water loss or due to inadequate solutes in blood
- When the osmolarity is increased, thirst increases and the osmoreceptors are stimulated.
- Thirst causes the person to drink more water
- This causes stimulation of posterior pituitary to secrete antidiuretic hormone.
- ADH acts on the distal convoluted tubule to absorb more water through increased formation of aquaporin channels and increases water reabsorption.
- This causes dilution of ECF and decreases in osmolarity.
- The reverse happens in decreased osmolarity.

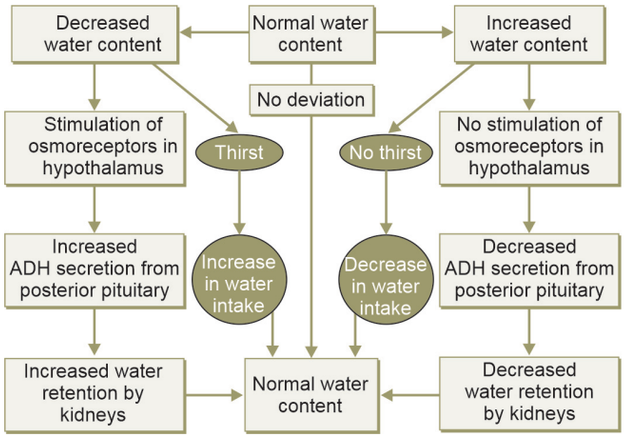


Fig. 1.4

2. RAAS Mechanism

- Renin is a hormone secreted by juxtaglomerular cells.
- It is secreted when there is a decrease in Na^+ concentration in the thick ascending limb. Sympathetic stimulation also causes renin release.
- Most of the actions are produced due to formation of angiotensin II.

Action on adrenal cortex

- Renin stimulates the adrenal cortex to produce aldosterone.
- Aldosterone is a mineralocorticoid and increases sodium retention and thus increases osmolarity.

Action on glomerular apparatus

- It constricts the afferent arteriole and decreases the blood flowing into the glomerulus and thus decreases glomerular filtration. This increases the ECF volume.
- It leads to contraction of the glomerular mesangial cells, thereby decreasing the surface area of glomerulus.
- It increases sodium reabsorption from the proximal tubules.

Action on brain

- Angiotensin II increases water intake by stimulating the thirst center.
- It increases the release of ADH from posterior pituitary.

SHORT ANSWERS

1. Explain negative feedback mechanisms with 2 examples.

Feedback Mechanisms

- Any change in pattern of any system activates sensors.
- These signals reach a control centre.
- The effectors bring about the necessary change by causing the required action.

Negative Feedback Mechanisms

- A change in homeostasis causes to inhibit the natural activity to bring the change under control
- ***Example:*** Thyroid hormone regulation

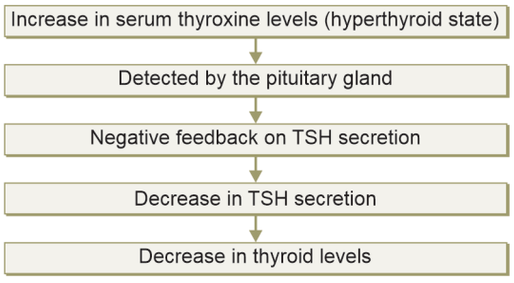


Fig. 1.5

- The same holds good for FSH regulation also.
- Another example of negative feedback is water regulation.

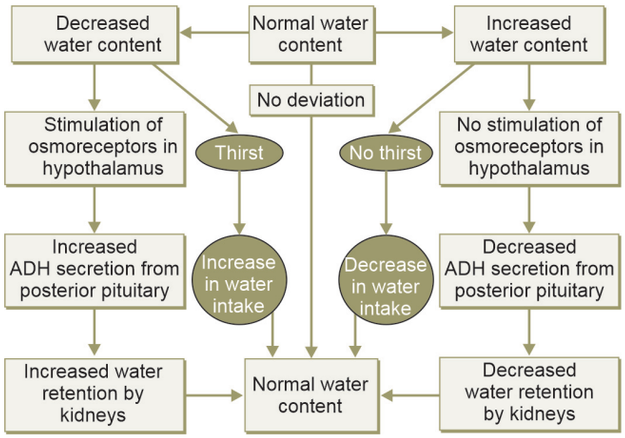


Fig. 1.6

2. Define homeostasis. Give the examples for positive feedback mechanisms.

- Homeostasis is a phenomenon of maintenance of constant internal environment.

Positive Feedback Mechanisms

- In this type of feedback, there is increase in the activity in the same direction.
- *Examples are:*

1. **Blood clotting**

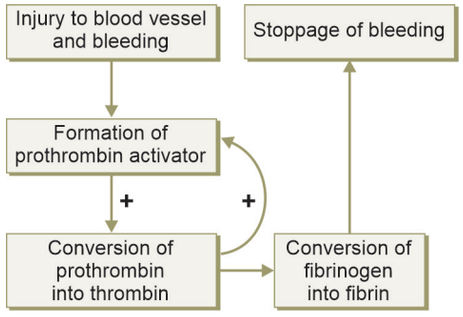


Fig. 1.7

2. **Labor**

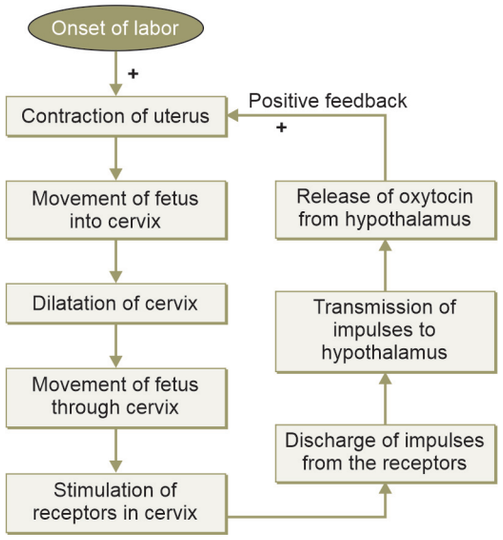


Fig. 1.8

3. **Milk ejection reflex**

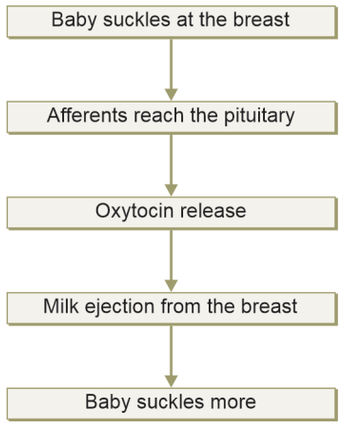


Fig. 1.9

1.3 DESCRIBE INTERCELLULAR COMMUNICATION

SHORT ESSAYS

1. Explain the types of intercellular communication. Mention one physiological significance of each.

Types of Intercellular Communication

Also called cell junctions.

1. Tight Junctions (Fig. 1.10)

- Also called zona occludens, it is an intercellular occluding junction between two cells which does not allow passage of macromolecules.
- Each tight junction consists of one-half ridge from each cell and the junction occupies the space between the two cells.
- They only allow specific molecules to pass through it.

Physiological importance

i. ***Blood–brain barrier:*** Tight junctions between capillaries form blood–brain barrier which does not allow penetration of chemicals across it thus protects the brain from harmful chemicals present in the blood.

ii. ***Gastrointestinal tract:*** Tight junctions in the epithelium of the mucosa of the stomach do not permit entry of substances to be absorbed excepting a few lipid-soluble substances like alcohol.

iii. ***Renal tubular cells***

- Tight junctions are present on the luminal side of the tubular cells which allow Na^+ ions and water to diffuse in.
- They are sensitive to ADH and control the amount of water absorption.

2. Gap Junctions (Fig. 1.11)

- These are intercellular junctions that allow passage of ions and smaller molecules between two cells.
- These are present in the cardiac muscle and basal epithelium of the gut mucosa.

Physiological significance

- They help in fast conduction of action potential. As a result, multiple cells with gap junctions function as a single unit—syncytium. These are found very commonly in smooth muscles of viscera like gut, bile ducts, uterus and many blood vessels.

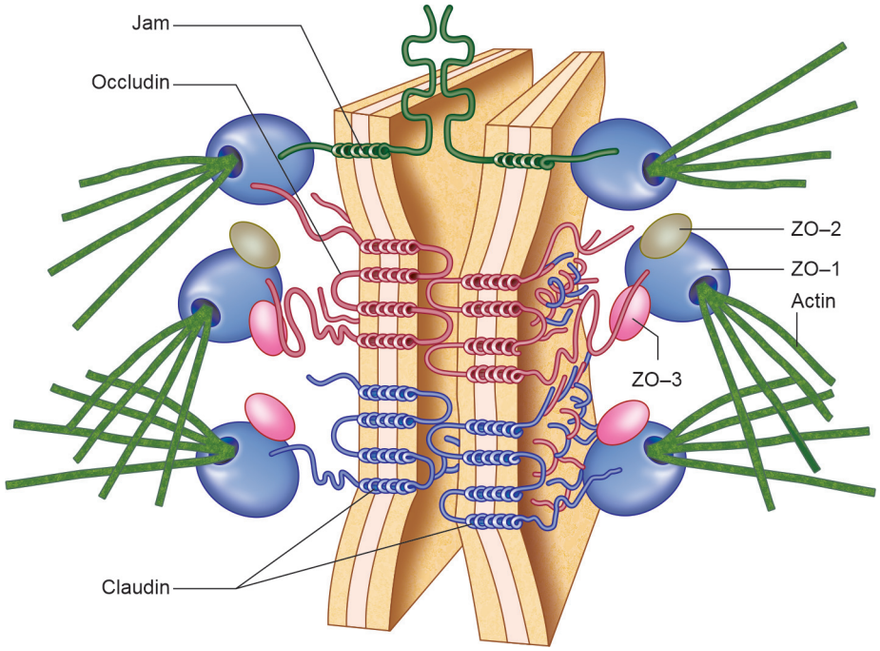


Fig. 1.10

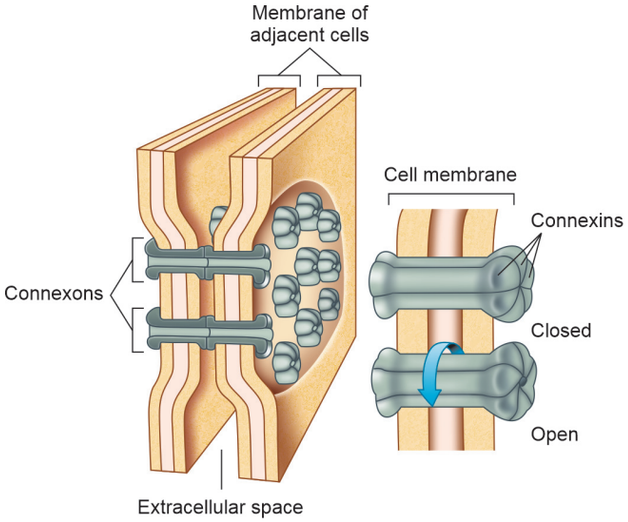


Fig. 1.11

- The cardiac muscles also are connected by gap junctions. They act like a syncytium such that cardiac cells are connect with each other. The heart is divided into atrial and ventricular syncytium by a fibrous band. As a result, action potential is conducted at the same time through all fibers of atria. Similarly, all muscle fibers of the ventricle contract together.
- In smooth muscle of the gut, these smooth muscles are connected with other by gap junctions, lengthwise such that peristalsis waves are conducted lengthwise.
- Estrogen acts on the uterine muscle to increase in gap junctions and forms a syncytium. During parturition, the whole uterus contracts as single unit.

3. Anchoring Junctions (Fig. 1.12)

- These form connections between actin filaments of one cell to another, just below tight junctions.
- The proteins responsible for this are called cadherins.
- Desmosomes are cell-to-cell junction, where intermediate filaments are held together. There is thickening of membrane intervening between two cells.

Physiological significance

- Adherent junctions are present in the intercalated discs between cardiac muscles. During contractions the cells are held together tightly.
- They are also present in epidermis.

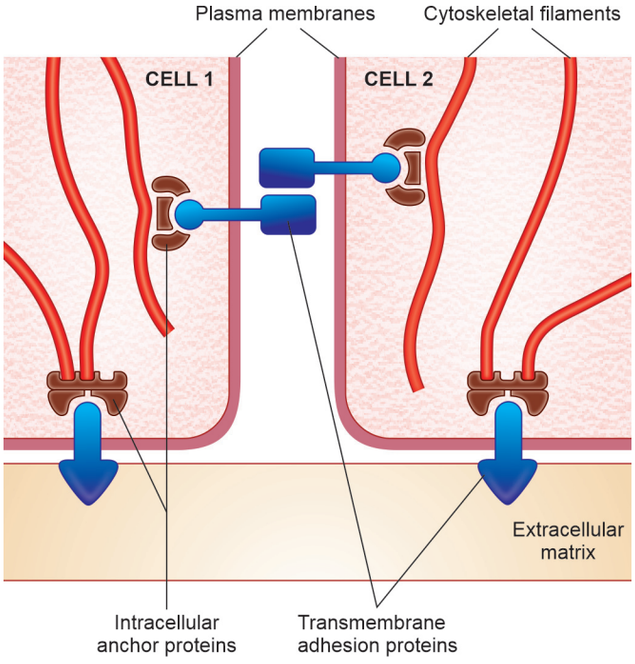


Fig. 1.12

SHORT ANSWERS

1. What are gap junctions? What is its physiological significance?

Gap Junctions

- These are intercellular junctions that allow passage of ions and smaller molecules between two cells.
- These are present in the cardiac muscle and basal epithelium of the gut mucosa.

Physiological Significance

- They help in fast conduction of action potential. As a result, multiple cells with gap junctions function as a single unit—syncytium. These are found very commonly in smooth muscles of viscera like gut, bile ducts, uterus and many blood vessels.
- The cardiac muscles also are connected by gap junctions. They act like a syncytium such that cardiac cells are connect with each other. The heart is divided into atrial and ventricular syncytium by a fibrous band. As a result, action potential is conducted at the same time through all fibers of atria. Similarly, all muscle fibers of the ventricle contract together.
- In smooth muscle of the gut, these smooth muscles are connected with other by gap junctions, lengthwise such that peristalsis waves are conducted lengthwise.
- Estrogen acts on the uterine muscle to increase in gap junctions and forms a syncytium. During parturition, the whole uterus contracts as single unit.

1.4 DESCRIBE APOPTOSIS—PROGRAMMED CELL DEATH

SHORT ESSAY

1. What is apoptosis? Give its physiological importance with examples.

Apoptosis

- Apoptosis is defined as programmed cell death.
- It is under genetic control, and thus referred to as 'cell suicide'.
- It is not associated with inflammation.
- It is related to the word 'ptosis'—which means 'fall'

Physiological Significance

1. Intrauterine life
   - It helps in normal development of organs.
   - It helps to sculpt organs, create the interdigital web spaced.
2. In adulthood
   - About 10 billion cells die every day to maintain stem cell homeostasis
   - In the bone marrow, millions of copies of stem cells are produced. They are destroyed by apoptosis to maintain normal miles.
3. If a cell is damaged by radiation or virus, the cell is destroyed mediated by P53 gene. Its importance has shown by the loss of P53 gene leading to an increased propensity to cancers where there is altered genetic make-up introduced by a mutagenic stimulus.
4. It is necessary for regression of certain ducts during sex differentiation in fetus (e.g. wolffian duct). Also, failure to absorb one of such ducts can lead to fistulae.

   Example: Patent urachus, patent ductus arteriosus.
5. Apoptosis of auto-aggressive T cells is needed to prevent autoimmune conditions.
6. Apoptosis is an important cause for shedding of endometrium during menstruation.
7. Increased apoptosis leads to pathological neurodegeneration as in Alzheimer's disease, Parkinson's disease and AIDS.
8. Decreased apoptosis leads to malignancies and autoimmune conditions.

1.5 DESCRIBE AND DISCUSS TRANSPORT MECHANISMS ACROSS CELL MEMBRANES

SHORT ANSWERS

1. Define

A. Osmotic pressure
B. Osmosis
C. Osmolality

A. Osmotic Pressure

- It is the pressure created by solutes in the fluid which drive fluid towards the region containing them by osmosis.
- Each solute has its own osmotic pressure.

B. Osmosis

Passive movement of water or other solvent molecules across a semipermeable membrane from a region of higher concentration to a region of lower concentration along the concentration gradient is called osmosis.

C. Osmolality

- It is a measure of a fluid's ability to create osmotic pressure.
- It is also called osmolar concentration of a solution.

2. Explain Facilitated Diffusion

Facilitate Diffusion

- It is a type of diffusion across a semipermeable membrane where water-soluble larger molecules are transported with the help of a carrier protein, irrespective of the concentration gradient.
- Based on the carrier protein, there are two types:
  1. **Channel proteins:** A passageway is formed by proteins which lead to fast passage of small ions and water molecules.
     Example: Potassium ions in nerve fiber, water molecules.
  2. **Uniporters:** They carry a single molecule at a time along a concentration gradient. Binding of the molecule causes conformational change in the protein.
     Example: Sugars, aminoacids.

3. What do mean by secondary active transport? Give examples.

Secondary Active Transport

- Transport of a molecule or an ion across a semipermeable membrane with the help of another ion (usually sodium) and a carrier protein.
- It can be in the same direction as sodium or in opposite direction.
- When both the ions are being transported, it is called co-transport and when the ions are transferred in opposite directions, it is called counter-transport.

Examples

1. **Sodium co-transport (Fig. 1.13)**
   - The carrier protein called symport takes both the ions in the same direction.

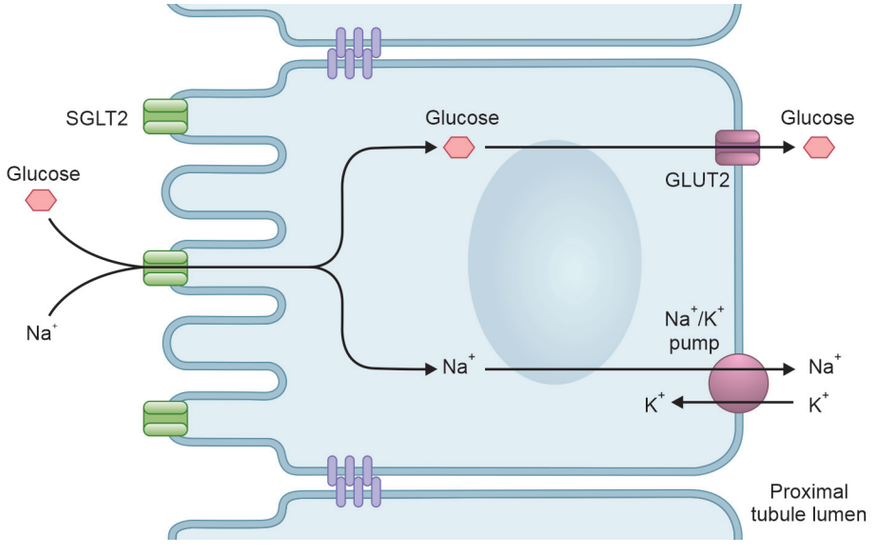


Fig. 1.13

- In proximal convoluted tubules of the kidney, the sodium and glucose molecules are carried towards the inside of the cell at the same time.
- Iron, urea, iodine and amino acids are also co-transported with sodium in the proximal convoluted tubules.
- The carrier protein has two sites for attachment of these substances.
- When both the substances attach, the carrier protein undergoes conformational change and leads to inward turning of the protein.
- Then the molecules detach from the carrier protein and transported into the intracellular space.

2. **Sodium counter-transport mechanism (Fig. 1.14)**
   - The carrier protein is called antiport.
   - Sodium is exchanged for various molecules along with sodium.

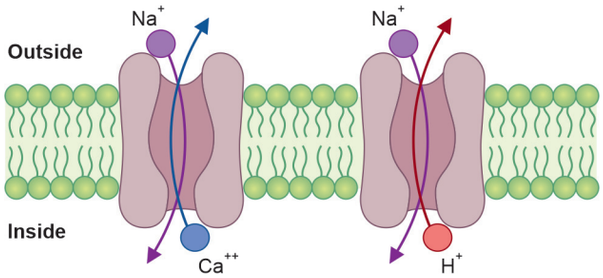


Fig. 1.14

- Sodium calcium channels are present in all cells. In this, sodium influxes along with efflux of calcium at the same time.
- Others are $Na^+ - H^+$ counter-transport in renal tubular cells, sodium–magnesium, $Na^+ - K^+$, $Ca^{++} - Mg^{++}$, $Ca^{++} - K^+$ counter-transport mechanisms.

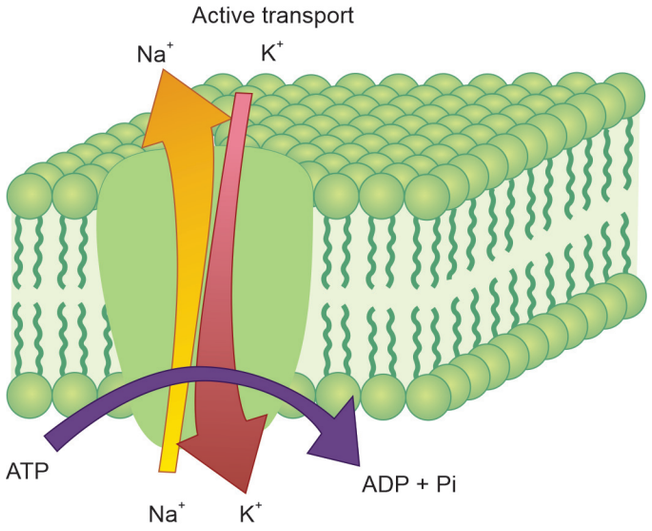
4. Explain Na^+ –K^+ transport mechanism and give its physiological importance (Fig. 1.15).

Na–K Transport Mechanism

- They are transported by active transport across the cell membrane with the help of a carrier protein and use of ATP.
- It is called the Na–K-ATPase pump.
- It transports sodium from inside the cell to outside and brings in potassium from outside to inside.

Physiological Importance

- This pump is very important to maintain the integrity and volume of the cell. Na^+ ions have more affinity to water molecules. Increase in Na^+ ions cause the cell to swell and die.
- As three sodium ions are removed for every 2 potassium ions, a negativity is created within the cell. This helps in creating a negative potential which is the basis for many activities like action potential in neurons and muscle fibers. Hence, this pump is said to be electrogenic.



Active transport against concentration gradient with input of energy

Fig. 1.15

5. What is the physiological importance of tight junctions? Explain with 2 examples.

Tight Junctions: Physiological Importance

- Also called zona occludens, it is an intercellular occluding junction between two cells which does not allow passage of macromolecules.
- Each tight junction consists of one-half ridge from each cell and the junction occupies the space between the two cells.
- They only allow specific molecules to pass through it.

Examples

1. **Blood–brain barrier:** Tight junctions between capillaries form blood–brain barrier which does not allow penetration of chemicals across it thus protects the brain from harmful chemicals present in the blood.
2. **Gastrointestinal tract:** Tight junctions in the epithelium of the mucosa of the stomach do not permit entry of substances to be absorbed excepting a few lipid-soluble substances like alcohol.
3. **Renal tubular cells**
   - Tight junctions are present on the luminal side of the tubular cells which allow Na^+ ions and water to diffuse in.
   - They are sensitive to ADH and control the amount of water absorption

1.6 DESCRIBE THE FLUID COMPARTMENTS OF THE BODY, ITS IONIC COMPOSITION AND MEASUREMENTS

SHORT ESSAYS

1. Define osmosis. When RBCs are suspended in hypotonic solution what happens to the cells? Mention 2 examples for isotonic solutions.

Osmosis

- Osmosis is defined as passive movement of water molecules across a semipermeable membrane from a region of higher concentration to a region of lower concentration along the concentration gradient.
- It should flow towards the region of higher concentration of solutes.
- 0.9% solution is considered isotonic. Solutions with concentration of NaCl lesser than that are considered hypotonic and concentration more than 0.9% are considered hypertonic.

RBC Suspended in Hypotonic Solution

- When RBCs are suspended in hypotonic solution, water enters the RBC and causes lysis of the cell. This is called osmotic fragility.
- Normal osmotic fragility of nRBC is 0.45% for older RBCs and 0.35% for younger RBCs.

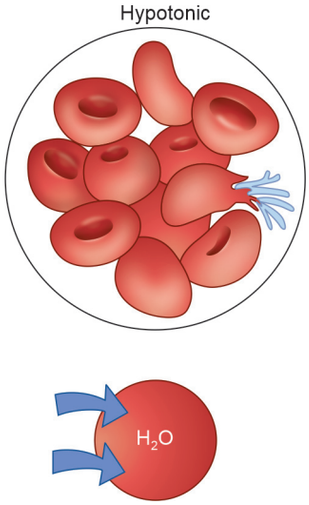


Fig. 1.16

Examples for Isotonic Solutions

- 0.45% saline is considered half-normal saline. It is used in conditions called diabetic ketoacidosis to rehydrate the cells.

1.7 DESCRIBE THE CONCEPT OF pH AND BUFFER SYSTEMS IN THE BODY

SHORT ESSAYS

1. What is metabolic acidosis? Why does it occur in diabetes mellitus?

Metabolic Acidosis

- It is an acid–base imbalance in the body characterized by increase in organic acids in the blood due to metabolic derangements.

Diabetic Ketoacidosis

- It is a complication of type 1 diabetes or insulin dependent diabetes.
- It is potentially fatal
- In this type, there is absolute deficiency of insulin.
- It is characterized by increased ketones in the body.

Pathophysiology (Figs 1.17 and 1.18)

It is precipitated by a stress or an infection which causes excess counter-regulatory hormones in blood.

2. What are the different mechanisms with which pH is regulated in the body?

Mechanisms of pH Regulation

- Acid–base balance is key regulator for maintenance of homeostasis. A lot of enzymes are dependent on normal pH of the body
- Normal pH of ECF is 7.38–7.42

$$pH = \log \frac{1}{H^+}$$

where H^+ is the concentration of hydrogen ions or protons

- An increase in pH causes alkalosis and a decrease in pH causes acidosis.
- Whenever there is a disturbance in the pH, there are three compensatory mechanisms that kick in:
  1. Acid–base buffer mechanism
  2. Respiratory mechanism
  3. Renal mechanism

1. Acid–Base Buffer Mechanism

- An acid–base buffer is a combination of a weak acid with a strong base salt.
- It acts immediately. It is of three types:
  i. ***Bicarbonate buffer system***
  - It consists of a weak acid, carbonic acid and a base salt-sodium bicarbonate.
  - Its pK is 6.1. It is not a very strong buffer but is very efficient due to both acid and base buffers work separately and simultaneously.

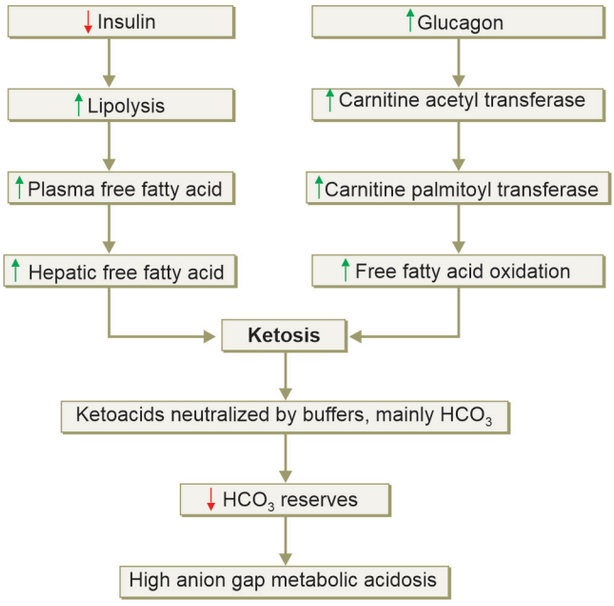


Fig. 1.17

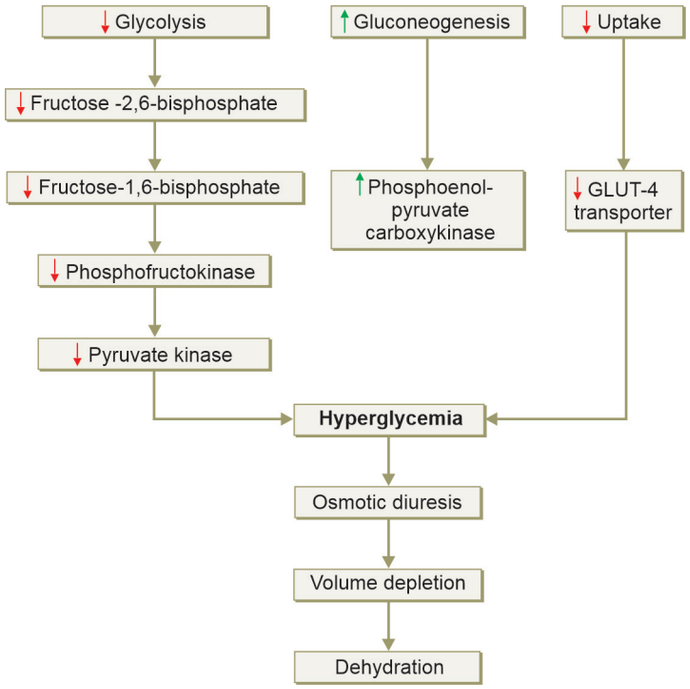


Fig. 1.18

- In acidic environment
  - o When the pH decreases in situations where there is excess H^+, it combines with $NaHCO_3$ to form carbonic acid and Na^+.
  - o Carbonic acid (H_2CO_3) is a weak acid and readily dissociates into CO_2 and H_2O.
- In alkaline environment
  - o When there is excess HCO_3, the milieu becomes alkaline.
  - o The H_2CO_3 acts as the buffer. The OH^- ion of the base combines with H^+ of the carbonic acid and forms water.
  - o Na^+ combines bicarbonate to form $NaHCO_3$

ii. ***Phosphate buffer system***

- This buffer system consists of a weak acid: Dihydrogen phosphate as acidic substance and sodium dihydrogen phosphate as the salt—NaH_2PO_4
- It has a pK of 6.8. hence more powerful than bicarbonate system.
- It consists of disodium hydrogen phosphate as the base—Na_2HPO_4
- It mainly operates in the intracellular fluid and renal tubules.
- In RBCs it is present as potassium dihydrogen phosphate and dipotassium hydrogen phosphate.
- In acidic environment
  - o When a strong acid like HCl is added to fluid consisting of phosphate buffer, hydrogen ions combine with Na_2HPO_4 to form NaH_2PO_4 (sodium dihydrogen phosphate)
- In alkaline environment
  - o When a strong base-like NaOH is added to a fluid consisting of phosphate buffer, OH^- combines with NaH_2PO_4 to form disodium hydrogen phosphate.

iii. ***Protein buffer***

- It is present in plasma and erythrocytes.
- The proteins which take part in buffer system are hemoglobin (most powerful), C-terminal carboxy group and N-terminal amino end of glutamic acid, side chain amino group of lysine, imidazole ring of histidine.
- They have a pK of 7.4. hence, they are powerful.
- When a deoxygenated hemoglobin molecule is exposed to low pH, it readily combines with hydrogen ions.

2. Respiratory Mechanism

- When pH of the blood falls, there is an increase in hydrogen ions.
- It combines with bicarbonate in blood to form, H_2O and CO_2.
- CO_2 is easily blown out by hyperventilation by the lungs. Hyperventilation is caused by chemoreceptors which are triggered by hydrogen excess.

3. Renal Mechanisms (Fig. 1.19)

- In presence of acidosis, kidneys excrete hydrogen ions and retain bicarbonate ions.
- In cases of metabolic acidosis, kidneys play an important role in preventing metabolic acidosis, by excreting excess H^+ ions
- It is done by 3 methods:

i. ***Bicarbonate mechanism***
- Excess bicarbonate and H^+ in urine combine to form H_2CO_3 (unstable). It dissociates to form H_2O and CO_2 which enter the tubular cell.
- In presence of carbonic anhydrase, they form H_2CO_3 which is catalyzed into H^+ and HCO_3^-
- Bicarbonate ions enter the interstitium
- The H^+ ions are exchanged for Na^+ at the luminal end.

ii. ***Phosphate mechanism***
- In the tubular lumen, Na_2HPO_4 splits into Na^+ and $NaHPO_4^-$
- In the tubular cell, $H_2O + CO_2 = H_2CO_3$. It splits immediately into H^+ and HCO_3^-
- The H^+ is exchanged for Na^+
- The H^+ combines with $NaHPO_4^-$ to sodium dihydrogen phosphate

iii. ***Ammonia mechanism***
- Ammonia is generated with the tubular cell from glutamine.
- It is transported to the tubular lumen in exchange for Na^+
- The hydrogen that is normally excreted combines with ammonia to form ammonium
- Thus, for each molecule of ammonia formed one H^+ is excreted and NCO_3^- is retained.

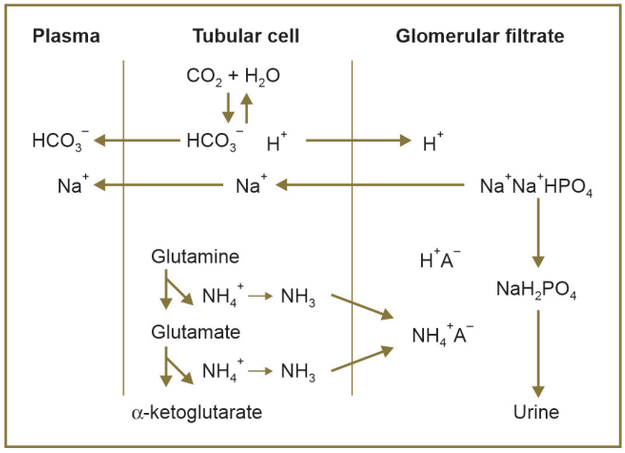


Fig. 1.19

1.8 DESCRIBE AND DISCUSS THE MOLECULAR BASIS OF RESTING MEMBRANE POTENTIAL AND ACTION POTENTIAL IN EXCITABLE TISSUE

SHORT ESSAYS

1. The resting membrane potential of a nerve is –70 mV. Substantiate.

Resting Membrane Potential

- It is the potential difference across the membrane of a neuron prior to beginning of an action potential and its value is –70 mV. That means the potential inside the nerve fibre is –70 mV lower than its exterior.
- The factors involved in maintaining this potential is the ionic gradient created across the membrane.
- It is mainly maintained through Na-K pump and Na-K leaky channels (Fig. 1.20).

Role of Sodium Potassium Active Pumps

- It is a powerful pump that continuously pumps K^+ ions inside the cell and Na^+ ions outside the cell with the help of ATP.
- It is an electrogenic pump, in the sense that, it pumps 3 Na^+ ions out and allows two K^+ ions inside the cell.
- As a result, a negative charge is created. Also, a gradient is created.

Na^+ (extracellular)	142 mEq/L	Ratio: 0.1
Na^+ (intracellular)	14 mEq/L	(inside:outside)
K^+ (extracellular)	4 mEq/L	Ratio: 35
K^+ (intracellular)	140 mEq/L	(inside:outside)

Role of Leak Channels

- These provide leakage of ions across the membrane and are 100 times more permeable to potassium influx.
- As a result, passive influx of sodium ions is much less compared to passive outflux of potassium ions.
- Further efflux of potassium ions is prevented by relative positivity outside the cell which prevents its efflux and negativity within the cell which keeps the potassium within.

2. Explain the ionic basis of the action potential in skeletal muscle

Ionic Basis of Action Potential

- Action potential is a series of electrical changes that occur in membrane potential when the muscle or nerve is stimulated (Fig. 1.21).
- Voltage-gated sodium and potassium channels play an important role in causing an action potential.
- It has three phases: Latent phase, depolarization and repolarization.

Latent Period

- It is the time taken when no change takes place in the membrane potential after applying a stimulus.
- There is no change in resting membrane potential (–90 mV)
- It is 0.5–1 ms in length.
- *Stimulus artifact:* It occurs at the time of application of stimulating electrode due to leakage of current from the stimulating electrode to the recording electrode. It occurs prior to latent period.

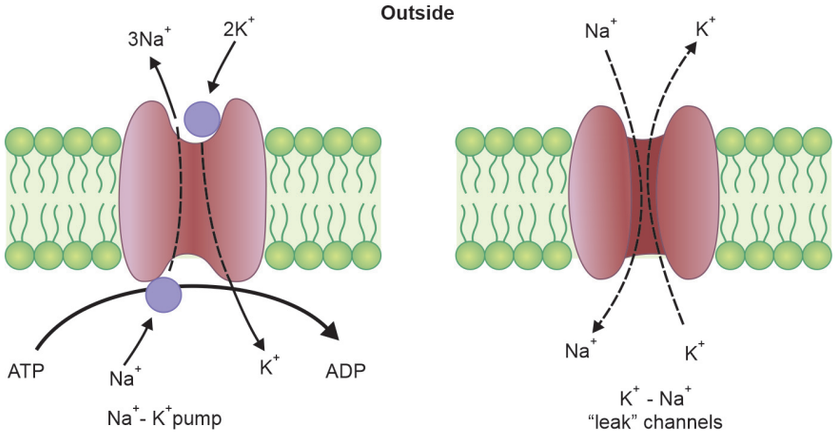


Fig. 1.20

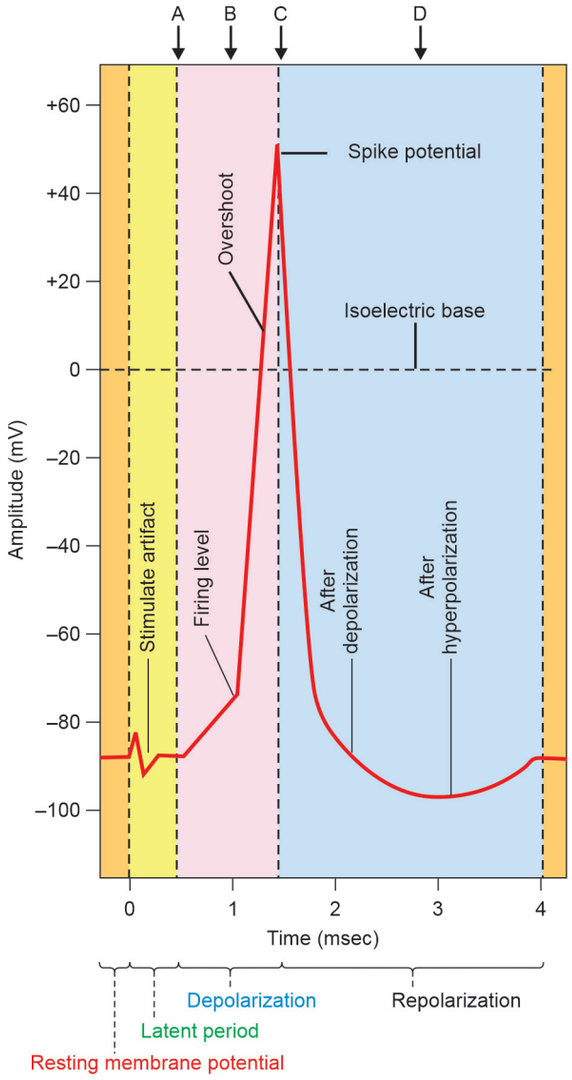


Fig. 1.21

A. Opening of sodium channels leading to influx of sodium ions, B. opening of more and more sodium channels causing influx of Na+, C. closure of sodium channels and opening of potassium channels leading to efflux of potassium, D. continued efflux of potassium ions leading to increase in negativity inside the cell

Depolarization

- It is a positive wave. For the first 15 mV it is very slow.
- Ionic basis for initial depolarisation: Represented by A in the diagram: It is due to opening of new sodium channels.
- After about 15 mV of depolarization, there is an increase in slope of the depolarization wave. Depolarization crosses the isoelectric point (0 mV) and overshoots by +55 mV.
- Ionic basis for firing level: Opening of more and more sodium channels. It is represented by B in the diagram.

Repolarization

- It is marked by reversal of potential from positive to negative. Ionic basis: Closure of sodium ions and opening of potassium ions. It is marked C in the diagram.
- It is followed by slow repolarization. Ionic basis: Open potassium ions leading to continuous influx of potassium ions.
- It is then followed by a slow hyperpolarization. Ionic basis: Potassium channels remain open for longer than sodium channels leading to further efflux of sodium ions leading to hyperpolarization. It is represented as D in the diagram.

SHORT ANSWER

1. Give the normal resting membrane potential of nerve, skeletal muscle and smooth muscle.

- Resting membrane potential is the difference between the electrical potential that exists within and outside a cell prior to excitation.
- Also called transmembrane potential.

Nerve	– 70 mV
Skeletal muscle	– 90 mV
Smooth muscle	– 50 to –60 mV

1.9 DEMONSTRATE THE ABILITY TO DESCRIBE AND DISCUSS THE METHODS USED TO DEMONSTRATE THE FUNCTIONS OF THE CELLS AND ITS PRODUCTS, ITS COMMUNICATIONS AND THEIR APPLICATIONS IN CLINICAL CARE AND RESEARCH

SHORT ESSAY/SHORT ANSWER

1. Explain patch clamp technique.

- It is a method to measure ion current across biological membranes.
- It was discovered in 1992 and is useful for studying ion potential across cell membranes.

Procedure (Fig. 1.22)

- The cells isolated for the body and is isolated in a dish.
- It is placed in culture media and placed in the incubator.
- A micropipette with an opening of around 0.5 micron is placed on the surface of the cell under a microscope.
- It is filled with saline solution.
- A recorder is fitted to the pipette and is connected to an amplifier.
- The pipette is applied firmly to the surface of the cell and gentle suction is created.
- The part of the cell membrane within the pipette is called the patch.

Methods of Studying Ion Potentials (Fig. 1.23)

1. **Cell attached patch:** The cell is intact and allows flow of current through the channels under the micropipette.

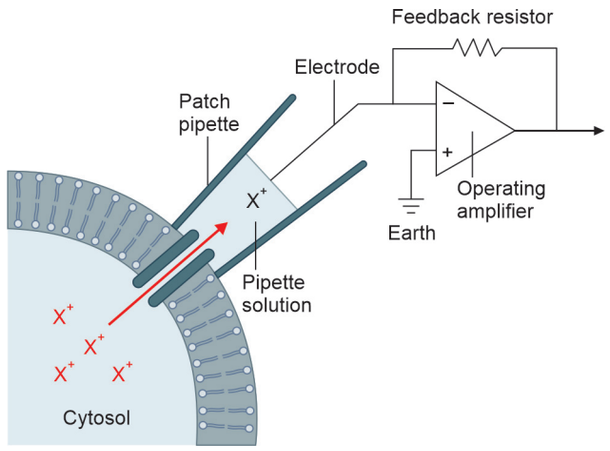


Fig. 1.22

2. **Inside-out patch**
   - When the pipette is gently pulled out, a part of the cell is broughtout.
   - Now the inside of the cell is exteriorized.
   - Then, this part of the cell along with the pipette is placed in another solution.
   - This procedure helps to understand effects of different ionic concentration on the cell membrane.
3. **Whole cell patch**
   - If the pipette is advanced further, the solution in the pipette mixes with the ICF.
   - When the mixing is complete, an equilibrium is reached.
   - It is useful in studying current flow through all channels.
4. **Outside-out patch**
   - From the whole cell patch, a portion of the membrane is torn away from the cell.
   - Immediately, the free ends of the torn membrane seal to form a vesicle.
   - The vesicle is placed in a bath solution and the fluid within the cell behaves like ICF.

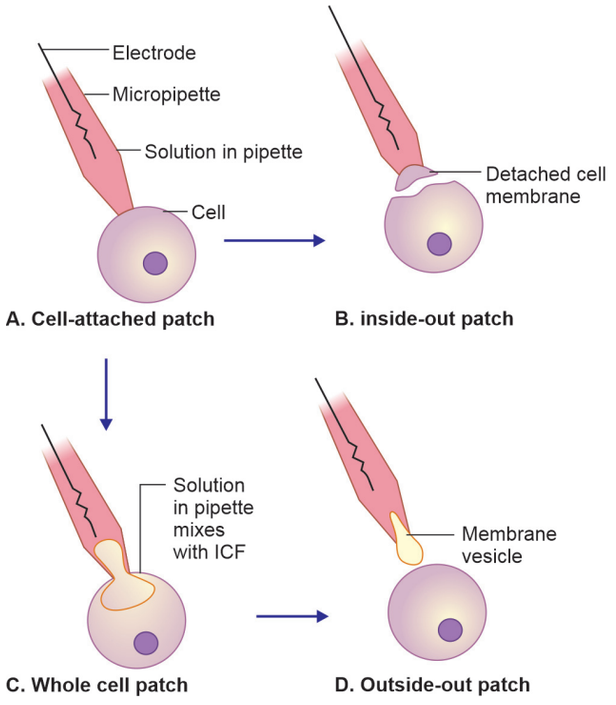


Fig. 1.23