A. HEMATOLOGY
A.1. RBC

LONG ESSAYS

1. A 30 years old woman comes to the hospital with complaints of fatigue for many months. On physical examination she has pale conjunctiva and spooning of nails. Her hemoglobin is 8gm% PCV is 20% and MCV is 80 fL. Stools are negative for occult blood.

Q: Name the clinical condition?
Iron deficiency anemia

Q: Describe the blood picture.
♦ Peripheral blood picture
- Hemoglobin – decreased
- RBC count – decreased
- PCV – decreased
- Color index – decreased
- MCV – decreased or low normal
- MCH and MCHC – decreased

♦ Peripheral smear
- Microcytic hypochromic RBCs
- Anisocytosis
- Poikilocytosis
- Pencil cells may be seen

♦ Reticulocyte count
Usually normal or slightly increased after treatment

Q: What other investigations would you like to do in this condition?
♦ Investigations
i. Serum iron – decreased
ii. Serum ferritin – decreased
iii. Total iron binding capacity – increased
iv. Transferrin saturation – decreased
v. Bone marrow examination – absent iron stores
vi. Stool examination for hookworm infestation
vii. Hb electrophoresis if needed to rule out thalassemia

Q: What are the dietary options for her betterment?
♦ Iron rich diet
- Green leafy vegetables
- Liver and red meat
- Egg yolk
- Dates and jaggery
- Beans and pulses
- Dry fruits
- Fish

♦ Substances increasing iron absorption
Vitamin C containing foods
- Lemon
- Orange
- Amla

♦ Avoid excess
Tea and coffee with meals as they reduce iron absorption

2. A 35-year-old female had come to a medical outpatient department with complaints of weakness. giddiness and loss of appetite. On examination she was pale; On investigation RBC count : 3.5 millions/mm³, Hb:9gm%. Peripheral smear showed microcytes with hypochromia

Q: Identify the condition
Iron deficiency anemia

Q: Discuss the physiological basis for the above condition and its management

♦ Physiological basis -
Iron is essential for:
- Hemoglobin synthesis
- Oxygen transport
- Erythropoiesis

Deficiency of iron causes:
- Decreased hemoglobin synthesis
- Formation of smaller RBCs → microcytosis

- Reduced hemoglobin content → hypochromia
- Reduced oxygen carrying capacity leading to:
  - Weakness
  - Fatigue
  - Pallor
  - Giddiness

Common causes:

- Poor dietary intake
- Chronic blood loss
- Menorrhagia
- Hookworm infestation
- Increased requirement during pregnancy

♦ Management -

a. Treat the cause

- Control bleeding
- Deworming
- Treat menorrhagia

b. Iron therapy

Oral iron

- Ferrous sulfate
- Ferrous fumarate

Parenteral iron

- If oral iron not tolerated

c. Dietary advice

- Iron rich foods
- Vitamin C supplementation

d. Blood transfusion

In severe anemia

Q: Discuss the stages of erythropoiesis

♦ Stages of erythropoiesis

a. Hemocytoblast (Pluripotent stem cell)

↓

b. Myeloid stem cell

↓

c. Proerythroblast

- Large nucleus
- Basophilic cytoplasm

↓

d. Early normoblast (Basophilic normoblast)

- Hemoglobin formation begins

↓

e. Intermediate normoblast (Polychromatophilic normoblast)

- Hb increases
- Nucleus condenses

↓

f. Late normoblast (Orthochromatic normoblast)

- Small dense nucleus
- Cytoplasm pink

↓

g. Reticulocyte

- Nucleus absent
- Slight reticular network present

↓

h. Mature erythrocyte

- Biconcave RBC
- No nucleus

Q: Describe the various factors which regulate erythropoiesis

♦ Factors regulating erythropoiesis -

a. Erythropoietin

- Main regulator
- Secreted mainly by kidney
- Stimulated by hypoxia

b. Hypoxia

- High altitude
- Hemorrhage
- Anemia stimulates RBC production

c. Nutritional factors

- Iron
- Proteins
- Vitamin B12
- Folic acid
- Vitamin C

d. Hormones

- Thyroxine
- Growth hormone
- Testosterone
- Cortisol

e. Healthy bone marrow

Necessary for normal erythropoiesis

3. A 12 years old girl child complains of lethargy and fatiguability for the last three months. Physical examination revealed pallor. Routine blood investigation showed Hb -8 gm% and peripheral smear revealed microcytic hypochromic RBCs.
Answer the following:

Q: Identify the clinical condition and what is the cause

Clinical condition - Iron deficiency anemia
Cause - Deficiency of iron causing defective hemoglobin synthesis

Q: Define anemia.
Anemia is a decrease in hemoglobin concentration below normal for age and sex, resulting in reduced oxygen carrying capacity of blood.

Q: Classify anemia based on etiology.
♦ Classification of anemia based on etiology -
a. Blood loss anemia
Acute
- Hemorrhage

Chronic
- Hookworm infestation
- Menorrhagia

b. Decreased RBC production
Nutritional deficiency
- Iron deficiency anemia
- Megaloblastic anemia

Bone marrow failure
- Aplastic anemia

c. Increased RBC destruction
Hemolytic anemia
- Hereditary
- Acquired

Q: Enumerate stages of erythropoiesis and discuss the factors regulating
♦ Stages of erythropoiesis -
i. Hemocytoblast
ii. Myeloid stem cell
iii. Proerythroblast
iv. Early normoblast
v. Intermediate normoblast
vi. Late normoblast
vii. Reticulocyte
viii. Mature erythrocyte

♦ Factors regulating erythropoiesis
i. Erythropoietin
ii. Hypoxia
iii. Iron
iv. Vitamin B12
v. Folic acid
vi. Proteins
vii. Hormones
  - Thyroxine
  - Testosterone
  - Growth hormone

4. A 30 years old woman visits a clinic with the complaints of difficulty in breathing and fatigue. She has menorrhagia for the past 3 months. Her Hb level is 6 gm%, PCV 20% and the reticulocyte count is 8%.Answer the following:

Q: Name the clinical condition
Iron deficiency anemia

Q: Describe the blood picture in this condition
♦ Blood picture in iron deficiency anemia -
a. Hemoglobin
- Decreased

b. RBC count
- Decreased

c. PCV
- Decreased

d. Color index
- Decreased

e. Red cell indices
- MCV – decreased
- MCH – decreased
- MCHC – decreased

f. Peripheral smear
- Microcytic hypochromic RBCs
- Anisocytosis
- Poikilocytosis
- Pencil cells

g. Reticulocyte count
- Increased after therapy or blood loss

Q: Classify anemia based on etiology
Etiological classification of anemia -
a. Due to blood loss
- Acute hemorrhage
- Chronic blood loss

b. Due to decreased RBC production
- Iron deficiency anemia
- Megaloblastic anemia
- Aplastic anemia

c. Due to increased destruction of RBCs
- Hemolytic anemia

Q: Describe iron deficiency anemia

♦ Iron deficiency anemia – Definition -
Anemia caused by deficiency of iron leading to defective hemoglobin synthesis.

♦ Causes -
- Poor dietary intake
- Chronic blood loss
- Menorrhagia
- Hookworm infestation
- Pregnancy

♦ Clinical features -
- Pallor
- Fatigue
- Dyspnea
- Weakness
- Koilonychia
- Glossitis

♦ Blood picture -
Microcytic hypochromic anemia

♦ Investigations -
- Serum iron decreased
- Serum ferritin decreased
- TIBC increased

♦ Treatment -
- Treat cause
- Oral iron therapy
- Iron rich diet
- Blood transfusion if severe

SHORT ESSAYS

5. Describe the steps of erythropoiesis using neat, labelled diagrams. List the factors regulating it.

♦ Erythropoiesis - Definition:
Formation of RBCs is called erythropoiesis.

♦ Steps of erythropoiesis -

Hemocytoblast
↓
Myeloid stem cell
↓
Proerythroblast
↓
Early normoblast
↓
Intermediate normoblast
↓
Late normoblast
↓
Reticulocyte
↓
Mature erythrocyte

♦ Features of stages -
a. Proerythroblast
- Large cell
- Large nucleus
- Basophilic cytoplasm

b. Early normoblast
- Hb synthesis begins

c. Intermediate normoblast
- Cytoplasm becomes pinkish

d. Late normoblast
- Dense nucleus
- Nucleus extruded

e. Reticulocyte
- No nucleus
- Reticular network present

f. Mature RBC
- Biconcave disc

- No nucleus

♦ Factors regulating erythropoiesis -

a. Erythropoietin
- Produced mainly by kidney
- Stimulated by hypoxia

b. Hypoxia
- Most important stimulus

c. Nutritional factors
- Iron
- Vitamin B12
- Folic acid
- Proteins

d. Hormones
- Testosterone
- Thyroxine
- Growth hormone

e. Healthy bone marrow
- Essential for RBC formation

6. Describe the stages of erythropoiesis with the help of diagrams. Describe the factors regulating it. Add a note on polycythemia.

♦ Definition -

Erythropoiesis is the process of formation of red blood cells (RBCs) from hematopoietic stem cells in the bone marrow.

♦ Stages of Erythropoiesis -

Hemocytoblast
↓
Common myeloid stem cell
↓
Proerythroblast
↓
Early normoblast (Basophilic erythroblast)
↓
Intermediate normoblast (Polychromatophilic erythroblast)
↓
Late normoblast (Orthochromatic erythroblast)
↓
Reticulocyte
↓
Mature erythrocyte

♦ Features of Stages -

a. Proerythroblast
- Large cell with large nucleus
- Deeply basophilic cytoplasm
- No hemoglobin

b. Early Normoblast (Basophilic erythroblast)
- Cell size decreases
- Cytoplasm deeply basophilic due to ribosomes
- Hemoglobin synthesis begins

c. Intermediate Normoblast (Polychromatophilic erythroblast)
- Cytoplasm becomes grayish
- Hemoglobin content increases
- Nucleus smaller and condensed

d. Late Normoblast (Orthochromatic erythroblast)
- Cytoplasm pink due to hemoglobin
- Nucleus becomes pyknotic and extruded

e. Reticulocyte
- Anucleate immature RBC
- Contains reticular network of ribonucleic acid
- Enters blood and matures within 1–2 days

f. Mature Erythrocyte
- Biconcave non-nucleated cell
- Life span: 120 days

♦ Factors Regulating Erythropoiesis

a. Tissue Hypoxia

Main stimulus for erythropoiesis.
Causes:
- Hemorrhage
- Anemia
- High altitude
- Cardiorespiratory disease

b. Erythropoietin
- Glycoprotein hormone
- Secreted mainly by kidneys
- Stimulates proliferation and maturation of erythroid cells

c. Nutritional Factors

Maturation factors

- Vitamin B12
- Folic acid

Hemoglobin formation factors

- Iron
- Proteins
- Vitamin B6
- Vitamin C
- Copper

d. Hormones

Stimulate erythropoiesis:

- Testosterone
- Thyroxine
- Growth hormone
- Cortisol

Q: Polycythemia

Definition - Increase in total RBC count, hemoglobin concentration and packed cell volume.

Types

a. Primary polycythemia (Polycythemia vera)

- Bone marrow disorder
- Excessive RBC production

b. Secondary polycythemia

Occurs due to increased erythropoietin secretion.

Causes:

- High altitude
- Chronic hypoxia
- Congenital heart disease

Effects:

- Increased blood viscosity
- Increased blood pressure
- Increased cardiac workload
- Thrombosis

7. Describe the different stages and factors influencing and regulating erythropoiesis

Definition - Erythropoiesis is the formation of RBCs in red bone marrow.

Stages of Erythropoiesis -

Hemocytoblast
↓
Common myeloid stem cell
↓
Proerythroblast
↓
Early normoblast
↓
Intermediate normoblast
↓
Late normoblast
↓
Reticulocyte
↓
Mature erythrocyte

♦ Salient Features -

- Cell size progressively decreases
- Hemoglobin increases
- Nucleus condenses and disappears
- Reticulocyte loses reticulum and becomes mature RBC

♦ Factors Influencing and Regulating Erythropoiesis

a. Hypoxia

Most important stimulus.

b. Erythropoietin

- Produced mainly in kidneys
- Increases RBC production

c. Nutritional Factors

- Iron
- Proteins
- Vitamin B12
- Folic acid
- Vitamin B6
- Vitamin C
- Copper

d. Hormones

- Testosterone
- Thyroxine
- Growth hormone

- Cortisol

e. Healthy Bone Marrow
Necessary for normal erythropoiesis.

8. Explain the factors regulating erythropoiesis

♦ Factors Regulating Erythropoiesis
a. Tissue Hypoxia
Major stimulus for erythropoiesis.
Occurs in:
- Anemia
- Hemorrhage
- High altitude
- Cardiorespiratory disease

b. Erythropoietin
- Glycoprotein hormone
- Secreted mainly by kidneys
- Stimulates RBC production

c. Nutritional Factors
Maturation factors
- Vitamin B12
- Folic acid

Hemoglobin synthesis factors
- Iron
- Protein
- Vitamin B6
- Copper
- Vitamin C

d. Hormones
- Testosterone
- Thyroxine
- Growth hormone
- Cortisol

e. Intact Bone Marrow
Required for normal erythropoiesis.

SHORT ANSWERS

9. What is the fate of RBCs? How is bilirubin produced?

♦ Fate of RBCs
- Life span of RBC: about 120 days
- Old RBCs are destroyed mainly in spleen, liver and bone marrow by macrophages.

♦ Fate of Hemoglobin
Globin -
- Broken into amino acids and reused.

Heme -
- Iron separated and reused.
- Porphyrin converted to biliverdin and then bilirubin.

♦ Formation of Bilirubin

Heme
↓
Biliverdin
↓
Unconjugated bilirubin
↓
Liver
↓
Conjugated bilirubin
↓
Bile
↓
Intestine

Some converted to:
- Stercobilin → gives stool color
- Urobilinogen → excreted in urine

10. Describe the factors regulating erythropoiesis
i. Tissue hypoxia
ii. Erythropoietin
iii. Nutritional factors:
   - Iron
   - Protein
   - Vitamin B12
   - Folic acid
   - Vitamin B6
   - Vitamin C

iv. Hormones:
   - Testosterone
   - Thyroxine
   - Growth hormone

v. Healthy bone marrow

11. List the classification of Anemia based on the cause.

a. Blood loss anemia -
- Acute hemorrhage
- Chronic blood loss

b. Hemolytic anemia -
- Increased destruction of RBCs

c. Decreased RBC production -
- Iron deficiency anemia
- Aplastic anemia
- Megaloblastic anemia
- Pernicious anemia

12. Physiological basis for anemia in chronic renal failure.
- Kidneys produce erythropoietin.
- In chronic renal failure, erythropoietin production decreases.
- Reduced erythropoietin causes decreased erythropoiesis.
- Hence normocytic normochromic anemia develops.

13. Polycythemia in High altitude areas. Why?
- High altitude has low oxygen tension.
- Tissue hypoxia develops.
- Kidneys increase erythropoietin secretion.
- Erythropoiesis increases.
- RBC count and hemoglobin increase causing secondary polycythemia.

14. ESR can be low in spherocytosis - why.
- In spherocytosis, RBCs are spherical and do not form rouleaux.
- Rouleaux formation is necessary for sedimentation.
- Hence ESR decreases.

15. Draw and label: steps of erythropoiesis

[REFER DIAGRAM SECTION]

16. Iron deficiency anemia

♦ **Definition -** Anemia due to deficiency of iron resulting in reduced hemoglobin synthesis.

♦ **Causes -**
- Nutritional deficiency
- Chronic blood loss
- Hookworm infestation
- Pregnancy

♦ **Features -**
- Microcytic hypochromic anemia
- Pallor
- Fatigue
- Koilonychia

17. Polycythemia at high altitude, why?
- At high altitude oxygen tension decreases.
- Tissue hypoxia stimulates erythropoietin secretion.
- Increased erythropoiesis occurs.
- RBC count rises causing secondary polycythemia.

18. Pernicious anemia

♦ **Definition -** Megaloblastic anemia caused by vitamin B12 deficiency due to intrinsic factor deficiency.

♦ **Cause -**
- Atrophy of gastric mucosa
- Lack of intrinsic factor

♦ **Features -**
- Macrocytic anemia
- Glossitis
- Neurological manifestations

19. Megaloblast in vitamin B12 deficiency anemia, why?
- Vitamin B12 is essential for DNA synthesis.
- Deficiency causes defective nuclear maturation.

- Cytoplasmic maturation continues normally.
- Large immature cells called megaloblasts appear.

20. Gastrectomy produces pernicious anemia, why?

- Intrinsic factor is secreted by parietal cells of stomach.
- Gastrectomy removes parietal cells.
- Vitamin B12 absorption decreases.
- Megaloblastic/pernicious anemia develops.

21. Maturation factors

♦ **Maturation Factors for RBCs -**

i. Vitamin B12
ii. Folic acid

♦ **Functions -**

- Necessary for DNA synthesis
- Required for maturation of RBCs

♦ **Deficiency Causes -**

- Megaloblastic anemia

22. Fetal hemoglobin

♦ **Definition -** Hemoglobin present in fetus.
♦ **Structure -** Two alpha chains and two gamma chains (α2γ2)
♦ **Features -**

- Higher affinity for oxygen
- Facilitates oxygen transfer from mother to fetus

♦ **Normal level -**

- Predominant during fetal life
- Replaced by adult hemoglobin after birth

23. Hemophilia

♦ **Definition -** Inherited bleeding disorder due to deficiency of clotting factors.
♦ **Types -**

- Hemophilia A – factor VIII deficiency
- Hemophilia B – factor IX deficiency

♦ **Features -**

- Prolonged bleeding
- Hemarthrosis
- Delayed clotting

24. Physiological jaundice

♦ **Definition –** Mild transient jaundice occurring in newborns.
♦ **Cause -**

- Increased RBC destruction
- Immature liver unable to conjugate bilirubin efficiently

♦ **Features -**

- Appears after 24 hours of birth
- Disappears within 1–2 weeks

25. Sickle cell anemia

♦ **Definition -** Inherited hemolytic anemia caused by abnormal hemoglobin S.
♦ **Cause -**

- Mutation in beta globin chain

♦ **Features -**

- Sickling of RBCs in hypoxia
- Hemolytic anemia
- Vaso-occlusive crisis

26. Reticulocytosis

♦ **Definition -** Increase in reticulocyte count in blood.
♦ **Causes -**

- Hemolytic anemia
- Acute blood loss
- Recovery after anemia treatment

♦ **Significance -**
Indicates increased erythropoietic activity of bone marrow.

A.2. WBC

LONG ESSAYS

1. A 25-year-old male nurse reported to the medicine department with complaint of chronic cough with sputum and fever with night sweats for the past 6 months, which is not relieved with routine antibiotic therapy. His lab report showed: Total WBC-13000/cumm3 , N- 32%, L-55%, M-8%, E-4%, B-1%, ESR-50. Chest x-rays showed cavities

Q: Name the most probable clinical condition

Pulmonary tuberculosis.

♦ Reasons

- Chronic cough with sputum
- Fever with night sweats
- Cavitary lesions in chest X-ray
- Lymphocytosis
- Raised ESR

Q: Comment on the ESR of this patient and describe the physiological basis for that

♦ ESR in This Patient - is markedly increased (50 mm/hour).

♦ Physiological Basis -

- Tuberculosis increases plasma fibrinogen and globulins.
- These proteins decrease zeta potential.
- Rouleaux formation increases.
- RBCs sediment faster.
- Therefore, ESR rises.

Q: Describe cell mediated immunity

♦ Definition -

Immunity mediated by T lymphocytes.

♦ Cells Involved -

- T lymphocytes
- Macrophages
- Antigen presenting cells

♦ Mechanism -

a. Antigen presentation - Macrophages present antigen to helper T cells.
b. Activation of T cells - Helper T cells release cytokines.
c. Clonal expansion - Activated T cells proliferate.
d. Effector functions
Cytotoxic T cells - Destroy infected cells.
Helper T cells - Activate macrophages and other immune cells.
e. Memory T cells - Provide long term immunity.

♦ Functions of Cell Mediated Immunity

- Defense against intracellular organisms
- Rejection of grafts
- Tumor immunity
- Delayed hypersensitivity reactions

Q: List the functions of lymph

i. Returns tissue fluid to blood
ii. Absorption of fats from intestine
iii. Transport of proteins
iv. Immunological defense
v. Removal of bacteria and debris

2. A two-year-old baby girl was admitted presenting with pallor, recurrent fever episodes, weakness and fatigue since 4 months. On examination, the spleen was found to be enlarged. The peripheral blood picture revealed normocytic normochromic RBCs, however, the WBCs showed a significant number of blast cells. Blood tests also revealed that

platelets were reduced and there was thrombocytopenia.

Q: What is the patient suffering from? / Diagnosis
Acute leukemia (most probably acute lymphoblastic leukemia).
Features Supporting Diagnosis -

- Pallor and fatigue
- Recurrent fever
- Splenomegaly
- Blast cells in peripheral smear
- Thrombocytopenia

Q: What is the significance of seeing blast cells in a peripheral blood smear

- Blast cells are immature precursor cells.
- Presence in peripheral blood indicates leukemia.
- Suggests uncontrolled proliferation of immature WBCs in bone marrow.
- Normal marrow function becomes suppressed causing anemia and thrombocytopenia.

Q: Explain the steps of leucopoiesis
Definition - Formation of white blood cells from hematopoietic stem cells.
Stem Cell Pathway -
Hemocytoblast
↓
Myeloid stem cell / Lymphoid stem cell

I) Granulopoiesis :
Myeloblast
↓
Promyelocyte
↓
Myelocyte
↓
Metamyelocyte
↓
Band cell
↓
Mature granulocyte (neutrophil/eosinophil/basophil)

II) Monocyte Formation :
Monoblast
↓
Promonocyte
↓
Monocyte

III) Lymphopoiesis :
Lymphoblast
↓
Prolymphocyte
↓
Lymphocyte

♦ Regulation of Leucopoiesis

- Colony stimulating factors
- Interleukins
- Infections stimulate WBC production

♦ Functions of WBCs

- Defense against infection
- Phagocytosis
- Antibody production
- Immune reactions

Q: Why does thrombocytopenia occur in this condition?
Thrombocytopenia in acute leukemia occurs due to replacement and suppression of normal bone marrow by leukemic blast cells.
♦ Mechanism -

i. In acute leukemia, abnormal immature white cells (blast cells) proliferate excessively in bone marrow.
ii. These leukemic cells crowd out normal hematopoietic cells.
iii. Megakaryocyte production decreases.
iv. Platelet formation becomes reduced.

v. Hence platelet count falls, causing thrombocytopenia.

♦ **Additional causes -**
- Increased destruction/consumption of platelets
- Chemotherapy-induced marrow suppression
- Splenic sequestration in some cases

♦ **Result -**

Low platelet count leads to:
- Petechiae
- Purpura
- Gum bleeding
- Prolonged bleeding tendency.

SHORT ESSAYS

3. Define and classify immunity. Add a note on cell mediated immunity.

♦ **Definition -** Immunity is the ability of the body to resist and defend itself against infectious agents, toxins and foreign substances.

♦ **Classification of Immunity**

a. Innate (Natural / Inborn / Non-specific) Immunity

Present from birth and acts immediately.

‣ **Types -**

i. Species immunity
ii. Racial immunity
iii. Individual immunity

‣ **Mechanisms -**
- Physical barriers – skin, mucous membrane
- Chemical barriers – hydrochloric acid, lysozyme
- Cellular defense – neutrophils, macrophages, natural killer cells
- Fever and inflammation

b. Acquired (Adaptive / Specific) Immunity

Develops after birth following exposure to antigen.

‣ **Active immunity -** Body produces its own antibodies.

i. Natural active immunity

Occurs after infection.

ii. Artificial active immunity

Produced by vaccination.

‣ **Passive immunity –** Ready made antibodies are transferred.

i. Natural passive immunity

Maternal antibodies through placenta and breast milk.

ii. Artificial passive immunity

Injection of antisera or immunoglobulins.

♦ **Types of Acquired Immunity**

I. Humoral immunity – mediated by B lymphocytes and antibodies
II. Cell mediated immunity – mediated by T lymphocytes

Cell Mediated Immunity (CMI)

Cell mediated immunity is immunity mediated by T lymphocytes without the direct participation of antibodies.

♦ **Cells involved**
- T lymphocytes
- Macrophages
- Natural killer cells

♦ **Mechanism**
- Antigen enters the body.
- Antigen presenting cells present antigen to T lymphocytes.
- T helper cells become activated and release cytokines.
- Cytokines stimulate proliferation of T cells.
- Cytotoxic T cells destroy infected or abnormal cells.
- Memory T cells are formed.

♦ **Functions of Cell Mediated Immunity**
- Defense against viral, fungal and intracellular bacterial infections
- Destruction of tumor cells
- Rejection of transplanted organs

- Delayed hypersensitivity reactions
- Activation of macrophages

♦ **Features**

- Specific
- Has memory
- Transferable by lymphocytes but not by serum

4. Classify white blood cells and explain their morphology and functions. Add a note on leukemia.

♦ **Classification of White Blood Cells**

A. Granulocytes

- Neutrophils
- Eosinophils
- Basophils

B. Agranulocytes

- Lymphocytes
- Monocytes

♦ **Morphology and Functions**

a. Neutrophils -

Morphology

- Diameter: 10–14 μm
- Multilobed nucleus
- Fine cytoplasmic granules
- Most numerous leukocyte

Functions

- Phagocytosis of bacteria
- First line of defense
- Formation of pus
- Release of enzymes during inflammation

b. Eosinophils -

Morphology

- Bilobed nucleus
- Large eosinophilic granules

Functions

- Defense against parasites
- Allergic reactions
- Inactivation of histamine
- Phagocytosis of antigen-antibody complexes

c. Basophils -

Morphology

- S-shaped nucleus
- Coarse basophilic granules

Functions

- Release histamine, heparin and serotonin
- Role in allergy and inflammation

d. Lymphocytes -

Morphology

- Large round nucleus
- Thin rim of cytoplasm

Functions

- Immunity
- B cells produce antibodies
- T cells mediate cellular immunity
- Natural killer cells destroy abnormal cells

e. Monocytes -

Morphology

- Largest leukocyte
- Kidney-shaped nucleus

Functions

- Become macrophages in tissues
- Powerful phagocytosis
- Antigen presentation

<u>Leukemia</u>

Leukemia is a malignant disorder characterized by uncontrolled proliferation of white blood cells in bone marrow and blood.

♦ **Types**

i. Acute lymphocytic leukemia
ii. Acute myeloid leukemia
iii. Chronic lymphocytic leukemia
iv. Chronic myeloid leukemia

♦ **Features**

- Marked leukocytosis
- Anemia
- Recurrent infections
- Bleeding tendency
- Enlarged spleen and lymph nodes

5. Explain T lymphocyte

T lymphocytes are lymphocytes responsible for cell mediated immunity.

♦ **Origin and Maturation**

- Origin: Bone marrow stem cells
- Maturation: Thymus gland

♦ **Types and Functions**

a. Helper T cells (CD4 cells)

- Secrete cytokines
- Activate B cells and macrophages

b. Cytotoxic T cells (CD8 cells)

- Destroy virus infected and tumor cells

c. Suppressor / Regulatory T cells

- Suppress excessive immune response

d. Memory T cells

- Provide long lasting immunity

♦ **Functions of T lymphocytes**

i. Cell mediated immunity
ii. Graft rejection
iii. Delayed hypersensitivity
iv. Activation of macrophages
v. Regulation of immune response

6. Define immunity and classify it. Explain the mechanism of cell-mediated immunity. Add a note on natural killer cells.

♦ **Definition -** Immunity is the resistance offered by the body against infections and foreign substances.

♦ **Classification of Immunity**

A. Innate immunity

- Inborn
- Non-specific
- Immediate response

B. Acquired immunity

- Specific
- Develops after exposure

♦ **Types**

i. Active immunity
ii. Passive immunity
iii. Humoral immunity
iv. Cell mediated immunity

♦ **Mechanism of Cell-Mediated Immunity**

i. Antigen enters the body.
ii. Antigen presenting cells process antigen.
iii. Antigen is presented to T helper cells.
iv. T helper cells release cytokines.
v. Cytotoxic T cells proliferate.
vi. Cytotoxic T cells destroy infected cells.
vii. Memory cells are formed.

♦ **Natural Killer Cells**

Natural killer cells are large granular lymphocytes that destroy virus infected and tumor cells without prior sensitization.

Functions

i. Kill virus infected cells
ii. Destroy tumor cells
iii. Produce interferons and cytokines
iv. Provide innate immune defense

7. Describe the role of T-lymphocytes in immune mechanisms

a. Cell mediated immunity - T cells directly destroy infected cells.

b. Helper function - Helper T cells stimulate B cells, macrophages and cytotoxic T cells through cytokines.

c. Cytotoxic action - Cytotoxic T cells kill virus infected, transplanted and malignant cells.

d. Regulation of immunity - Regulatory T cells suppress excessive immune reactions.

e. Immunological memory - Memory T cells provide rapid response during subsequent exposure.

f. Delayed hypersensitivity - Responsible for tuberculin reaction and contact dermatitis.

g. Transplant rejection - T cells play major role in graft rejection.

h. Reticulo-endothelial system (RES)

8. Reticulo-endothelial system

Reticulo-endothelial system is a system of phagocytic cells present throughout the body that remove foreign particles and dead cells.

♦ **Components of RES**

i. Tissue macrophages
ii. Kupffer cells of liver
iii. Alveolar macrophages of lungs
iv. Splenic macrophages
v. Microglia of brain
vi. Monocytes
vii. Lymph node macrophages

♦ **Functions**

i. Phagocytosis of bacteria and foreign particles
ii. Removal of dead cells
iii. Destruction of aged red blood cells
iv. Antigen presentation
v. Immune defense
vi. Storage of iron

9. Functions of neutrophil

a) Phagocytosis of bacteria and foreign particles
b) First line of defense against infection
c) Migration to inflamed area by chemotaxis
d) Formation of pus
e) Release of lysosomal enzymes
f) Destruction of microorganisms by respiratory burst

SHORT ANSWERS

10. Explain the composition and functions of lymph.

♦ **Composition of Lymph**

i. Water
ii. Electrolytes
iii. Plasma proteins
iv. Lymphocytes
v. Fats absorbed from intestine
vi. Glucose and waste products

♦ **Functions of Lymph**

i. Returns tissue fluid to blood
ii. Absorption of fats from intestine
iii. Transport of proteins
iv. Defense by lymphocytes and antibodies
v. Maintains fluid balance

11. Describe the structure and functions of neutrophil

♦ **Structure of Neutrophil**

- Diameter: 10–14 μm
- Multilobed nucleus
- Fine cytoplasmic granules
- Most numerous leukocyte

♦ **Functions**

i. Phagocytosis
ii. Defense against bacteria
iii. Chemotaxis
iv. Formation of pus
v. Release of enzymes during inflammation

12. Functions of reticulo-endothelial system

i. Phagocytosis of microbes and foreign particles
ii. Removal of dead cells
iii. Destruction of aged RBCs
iv. Antigen presentation
v. Formation of antibodies indirectly
vi. Iron storage and metabolism
vii. Detoxification

13. Neutrophil

Neutrophils are granular leukocytes forming the first line of defense against bacterial infection.

♦ **Features**

- Diameter: 10–14 μm
- Multilobed nucleus
- Fine granules
- 40–75% of total WBCs

♦ **Functions**
i. Phagocytosis
ii. Chemotaxis
iii. Killing of bacteria
iv. Formation of pus

14. Neutrophilia in acute bacterial infections. Why?
Neutrophilia occurs in acute bacterial infections because bacterial toxins stimulate bone marrow to increase production and release of neutrophils into blood.
Neutrophils are the primary cells responsible for phagocytosis and destruction of bacteria.

15. HIV infection reduces immunity. Why?
Human Immunodeficiency Virus infects and destroys CD4 helper T lymphocytes. Loss of helper T cells impairs both humoral and cell mediated immunity, leading to severe immunodeficiency.

16. T-lymphocyte
T lymphocytes are lymphocytes responsible for cell mediated immunity.
♦ **Origin -** Bone marrow
♦ **Maturation -** Thymus gland
♦ **Types**
i. Helper T cells
ii. Cytotoxic T cells
iii. Regulatory T cells
iv. Memory T cells
♦ **Functions**
i. Cell mediated immunity
ii. Destruction of infected cells
iii. Regulation of immune response
iv. Graft rejection

17. Leukocytosis
Leukocytosis is increase in total white blood cell count above normal.
♦ **Normal count :** 4,000–11,000/cu mm
♦ **Causes**
i. Bacterial infections
ii. Inflammation
iii. Hemorrhage
iv. Leukemia
v. Stress and exercise

18. Protective effect of vaccination
Vaccination produces artificial active immunity by stimulating antibody production and memory cell formation.
Protective effects
i. Prevents infectious diseases
ii. Produces long lasting immunity
iii. Reduces mortality and morbidity
iv. Provides herd immunity
v. Helps eradication of diseases

19. Plasma cell
Plasma cells are mature B lymphocytes specialized for antibody production.
♦ **Features**
- Oval cell
- Eccentric nucleus
- Basophilic cytoplasm
- Cartwheel appearance of nucleus

♦ **Function**
Production and secretion of immunoglobulins.

20. Role of lymphocytes in immune functions
i. B lymphocytes produce antibodies
ii. T lymphocytes mediate cellular immunity
iii. Helper T cells activate other immune cells
iv. Cytotoxic T cells destroy infected cells
v. Memory cells provide long term immunity
vi. Natural killer cells destroy tumor and virus infected cells

A.3. PLATELETS

LONG ESSAYS

1. A 40-year-old woman was presented with fever and reddish-purple spots on her skin for the past two weeks. Her platelet count was 40000/cumm of blood.

Q: Name the most probable condition.
Thrombocytopenic purpura.

Q: What are platelets. Add a note on the structure and function of platelets.
Platelets or thrombocytes are small non-nucleated disc-shaped cytoplasmic fragments derived from megakaryocytes.
♦ Normal platelet count
1.5–4 lakh/cu mm of blood.
♦ Site of production
Bone marrow.
Structure of Platelets

i. Small discoid bodies
ii. Diameter: 2–4 μm
iii. Non-nucleated
iv. Cell membrane contains clotting factors
v. Cytoplasm contains:
    - Alpha granules
    - Dense granules
    - Mitochondria
    - Contractile proteins

♦ Functions of Platelets
a. Formation of platelet plug
Platelets adhere and aggregate at injured vessel wall.
b. Blood coagulation
Provide phospholipid surface for clotting.
c. Clot retraction
Actomyosin causes clot retraction.
d. Vasoconstriction
Release serotonin causing vasoconstriction.
e. Repair of blood vessels
Release platelet derived growth factor.
Q: Comment on the bleeding time and clotting time expected in this patient.
♦ Bleeding time
Prolonged due to thrombocytopenia.
♦ Clotting time
Usually normal because coagulation factors are normal.

2. A forty-five-year-old female complains of fatigue and generalized weakness. She has observed the appearance of small, red dots on her skin and gums two days back. When she was injured during her domestic work, wound bled for a prolonged period. On examination and investigations, her platelet count was 30,000/cu mm and her clotting time was prolonged. She has no previous history of taking any medications, nor did she suffer from any viral infections recently.

Q: What is she suffering from / Diagnosis?
Thrombocytopenic purpura.

Q: What is the normal platelet count and where they are produced?
♦ Normal Platelet Count
1.5–4 lakh/cu mm of blood.
♦ Site of Production
Bone marrow from megakaryocytes.

Q: Explain the role of Platelets in clotting mechanism
a. Platelet adhesion
Platelets adhere to damaged vessel wall.
b. Platelet aggregation
Platelets aggregate to form platelet plug.
c. Release reaction
Platelets release ADP, serotonin and thromboxane A2.
d. Activation of coagulation
Platelet phospholipid provides surface for coagulation factors.
e. Clot retraction

Platelets help in clot retraction.

f. Repair of vessel wall

Release growth factors for healing.

Q: What are the causes of platelet deficiency suffered from any viral infection recently?

a. Decreased production

- Aplastic anemia
- Bone marrow suppression
- Leukemia
- Radiation

b. Increased destruction

- Immune thrombocytopenic purpura
- Drug induced thrombocytopenia
- Disseminated intravascular coagulation

c. Sequestration

- Hypersplenism

d. Infections

- Viral infections such as dengue and HIV

SHORT ESSAYS

3. Describe the structure, morphology, properties and functions of platelets

♦ **Definition -** Platelets (thrombocytes) are small, non-nucleated cytoplasmic fragments derived from megakaryocytes.

♦ **Normal count** is 1.5–4 lakhs/mm³.

♦ **Structure and Morphology of Platelets -**

- Small, disc-shaped bodies
- Diameter: 2–4 μm
- Non-nucleated
- Formed in red bone marrow from megakaryocytes
- Life span: 7–10 days
- Destroyed mainly in spleen

♦ **Ultrastructure**

Platelets contain:

i. **Peripheral zone**
   - Cell membrane with glycoprotein receptors
   - Phospholipid surface for coagulation

ii. **Sol gel zone**
   - Microtubules and microfilaments
   - Helps in clot retraction

iii. **Organelle zone**
   - Mitochondria
   - Lysosomes
   - Dense granules
   - Alpha granules

iv. **Membrane system**
   - Open canalicular system
   - Dense tubular system

♦ **Properties of Platelets**

a) **Adhesiveness**
   - Ability to adhere to damaged vessel wall

b) **Aggregation**
   - Platelets stick to one another

c) **Agglutination**
   - Clumping of platelets

d) **Contractility**
   - Helps in clot retraction

e) **Release reaction**
   - Release of serotonin, adenosine diphosphate and thromboxane A_2

f) **Viscous metamorphosis**
   - Platelets become sticky and swollen during clotting

♦ **Functions of Platelets**

a. Hemostasis

- Formation of platelet plug
- Initiates blood clotting

b. Role in coagulation

- Provide platelet phospholipid factor
- Release clotting factors

c. Clot retraction

- Platelet contractile proteins retract clot

d. Vasoconstriction

- Release serotonin and thromboxane A_2

e. Repair of blood vessels

- Release platelet derived growth factor

f. Maintenance of capillary integrity

- Prevent capillary bleeding

g. Fibrinolysis

- Participate in dissolution of clot

SHORT ANSWERS

4. Functions of platelets

i. Formation of platelet plug
ii. Provide phospholipid surface for coagulation
iii. Clot retraction
iv. Release serotonin causing vasoconstriction
v. Repair of blood vessels by platelet derived growth factor
vi. Maintain capillary integrity
vii. Help in hemostasis and thrombosis

5. Splenectomy in idiopathic thrombocytopenic purpura. Why?

In idiopathic thrombocytopenic purpura, platelets are destroyed prematurely in the spleen due to antiplatelet antibodies. Splenectomy is done because:

i. Spleen is the major site of platelet destruction
ii. Spleen is also a source of antibody production
iii. Removal increases platelet survival and platelet count

6. Idiopathic thrombocytopenic purpura

♦ **Definition -** An autoimmune disorder characterized by destruction of platelets causing thrombocytopenia and bleeding manifestations.

♦ **Features**

- Low platelet count
- Petechiae and purpura
- Bleeding gums
- Epistaxis
- Prolonged bleeding time
- Normal clotting time

♦ **Cause**

Autoantibodies against platelets causing splenic destruction.

7. Purpura and Hemophilia

♦ **Purpura**

- Bleeding disorder due to platelet or vascular defect
- Features:
  - Petechiae
  - Ecchymosis
  - Mucosal bleeding
- Bleeding time prolonged

♦ **Hemophilia**

- Hereditary coagulation disorder due to factor VIII or IX deficiency
- X-linked recessive disorder
- Features:
  - Hemarthrosis
  - Deep tissue bleeding
  - Delayed bleeding
- Clotting time prolonged

A.4. HEMOSTASIS

LONG ESSAYS

1. A 7-year-old boy was brought to emergency room by her mother with the complaints of profuse bleeding from mouth, right shoulder joint swelling and pain following a fall while playing. She gives past history of similar episodes s of bleeding with trivial injuries and further added that his cousin brother also has similar problem. Blood investigations showed- platelet count-3.5 lakhs, bleeding time-3mins, clotting time 25 mins, Prothrombin time-11 secs. Partial thromboplastin time-42 secs

Q: What is the most probable clinical condition & substantiate with finding of blood investigation

► Hemophilia A

► It is due to deficiency of clotting factor VIII.

♦ Substantiation with blood investigations

Investigation	Finding	Interpretation
Platelet count	3.5 lakhs/mm^3	Normal
Bleeding time	3 min	Normal
Clotting time	25 min	Prolonged
Prothrombin time	11 sec	Normal
Partial thromboplastin time	42 sec	Prolonged

♦ Clinical correlation

- Recurrent bleeding after trivial injury
- Hemarthrosis (joint swelling)
- Positive family history
- Male child affected

These findings suggest defect in intrinsic pathway → Hemophilia.

Q: Discuss the pathophysiology of above condition

♦ Definition - Hereditary coagulation disorder caused by deficiency of clotting factors.

♦ Types -

i. Hemophilia A – factor VIII deficiency
ii. Hemophilia B – factor IX deficiency

♦ Inheritance - X-linked recessive disorder

♦ Pathogenesis -

- Deficiency of factor VIII impairs intrinsic pathway
- Reduced activation of factor X
- Reduced thrombin formation
- Defective fibrin clot formation
- Delayed and prolonged bleeding

♦ Clinical features -

- Hemarthrosis
- Muscle hematoma
- Bleeding after trauma
- Prolonged bleeding

Q: Describe the intrinsic pathway of blood coagulation

♦ Intrinsic pathway - Initiated when blood comes in contact with negatively charged surface.

♦ Steps -

i. Activation of factor XII → XIIa
ii. XIIa activates factor XI → XIa
iii. XIa with calcium activates factor IX → IXa
iv. IXa + factor VIII + platelet phospholipid + calcium activate factor X → Xa
v. Xa converts prothrombin to thrombin
vi. Thrombin converts fibrinogen to fibrin
vii. Fibrin clot formed

Factor XII → Factor XIIa
↓
Factor XI → XIa
↓
Factor IX → IXa
↓ (with factor VIII, calcium, platelet phospholipid)
Factor X → Xa
↓
Prothrombin → Thrombin
↓
Fibrinogen → Fibrin clot

2. Depict the coagulation pathways using suitable flow charts. Briefly describe the fibrinolytic system. Write the physiological basis for why blood does not clot in the circulation normally

♦ Coagulation pathways :

I) Extrinsic pathway

Tissue injury
↓
Tissue thromboplastin released
↓
Activates factor VII → VIIa
↓
Factor X → Xa
↓
Prothrombin → Thrombin
↓
Fibrinogen → Fibrin clot

II) Intrinsic pathway

Factor XII
↓
Factor XI
↓
Factor IX + factor VIII
↓
Factor X → Xa
↓
Prothrombin → Thrombin
↓
Fibrinogen → Fibrin clot

(Common pathway)

Factor Xa
↓
Prothrombin activator
↓
Prothrombin → Thrombin
↓
Fibrinogen → Fibrin
↓
Stable fibrin clot

♦ Fibrinolytic system

‣ Definition

Mechanism responsible for dissolution of fibrin clot.

‣ Mechanism

- Plasminogen is converted to plasmin by tissue plasminogen activator
- Plasmin digests fibrin into fibrin degradation products

‣ Functions

i. Removes unwanted clots
ii. Maintains vascular patency
iii. Prevents excessive thrombosis

♦ Physiological basis for why blood does not clot normally in circulation

i. Smooth vascular endothelium prevents platelet adhesion
ii. Glycocalyx repels clotting factors
iii. Thrombomodulin inhibits thrombin
iv. Heparin inhibits thrombin
v. Antithrombin III inactivates clotting factors
vi. Continuous blood flow dilutes clotting factors
vii. Fibrinolytic system removes small clots

3. A male child 3 years old was brought to a doctor with a complaint of bleeding from the nose, mouth, urinary tract, alimentary tract and skin after trivial injury. Sometimes swelling of the joints with pain and fever was also noticed. The bleeding was not profuse, but it was persistent. A careful history revealed similar bleeding tendency in male relatives. Investigations revealed that the coagulation time was prolonged. The bleeding time, prothrombin time and platelet count was normal.

Q: What is the most likely diagnosis

Hemophilia

Q: Describe the physiological basis coagulation mechanism of the two pathways involved in the coagulation mechanism

I) Intrinsic pathway :

Factor XII
↓
Factor XI
↓
Factor IX + VIII
↓
Factor X activation
↓

Prothrombin → Thrombin
↓
Fibrinogen → Fibrin clot

II) Extrinsic pathway :

Tissue thromboplastin
↓
Factor VII activation
↓
Factor X activation
↓
Thrombin formation
↓
Fibrin clot formation

Q: Why females are not usually affected by this bleeding disorder

Hemophilia is an X-linked recessive disorder.

- Males have only one X chromosome
- Defective gene expression occurs in males easily
- Females usually possess one normal X chromosome which masks the defective gene
- Females are usually carriers

Q: What is the physiological basis for treatment of this disorder

Replacement therapy - Administration of deficient clotting factor
In Hemophilia A - Factor VIII concentrate
In Hemophilia B - Factor IX concentrate

Physiological Basis : Replacement restores intrinsic coagulation pathway and fibrin clot formation.

4. A 16-year-old boy had continuous oozing of blood following tooth extraction. Answer the following :

Q: What is the probable cause of bleeding?

Hemophilia **-** Due to deficiency of clotting factor VIII.

Q: Describe the extrinsic pathway of clotting using a schematic diagram.

Tissue injury
↓
Release of tissue thromboplastin
↓
Activation of factor VII
↓
Activation of factor X
↓
Formation of prothrombin activator
↓
Prothrombin → Thrombin
↓
Fibrinogen → Fibrin clot

Q: Mechanism of action of heparin as an anticoagulant.

- Heparin activates antithrombin III
- Antithrombin III inhibits thrombin and factor Xa
- Prevents conversion of fibrinogen to fibrin
- Thus, prevents clot formation

Q: Role of vitamin K in clotting

Vitamin K is essential for hepatic synthesis of:

1. Factor II (prothrombin)
2. Factor VII
3. Factor IX
4. Factor X

It helps gamma carboxylation of clotting factors.

Q: Explain why blood does not normally clot inside the body?

i. Smooth endothelial lining
ii. Presence of heparin and antithrombin III
iii. Thrombomodulin activity
iv. Continuous blood flow
v. Fibrinolytic system
vi. Negative charge on vascular endothelium repels platelets

5. A 12 years old boy had swelling in the knee joint after a small injury. His clotting time was 12 min. Answer the following :

Q: What may be the probable diagnosis and what is its cause ?

Hemophilia

Cause:

- It is a hereditary bleeding disorder caused by deficiency of clotting factors.
- Most commonly due to deficiency of Factor VIII — Hemophilia A.
- Less commonly due to deficiency of Factor IX — Hemophilia B (Christmas disease).
- It is an X-linked recessive disorder, commonly affecting males.

Reason for swelling in knee joint:

Bleeding into the joint cavity (Hemarthrosis), commonly seen in hemophilia.

Q: Explain the clotting mechanism in detail.

Blood clotting occurs through a series of reactions in which inactive clotting factors are converted into active forms.

It occurs in 3 stages:

I) Formation of Prothrombin Activator

This occurs by two pathways:

a. Extrinsic Pathway

- Initiated by tissue injury.
- Damaged tissues release Tissue thromboplastin (Factor III).
- Tissue thromboplastin combines with:
  - Factor VII
  - Calcium ions
- Activates Factor X.
- Factor X with Factor V forms Prothrombin activator.

b. Intrinsic Pathway

- Initiated by damage within blood vessels.
- Activation sequence:
  - Factor XII → XIIa
  - XI → XIa
  - IX → IXa
- Factor IXa combines with:
  - Factor VIII
  - Platelet phospholipid
  - Calcium ions
- Activates Factor X.
- Factor Xa with Factor V forms Prothrombin activator.

II) Conversion of Prothrombin into Thrombin

Prothrombin activator converts:

Prothrombin → Thrombin

- Requires calcium ions.
- Thrombin is the active enzyme necessary for clot formation.

III) Conversion of Fibrinogen into Fibrin

Thrombin converts:

Fibrinogen → Fibrin

- Fibrin threads form a meshwork.
- Blood cells get trapped in the mesh.
- Stable clot is formed.
- Factor XIII stabilizes fibrin clot.

Injury
↓
Extrinsic pathway / Intrinsic pathway
↓
Formation of Prothrombin activator
↓
Prothrombin → Thrombin
↓
Fibrinogen → Fibrin
↓
Blood clot formation

Q: Mention and interpret the tests for assessing bleeding and clotting time

♦ Tests for Bleeding Time

a. Duke's Method - Normal value: 2–5 minutes

b. Ivy's Method - Normal value: 2–7 minutes

Interpretation

- Prolonged in:
  - Thrombocytopenia
  - Platelet disorders
  - Vascular defects
- Normal in hemophilia.

♦ Tests for Clotting Time

a. Capillary Tube Method - Normal value: 3–6 minutes

b. Lee and White Method - Normal value: 6–10 minutes

Interpretation

- Prolonged in:
  - Hemophilia
  - Deficiency of clotting factors
  - Liver diseases
  - Anticoagulant therapy
- In this case, clotting time is 12 minutes, which is prolonged and suggests a coagulation disorder like hemophilia.

SHORT ESSAYS

6. With the help of a schematic diagram, show the steps of intrinsic pathway of blood coagulation. Explain the significance of clot retraction.

Intrinsic Pathway of Blood Coagulation

Contact with collagen / rough surface
→ Factor XII activated
→ XIIa activates factor XI
→ XIa activates factor IX
→ IXa + VIIIa + platelet phospholipid + Ca^{2+}
→ activates factor X
→ Xa + Va + phospholipid + Ca^{2+}
→ forms prothrombin activator
→ prothrombin converted to thrombin
→ fibrinogen converted to fibrin
→ stable fibrin clot.

Significance of Clot Retraction

- Makes clot firm and strong.
- Brings cut edges of vessel together.
- Helps haemostasis.
- Squeezes out serum from clot.
- Indicates normal platelet function.

7. Describe the intrinsic pathway of coagulation. Mention one test assessing it.

Intrinsic Pathway

The intrinsic pathway is initiated when blood comes in contact with collagen or rough surfaces.

Sequence:

- Factor XII → XIIa
- XIIa activates factor XI
- XIa activates factor IX
- IXa with factor VIII, phospholipid and Ca2+ activates factor X
- Xa with factor V forms prothrombin activator
- Prothrombin → thrombin
- Fibrinogen → fibrin clot.

Test Assessing Intrinsic Pathway

Activated partial thromboplastin time (APTT).

8. Describe the mechanism of clotting in glass tubes during blood collection.

When blood is collected in a glass tube, contact with the negatively charged rough glass surface activates factor XII.
This initiates the intrinsic pathway: Factor XII → XI → IX → X.
‣ Factor Xa with factor V forms prothrombin activator.
‣ Prothrombin is converted to thrombin.
‣ Thrombin converts fibrinogen into fibrin.
‣ Fibrin threads trap blood cells and form clot.

9. Describe the mechanisms of blood coagulation.
Blood coagulation occurs in three stages:
a. Formation of Prothrombin Activator
By intrinsic and extrinsic pathways.
b. Conversion of Prothrombin into Thrombin
Occurs in presence of calcium.
c. Conversion of Fibrinogen into Fibrin
‣ Thrombin converts fibrinogen to fibrin.
‣ Factor XIII stabilizes clot.

SHORT ANSWERS

10. Use of anticoagulant - Heparin, in prolonging clotting time. Why?
‣ Heparin activates antithrombin III.
‣ It inhibits thrombin and factors IX, X, XI and XII.
‣ Hence clotting time is prolonged.

11. Draw the schematic diagram to show the intrinsic pathway of blood clotting.
[REFER DIAGRAM SECTION]

12. Fibrinolytic system
‣ The fibrinolytic system dissolves fibrin clot.
‣ Plasminogen is converted to plasmin by tissue plasminogen activator (tPA).
‣ Plasmin digests fibrin into fibrin degradation products.
‣ Functions:
- Removes clot after healing.
- Prevents excessive thrombosis.
- Maintains blood flow.

13. Heparin prevents blood coagulation in vivo. Why?
‣ Heparin activates antithrombin III.
‣ Antithrombin III inhibits thrombin and other clotting factors.
‣ Thus coagulation is prevented in vivo.

14. Fibrinolytic system
‣ The fibrinolytic system is responsible for dissolution of clot.
‣ Plasminogen → plasmin.
‣ Plasmin digests fibrin and removes clot.
‣ Physiological importance:
- Prevents intravascular thrombosis.
- Recanalizes blood vessels.

15. Dicumarol as an anticoagulant. Why?
‣ Dicumarol inhibits vitamin K action.
‣ Hence synthesis of vitamin K dependent clotting factors (II, VII, IX, X) decreases.
‣ Therefore blood coagulation is inhibited.

16. Bleeding tendency of vitamin K deficiency. Why?
Vitamin K is essential for synthesis of clotting factors II, VII, IX and X.
Deficiency decreases these clotting factors and impairs coagulation.
Hence bleeding tendency occurs.

17. Clotting occurs when blood is kept in a glass tube. Why?
‣ Contact with rough glass surface activates factor XII.
‣ This initiates intrinsic pathway and causes clotting.

18. Intrinsic mechanism of coagulation
‣ Intrinsic coagulation pathway is initiated by contact activation.
‣ Sequence: Factor XII → XI → IX + VIII → X.
‣ Factor Xa forms prothrombin activator.
‣ Prothrombin → thrombin.
‣ Fibrinogen → fibrin clot.

24. Deficiency of clotting factor XI leads to
Hemophilia C.
25. Purpura is caused due to deficiency of
Platelets (thrombocytopenia).

A.5. BLOOD GROUPS

LONG ESSAYS

1. A 20-year-old boy who lost about 2 litres of blood following a road traffic accident, when transfused with blood developed, irritability, itching at the infusion site and all over the body, pain in the back and difficulty in breathing

Q: What can be the cause for the symptoms?
Acute haemolytic transfusion reaction due to incompatible blood transfusion.
Manifestations:

- Fever
- Chills
- Itching
- Back pain
- Dyspnoea
- Haemoglobinuria

Cause:
Agglutination and haemolysis due to antigen-antibody reaction.

Q: Define Landsteiner's law

i. If an agglutinogen (antigen) is present on RBCs, corresponding agglutinin (antibody) will be absent in plasma.
ii. If agglutinogen is absent on RBCs, corresponding agglutinin will be present in plasma.

Applicable to ABO system.

Q: What is the physiological basis of blood grouping systems?
Blood grouping depends on presence or absence of antigens on red blood cell membrane.
ABO Blood Group System

- Group A – A antigen and anti-B antibody.
- Group B – B antigen and anti-A antibody.
- Group AB – A and B antigens; no antibodies.
- Group O – no antigens; both antibodies.

Rh System
Presence of D antigen indicates Rh positive. Absence indicates Rh negative.

Q: What are the precautions to be taken before blood transfusion?

- Proper blood grouping.
- Rh typing.
- Cross matching.
- Screening for infections.
- Check expiry date of blood.
- Use sterile equipment.
- Monitor patient during transfusion.

Q: What is autologous blood transfusion?
Transfusion of one's own stored blood.
Advantages:

- No incompatibility reaction.
- No transmission of infections.
- Safe and economical.

SHORT ESSAYS

2. A two-day-old newborn child had severe pallor and jaundice on examination. The mother reveals a history of previous miscarriages, and her blood group was "O" negative. What is the most probable reason for this clinical condition. Write briefly on the skills needed to educate the family about this clinical condition.

Q: Most Probable Reason
‣ Erythroblastosis fetalis due to Rh incompatibility.
‣ Mother is Rh negative and fetus is Rh positive.
‣ Maternal anti-Rh antibodies cross placenta and destroy fetal RBCs.
Clinical Features

- Severe anaemia
- Jaundice

- Hepatosplenomegaly
- Hydrops fetalis

Q: Education of Family

- Importance of antenatal blood grouping.
- Rh typing of parents.
- Need for anti-D immunoglobulin after first delivery, abortion or miscarriage.
- Regular antenatal checkup.
- Early treatment of neonatal jaundice.
- Importance of compatible blood transfusion.

3. What is erythroblastosis fetalis. How can this be prevented.

Erythroblastosis Fetalis

It is hemolytic disease of newborn caused by Rh incompatibility between Rh negative mother and Rh-positive fetus.
Maternal anti-Rh antibodies destroy fetal RBCs.

Features

- Anemia
- Jaundice
- Oedema
- Hepatosplenomegaly

Prevention

- Blood grouping and Rh typing during pregnancy.
- Administration of anti-D immunoglobulin to Rh negative mother within 72 hours after delivery of Rh-positive baby.
- Anti-D after abortion, miscarriage or amniocentesis.
- Avoid sensitization by incompatible transfusion.

4. Describe the dangers associated with blood transfusion. Explain what precautions could be taken to prevent them.

♦ Dangers of Blood Transfusion

a. Incompatibility Reaction - Due to mismatched blood causing haemolysis.
b. Allergic Reactions - Manifested by itching, urticaria and fever.
c. Transmission of Infections

- Hepatitis B
- HIV
- Malaria
- Syphilis

d. Circulatory Overload - Especially in cardiac patients.
e. Iron Overload - After repeated transfusions.
f. Hyperkalaemia - Due to stored blood.
g. Air Embolism - Rare complication.

♦ Precautions

- Proper ABO and Rh matching.
- Cross matching.
- Screening donor blood for infections.
- Sterile transfusion technique.
- Observe patient during transfusion.
- Use fresh compatible blood.
- Avoid unnecessary transfusion.

SHORT ANSWERS

5. Describe the physiological basis and importance of Bombay blood group

‣ Bombay blood group lacks H antigen on RBCs.
‣ Therefore A and B antigens cannot be formed.
‣ Individuals possess anti-A, anti-B and anti-H antibodies.

♦ Importance

- Cannot receive blood from ordinary O group.
- Can receive blood only from Bombay group.
- Important during blood transfusion and cross matching.

6. Hemolytic disease of newborn (HDN)

Hemolytic disease of newborn is destruction of fetal red blood cells due to blood group incompatibility between mother and fetus.

♦ **Common cause:**
- Rh incompatibility

♦ **Mechanism:**
- Rh negative mother carrying Rh positive fetus.
- Fetal red cells enter maternal circulation.
- Mother develops anti-Rh antibodies.
- In next Rh positive pregnancy, maternal antibodies cross placenta and destroy fetal RBCs.

♦ **Features:**
- Anemia
- Jaundice
- Hepatosplenomegaly
- Hydrops fetalis

♦ **Prevention:**
- Anti-D immunoglobulin to Rh negative mother.

7. Mismatched blood transfusion

Mismatched transfusion occurs when incompatible blood is transfused.

♦ **Cause:**
- Usually ABO incompatibility.

♦ **Mechanism:**
- Recipient antibodies react with donor RBC antigens.
- Agglutination and hemolysis occur.

♦ **Effects:**
i. Fever and chills
ii. Hemoglobinemia
iii. Hemoglobinuria
iv. Renal failure
v. Shock
vi. Death in severe cases

♦ **Prevention:**
- Proper blood grouping and cross matching.

8. Concept of universal donor and recipient

♦ **Universal donor**
- Blood group O negative.
- RBCs lack A, B and Rh antigens.
- Can donate blood to all groups.

♦ **Universal recipient**
- Blood group AB positive.
- Plasma lacks anti-A and anti-B antibodies.
- Can receive blood from all groups.

9. Exchange transfusion in Erythroblastosis fetalis

Exchange transfusion is replacement of infant blood with compatible donor blood.

♦ **Indications:**
- Severe erythroblastosis fetalis
- Severe neonatal jaundice

♦ **Procedure:**
- Small quantity of infant blood removed.
- Equal quantity of compatible blood infused repeatedly.

♦ **Uses:**
i. Removes bilirubin
ii. Removes maternal antibodies
iii. Corrects anemia
iv. Prevents kernicterus

♦ **Preferred blood:**
- O negative blood

10. List the hazards of blood transfusion

Hazards:
i. Hemolytic reactions
ii. Allergic reactions
iii. Febrile reactions
iv. Circulatory overload
v. Transmission of infections
   - Hepatitis
   - Human immunodeficiency virus
   - Malaria
vi. Air embolism
vii. Hyperkalemia
viii. Iron overload
ix. Transfusion shock

11. Erythroblastosis fetalis

Erythroblastosis fetalis is hemolytic anemia in fetus due to Rh incompatibility.

♦ **Cause:**
- Rh negative mother with Rh positive fetus.

♦ **Pathogenesis:**
- Maternal anti-Rh antibodies cross placenta.
- Destruction of fetal RBCs occurs.

♦ **Features:**
i. Severe anemia
ii. Jaundice
iii. Edema
iv. Hepatosplenomegaly
v. Kernicterus

♦ **Prevention:**
- Anti-D immunoglobulin.

12. Rh incompatibility

Rh incompatibility occurs when Rh negative mother carries Rh positive fetus.

♦ **Mechanism:**
i. Fetal RBCs enter maternal circulation.
ii. Mother develops anti-D antibodies.
iii. Antibodies cross placenta in next pregnancy.
iv. Hemolysis of fetal RBCs occurs.

♦ **Result:**
- Hemolytic disease of newborn.

♦ **Prevention:**
- Anti-D immunoglobulin after delivery or abortion.

13. Bombay blood group

Bombay blood group is a rare blood group lacking H antigen.

♦ **Features:**
- Genotype: hh
- No A, B or H antigen on RBCs.
- Serum contains:
  - Anti-A
  - Anti-B
  - Anti-H antibodies

♦ **Importance:**
- Cannot receive blood from ordinary O group.
- Can receive only Bombay group blood.

14. Rh blood group system

Rh blood group system is determined by presence or absence of Rh antigen on RBCs.

♦ **Important antigen:**
- D antigen

♦ **Types:**
i. Rh positive – D antigen present
ii. Rh negative – D antigen absent

♦ **Features:**
- No naturally occurring antibodies.
- Antibodies develop after exposure.

♦ **Importance:**
i. Blood transfusion
ii. Hemolytic disease of newborn

15. Rh factor and its clinical significance

Rh factor refers to D antigen present on red blood cells.

♦ **Types:**
- Rh positive
- Rh negative

♦ **Clinical significance:**
i. Important in blood transfusion
ii. Causes transfusion reactions
iii. Causes erythroblastosis fetalis
iv. Important in antenatal screening

♦ **Prevention of Rh sensitization:**
- Anti-D immunoglobulin administration.

A.6. TISSUE FLUID

SHORT ANSWERS

1. Explain the physiological basis of edema formation in hypoproteinemia

♦ **Definition:** Edema is accumulation of excess fluid in interstitial spaces.

♦ **Physiological basis:**

- Plasma proteins, mainly albumin, produce plasma colloid osmotic pressure (oncotic pressure).
- Normal plasma oncotic pressure is about 25 millimeter of mercury.
- In hypoproteinemia, plasma protein level decreases.
- Hence colloid osmotic pressure falls.
- Reabsorption of fluid at venous end of capillary decreases.
- More fluid remains in interstitial space.
- Interstitial fluid volume increases causing edema.

♦ **Causes of hypoproteinemia:**

- Malnutrition
- Nephrotic syndrome
- Liver disease
- Protein losing enteropathy

♦ **Features:**

- Pitting edema
- Ascites may occur

2. With the aid of a diagram, Explain how capillary fluid exchange is modified in hypoproteinemia.

♦ **Normal capillary exchange:**

- At arterial end:
  - Capillary hydrostatic pressure exceeds oncotic pressure.
  - Filtration occurs.
- At venous end:
  - Plasma oncotic pressure exceeds hydrostatic pressure.
  - Reabsorption occurs.

♦ **In hypoproteinemia:**

- Plasma oncotic pressure decreases.
- Reabsorption at venous end decreases markedly.
- Filtration predominates throughout capillary.
- Excess fluid accumulates in tissue spaces causing edema.

♦ **Diagram:**

[REFER DIAGRAM SECTION]

B. CARDIOVASCULAR SYSTEM
B.1. FUNCTIONAL ANATOMY OF THE HEART

SHORT ANSWERS

1. Brief note on heart sounds

Heart sounds are sounds produced during cardiac activity.

‣ **First heart sound (S1)**

- Produced due to closure of:
  - Mitral valve
  - Tricuspid valve
- Occurs at beginning of ventricular systole.
- Low pitched and long sound.
- "LUB"

‣ **Second heart sound (S2)**

- Produced due to closure of:
  - Aortic valve
  - Pulmonary valve
- Occurs at beginning of ventricular diastole.
- Short and high pitched.
- "DUP"

‣ **Third heart sound (S3)**

- Due to rapid ventricular filling.
- Heard in children and young adults.
- Pathological in older adults.

‣ **Fourth heart sound (S4)**

- Due to atrial contraction.
- Usually pathological.

♦ **Significance:**

- Helps assess valve function and cardiac abnormalities.

2. Physiological basis of pacemaker potential

Pacemaker potential is the spontaneous slow depolarization occurring in pacemaker cells before action potential generation.

♦ **Basis:**

Occurs in sinoatrial node due to:

a) Decreased potassium efflux.

b) Slow sodium influx through funny channels.
c) Calcium influx through transient calcium channels.
- Membrane potential gradually reaches threshold.
- Action potential is generated automatically.
- Responsible for rhythmicity of heart.

♦ **Normal pacemaker:**
- Sinoatrial node.

3. Draw and label : Conducting system of heart

♦ **Components:**
i. Sinoatrial node
ii. Internodal pathways
iii. Atrioventricular node
iv. Bundle of His
v. Right bundle branch
vi. Left bundle branch
vii. Purkinje fibers

♦ **Diagram:**
[REFER DIAGRAM SECTION]

4. Explain Pacemaker potential with Diagram

Pacemaker potential is the spontaneous gradual depolarization occurring in pacemaker cells during diastole.

♦ **Diagram:** [REFER DIAGRAM SECTION]

♦ **Site:**
- Sinoatrial node

♦ **Mechanism:**
- Reduced potassium efflux
- Slow sodium influx
- Calcium influx

♦ **Significance:**
- Produces automatic rhythmic discharge.
- Maintains heart rate.

B.2. RECORDING OF ELECTRICAL ACTIVITY OF HEART

LONG ESSAYS

1. A 45-year-old man was brought to the emergency department with pain in the chest and left upper arm for the past 30 minutes. His ECG showed ST segment elevation and the cardiac enzymes were elevated.

Q: Name the most probable clinical condition

Acute myocardial infarction (ST elevation myocardial infarction).

Q: Describe the physiological basis for the changes in the ECG and cardiac enzymes

♦ **ST segment elevation**
- Due to acute transmural myocardial ischemia.
- Injured myocardial cells remain partially depolarized.
- Produces injury current causing ST elevation.

♦ **T wave inversion**
- Due to abnormal ventricular repolarization.

♦ **Pathological Q wave**
- Due to myocardial necrosis.
- Dead tissue fails to conduct electrical impulses.

♦ **Physiological basis of elevated cardiac enzymes**

Myocardial cell damage causes leakage of intracellular enzymes into blood.

♦ **Important enzymes/markers:**
i. Creatine kinase-MB
ii. Troponin I
iii. Troponin T
iv. Lactate dehydrogenase

Troponins: Most sensitive and specific markers.

Q: List the uses of ECG

i. Diagnosis of arrhythmias
ii. Diagnosis of myocardial infarction
iii. Detection of conduction defects
iv. Detection of electrolyte imbalance
v. Diagnosis of chamber enlargement
vi. Monitoring cardiac status
vii. Diagnosis of ischemic heart disease
viii. Assessment of pacemaker function

Q: Describe the special features of coronary circulation

i. Coronary arteries are functional end arteries.
ii. Coronary blood flow is high.
iii. Blood flow occurs mainly during diastole.
iv. Myocardium extracts large amount of oxygen.
v. Increased demand is met by increased blood flow.
vi. Presence of autoregulation.
vii. Sympathetic stimulation indirectly increases coronary flow.
viii. Subendocardial region is more prone to ischemia.

2. A 60-year-old man presented with acute retro sternal chest pain radiating to the inner aspect of left arm. The ECG showed ST segment elevation in some of the leads.

Q: What is the most probable diagnosis?
Acute myocardial infarction.

Q: Explain the other ECG changes that may occur in this condition?

i. ST segment elevation
ii. Hyperacute tall T waves
iii. T wave inversion
iv. Pathological Q waves
v. Reduced R wave amplitude
vi. Arrhythmias may occur
vii. Conduction defects may occur

Q: Explain leads used in recording ECG

♦ Standard bipolar limb leads

‣ Lead I
- Right arm negative
- Left arm positive

‣ Lead II
- Right arm negative
- Left leg positive

‣ Lead III
- Left arm negative
- Left leg positive

Diagram:
[REFER DIAGRAM SECTION]

♦ Augmented unipolar limb leads

i. aVR – Right arm
ii. aVL – Left arm
iii. aVF – Left foot

♦ Chest leads

i. V1 – Fourth right intercostal space
ii. V2 – Fourth left intercostal space
iii. V3 – Between V2 and V4
iv. V4 – Fifth left intercostal space, midclavicular line
v. V5 – Left anterior axillary line
vi. V6 – Left midaxillary line

Q: With the help of a diagram describe the waves, intervals and segments of normal ECG recording in lead I

♦ Waves of ECG

‣ P wave
- Atrial depolarization

‣ QRS complex
- Ventricular depolarization

‣ T wave
- Ventricular repolarization

♦ Intervals

‣ PR interval
- Beginning of P wave to beginning of QRS complex.
- Normal: 0.12–0.20 second

‣ QT interval

- Beginning of QRS complex to end of T wave.

‣ **RR interval**
- Interval between two R waves.

♦ **Segments**

‣ **PR segment**
- Between end of P wave and start of QRS complex.

‣ **ST segment**
- Between end of QRS complex and beginning of T wave.

♦ **Diagram**
[REFER DIAGRAM SECTION]

SHORT ESSAYS

3. Describe the ionic basis of phases in pacemaker potential. Explain the conduction of impulse in cardiac junctional tissue.

♦ **Ionic basis of pacemaker potential**
Pacemaker potential is seen in SA node and AV node. It has no true resting membrane potential.

♦ **Phases and ionic basis**

‣ **Phase 4 – Slow diastolic depolarization (Pacemaker potential)**
- Due to opening of funny sodium channels (If current).
- Slow inward sodium influx occurs.
- Decreased potassium efflux.
- Transient calcium channels (T-type) open near threshold.
- Membrane potential gradually rises from –60 mV to threshold.

‣ **Phase 0 – Depolarization**
- Opening of L-type calcium channels.
- Slow calcium influx causes depolarization.
- No fast sodium channel participation.

‣ **Phase 3 – Repolarization**
- Closure of calcium channels.
- Opening of potassium channels.
- Potassium efflux causes repolarization.

♦ **Conduction of impulse in cardiac junctional tissue**
Pathway components – [REFER DIAGRAM SECTION]

i. SA node
ii. Internodal pathways
iii. AV node
iv. Bundle of His
v. Right and left bundle branches
vi. Purkinje fibers
vii. Ventricular muscle

♦ **Conduction velocities**
- SA node: 0.05 m/s
- Atrial muscle: 1 m/s
- AV node: 0.02–0.05 m/s (slowest)
- Bundle of His: 1–2 m/s
- Purkinje fibers: 4 m/s (fastest)
- Ventricular muscle: 0.3–1 m/s

♦ **Physiological significance of AV nodal delay**
- Delay about 0.1 second.
- Allows atrial contraction before ventricular contraction.
- Ensures adequate ventricular filling.

4. Describe the pacemaker potential and its conduction (spread) using diagrams.
Pacemaker potential is spontaneous rhythmic depolarization seen in SA node.

♦ **Diagram :**
[REFER DIAGRAM SECTION]

♦ **Ionic basis**

‣ **Phase 4**
- Funny sodium current.
- Reduced potassium efflux.
- T-type calcium influx.

‣ **Phase 0**
- L-type calcium influx.

‣ **Phase 3**

- Potassium efflux.

♦ Conduction (spread) of cardiac impulse
SA node → Atria → AV node → Bundle of His → Bundle branches → Purkinje fibers → Ventricles [REFER DIAGRAM SECTION]

♦ Important points
- SA node is normal pacemaker.
- AV node produces physiological delay.
- Purkinje fibers conduct fastest.

SHORT ANSWERS

5. Draw and label the ionic basis of the ventricular action potential. Describe the physiological basis of A-V nodal delay.

[REFER DIAGRAM SECTION]
♦ Physiological basis of AV nodal delay
- Small diameter fibers.
- Few gap junctions.
- Slow calcium-mediated depolarization.
- Slow conduction through AV node.

♦ Significance
- Allows completion of atrial systole.
- Improves ventricular filling.

6. With the help of a neat labelled diagram depict the physiological basis for ECG changes in acute myocardial infarction.

Normal ECG	MI ECG
ST normal	ST elevation
Normal Q	Pathological Q
Normal T	Inverted T

♦ Physiological basis
‣ ST elevation
- Due to injury current from ischemic myocardium.

‣ Pathological Q wave
- Due to myocardial necrosis.
- Dead tissue fails to depolarize.

‣ T wave inversion
- Due to abnormal ventricular repolarization.

7. Physiological basis of Prolongation of PR interval
♦ Causes
- Delayed AV nodal conduction.
- Increased vagal tone.
- AV nodal ischemia.
- First-degree heart block.

♦ Physiological basis
- Slow conduction through AV node prolongs PR interval.
- Normal PR interval: 0.12–0.20 second.

8. Origin and spread of cardiac impulse

♦ Origin - SA node is the normal pacemaker.
♦ Spread
i. SA node
ii. Atrial muscle
iii. AV node
iv. Bundle of His
v. Right and left bundle branches
vi. Purkinje fibers
vii. Ventricular muscle

♦ Features
- AV node delays impulse.
- Purkinje fibers conduct rapidly.

9. AV nodal delay

♦ Definition - Delay in transmission of cardiac impulse through AV node.
♦ Duration - About 0.1 second.
♦ Causes -
- Small fibers.
- Fewer gap junctions.
- Slow calcium channel depolarization.

♦ **Significance -** Allows atrial emptying before ventricular systole.

10. PR interval is prolonged in first degree heart block .Why?

♦ **Reason -** Due to delayed conduction through AV node.
♦ **Mechanism -**
Increased AV nodal conduction time prolongs PR interval beyond 0.20 second.

11. P-R interval

♦ **Definition -** Time from beginning of P wave to beginning of QRS complex.
♦ **Duration -** 0.12–0.20 second.
♦ **Significance -**
- Indicates conduction from atria to ventricles.
- Includes AV nodal delay.

12. Q wave in ECG
♦ **Definition -** First negative deflection before R wave.
♦ **Cause -** Septal depolarization from left to right.
♦ **Significance -**
- Small Q wave may be normal.
- Deep Q wave indicates myocardial infarction.

B.3. CARDIAC CYCLE

LONG ESSAYS

1. Define cardiac cycle. Enumerate the phases of cardiac cycle. With the help of a neat labelled diagram, describe the pressure and volume changes in the ventricles. Write the physiological basis and functional significance of AV nodal delay.

♦ **Definition -** Cardiac cycle is the sequence of events occurring in the heart during one heartbeat.
♦ **Duration -** 0.8 second at heart rate of 75/minute.
♦ **Phases of cardiac cycle**
- **Atrial systole – 0.1 second**
- **Ventricular systole – 0.3 second**
  i. Isovolumetric contraction
  ii. Ejection phase
    - Rapid ejection
    - Reduced ejection
- **Ventricular diastole – 0.5 second**
  i. Protodiastole
  ii. Isovolumetric relaxation
  iii. Rapid filling
  iv. Reduced filling (diastasis)
- **Atrial diastole – 0.7 second**

♦ **Pressure and volume changes in ventricles**
- Pressure ↑ during systole
- Volume ↓ during ejection
- Volume ↑ during ventricular filling

♦ **Important ventricular volumes**
- End diastolic volume: 120–130 mL
- Stroke volume: 70 mL
- End systolic volume: 50–60 mL
- Ejection fraction: 60–65%

♦ **Physiological basis of AV nodal delay**
- Small diameter AV nodal fibers.
- Fewer gap junctions.
- Slow calcium-mediated conduction.

♦ **Functional significance**
- Allows atrial contraction before ventricular contraction.
- Improves ventricular filling.
- Prevents simultaneous contraction.

SHORT ESSAYS

2. Describe the pressure changes in left ventricle and aorta during one cardiac cycle.

♦ **Left ventricular pressure changes**

‣ **During ventricular filling**
- Pressure low: 0–5 mm Hg.

‣ **Isovolumetric contraction**
- Pressure rises rapidly.
- Mitral valve closes.

‣ **Ejection phase**
- Pressure reaches about 120 mm Hg.
- Aortic valve opens.

‣ **Isovolumetric relaxation**
- Pressure falls rapidly.
- Aortic valve closes.

♦ **Aortic pressure changes**
- Normal pressure: 120/80 mm Hg.
- Pressure rises during ventricular ejection.
- Dicrotic notch occurs due to closure of aortic valve.
- Pressure gradually falls during diastole.

3. Define cardiac cycle. Explain the mechanical and pressure events of it with help of a neat labelled diagram.

♦ **Definition -** Cardiac cycle is the sequence of events occurring in the heart during one heartbeat.

♦ **Mechanical events**

‣ **Atrial systole :** Completes ventricular filling.

‣ **Ventricular systole :**
i. Isovolumetric contraction
ii. Rapid ejection
iii. Reduced ejection

‣ **Ventricular diastole :**
i. Isovolumetric relaxation
ii. Rapid filling
iii. Reduced filling

‣ **Atrial diastole :** it overlaps ventricular systole

♦ **Pressure events**
- Atrial pressure rises during atrial systole.
- Ventricular pressure rises during systole.
- Aortic pressure rises during ejection.
- Pressure falls during diastole.

4. Describe briefly the mechanical events of cardiac cycle

♦ **Mechanical events**

‣ **Atrial systole**
- Last part of ventricular filling.

‣ **Ventricular systole**
i. Isovolumetric contraction
   - AV valves close.
ii. Ejection phase
   - Semilunar valves open.

‣ **Ventricular diastole**
i. Protodiastole
ii. Isovolumetric relaxation
iii. Rapid filling
iv. Reduced filling

‣ **Atrial diastole -** it overlaps ventricular systole.

SHORT ANSWERS

5. Heart sounds

♦ **First heart sound (S1)**
- Due to closure of AV valves.
- Beginning of systole.

♦ **Second heart sound (S2)**
- Due to closure of semilunar valves.
- Beginning of diastole.

♦ **Third heart sound (S3)**
- Due to rapid ventricular filling.

♦ **Fourth heart sound (S4)**
- Due to atrial contraction.

6. Fourth heart sound

♦ **Cause**
- Produced during atrial systole.
- Due to vibration during forceful atrial contraction.

♦ **Characteristics**
- Low-pitched.
- Occurs before first heart sound.

♦ **Clinical significance**
- Seen in ventricular hypertrophy.

7. End diastolic ventricular volume

♦ **Definition -** Volume of blood present in ventricle at end of diastole.
♦ **Normal value -** 120–130 mL.
♦ **Significance**
- Determines stroke volume.
- Reflects ventricular filling.

8. First and second heart sounds
♦ **First heart sound (S1)**
- Closure of mitral and tricuspid valves.
- Long and low pitched.
- Beginning of systole.

♦ **Second heart sound (S2)**
- Closure of aortic and pulmonary valves.
- Short and high pitched.
- Beginning of diastole.

9. Right atrial pressure changes

♦ **Waves**
‣ **a wave -** Due to atrial systole.
‣ **c wave -** Bulging of tricuspid valve during ventricular systole.
‣ **v wave -** Venous filling of atrium.

♦ **Descents**
‣ **x descent -** Atrial relaxation.
‣ **y descent -** Emptying of atrium into ventricle.

B.4. HEMODYNAMICS

SHORT ANSWERS

1. Skin is cold in hypovolemic shock. Why?
In hypovolemic shock, there is decreased blood volume leading to fall in arterial blood pressure. This activates the sympathetic nervous system causing intense peripheral vasoconstriction, especially in skin vessels, to maintain blood supply to vital organs like heart and brain.
Due to reduced cutaneous blood flow:
- Skin becomes cold
- Skin appears pale and clammy
- Sweating occurs due to sympathetic stimulation

Hence, skin is cold in hypovolemic shock because of peripheral vasoconstriction and reduced skin perfusion.

B.5. HEART RATE

SHORT ANSWERS

1. Describe the factors regulating heart rate
Heart rate is regulated by the following factors:
A. Autonomic nervous system
♦ **Sympathetic stimulation**
- Increases heart rate
- Noradrenaline acts on beta-1 receptors
- Causes tachycardia

♦ **Parasympathetic stimulation**
- Vagus nerve decreases heart rate
- Acetylcholine acts on muscarinic receptors
- Causes bradycardia

B. Reflexes
♦ **Baroreceptor reflex**
- Increased blood pressure → decreases heart rate

- Decreased blood pressure → increases heart rate

♦ **Bainbridge reflex**

- Increased venous return stretches right atrium
- Causes increase in heart rate

C. Hormones

- Adrenaline and noradrenaline increase heart rate
- Thyroxine increases heart rate

D. Temperature

- Fever increases heart rate
- Cold decreases heart rate

E. Electrolytes

- Increased potassium decreases heart rate
- Increased calcium increases heart rate

F. Age and sex

- Heart rate is higher in infants
- Females have slightly higher heart rate than males

G. Exercise and emotions

- Exercise, anxiety and excitement increase heart rate

♦ **Normal heart rate -** 72/minute in adults

2. Severe tachycardia is harmful to the individual Why?

a. Diastolic duration decreases

- Ventricular filling becomes inadequate
- Coronary blood flow decreases because coronary perfusion occurs mainly during diastole

b. Cardiac output decreases

- Due to reduced ventricular filling
- Stroke volume falls

c. Myocardial oxygen demand increases

- Heart works excessively
- May produce ischemia

d. Efficiency of heart decreases

- Heart becomes fatigued
- May lead to heart failure

Hence severe tachycardia reduces cardiac efficiency and coronary perfusion.

3. Change in heart rate during exercise. Why?

♦ **Change in heart rate during exercise**

- Heart rate increases during exercise
- This is called exercise tachycardia

♦ **Causes**

i. Increased sympathetic activity
ii. Decreased vagal tone
iii. Increased secretion of adrenaline
iv. Increased venous return activates Bainbridge reflex
v. Increased body temperature during exercise

♦ **Significance**

- Helps to increase cardiac output
- Meets increased oxygen demand of tissues

B.6. CARDIAC OUTPUT

LONG ESSAYS

1. Define cardiac output. Give the formula for cardiac index & mention the normal value. Describe the various factors maintaining cardiac output

♦ **Cardiac output**

‣ **Definition -** Cardiac output is the amount of blood pumped by each ventricle per minute.

‣ **Formula -** Cardiac output = Stroke volume × Heart rate

‣ **Normal value -** About 5 L/minute in adults at rest

♦ **Cardiac Index**

‣ **Definition -** Cardiac index is the cardiac output per square meter of body surface area.
‣ **Formula -** Cardiac Index (CI) = Cardiac Output / Body Surface Area
‣ **Normal value -** 3 to 3.5 L/min/m²

♦ Factors maintaining cardiac output
Cardiac output depends upon:
i. Heart rate
ii. Stroke volume
Stroke volume depends on:
- Preload
- Contractility
- Afterload

1. Heart rate :
‣ **Normal heart rate**
- About 72/minute

‣ **Effect on cardiac output**
- Moderate increase in heart rate increases cardiac output
- Severe tachycardia decreases cardiac output due to reduced ventricular filling
- Severe bradycardia also decreases cardiac output

‣ **Regulation**
- Sympathetic stimulation increases heart rate
- Parasympathetic stimulation decreases heart rate

2. Stroke volume :
I) Venous return (Preload)
‣ **Definition**
Preload is the degree of ventricular filling before contraction.
‣ **Frank-Starling law**
Within physiological limits, greater venous return stretches cardiac muscle and increases force of contraction.

Force of Contraction ∝ Initial Length of Cardiac Muscle Fiber
OR
$Stroke\ Volume \propto End\ Diastolic\ Volume$

‣ **Factors affecting venous return**
- Blood volume
- Skeletal muscle pump
- Respiratory pump
- Venous tone
- Gravity

II) Myocardial contractility
‣ **Definition**
Intrinsic ability of cardiac muscle to contract independent of preload.
‣ **Increased by**
- Sympathetic stimulation
- Adrenaline
- Digitalis
- Increased calcium

‣ **Decreased by**
- Myocardial ischemia
- Acidosis
- Hyperkalemia

Increased contractility increases stroke volume and cardiac output.

III) Afterload
‣ **Definition**
Resistance against which ventricles pump blood.
‣ **Causes of increased afterload**
- Hypertension
- Aortic stenosis

Increased afterload decreases cardiac output.

3. Peripheral factors
‣ **Tissue metabolism -** Increased metabolism increases venous return and cardiac output
‣ **Venous tone -** Venoconstriction increases venous return
‣ **Blood volume -** Increased blood volume increases cardiac output

♦ Regulation of cardiac output
‣ **Intrinsic regulation**
- Frank-Starling mechanism

‣ **Extrinsic regulation**

- Sympathetic nervous system
- Parasympathetic nervous system
- Hormones

SHORT ESSAYS

2. Regulation of cardiac output

♦ **Definition -** Cardiac output is the amount of blood pumped by each ventricle per minute.

♦ **Formula -** Cardiac output = Stroke volume × Heart rate

♦ **Normal value -** 5 L/minute

♦ **Regulation of cardiac output**

i. Intrinsic regulation
ii. Extrinsic regulation

I. Intrinsic regulation

♦ **Frank-Starling law of heart**

Within physiological limits, the force of contraction is directly proportional to the initial length of cardiac muscle fibers.

♦ **Mechanism**

- Increased venous return increases end diastolic volume
- Myocardial fibers are stretched
- Force of contraction increases
- Stroke volume and cardiac output increase

♦ **Importance**

- Maintains equality between venous return and cardiac output

II. Extrinsic regulation

A. Nervous regulation

Sympathetic stimulation

- Increases heart rate
- Increases force of contraction
- Increases cardiac output

Parasympathetic stimulation

- Decreases heart rate
- Decreases cardiac output

B. Hormonal regulation

- Adrenaline and noradrenaline increase cardiac output
- Thyroxine increases cardiac output

C. Factors affecting venous return

- Blood volume
- Skeletal muscle pump
- Respiratory pump
- Venous tone

D. Peripheral factors

- Tissue metabolism
- Peripheral resistance

3. Explain the factors that determine cardiac output. What is cardiac failure.

♦ **Cardiac output -** is the amount of blood pumped by each ventricle per minute.

♦ **Formula -** Cardiac output = Stroke volume × Heart rate

♦ **Normal value -** 5 L/minute

♦ **Factors determining cardiac output**

I. Heart rate

- Moderate increase increases cardiac output
- Severe tachycardia decreases cardiac output
- Severe bradycardia decreases cardiac output

II. Stroke volume

Stroke volume depends on:

A. Preload

- Increased venous return increases stroke volume by Frank-Starling law

B. Contractility

- Increased sympathetic activity increases contractility
- Increases stroke volume

C. Afterload

- Increased arterial pressure decreases stroke volume

III. Venous return

Affected by:

- Blood volume
- Venous tone
- Skeletal muscle pump
- Respiratory pump

IV. Peripheral resistance

- Increased peripheral resistance decreases cardiac output

♦ **Cardiac failure**
‣ **Definition -** Cardiac failure is the inability of the heart to pump sufficient blood to meet the metabolic demands of the body.
‣ **Causes**
- Hypertension
- Coronary artery disease
- Valvular heart disease
- Cardiomyopathy

‣ **Features**
- Dyspnea
- Edema
- Fatigue
- Cyanosis

4. How cardiac output is regulated

♦ **Definition -** Cardiac output is the amount of blood pumped by each ventricle per minute.
♦ **Formula -** Cardiac output = Stroke volume × Heart rate
♦ **Regulation of cardiac output**
I. Intrinsic regulation
Frank-Starling mechanism
- Increased venous return stretches myocardium
- Force of contraction increases
- Cardiac output increases

II. Extrinsic regulation
‣ **Nervous factors**
Sympathetic stimulation
- Increases heart rate
- Increases contractility
- Increases cardiac output

Parasympathetic stimulation
- Decreases heart rate
- Decreases cardiac output

‣ **Hormonal factors**
- Adrenaline increases cardiac output
- Thyroxine increases cardiac output

‣ **Factors affecting venous return**
- Blood volume
- Venous tone
- Muscle pump
- Respiratory pump

‣ **Peripheral factors**
- Tissue metabolism
- Peripheral resistance

5. Define cardiac output , cardiac index. Regulation of cardiac output

Cardiac output - is the amount of blood pumped by each ventricle per minute.
Formula - Cardiac output = Stroke volume × Heart rate
Normal value - About 5 L/minute

Cardiac index - is cardiac output per square meter of body surface area.
Formula - Cardiac Index (CI) = Cardiac Output / Body Surface Area
Normal value - 3 to 3.5 L/min/m²

♦ **Regulation of cardiac output**
I. Intrinsic regulation
- Frank-Starling mechanism

II. Extrinsic regulation
‣ **Nervous regulation**
- Sympathetic stimulation increases cardiac output
- Parasympathetic stimulation decreases cardiac output

‣ **Hormonal regulation**
- Adrenaline
- Thyroxine

‣ **Factors affecting venous return**
- Blood volume
- Muscle pump
- Respiratory pump
- Venous tone

6. Explain factors regulating cardiac output
Cardiac output depends on:
i. Heart rate
ii. Stroke volume

I. Heart rate

- Sympathetic stimulation increases heart rate
- Parasympathetic stimulation decreases heart rate
- Moderate increase increases cardiac output
- Severe tachycardia decreases cardiac output

II. Stroke volume

Depends on:

A. Preload

- Increased venous return increases stroke volume

B. Contractility

- Sympathetic stimulation increases contractility

C. Afterload

- Increased arterial pressure decreases stroke volume

III. Venous return

Affected by:

- Blood volume
- Venous tone
- Muscle pump
- Respiratory pump

IV. Hormones

- Adrenaline
- Thyroxine

V. Peripheral resistance

- Increased resistance decreases cardiac output

7. Describe factors affecting cardiac output and add a note on Brain bridge reflex

Cardiac output - is the amount of blood pumped by each ventricle per minute.

♦ Factors affecting cardiac output

I. Heart rate

- Increased heart rate moderately increases cardiac output
- Severe tachycardia decreases cardiac output

II. Stroke volume

Depends on:

- Preload
- Contractility
- Afterload

III. Venous return

Affected by:

- Blood volume
- Muscle pump
- Respiratory pump
- Venous tone

IV. Peripheral resistance

- Increased resistance decreases cardiac output

V. Hormones

- Adrenaline and thyroxine increase cardiac output

Bainbridge reflex (Brain bridge reflex)

Definition - Increase in heart rate due to increased venous return and stretching of right atrium.

Receptors

- Stretch receptors in right atrium

Pathway

- Afferent impulses through vagus nerve to medulla
- Efferent sympathetic fibers increase heart rate

Mechanism

- Increased venous return stretches atrium
- Heart rate increases

Importance

- Prevents pooling of blood in veins
- Helps maintain cardiac output

B.7. VASCULAR SYSTEM, ARTERIAL BLOOD PRESSURE AND ARTERIAL AND VENOUS PULSE

LONG ESSAYS

1. An individual was admitted to the hospital following an accident. He was unable to move his right leg due to pain and had blood-soaked clothes. His symptoms included restlessness, extreme weakness, pale and clammy skin, a rapid thready pulse, hypotension, and oliguria.

Q: What is the most probable condition
Hypovolemic shock (hemorrhagic shock)

Q: Define and classify the above-mentioned condition
Shock is a state of acute circulatory failure resulting in inadequate tissue perfusion and reduced oxygen supply to tissues.

Classification of shock
A. Hypovolemic shock
- Hemorrhage
- Burns
- Dehydration

B. Cardiogenic shock
- Myocardial infarction
- Heart failure

C. Distributive shock
- **Septic shock**
- **Anaphylactic shock**
- **Neurogenic shock**

D. Obstructive shock
- Pulmonary embolism
- Cardiac tamponade

Q: Explain the physiological basis of clinical feature mentioned above
a. Restlessness
- Reduced cerebral blood flow and cerebral hypoxia

b. Extreme weakness
- Reduced tissue perfusion and oxygen supply

c. Pale and clammy skin
- Sympathetic stimulation causes peripheral vasoconstriction
- Sweating due to sympathetic activity

d. Rapid thready pulse
- Tachycardia due to sympathetic stimulation
- Low pulse volume due to reduced stroke volume

e. Hypotension
- Reduced blood volume decreases venous return and cardiac output

f. Oliguria
- Reduced renal blood flow
- Increased secretion of antidiuretic hormone and aldosterone

Q: Describe the physiological basis of management of this condition
a. Control of hemorrhage
- Prevents further blood loss

b. Fluid replacement
- Restores blood volume
- Improves venous return and cardiac output

c. Blood transfusion
- Restores oxygen carrying capacity

d. Oxygen administration
- Improves tissue oxygenation

e. Vasopressor drugs
- Increase blood pressure in severe cases

f. Positioning patient
- Head low position improves venous return

Conclusion
Early restoration of blood volume and tissue perfusion is essential in hypovolemic shock.

2. 5-year-old child was brought to the emergency in a semi-conscious state. She had 7-8 episodes of loose motion and 4 episodes of vomiting in a day. On examination she was drowsy, pulse was 106/min, regular low volume, B.P was 80/60 mm Hg, skin turgor was reduced, mouth was dry and respiratory rate was 24/min.

Q: Name the clinical condition
Hypovolemic shock due to severe dehydration.

Q: Describe the patho-physiology of this condition
‣ **Cause -** Excessive fluid loss due to diarrhea and vomiting.
‣ **Mechanism**

i. Loss of extracellular fluid decreases blood volume
ii. Venous return decreases
iii. End diastolic volume decreases
iv. Stroke volume decreases
v. Cardiac output decreases
vi. Blood pressure falls
vii. Tissue perfusion decreases
viii. Cellular hypoxia develops

Compensatory mechanisms:

- Sympathetic activation
- Tachycardia
- Peripheral vasoconstriction
- Renin-angiotensin-aldosterone activation
- Increased antidiuretic hormone secretion

Q: Comment on the patient's pulse and its physiological basis
Pulse - is tachycardic, low volume and thready.
Physiological basis -

- Sympathetic stimulation increases heart rate
- Reduced stroke volume produces low volume pulse
- Peripheral vasoconstriction makes pulse thready

Q: Describe the management of this patient

a. Oral or intravenous fluid replacement - Restores blood volume
b. Electrolyte correction - Corrects sodium and potassium imbalance
c. Treat dehydration - Oral rehydration solution or intravenous fluids
d. Oxygen administration - Improves tissue oxygenation
e. Monitor vital signs - Pulse, blood pressure and urine output
f. Treat cause - Management of diarrhea and vomiting

3. A 40-year-old man was admitted to hospital with complaints of diarrhea and vomiting since last 2 days. On examination, heart rate of 125 bpm, bp 90/60 and tachypnoea were recorded.

Q: What is this condition?
The patient is suffering from Hypovolemic shock due to severe loss of fluids from diarrhea and vomiting.

Q: Explain the physiological basis of tachycardia, tachypnoea and hypotension?
I) Physiological basis of tachycardia

- Severe fluid loss decreases blood volume and venous return.
- This reduces cardiac output and arterial blood pressure.
- Baroreceptors in carotid sinus and aortic arch are stimulated less.
- This activates sympathetic nervous system.
- Increased sympathetic discharge increases heart rate to maintain cardiac output.

Cardiac output = Stroke volume × Heart rate
Thus, tachycardia is a compensatory mechanism to maintain cardiac output.
II) Physiological basis of tachypnoea

- Reduced tissue perfusion causes tissue hypoxia.
- Anaerobic glycolysis occurs with accumulation of lactic acid.
- Metabolic acidosis develops.
- Respiratory centre is stimulated to remove excess carbon dioxide.

- Hence respiratory rate increases producing tachypnoea.

III) Physiological basis of hypotension

- Excessive loss of water and electrolytes decreases circulating blood volume.
- Venous return and preload decrease.
- Stroke volume falls leading to reduced cardiac output.
- As cardiac output decreases, arterial blood pressure falls causing hypotension.

Q: What is the cause for weak thready pulse and cold clammy skin in this condition?

I) Cause for weak thready pulse

- Due to reduced stroke volume and low pulse pressure resulting from decreased cardiac output.
- Peripheral vasoconstriction also makes the pulse feeble and thready.

II) Cause for cold clammy skin

- Sympathetic stimulation causes intense cutaneous vasoconstriction to preserve blood supply to vital organs.
- Reduced blood flow to skin makes the skin cold.
- Simultaneous sympathetic stimulation of sweat glands causes sweating, producing clammy skin.

4. A forty-two-year-old male complains of severe headaches in the morning, with a blurring of vision for a week. For two days, he complains of severe fatigue and this morning had an episode of a nose bleed with increasing severity of the headache. He reported to the emergency room and was examined by the doctors. There was no previous history of similar illness. On Examination, his blood pressure was 160/110 mmHg and when repeated after 15 minutes was 158/110 mmHg.

Q: What is the patient suffering from?

Diagnosis: Hypertension (Systemic arterial hypertension)

Q: Define the term blood pressure. What are the normal values for systolic and diastolic blood pressure?

♦ **Definition -** Blood pressure is the lateral pressure exerted by flowing blood on the walls of blood vessels, especially arteries.

♦ **Normal Values -**

- **Systolic blood pressure:** 120 mmHg
- **Diastolic blood pressure:** 80 mmHg

Normal blood pressure = 120/80 mmHg

Q: Explain the long-term regulation of blood pressure.

Long-term regulation is mainly by the kidneys through regulation of extracellular fluid volume and blood volume.

a. Renal-body fluid mechanism

- Increase in arterial pressure increases urine output (pressure diuresis)
- Also increases sodium excretion (pressure natriuresis)
- Blood volume decreases
- Venous return and cardiac output decrease
- Blood pressure returns to normal

b. Renin–Angiotensin–Aldosterone System (RAAS)

‣ Mechanism

- Fall in renal perfusion stimulates release of renin
- Renin converts angiotensinogen to angiotensin I
- Angiotensin-converting enzyme converts it to angiotensin II

‣ Actions of Angiotensin II

- Vasoconstriction → increases peripheral resistance
- Stimulates aldosterone secretion

- Aldosterone causes sodium and water retention
- Blood volume and blood pressure increase

c. Antidiuretic Hormone (ADH)

- Released from posterior pituitary
- Causes water reabsorption in kidneys
- Increases blood volume and blood pressure

d. Atrial Natriuretic Peptide (ANP)

- Released from atria due to atrial stretch
- Causes sodium and water loss
- Lowers blood pressure

Q: What are the non-pharmacologic methods to reduce blood pressure?

- Reduction of salt intake
- Weight reduction
- Regular physical exercise
- Avoid smoking
- Avoid alcohol intake
- Low-fat balanced diet
- Stress reduction and relaxation techniques
- Adequate sleep
- Control of diabetes and hyperlipidemia

5. Describe the regulation of blood pressure

Regulation occurs by:

i. Short-term mechanisms
ii. Intermediate mechanisms
iii. Long-term mechanisms

I) Short-term Regulation (Neural Mechanisms)

Acts within seconds to minutes.

a. Baroreceptor Reflex

‣ **Receptors**

- Carotid sinus
- Arch of aorta

‣ **Mechanism**

- Increased BP stimulates baroreceptors
- Impulses carried through:
  - Glossopharyngeal nerve from carotid sinus
  - Vagus nerve from aortic arch
- Vasomotor center inhibited
- Sympathetic activity decreases
- Heart rate, cardiac output and peripheral resistance decrease
- BP falls

b. Chemoreceptor Reflex

- Chemoreceptors present in carotid and aortic bodies
- Stimulated by:
  - Hypoxia
  - Hypercapnia
  - Acidosis
- Causes sympathetic stimulation and rise in BP

c. CNS Ischemic Response

- Severe fall in cerebral blood flow stimulates vasomotor center
- Produces marked vasoconstriction
- Raises BP

II) Intermediate Regulation

Acts within minutes to hours.

a. Capillary Fluid Shift

- Low BP → fluid moves from tissues to blood
- High BP → fluid moves out of circulation

b. Stress Relaxation of Blood Vessels

- Blood vessels adjust to altered pressure by relaxation or constriction

c. Renin–Angiotensin Mechanism

- Renin release forms angiotensin II
- Causes vasoconstriction and aldosterone secretion

III) Long-term Regulation

Mainly by kidneys.

‣ **Mechanisms**

- Pressure diuresis
- Pressure natriuresis

- RAAS
- ADH
- ANP

Maintains blood pressure by controlling blood volume.

6. An individual was brought to a hospital from the site of an accident. He showed following signs and symptoms: Restlessness, extreme weakness, pale, cold, clammy skin, rapid, thready pulse hypotension, oliguria

Q:What is your diagnosis?
Hypovolemic shock

Q: Define it and classify it. Explain it with examples
♦ **Definition -** Shock is a state of circulatory failure in which tissue perfusion becomes inadequate to meet cellular metabolic needs.
♦ **Classification of Shock**
(a) Hypovolemic Shock
Due to loss of blood or plasma volume.
‣ Examples -

- Hemorrhage
- Burns
- Severe diarrhea
- Vomiting

(b) Cardiogenic Shock
Due to failure of heart pumping.
‣ Examples -

- Myocardial infarction
- Severe arrhythmias

(c) Distributive (Vasogenic) Shock
i) Septic shock

- Severe infection

ii) Anaphylactic shock

- Allergy/drug reaction

iii) Neurogenic shock

- Spinal cord injury

(d) Obstructive Shock
Due to obstruction to blood flow.
‣ Examples -

- Cardiac tamponade
- Pulmonary embolism

Q: How do you explain the signs and symptoms?

a. Restlessness - Due to cerebral hypoxia.
b. Extreme weakness - Due to reduced tissue perfusion and oxygen supply.
c. Pale, cold, clammy skin - Due to sympathetic vasoconstriction and sweating.
d. Rapid, thready pulse - Due to tachycardia with reduced stroke volume.
e. Hypotension - Due to decreased circulating blood volume and cardiac output.
f. Oliguria - Due to reduced renal blood flow causing decreased urine formation.

Q: What compensatory regulatory mechanisms which will operate in the body to bring back all the signs and symptoms to normal?

a. Baroreceptor Reflex

- Fall in BP stimulates sympathetic discharge
- Tachycardia and vasoconstriction occur

b. Chemoreceptor Reflex

- Hypoxia stimulates sympathetic activity

c. CNS Ischemic Response

- Severe hypotension strongly activates vasomotor center

d. RAAS Activation

- Renin release forms angiotensin II
- Vasoconstriction and aldosterone secretion increase BP

e. ADH Secretion

- Water retention increases blood volume

f. Reverse Stress Relaxation

- Blood vessels constrict to maintain pressure

g. Capillary Fluid Shift

- Interstitial fluid enters circulation

Q: What immediate treatment do you suggest?

- Maintain airway and oxygen supply
- Control bleeding
- Intravenous fluid replacement
- Blood transfusion if necessary
- Vasopressors if needed
- Monitor blood pressure and urine output

7. An 18-year-old boy meets with a road traffic accident, gets injured and loses 20% of blood volume. Answer the following

Q: Define shock

Shock is a state of circulatory failure resulting in inadequate tissue perfusion and inadequate oxygen supply to tissues.

Q: Describe the Baroreceptor Mechanism of blood pressure regulation

It is a rapid short-term mechanism for regulation of blood pressure.

‣ **Receptors**

- Carotid sinus
- Aortic arch

‣ **Pathway**

- Carotid sinus impulses travel through glossopharyngeal nerve
- Aortic arch impulses travel through vagus nerve
- Reach nucleus tractus solitarius in medulla

Mechanism

When BP rises

- Baroreceptors stretched
- Increased impulses to medulla
- Sympathetic activity inhibited
- Parasympathetic activity increased
- Heart rate, cardiac output and peripheral resistance decrease
- BP decreases

When BP falls

- Decreased baroreceptor firing
- Sympathetic activity increases
- Tachycardia and vasoconstriction occur
- BP increases

• Classification and major causes of various types of shock

Classification of Shock and Causes

1. Hypovolemic Shock

Causes

- Hemorrhage
- Burns
- Diarrhea
- Vomiting

2. Cardiogenic Shock

Causes

- Myocardial infarction
- Heart failure
- Arrhythmias

3. Septic Shock

Causes

- Severe bacterial infection

4. Anaphylactic Shock

Causes

- Drug allergy
- Insect bite
- Food allergy

5. Neurogenic Shock

Causes

- Spinal cord injury
- Deep anesthesia

6. Obstructive Shock

Causes

- Pulmonary embolism
- Cardiac tamponade

8. A 55-year old man is brought to the casualty after a road traffic accident. He was disoriented and irritable. On examination his blood pressure was 90/40 mmHg, respiratory rate was 24/minute and pulse rate was 150/minute. His ECG did not show any abnormality.

• What is your diagnosis

Diagnosis: Hypovolemic shock

• Discuss the physiological basis for various clinical features seen and management of this condition

Physiological Basis of Clinical Features

1. Hypotension
Due to decreased blood volume causing reduced cardiac output.
2. Tachycardia
Due to sympathetic stimulation.
3. Tachypnea
Due to hypoxia and metabolic acidosis.
4. Disorientation and irritability
Due to reduced cerebral perfusion.
5. Cold clammy skin
Due to peripheral vasoconstriction and sweating.
Management

- Airway maintenance
- Oxygen therapy
- Control hemorrhage
- Intravenous fluids
- Blood transfusion
- Monitor urine output and vital signs
- Vasopressor drugs if required

• Describe baroreceptor reflex
Baroreceptor Reflex
Receptors

- Carotid sinus
- Aortic arch

Afferent Pathway

- Glossopharyngeal nerve
- Vagus nerve

Center

- Medullary cardiovascular center

Response to Increased BP

- Increased baroreceptor firing
- Decreased sympathetic activity
- Vasodilation and bradycardia
- BP decreases

Response to Decreased BP

- Decreased baroreceptor firing
- Increased sympathetic activity
- Tachycardia and vasoconstriction
- BP increases

9. A 55-year-old businessman was brought to medicine casualty with severe chest pain. He was sweating and his BP was 140/94 mm Hg, heart sounds were muffled and the ECG showed ST elevation in lead II and avf.

• What is the most probable diagnosis?
Diagnosis: Acute inferior wall myocardial infarction
(ST elevation in leads II and aVF indicates inferior wall myocardial infarction.)
• Discuss the pathophysiology of this condition and principles of management
Pathophysiology of Myocardial Infarction
Definition
Myocardial infarction is necrosis of cardiac muscle due to prolonged ischemia.
Pathophysiology

- Atherosclerotic plaque rupture occurs
- Platelet aggregation and thrombus formation occur
- Coronary artery occlusion develops
- Myocardial ischemia and hypoxia occur
- Anaerobic metabolism produces lactic acidosis
- Myocardial cell death occurs

Clinical Features

- Severe chest pain
- Sweating
- Dyspnea
- Tachycardia
- ECG changes

Principles of Management
Immediate Measures

- Bed rest
- Oxygen administration
- Pain relief with morphine
- Aspirin and antiplatelet therapy
- Nitrates

Reperfusion Therapy

- Thrombolysis
  OR
- Percutaneous coronary intervention

Monitoring

- ECG monitoring
- Blood pressure monitoring

Drugs

- Beta blockers
- Anticoagulants
- Statins

Prevention

- Stop smoking
- Diet control
- Exercise
- Control hypertension and diabetes

• What are the special features of coronary circulation?

1. Coronary arteries are functional end arteries with poor anastomosis.
2. Coronary blood flow is maximum during diastole and reduced during systole.
3. Myocardium has very high oxygen consumption.
4. Oxygen extraction by heart is very high (about 70–80%).
5. Coronary blood flow is closely related to myocardial metabolism.
6. Subendocardial region is more prone to ischemia.
7. Coronary circulation shows autoregulation.
8. Sympathetic stimulation increases coronary flow indirectly by increasing cardiac metabolism.
9. Coronary sinus drains most venous blood into right atrium.
10. Phasic variation in blood flow is present, especially in left coronary artery.

10. A 50-year-old chronic smoker complains of severe chest pain, crushing in nature, radiating to left shoulder and inside of the left arm. The chest discomfort brought on by the exertion was relieved by rest. After 2 hours he visits a hospital. Emergency room examination showed ST segment elevation, tachycardia and hypertension. What is he probably suffering from?

He is probably suffering from **Acute Myocardial Infarction (ST elevation myocardial infarction)**.

What is the cause for this pain?

- Atherosclerotic narrowing of coronary arteries with superadded thrombotic occlusion.
- Ischemia and necrosis of myocardium produce pain.
- Accumulation of metabolites like lactic acid, potassium ions, bradykinin and proteolytic enzymes stimulates pain endings.

What is the underlying mechanism for the above complaints ?

1. Coronary artery occlusion causes decreased blood supply to myocardium.
2. Myocardial ischemia leads to anaerobic metabolism and accumulation of pain-producing substances.
3. Pain radiates to left shoulder and arm due to referred pain through T1–T5 spinal segments.
4. Sympathetic activation causes tachycardia and hypertension.
5. ST segment elevation occurs due to transmural myocardial injury.

Explain the salient features of coronary circulation

Coronary blood vessels

- Right and left coronary arteries arise from ascending aorta.
- Venous drainage mainly through coronary sinus.

Coronary blood flow

- Normal coronary blood flow: about 225 mL/min (4–5% of cardiac output).

Phasic blood flow

- Left coronary flow occurs mainly during diastole because systolic contraction compresses vessels.
- Right coronary flow occurs during both systole and diastole.

High oxygen extraction

- Myocardium extracts 70–80% oxygen from blood.

- Increased oxygen demand is met mainly by increasing blood flow.

Metabolic regulation

- Coronary flow regulated by metabolites:
  - Adenosine
  - Carbon dioxide
  - Hydrogen ions
  - Potassium ions
  - Nitric oxide

Functional end arteries

- Coronary arteries have poor collateral circulation.
- Sudden occlusion leads to infarction.

Autoregulation

- Coronary circulation maintains constant blood flow over a range of pressures.

Nervous influence

- Sympathetic stimulation increases coronary flow indirectly by increasing cardiac work.

Vulnerability of subendocardium

- Subendocardial region is most susceptible to ischemia.

11. A 16 year old NCC cadet, lined up for a parade fell down unconscious. He had been standing in the hot sun for an hour. On examination, his blood pressure was 60/50 mmHg. Pulse rate was regular and was breathing normally. Soon, he regained consciousness. From your knowledge of physiology, Answer the following:

What is the most likely diagnosis?

Postural hypotension (Orthostatic hypotension) with vasovagal syncope.

What are the factors determining blood pressure?

Main factors

1. Cardiac output
2. Peripheral resistance

Other factors

3. Blood volume
4. Venous return
5. Elasticity of blood vessels
6. Heart rate
7. Stroke volume
8. Blood viscosity

What are the physiological principles applicable for the immediate management here?

1. Keep patient in supine position with legs elevated.
2. This increases venous return and cardiac output.
3. Improves cerebral blood flow and restores consciousness.
4. Adequate hydration should be given.
5. Avoid prolonged standing in hot environment.

Explain the short term regulation of blood pressure.

1. Baroreceptor mechanism

- Receptors present in carotid sinus and aortic arch.
- Fall in blood pressure decreases baroreceptor firing.
- Vasomotor center stimulated.
- Sympathetic discharge increases:
  - Heart rate
  - Cardiac contractility
  - Vasoconstriction
- Blood pressure rises.

2. Chemoreceptor mechanism

- Carotid and aortic bodies stimulated by:
  - Hypoxia
  - Hypercapnia
  - Acidosis
- Causes sympathetic stimulation and rise in blood pressure.

3. Central nervous system ischemic response

- Severe fall in cerebral perfusion stimulates vasomotor center.
- Produces intense vasoconstriction.

4. Adrenal medullary mechanism

- Sympathetic stimulation releases adrenaline and noradrenaline.
- Increases cardiac output and peripheral resistance.

12. A 60 years old man complains of chest pain on exertion, radiating to his left arm and severe shortness of breath. Answer the following.

What is the most probable condition he is suffering from?

Myocardial infarction / Ischemic heart disease.

Mention the most common investigation done in such a patient and describe with the help of diagram the changes that are expected in this patients.

Most common investigation

Electrocardiogram (ECG).

ECG changes in myocardial infarction

1. ST segment elevation
2. Deep Q waves
3. T wave inversion
4. Arrhythmias may occur

Diagrammatic representation

Normal ECG:

- Normal P wave, QRS complex and T wave.

Myocardial infarction ECG:

- Elevated ST segment
- Pathological Q wave
- Inverted T wave

What are the functional features of coronary circulation?

1. Coronary blood flow is mainly during diastole.
2. Coronary circulation has high oxygen extraction.
3. Increased demand met by increased coronary blood flow.
4. Coronary arteries are functional end arteries.
5. Coronary flow regulated by local metabolites.
6. Autoregulation present.
7. Subendocardial region more vulnerable to ischemia.
8. Sympathetic activity indirectly increases coronary flow.

13. A motor cyclist met with a road traffic accident and was admitted in the casualty. Clinical examination reveal cold and clammy extremities, rapid thread pulse, and a blood pressure of 70/50mm of Hg. Answer the following.

What is the probable clinical condition?

Shock (Hypovolemic shock).

Define shock and name the different stages of shock.

Definition

Shock is a state of circulatory failure resulting in inadequate tissue perfusion and oxygen supply.

Stages of shock

1. Non-progressive (compensated) stage
2. Progressive stage
3. Irreversible stage

Describe the compensatory mechanism in the first stages of shock.

Compensatory mechanisms

1. Baroreceptor reflex

- Fall in blood pressure stimulates sympathetic activity.
- Causes:
  - Tachycardia
  - Increased contractility
  - Vasoconstriction

2. Chemoreceptor reflex

- Stimulated by hypoxia.
- Produces vasoconstriction.

3. Central nervous system ischemic response

- Severe hypotension activates vasomotor center strongly.

4. Hormonal mechanisms

- Adrenaline and noradrenaline secretion increase.
- Renin–angiotensin–aldosterone system activated.
- Antidiuretic hormone secretion increases.

5. Fluid shift mechanism

- Fluid moves from tissues into circulation.

What is neurogenic shock?

Neurogenic shock is shock caused by sudden loss of sympathetic vasoconstrictor tone leading to widespread vasodilatation and fall in blood pressure.

Causes

- Spinal cord injury
- Deep anesthesia
- Severe pain
- Emotional stress

14. A 45 years old man is having high blood pressure. Answer the following

What are the probable causes of high BP?

Primary (essential) hypertension

- Genetic factors
- Obesity
- Stress
- Excess salt intake
- Sedentary lifestyle

Secondary hypertension

- Renal disease
- Endocrine disorders
- Coarctation of aorta
- Pregnancy induced hypertension

Mention the factors maintaining blood pressure.

1. Cardiac output
2. Peripheral resistance
3. Blood volume
4. Venous return
5. Elasticity of arteries
6. Blood viscosity
7. Heart rate
8. Stroke volume

Describe the neural regulation of blood pressure.

Vasomotor center

- Present in medulla oblongata.
- Maintains vasoconstrictor tone.

Baroreceptor reflex

- Receptors in carotid sinus and aortic arch.
- Increased blood pressure stimulates baroreceptors.
- Inhibits sympathetic activity and lowers blood pressure.

Chemoreceptor reflex

- Activated by hypoxia and hypercapnia.
- Produces vasoconstriction and rise in blood pressure.

Central nervous system ischemic response

- Severe cerebral ischemia causes intense sympathetic discharge.

Role of higher centers

- Hypothalamus and cerebral cortex influence blood pressure during emotions and stress.

15.A 55 year old obese man complained of headache, giddiness, irritability for the last two months. On examination by a doctor, his BP was found to be 130/100 mmHg by auscultatory method. Three days later, he visited another doctor. According to him, his BP was found to be 170/100 mmHg after using both palpatory and auscultatory methods

• What is the correct BP in this patient and why?

• What is the cause for this difference in the recording?

• Define mean arterial pressure & pulse pressure giving their values

• Describe the possible renal mechanism causing hypertension

• Mention Physiological basis for management of hypertension

• What is the correct BP in this patient and why?

The correct blood pressure is **170/100 mmHg**.

Reason:

- The first doctor recorded blood pressure only by auscultatory method.
- In hypertensive patients, an **auscultatory gap** may be present.
- Because of this gap, systolic pressure may be falsely recorded as low.
- The second doctor used both palpatory and auscultatory methods, hence the reading is more accurate.

• What is the cause for this difference in the recording?

The difference is due to **auscultatory gap**.

Auscultatory gap:

- Temporary disappearance of Korotkoff sounds between systolic and diastolic pressure during auscultation.
- Commonly seen in hypertension and arteriosclerosis.
- If palpatory method is not done first, systolic pressure is underestimated.

• Define mean arterial pressure & pulse pressure giving their values

Mean Arterial Pressure (MAP)

It is the average arterial pressure during one cardiac cycle.

Formula:

$$MAP = DP + \frac{1}{3}(SP - DP)$$

Normal value:

- Approximately **93 mmHg**

Pulse Pressure

It is the difference between systolic and diastolic blood pressure.

Formula:

$$Pulse\ Pressure = SP - DP$$

Normal value:

- Approximately **40 mmHg**

• Describe the possible renal mechanism causing hypertension

Renal mechanism causing hypertension:

1. **Reduced renal blood flow**
    - Due to renal artery constriction or renal disease.
2. **Increased renin secretion**
    - Juxtaglomerular cells secrete renin.
3. **Formation of angiotensin II**
    - Renin converts angiotensinogen to angiotensin I.
    - Angiotensin-converting enzyme converts it to angiotensin II.
4. **Actions of angiotensin II**
    - Powerful vasoconstriction.
    - Increases peripheral resistance.
    - Stimulates aldosterone secretion.
5. **Aldosterone action**
    - Increases sodium and water reabsorption.
    - Increases blood volume.
6. **Result**
    - Increased cardiac output and peripheral resistance leading to hypertension.

• Mention Physiological basis for management of hypertension

Physiological basis for management of hypertension:

1. **Low salt diet**
    - Reduces water retention and blood volume.
2. **Weight reduction**
    - Decreases cardiac workload and peripheral resistance.
3. **Regular exercise**
    - Improves vascular compliance and reduces sympathetic activity.
4. **Diuretics**
    - Reduce extracellular fluid volume and cardiac output.
5. **Vasodilator drugs**
    - Decrease peripheral resistance.
6. **Angiotensin-converting enzyme inhibitors / Angiotensin receptor blockers**
    - Inhibit renin–angiotensin system.
7. **Sympatholytic drugs**
    - Reduce sympathetic vasoconstrictor activity.
8. **Stress reduction**
    - Decreases sympathetic discharge.
9. **Avoid smoking and alcohol**

- Prevents vasoconstriction and cardiovascular complications. dra

LONG ESSAY

15. A 55 year old obese man complained of headache, giddiness, irritability for the last two months. On examination by a doctor, his BP was found to be 130/100 mmHg by auscultatory method. Three days later, he visited another doctor. According to him, his BP was found to be 170/100 mmHg after using both palpatory and auscultatory methods.

• What is the correct BP in this patient and why?

• What is the cause for this difference in the recording?

• Define mean arterial pressure & pulse pressure giving their values

• Describe the possible renal mechanism causing hypertension

• Mention Physiological basis for management of hypertension

Answer

Correct BP and reason

Correct blood pressure is **170/100 mmHg**.

Reason:

- First doctor used only auscultatory method.
- Due to auscultatory gap, systolic pressure was missed.
- Second doctor used palpatory and auscultatory methods together, therefore correct systolic pressure was obtained.

Cause for difference in recording

Cause is **auscultatory gap**.

Auscultatory gap

- Temporary disappearance of Korotkoff sounds during deflation of cuff.
- Common in hypertension and arteriosclerosis.
- If palpatory method is not done before auscultation, systolic pressure may be underestimated.

Mean arterial pressure (MAP)

Average pressure driving blood through circulation during cardiac cycle.

Formula:

MAP = Diastolic BP + 1/3 Pulse pressure

Normal value:

- About 93 mmHg

Pulse pressure

Difference between systolic and diastolic pressure.

Formula:

Pulse pressure = Systolic BP − Diastolic BP

Normal value:

- About 40 mmHg

Possible renal mechanism causing hypertension

Kidney plays major role in long term regulation of blood pressure.

Renin–Angiotensin–Aldosterone mechanism

1. Reduced renal blood flow stimulates juxtaglomerular cells.
2. Renin secretion increases.
3. Renin converts angiotensinogen to angiotensin I.
4. Angiotensin converting enzyme converts it to angiotensin II.
5. Angiotensin II causes:
   - Vasoconstriction
   - Increased peripheral resistance
   - Aldosterone secretion
   - Sodium and water retention
6. Blood volume and cardiac output increase.
7. Blood pressure rises.

Physiological basis for management of hypertension

1. Salt restriction
   - Reduces extracellular fluid volume and blood pressure.
2. Weight reduction
   - Decreases peripheral resistance and cardiac workload.
3. Exercise

- Improves vascular compliance and reduces sympathetic activity.

4. Diuretics
   - Reduce blood volume.
5. Vasodilators
   - Reduce peripheral resistance.
6. ACE inhibitors/ARB
   - Block renin–angiotensin system.
7. Stress reduction
   - Decreases sympathetic discharge.

SHORT ESSAYS

16. Describe the baroreceptor response to high blood pressure.

Answer

Definition

Baroreceptors are stretch receptors situated in carotid sinus and arch of aorta which regulate blood pressure by reflex mechanism.

Baroreceptors

- Carotid sinus baroreceptors
- Aortic arch baroreceptors

Pathway

Afferent fibers

- Carotid sinus → Hering's nerve → Glossopharyngeal nerve
- Aortic arch → Vagus nerve

Both terminate in nucleus tractus solitarius of medulla.

Response to rise in blood pressure

1. Increased arterial pressure stretches baroreceptors.
2. Frequency of impulses increases.
3. Vasomotor center is inhibited.
4. Cardioinhibitory center is stimulated.
5. Sympathetic discharge decreases.
6. Parasympathetic activity increases.

Effects

On heart

- Bradycardia
- Decreased force of contraction
- Reduced cardiac output

On blood vessels

- Vasodilation
- Decreased peripheral resistance

Result

Blood pressure decreases toward normal.

Importance

- Short term regulation of blood pressure
- Prevents sudden fluctuations in blood pressure

17. Short term regulation of blood pressure

Answer

Short term regulation acts within seconds to minutes.

Mechanisms

1. Baroreceptor mechanism
2. Chemoreceptor mechanism
3. CNS ischemic response
4. Adrenal medullary mechanism

1. Baroreceptor mechanism

Receptors

- Carotid sinus
- Aortic arch

Action

- Increased BP → increased firing → inhibition of vasomotor center
- Causes bradycardia and vasodilation
- BP falls.

2. Chemoreceptor mechanism

Receptors

- Carotid bodies
- Aortic bodies

Stimuli

- Hypoxia
- Hypercapnia
- Increased H+ ions

Action

Stimulates vasomotor center causing vasoconstriction and rise in BP.

3. CNS ischemic response

- Occurs in severe hypotension.
- Cerebral ischemia strongly stimulates vasomotor center.
- Produces intense vasoconstriction.

4. Adrenal medullary mechanism

- Sympathetic stimulation releases adrenaline and noradrenaline.
- Causes tachycardia and vasoconstriction.

Importance

Maintains arterial pressure during sudden changes like standing and hemorrhage.

18. Short answer about intermediate and long term regulation of blood pressure

Answer

Intermediate regulation

Acts within minutes to hours.

Mechanisms

1. Capillary fluid shift mechanism
2. Stress relaxation of blood vessels
3. Renin–angiotensin mechanism

Capillary fluid shift

- Increased BP → fluid moves from capillaries to tissues.
- Blood volume decreases.

Stress relaxation

- Blood vessels gradually dilate in response to increased pressure.
- Peripheral resistance decreases.

Renin–angiotensin mechanism

- Renin release produces angiotensin II.
- Causes vasoconstriction and sodium retention.

Long term regulation

Acts over hours to days.

Main mechanism

Kidney body fluid mechanism.

Mechanism

1. Increased BP increases renal excretion of salt and water.
2. Blood volume decreases.
3. Venous return and cardiac output decrease.
4. BP returns to normal.

Hormones involved

- Renin
- Angiotensin II
- Aldosterone
- Antidiuretic hormone
- Atrial natriuretic peptide

19. Explain homometric and heterometric regulation of blood pressure.

Answer

Heterometric regulation

Also called Frank–Starling mechanism.

Definition

Increase in force of cardiac contraction due to increase in initial length of muscle fibers.

Mechanism

- Increased venous return increases end diastolic volume.
- Cardiac muscle fibers stretch.
- Force of contraction increases.
- Stroke volume and cardiac output increase.

Importance

Maintains cardiac output according to venous return.

Homometric regulation

Regulation without change in muscle fiber length.

Mechanism

- Sympathetic stimulation increases myocardial contractility.
- Stroke volume increases without increase in end diastolic fiber length.

Factors

- Catecholamines
- Increased heart rate

Importance

Helps heart pump more effectively during exercise and stress.

20. Long term regulation of blood pressure

Answer

Long term regulation is mainly by kidneys through regulation of extracellular fluid volume.

Mechanisms

1. Renal body fluid mechanism
2. Renin–angiotensin–aldosterone system
3. Antidiuretic hormone
4. Atrial natriuretic peptide

Renal body fluid mechanism

Increased BP causes

- Increased pressure diuresis
- Increased pressure natriuresis

Effects

- Increased water and sodium excretion
- Decreased blood volume
- Decreased venous return
- Decreased cardiac output
- BP falls

Renin–angiotensin–aldosterone system

1. Decreased renal perfusion releases renin.
2. Angiotensin II formed.
3. Causes vasoconstriction.
4. Stimulates aldosterone secretion.
5. Sodium and water retention occur.
6. BP increases.

Antidiuretic hormone

- Increases water reabsorption.
- Increases blood volume.

Atrial natriuretic peptide

- Increases sodium excretion.
- Reduces blood volume and BP.

Importance

Maintains blood pressure for prolonged periods.

21. Change of posture from supine to standing causes tachycardia

Answer

Mechanism

1. On standing, blood pools in lower limbs due to gravity.
2. Venous return decreases.
3. Cardiac output and arterial pressure decrease.
4. Baroreceptor firing decreases.
5. Vasomotor center is stimulated.
6. Sympathetic activity increases and vagal activity decreases.
7. Heart rate increases causing tachycardia.

Significance

Maintains blood pressure and cerebral blood flow during standing.

22. Jugular venous pulse

Answer

Definition

Jugular venous pulse is the visible pulsation of internal jugular vein reflecting pressure changes in right atrium.

Waves of JVP

1. a wave – atrial contraction
2. c wave – bulging of tricuspid valve during ventricular systole
3. x descent – atrial relaxation
4. v wave – venous filling of atrium
5. y descent – opening of tricuspid valve and ventricular filling

Clinical importance

- Assesses right atrial pressure
- Helpful in tricuspid valve disease and heart failure

SHORT ANSWERS

23. A 35 year old male met with a road traffic accident and lost substantial amount of blood which lead to signs of fall in blood pressure, tachycardia and rapid breathing. Name the probable type of shock in this patient and discuss the pathophysiology and management of the same.

Answer

Type of shock

Hypovolemic (hemorrhagic) shock.

Pathophysiology

1. Blood loss decreases blood volume.
2. Venous return decreases.
3. Cardiac output decreases.
4. Blood pressure falls.
5. Tissue perfusion decreases.
6. Sympathetic activity increases causing:
    - Tachycardia
    - Vasoconstriction
    - Sweating
7. Tissue hypoxia leads to lactic acidosis.

Management

1. Control bleeding
2. Intravenous fluids
3. Blood transfusion
4. Oxygen administration

5. Vasopressors if required
6. Monitor vital signs

24. Draw and label a normal jugular venous pulsation tracing.

Answer

REFER DIAGRAM SECTION

25. Describe the long-term regulation of blood pressure. Add a note on hypertension

Answer

Long term regulation

Mainly by kidneys.

Mechanisms

1. Pressure diuresis
2. Pressure natriuresis
3. Renin–angiotensin–aldosterone system
4. Antidiuretic hormone
5. Atrial natriuretic peptide

Effects

- Regulation of blood volume
- Regulation of cardiac output
- Maintenance of arterial pressure

Hypertension

Definition

Persistent elevation of arterial blood pressure above normal.

Normal BP

120/80 mmHg

Causes

Primary hypertension

- No definite cause

Secondary hypertension

- Renal disease
- Endocrine disorders
- Coarctation of aorta

Complications

- Stroke
- Heart failure
- Renal failure
- Retinopathy

Management

- Salt restriction
- Exercise
- Weight reduction
- Antihypertensive drugs

26. Role of baroreceptors in blood pressure regulation

Answer

Baroreceptors

Stretch receptors present in:

- Carotid sinus
- Aortic arch

Function

Regulate blood pressure by reflex mechanism.

When BP rises

- Increased firing of baroreceptors
- Inhibition of sympathetic activity
- Increased vagal tone
- Bradycardia and vasodilation occur
- BP decreases

When BP falls

- Decreased firing
- Sympathetic stimulation increases
- Tachycardia and vasoconstriction occur
- BP increases

Importance

Maintains short term stability of blood pressure.

27. Tachycardia in hemorrhagic shock why?

Answer

In hemorrhagic shock, blood loss decreases arterial pressure.

Mechanism

1. Baroreceptor firing decreases.
2. Vasomotor center is stimulated.
3. Sympathetic discharge increases.
4. Adrenaline and noradrenaline are released.
5. Heart rate increases producing tachycardia.

Significance

Helps maintain cardiac output and blood pressure.

28. Draw a tracing of the jugular venous pressure and give the basis of each wave.

Answer

REFER DIAGRAM SECTION

Waves of JVP

1. a wave – atrial contraction
2. c wave – bulging of tricuspid valve during ventricular systole
3. x descent – atrial relaxation and downward movement of tricuspid valve
4. v wave – venous filling of right atrium
5. y descent – opening of tricuspid valve and rapid ventricular filling

29. Myocardial infarction

Answer

Definition

Death of cardiac muscle due to prolonged ischemia.

Causes

- Coronary artery thrombosis
- Atherosclerosis

Clinical features

- Severe chest pain
- Sweating
- Dyspnea
- Shock

ECG changes

- ST elevation
- T wave inversion
- Pathological Q wave

Enzymes increased

- Troponin
- Creatine kinase-MB

Complications

- Arrhythmia
- Heart failure
- Cardiogenic shock

30. Renin-Angiotensin mechanism in blood pressure regulation

Answer

Mechanism

1. Fall in renal perfusion stimulates juxtaglomerular cells.
2. Renin is secreted.
3. Renin converts angiotensinogen to angiotensin I.
4. Angiotensin converting enzyme converts it to angiotensin II.

Actions of angiotensin II

- Vasoconstriction
- Increased peripheral resistance
- Aldosterone secretion
- Sodium and water retention
- Increased BP

Importance

Long term regulation of blood pressure.

31. Factors affecting venous return

Answer

Factors

1. Blood volume
2. Venous tone
3. Skeletal muscle pump
4. Respiratory pump
5. Cardiac suction
6. Gravity
7. Intrathoracic pressure
8. Right atrial pressure

Increased venous return occurs in

- Exercise
- Inspiration
- Increased blood volume

Decreased venous return occurs in

- Hemorrhage
- Standing for long time

32. Starling's forces

Answer

Definition

Forces governing movement of fluid across capillary membrane.

Forces

1. Capillary hydrostatic pressure
    - Pushes fluid out.
2. Interstitial fluid hydrostatic pressure
    - Pushes fluid into capillary.
3. Plasma colloid osmotic pressure
    - Pulls fluid into capillary.
4. Interstitial fluid colloid osmotic pressure
    - Pulls fluid out.

Importance

Regulates capillary fluid exchange.

33. Starling's forces in capillary fluid exchange

Answer

Outward forces

1. Capillary hydrostatic pressure
2. Interstitial colloid osmotic pressure

Inward forces

1. Plasma colloid osmotic pressure
2. Interstitial hydrostatic pressure

At arterial end

Filtration predominates.

At venous end

Reabsorption predominates.

Importance

Maintains tissue fluid balance.

34. Starling's law of muscle contraction

Answer

Statement

Within physiological limits, force of contraction of cardiac muscle is directly proportional to initial length of muscle fibers.

Mechanism

- Increased venous return increases end diastolic volume.
- Myocardial fibers stretch.
- Force of contraction increases.
- Stroke volume increases.

Importance

Heart pumps blood according to venous return.

35. Raised intracranial pressure causes bradycardia and hypertension. Why?

Answer

Mechanism

1. Raised intracranial pressure compresses cerebral blood vessels.
2. Cerebral ischemia stimulates vasomotor center.
3. Sympathetic discharge increases.
4. Severe vasoconstriction causes hypertension.
5. Increased BP stimulates baroreceptors.
6. Reflex vagal stimulation causes bradycardia.

This is called Cushing reflex.

36. Venous return

Answer

Definition

Volume of blood returning to heart per minute.

Normal value

About 5 liters/minute.

Factors affecting venous return

- Blood volume
- Venous tone
- Skeletal muscle pump
- Respiratory pump
- Right atrial pressure

Importance

Determines cardiac output.

37. Prolonged standing results in fainting attacks. Why?

Answer

Mechanism

1. Blood pools in lower limbs due to gravity.
2. Venous return decreases.
3. Cardiac output decreases.
4. Cerebral blood flow decreases.
5. Cerebral hypoxia causes fainting (syncope).

38. Factors influencing venous return

Answer

Factors

1. Blood volume
2. Venous pressure gradient
3. Skeletal muscle pump
4. Respiratory pump
5. Venous tone
6. Gravity
7. Intrathoracic pressure
8. Right atrial pressure

CARDIOVASCULAR ADJUSTMENTS IN EXERCISE

SHORT ESSAYS

1. Describe the cardiorespiratory changes during exercise

Answer

Cardiovascular changes

1. Increased heart rate
2. Increased stroke volume
3. Increased cardiac output
4. Increased systolic BP
5. Increased venous return
6. Vasodilation in skeletal muscles
7. Increased coronary blood flow

Respiratory changes

1. Increased respiratory rate
2. Increased tidal volume
3. Increased pulmonary ventilation
4. Increased oxygen uptake
5. Increased carbon dioxide elimination

Mechanism

- Sympathetic stimulation
- Increased metabolic activity
- Increased oxygen demand

Significance

Provides adequate oxygen and nutrients to exercising muscles.

SHORT ANSWERS

2. Resting bradycardia in athletes

Answer

Cause

Regular exercise increases vagal tone and stroke volume.

Mechanism

- Increased stroke volume allows adequate cardiac output with lower heart rate.
- Enhanced parasympathetic activity decreases resting heart rate.

Significance

Indicates good cardiovascular efficiency.

CIRCULATION THROUGH SPECIAL REGIONS

LONG ESSAYS

1. Discuss the characteristic features of coronary circulation. Explain the various factors regulating coronary blood flow.

Characteristic features of coronary circulation

1. Coronary arteries are functional end arteries with poor anastomosis.
2. Coronary circulation is the circulation of the heart muscle.
3. Coronary blood flow is about 225–250 mL/min (4–5% of cardiac output).
4. Left coronary artery supplies most of the left ventricle and interventricular septum.
5. Coronary blood flow is phasic:
    - Left coronary flow occurs mainly during diastole.
    - Right coronary flow occurs during both systole and diastole.
6. During systole, myocardial contraction compresses coronary vessels and reduces blood flow.
7. Coronary circulation has very high oxygen extraction (about 70–80%).
8. Hence increased oxygen demand is met mainly by increasing coronary blood flow.
9. Myocardium has high metabolic activity and continuous oxygen requirement.

10. Coronary sinus drains most venous blood into the right atrium.
11. Subendocardial region is more prone to ischemia.
12. Coronary vessels show autoregulation.

Factors regulating coronary blood flow

1. Metabolic factors

Increased myocardial metabolism causes vasodilation.

Important metabolites:

- Adenosine
- Decreased oxygen tension
- Increased carbon dioxide
- Increased hydrogen ion concentration
- Potassium ions
- Lactate

2. Nervous factors

- Sympathetic stimulation:
  - Alpha receptors → vasoconstriction
  - Beta-2 receptors → vasodilation
  - Overall effect usually increases coronary flow due to increased cardiac work.
- Parasympathetic stimulation:
  - Mild vasodilation.

3. Mechanical factors

- During systole, compression of coronary vessels decreases flow.
- Coronary perfusion mainly occurs during diastole.
- Aortic pressure influences coronary perfusion.

4. Humoral factors

Vasodilators:

- Nitric oxide
- Bradykinin
- Prostaglandins

Vasoconstrictors:

- Vasopressin
- Angiotensin II
- Endothelin

5. Autoregulation

Coronary blood flow remains relatively constant despite moderate changes in perfusion pressure.

Applied physiology

- Coronary artery obstruction causes myocardial ischemia and myocardial infarction.
- Decreased diastolic pressure reduces coronary perfusion.

SHORT ESSAYS

2. Describe the peculiarities of the coronary circulation

1. Coronary arteries are functional end arteries.
2. Coronary blood flow is about 4–5% of cardiac output.
3. Blood flow is highest during diastole.
4. During systole, myocardial contraction compresses vessels and reduces flow.
5. Left ventricular coronary flow is mainly diastolic.
6. Coronary circulation has high oxygen extraction.

7. Increased oxygen demand is met by increased blood flow.
8. Coronary circulation shows autoregulation.
9. Subendocardial region is vulnerable to ischemia.
10. Coronary sinus drains most venous blood.
11. Myocardium depends mainly on aerobic metabolism.

SHORT ANSWERS

3. Entero-hepatic circulation

Entero-hepatic circulation is the circulation of bile salts from liver to intestine and back to liver.

Steps

1. Liver secretes bile salts into bile.
2. Bile enters intestine.
3. Bile salts aid fat digestion and absorption.
4. Most bile salts are reabsorbed from terminal ileum.
5. Reabsorbed bile salts return to liver through portal circulation.
6. Liver again secretes them into bile.

Importance

- Conserves bile salts.
- Helps fat digestion and absorption.
- Helps absorption of fat-soluble vitamins.

4. Describe the peculiarities of the coronary circulation

1. Coronary arteries are functional end arteries.
2. Coronary blood flow occurs mainly during diastole.
3. Systolic compression decreases blood flow.
4. Coronary circulation has high oxygen extraction.
5. Increased oxygen demand is met by increased blood flow.
6. Coronary circulation shows autoregulation.
7. Subendocardial region is more prone to ischemia.
8. Coronary sinus drains venous blood.

5. Special features of coronary circulation

1. Functional end arteries.
2. Diastolic predominance of blood flow.
3. High oxygen extraction.
4. Marked autoregulation.
5. Metabolic regulation is important.
6. Compression of vessels during systole.
7. Increased blood flow during exercise.
8. Subendocardial ischemia occurs easily.

RESPIRATORY SYSTEM

STRUCTURE AND FUNCTIONS OF RESPIRATORY SYSTEM

SHORT ESSAYS

1. Explain the role of surfactant in respiration and maintaining the stability of the alveoli.

Definition

Pulmonary surfactant is a surface tension lowering substance present in alveoli.

Source

Produced by type II alveolar epithelial cells.

Composition

- Dipalmitoyl phosphatidylcholine (lecithin) – major component
- Phospholipids
- Surfactant proteins
- Cholesterol

Functions of surfactant

1. Reduces surface tension

- Prevents alveolar collapse.
- Decreases work of breathing.

2. Maintains alveolar stability

According to Laplace law:

$$P = \frac{2T}{r}$$

Where:

- P = collapsing pressure
- T = surface tension
- r = radius of alveolus

Surfactant lowers surface tension and stabilizes small alveoli.

3. Increases lung compliance

Lungs expand easily during inspiration.

4. Prevents pulmonary edema

By reducing surface tension, fluid accumulation in alveoli is prevented.

5. Keeps alveoli dry

Prevents transudation of fluid into alveoli.

6. Antimicrobial function

Surfactant proteins help in lung defense.

Clinical importance

Deficiency causes neonatal respiratory distress syndrome in premature babies.

SHORT ANSWERS

2. Non-respiratory functions of lung

1. Acts as blood reservoir.
2. Filters small emboli.
3. Phonation.
4. Regulation of body temperature.
5. Water loss through expiration.
6. Metabolic functions:
    - Conversion of angiotensin I to angiotensin II by angiotensin converting enzyme.
    - Inactivation of bradykinin, serotonin and prostaglandins.
7. Defense mechanism by macrophages.
8. Acid-base balance.
9. Excretion of volatile substances.

3. Surfactant

Definition

Surfactant is a surface tension lowering substance lining alveoli.

Source

Type II alveolar epithelial cells.

Composition

- Dipalmitoyl phosphatidylcholine
- Phospholipids
- Cholesterol
- Surfactant proteins

Functions

1. Reduces surface tension.
2. Prevents alveolar collapse.
3. Increases lung compliance.
4. Prevents pulmonary edema.
5. Stabilizes alveoli.

4. What is surfactant. Write down its functions.

Definition

Surfactant is a phospholipid substance secreted by type II alveolar cells that reduces alveolar surface tension.

Functions

1. Reduces surface tension.
2. Prevents alveolar collapse.
3. Increases lung compliance.
4. Decreases work of breathing.
5. Prevents pulmonary edema.
6. Stabilizes alveoli.
7. Keeps alveoli dry.

5. Draw a neat labelled diagram of the respiratory membrane, indicating the factors affecting diffusion across it.

Respiratory membrane

REFER DIAGRAM SECTION

Factors affecting diffusion across respiratory membrane

According to Fick's law:

$$\boldsymbol{V = \frac{A \times D \times (P_1 - P_2)}{T}}$$

Meaning of symbols

- **V** = Rate of diffusion of gas
- **A** = Surface area of membrane
- **D** = Diffusion coefficient of gas
- $\mathbf{P_1 - P_2}$ = Partial pressure gradient across membrane
- **T** = Thickness of membrane

Factors:

1. Surface area of membrane.
2. Thickness of membrane.
3. Partial pressure difference.
4. Diffusion coefficient of gas.
5. Solubility of gas.
6. Molecular weight of gas.

6. Draw and label: Respiratory membrane

REFER DIAGRAM SECTION

7. Corticosteroids are administered to a lady in preterm labour. Why?

Corticosteroids accelerate maturation of fetal lungs and increase surfactant synthesis.

Importance

- Prevents neonatal respiratory distress syndrome.
- Improves lung compliance.
- Reduces alveolar collapse.

8. Pulmonary surfactant

Definition

Pulmonary surfactant is a phospholipid substance secreted by type II alveolar cells.

Composition

- Dipalmitoyl phosphatidylcholine
- Phospholipids

- Cholesterol
- Surfactant proteins

Functions

1. Reduces surface tension.
2. Prevents alveolar collapse.
3. Increases lung compliance.
4. Stabilizes alveoli.
5. Prevents pulmonary edema.

9. Alveoli are dry normally. Why?

Alveoli remain dry because pulmonary surfactant reduces surface tension and prevents movement of fluid into alveoli.

Other factors:

1. Tight alveolar epithelium.
2. Efficient lymphatic drainage.
3. Low pulmonary capillary pressure.

10. Alveoli do not collapse during expiration. Why?

1. Presence of pulmonary surfactant lowers surface tension.
2. Surfactant stabilizes alveoli.
3. Residual volume keeps alveoli partially inflated.
4. Negative intrapleural pressure prevents collapse.

11. Synthesis and functions of surfactants

Synthesis

- Synthesized by type II alveolar epithelial cells.
- Major component is dipalmitoyl phosphatidylcholine.
- Secretion increases late in fetal life.
- Corticosteroids stimulate synthesis.

Functions

1. Reduces surface tension.
2. Prevents alveolar collapse.
3. Increases lung compliance.
4. Decreases work of breathing.
5. Prevents pulmonary edema.
6. Stabilizes alveoli.

MECHANICS OF VENTILATION AND PULMONARY FUNCTION TESTS

LONG ESSAYS

1. A 55-year-old man who is a chronic smoker was brought to the medical emergency with complaints of breathlessness, wheeze and cough with sputum for the past one week. He gets similar illness during the cold season for the past five years. On examination he has mild cyanosis, wheeze and crepitations. His chest is barrel shaped, RBC count is increased and forced vital capacity (FVC) is decreased and FEV1 is 60%.

Name the most probable clinical condition

Chronic obstructive pulmonary disease with emphysema and chronic bronchitis.

Draw and label a spirogram showing the lung volumes and capacities

REFER DIAGRAM SECTION

Lung volumes

1. Tidal volume (TV) – 500 mL
2. Inspiratory reserve volume (IRV) – 3000 mL
3. Expiratory reserve volume (ERV) – 1100 mL
4. Residual volume (RV) – 1200 mL

Lung capacities

1. Inspiratory capacity (IC = TV + IRV)
2. Functional residual capacity (FRC = ERV + RV)
3. Vital capacity (VC = IRV + TV + ERV)
4. Total lung capacity (TLC = VC + RV)

Describe the physiological basis for the changes in RBC count and FVC

Increased RBC count

- Chronic hypoxia stimulates erythropoietin secretion.
- Erythropoietin increases erythropoiesis.
- Secondary polycythemia develops.

Decreased FVC

- Airway obstruction causes difficulty in expiration.
- Air trapping increases residual volume.
- Elastic recoil of lungs decreases.
- Hence forced vital capacity decreases.

Additional findings in chronic obstructive pulmonary disease

1. FEV1 markedly decreased.
2. FEV1/FVC ratio decreased.
3. Increased residual volume.
4. Barrel-shaped chest due to hyperinflation.

2. A 50 year old male come with complaint of difficulty in breathing. Auscultation revealed the presence of rhonchi in all the lung fields. Patient's pulmonary function tests revealed FVC decreased; FEV1=60%

Answer the following:

What is FVC and FEV1?

Forced vital capacity (FVC)

Maximum volume of air that can be expired forcefully after a maximal inspiration.

Forced expiratory volume in one second (FEV1)

Volume of air expired in the first second during forced expiration after maximal inspiration.

Interpretation

- FEV1 of 60% indicates obstructive airway disease.
- Common causes:
    - Bronchial asthma
    - Chronic bronchitis
    - Emphysema

Physiological basis

- Increased airway resistance decreases expiratory flow.
- Expiration becomes prolonged.
- FEV1 falls markedly.
- FEV1/FVC ratio decreases.

Give the normal values of FEV1 and FEV2

- FEV1 (Forced Expiratory Volume in 1 second) = About 80% of vital capacity.
- FEV2 (Forced Expiratory Volume in 2 seconds) = About 94% of vital capacity.

Describe the physiological basis for this change of FEV1

In COPD, there is obstruction to airflow due to:

- Bronchospasm
- Increased mucus secretion
- Narrowing of airways
- Loss of elastic recoil of lungs

Hence expiration becomes difficult and prolonged, causing marked reduction in FEV1.

What is the probable clinical condition?

- Chronic Obstructive Pulmonary Disease (COPD)
- Bronchial asthma
- Emphysema
- Chronic bronchitis

What is the significance of FEV1?

- FEV1 is an important index of airway resistance.
- It helps in diagnosis of obstructive lung diseases.
- Decreased FEV1 indicates airway obstruction.
- Used to assess severity and prognosis of COPD.

SHORT ESSAYS

3. Explain the role of dynamic lung function tests in the diagnosis of respiratory disorders.

Dynamic lung function tests

Dynamic lung function tests measure the rate of airflow during breathing.

Important dynamic lung function tests

1. Forced Vital Capacity (FVC)
2. Forced Expiratory Volume (FEV)
3. FEV1/FVC ratio
4. Peak Expiratory Flow Rate (PEFR)
5. Maximum Voluntary Ventilation (MVV)

1. Forced Vital Capacity (FVC)

- Maximum volume of air expired forcefully after maximal inspiration.
- Normal value: About 4–5 L.
- Reduced in restrictive lung diseases.

2. Forced Expiratory Volume (FEV)

- Volume of air expired during specific time interval after forced expiration.

Normal values

- FEV1 = 80% of FVC
- FEV2 = 94% of FVC
- FEV3 = 97% of FVC

Significance

- Reduced in obstructive lung diseases.

3. FEV1/FVC ratio

- Normal = About 80%
- Decreased in obstructive diseases.
- Normal or increased in restrictive diseases.

4. Peak Expiratory Flow Rate (PEFR)

- Maximum flow rate during forced expiration.
- Measured using peak flow meter.
- Reduced in asthma and airway obstruction.

5. Maximum Voluntary Ventilation (MVV)

- Maximum amount of air breathed in and out in one minute.
- Normal = 125–170 L/min.
- Reduced in respiratory muscle weakness and obstructive diseases.

Role in diagnosis of respiratory disorders

Obstructive lung diseases

Examples:

- Bronchial asthma
- Emphysema
- Chronic bronchitis

Findings:

- Marked decrease in FEV1
- Decreased FEV1/FVC ratio
- Decreased PEFR
- Increased airway resistance

Restrictive lung diseases

Examples:

- Pulmonary fibrosis
- Tuberculosis
- Pleural diseases

Findings:

- Reduced lung volumes
- FVC reduced
- FEV1/FVC ratio normal or increased

Conclusion

Dynamic lung function tests are useful for:

- Diagnosis of respiratory disorders
- Differentiation of obstructive and restrictive diseases
- Assessment of severity
- Monitoring treatment response

4. Intrapleural pressure is negative why?

Definition

Intrapleural pressure is the pressure within pleural cavity.

Normal intrapleural pressure:

- About –5 cm H2O during quiet breathing.

Why intrapleural pressure is negative?

Negative intrapleural pressure is due to opposite recoil tendencies of lungs and chest wall.

Factors responsible

1. Elastic recoil of lungs

- Lungs tend to collapse inward because of elastic tissue.
- This creates negative pressure in pleural cavity.

2. Elastic recoil of chest wall

- Chest wall tends to expand outward.
- Pulls parietal pleura outward.

3. Surface tension in alveoli

- Surface tension tends to collapse alveoli.
- Adds to inward pull of lungs.

4. Continuous lymphatic drainage

- Lymphatics continuously remove pleural fluid.
- Creates slight suction effect.

Significance of negative intrapleural pressure

- Keeps lungs expanded.
- Prevents lung collapse.
- Helps venous return.
- Aids inspiration.

5. Describe the respiratory pressure changes with diagrams. Add a note on V-P ratio.

Respiratory pressure changes during normal respiratory cycle

Pressures involved

1. Atmospheric pressure
2. Intra-alveolar pressure
3. Intrapleural pressure
4. Transpulmonary pressure

During inspiration

Intra-alveolar pressure

- Falls to about –1 cm H2O.
- Air enters lungs.

Intrapleural pressure

- Becomes more negative.
- Falls from –5 cm H2O to –7.5 cm H2O.

Transpulmonary pressure

- Increases.
- Causes expansion of lungs.

During expiration

Intra-alveolar pressure

- Rises to about +1 cm H2O.
- Air leaves lungs.

Intrapleural pressure

- Returns toward –5 cm H2O.

Transpulmonary pressure

- Decreases.

V-P ratio (Ventilation-Perfusion ratio)

Definition

Ratio between alveolar ventilation and pulmonary blood flow.

Normal value

- About 0.8
- Ventilation = 4 L/min
- Perfusion = 5 L/min

Significance

- Essential for proper gas exchange.
- Altered in lung diseases.

Increased V/Q ratio

- Pulmonary embolism
- Dead space ventilation

Decreased V/Q ratio

- Airway obstruction
- Asthma
- Pneumonia

6. Hyaline membrane disease

Definition

Hyaline membrane disease is respiratory distress syndrome occurring in premature newborn due to deficiency of surfactant.

Cause

- Deficiency of pulmonary surfactant.

- Common in premature babies.

Risk factors

- Prematurity
- Maternal diabetes mellitus
- Cesarean section
- Birth asphyxia

Pathophysiology

- Surfactant deficiency increases surface tension.
- Causes alveolar collapse (atelectasis).
- Decreased lung compliance.
- Hypoxia develops.
- Proteinaceous hyaline membrane forms in alveoli.

Clinical features

- Tachypnea
- Cyanosis
- Grunting respiration
- Chest retractions

Investigations

- Chest X-ray: Ground glass appearance.
- Blood gas analysis shows hypoxia.

Treatment

- Oxygen therapy
- Continuous positive airway pressure (CPAP)
- Artificial surfactant therapy
- Mechanical ventilation

Prevention

- Antenatal corticosteroids in premature labor.

7. Define dead space. Describe the types

Definition

Dead space is the volume of air in respiratory passages which does not participate in gas exchange.

Types of dead space

1. Anatomical dead space
2. Physiological dead space
3. Alveolar dead space

1. Anatomical dead space

- Air present in conducting airways.
- Includes nose, pharynx, larynx, trachea and bronchi.
- Normal value: About 150 mL.

Functions

- Warms inspired air.
- Filters air.
- Humidifies air.

2. Physiological dead space

- Total volume of air not participating in gas exchange.

- Normally equal to anatomical dead space.
- Increased in lung diseases.

3. Alveolar dead space

- Air present in alveoli that are ventilated but not perfused.
- Occurs in pulmonary embolism and shock.

Measurement

- Measured by Bohr's method.

Significance

- Increased dead space decreases efficiency of ventilation.

8. Explain pressure changes during normal respiratory cycle.

During inspiration

Intra-alveolar pressure

- Falls to –1 cm H2O.
- Causes entry of air.

Intrapleural pressure

- Falls from –5 to –7.5 cm H2O.
- Due to expansion of thoracic cavity.

Transpulmonary pressure

- Increases and expands lungs.

During expiration

Intra-alveolar pressure

- Increases to +1 cm H2O.
- Air flows out.

Intrapleural pressure

- Returns toward –5 cm H2O.

Transpulmonary pressure

- Decreases.

Significance

- Pressure changes are responsible for movement of air during breathing.

9. Physiological dead space

Definition

Physiological dead space is the total volume of air that does not take part in gas exchange.

Components

1. Anatomical dead space
2. Alveolar dead space

Normal value

- About 150 mL.

Causes of increase

- Pulmonary embolism
- Emphysema
- Shock

Measurement

- By Bohr's equation.

Significance

- Increased physiological dead space causes inefficient ventilation.

10. Lung compliance

Definition

Compliance is the ease with which lungs expand.

Normal value

- About 200 mL/cm H2O.

Types

1. Lung compliance
2. Thoracic compliance
3. Combined compliance

Factors affecting compliance

Increase compliance

- Emphysema
- Aging

Decrease compliance

- Pulmonary fibrosis
- Pulmonary edema
- Surfactant deficiency

Significance

- Determines work of breathing.
- Decreased compliance causes difficult inspiration.

SHORT ANSWERS

11. Forced Expiratory Volume in 1 second (FEV1) in COPD

Definition

FEV1 is the volume of air expired forcefully during first second after maximal inspiration.

In COPD

- FEV1 is markedly reduced.
- Due to airway obstruction and loss of elastic recoil.

Significance

- Used for diagnosis and grading severity of COPD.

12. Dead space

Definition

Dead space is the volume of air that does not participate in gaseous exchange.

Types

1. Anatomical dead space
2. Physiological dead space
3. Alveolar dead space

Normal value

- About 150 mL.

13. Timed vital capacity

Definition

Timed vital capacity is the volume of air expired in a specific time during forced expiration after maximal inspiration.

Examples

- FEV1
- FEV2
- FEV3

Significance

- Important test for obstructive lung diseases.

14. Vital capacity and timed vital capacity as lung function tests. Why?

Vital capacity

- Maximum amount of air expired after maximal inspiration.
- Indicates functional capacity of lungs.

Timed vital capacity

- Measures rate of expiration.
- Assesses airway resistance.

Why used as lung function tests?

- Detect obstructive and restrictive lung diseases.
- Assess severity of respiratory disorders.
- Monitor progression and treatment.

PULMONARY CIRCULATION

SHORT ESSAYS

1. Explain ventilation perfusion ratio

Definition

Ventilation perfusion ratio is the ratio between alveolar ventilation and pulmonary blood flow.

V/Q = \frac{Alveolar\ ventilation}{Pulmonary\ blood\ flow}

Normal value

- About 0.8
- Ventilation = 4 L/min
- Perfusion = 5 L/min

Regional variations

Apex of lung

- V/Q ratio high.
- About 3.

Base of lung

- V/Q ratio low.
- About 0.6.

Significance

- Necessary for efficient gas exchange.

Increased V/Q ratio

Occurs in:

- Pulmonary embolism
- Reduced pulmonary blood flow

Decreased V/Q ratio

Occurs in:

- Asthma
- Airway obstruction
- Pneumonia

Effects of V/Q mismatch

- Hypoxia
- Impaired gas exchange

2. Describe the characteristics of pulmonary circulation

Characteristics

1. Low pressure system

- Pulmonary arterial pressure is low.
- Mean pulmonary arterial pressure = 15 mmHg.

2. Low resistance circulation

- Pulmonary vascular resistance is very low.

3. High compliance

- Pulmonary vessels are highly distensible.

4. Entire cardiac output passes through lungs

- Right ventricular output equals pulmonary blood flow.

5. Unequal distribution of blood flow

- Blood flow greater at base than apex.

6. Acts as blood reservoir

- Lungs contain about 450 mL blood.

7. Filtration function

- Removes small emboli from blood.

8. Metabolic functions

- Converts angiotensin I to angiotensin II.
- Inactivates bradykinin and serotonin.

SHORT ANSWERS

3. Ventilation perfusion ratio

Definition

Ratio between alveolar ventilation and pulmonary blood flow.

□genui□{"math_block_widget_always_prefetch_v2":{"content":"V/Q = \frac{4\ L/min}{5\ L/min} = 0.8"}}□

Normal value

- 0.8

Significance

- Essential for normal gas exchange.

4. Physiological shunt

Definition

Physiological shunt is the passage of venous blood into arterial blood without oxygenation.

Causes

- Bronchial venous drainage into pulmonary veins.
- Thebesian veins draining into left heart.

Significance

- Causes arterial oxygen saturation to be less than 100%.

5. Haemoglobin saturation in arterial blood is usually less than 100%. Why?

Reasons

1. Physiological shunt.
2. Bronchial venous blood mixes with pulmonary venous blood.
3. Blood from Thebesian veins enters left ventricle.
4. Slight V/Q mismatch.

Hence arterial oxygen saturation is about 97%.

PULMONARY GAS EXCHANGE

SHORT ESSAYS

1. Classify hypoxia Explain the cause of the different types of hypoxia

Definition

Hypoxia is deficiency of oxygen at tissue level.

Classification

1. Hypoxic hypoxia
2. Anaemic hypoxia
3. Stagnant hypoxia
4. Histotoxic hypoxia

1. Hypoxic hypoxia

Definition

Decreased arterial oxygen tension.

Causes

- High altitude
- Hypoventilation
- Pneumonia
- Pulmonary edema
- Airway obstruction

2. Anaemic hypoxia

Definition

Reduced oxygen carrying capacity of blood.

Causes

- Anaemia
- Hemorrhage
- Carbon monoxide poisoning

3. Stagnant hypoxia

Definition

Reduced blood flow to tissues.

Causes

- Heart failure
- Shock
- Peripheral circulatory failure

4. Histotoxic hypoxia

Definition

Cells unable to utilize oxygen.

Causes

- Cyanide poisoning

Features of cyanide poisoning

- Tissue oxygen utilization blocked.
- Venous blood remains oxygenated.

Significance

- Severe hypoxia can lead to organ failure and death.

SHORT ANSWERS

2. Factors affecting diffusion across respiratory membrane

Factors affecting diffusion:

1. Thickness of respiratory membrane
2. Surface area of membrane
3. Diffusion coefficient of gases
4. Partial pressure gradient
5. Solubility of gases
6. Ventilation perfusion ratio

genui{"math_block_widget_always_prefetch_v2":{"content":"Diffusion\ rate \propto \frac{Surface\ area \times Pressure\ gradient}{Thickness}"}}

3. Hypoxia in cyanide poisoning .Why?

Reason

Cyanide inhibits cytochrome oxidase enzyme in tissues.

- Cells cannot utilize oxygen.
- Tissue respiration stops.
- Histotoxic hypoxia develops.

4. Differentiate between Haldane and Bohr effect

Feature	Haldane effect	Bohr effect
Definition	Oxygenation of blood decreases	Increased CO_2 decreases

Feature	Haldane effect	Bohr effect
	CO_2 carrying capacity	affinity of hemoglobin for oxygen
Site	Lungs	Tissues
Main effect	Promotes CO_2 unloading	Promotes oxygen unloading
Importance	CO_2 transport	Oxygen delivery

5. Role of oxygen in treatment of carbon monoxide poisoning

Role

- Oxygen competes with carbon monoxide for hemoglobin binding.
- Accelerates dissociation of carboxyhemoglobin.
- Improves tissue oxygenation.
- Hyperbaric oxygen therapy is useful in severe poisoning.

6. Draw and label : Respiratory membrane

REFER DIAGRAM SECTION

7.Hypoxia

Hypoxia is deficiency of oxygen at the tissue level.

Types

1. Hypoxic hypoxia – decreased arterial PO_2
2. Anaemic hypoxia – decreased oxygen carrying capacity of blood
3. Stagnant (ischaemic) hypoxia – reduced blood flow to tissues
4. Histotoxic hypoxia – tissues unable to utilize oxygen

Causes

- High altitude
- Respiratory diseases
- Anaemia
- Carbon monoxide poisoning
- Circulatory failure
- Cyanide poisoning

Features

- Dyspnoea
- Cyanosis
- Tachycardia
- Headache

8.Chloride shift

Chloride shift is exchange of bicarbonate ions and chloride ions across red blood cell membrane during transport of carbon dioxide.

Mechanism

- In tissues, carbon dioxide enters red blood cells and forms bicarbonate ions.
- Bicarbonate diffuses into plasma.
- Chloride ions enter red blood cells to maintain electrical neutrality.
- Reverse process occurs in lungs.

Significance

- Helps transport of carbon dioxide as bicarbonate.
- Maintains ionic balance.
- Increases carbon dioxide carrying capacity of blood.

TRANSPORT OF GASES

LONG ESSAYS

1. Oxygen delivery to tissues will be greatly reduced in a patient with carbon monoxide poisoning.

Answer the following:

• What is the physiological basis for reduced oxygen delivery to the tissues?
• Describe the functional significance of oxygen haemoglobin dissociation curve.
• Mention the factors which will shift oxygen dissociation curve to right and left.

Answer

Physiological basis for reduced oxygen delivery to tissues in carbon monoxide poisoning

Carbon monoxide (CO) combines with haemoglobin to form carboxyhaemoglobin.

- Affinity of haemoglobin for carbon monoxide is about 200–250 times greater than oxygen.
- Formation of carboxyhaemoglobin reduces oxygen carrying capacity of blood.
- Carbon monoxide also shifts oxygen-haemoglobin dissociation curve to the left.
- Left shift prevents unloading of oxygen to tissues.
- Hence tissue hypoxia develops despite normal partial pressure of oxygen.

Functional significance of oxygen-haemoglobin dissociation curve

The oxygen-haemoglobin dissociation curve is sigmoid in shape.

Significance

1. **Upper flat portion**
    - Ensures adequate oxygen loading in lungs even when alveolar PO2 falls moderately.
    - Haemoglobin remains highly saturated between PO2 of 60–100 mmHg.
2. **Lower steep portion**
    - Helps rapid unloading of oxygen in tissues.
    - Small fall in tissue PO2 causes large release of oxygen.
3. **Provides oxygen reserve**
    - Blood carries excess oxygen reserve during increased tissue demand.
4. **Helps adaptation during exercise**
    - Increased temperature, carbon dioxide and hydrogen ions shift curve to right and improve oxygen delivery.
5. **Facilitates oxygen transport efficiency**
    - Efficient loading in lungs and unloading in tissues.

Factors shifting oxygen dissociation curve to the right

Right shift decreases affinity of haemoglobin for oxygen and enhances oxygen unloading.

- Increased PCO2
- Increased hydrogen ion concentration (decreased pH)
- Increased temperature
- Increased 2,3-diphosphoglycerate (2,3-DPG)
- Exercise
- Anaemia
- High altitude

Factors shifting oxygen dissociation curve to the left

Left shift increases affinity of haemoglobin for oxygen.

- Decreased PCO2
- Decreased hydrogen ion concentration (increased pH)
- Decreased temperature
- Decreased 2,3-DPG
- Foetal haemoglobin
- Carbon monoxide poisoning

SHORT ESSAYS

2. Describe the transport of oxygen in blood. Add a note on Bohr effect.

Answer

Transport of oxygen in blood

Oxygen is transported in blood in two forms:

1. **Dissolved form**
    - About 3% of oxygen is transported dissolved in plasma.
    - 0.003 mL oxygen dissolves in 100 mL blood per mmHg PO2.
2. **Combined with haemoglobin**
    - About 97% of oxygen is transported as oxyhaemoglobin.
    - 1 gram haemoglobin combines with 1.34 mL oxygen.
    - Oxygen carrying capacity of blood is about 20 mL/100 mL blood.

Oxygen-haemoglobin dissociation curve

- Relationship between PO2 and percentage saturation of haemoglobin.
- Curve is sigmoid due to cooperative binding.

Bohr effect

Bohr effect states that increase in carbon dioxide concentration or hydrogen ion concentration decreases affinity of haemoglobin for oxygen.

Mechanism

- Increased PCO2 and H+ in tissues shift curve to right.
- Oxygen is released easily to tissues.
- In lungs, decreased PCO2 shifts curve to left and promotes oxygen uptake.

Significance

- Facilitates oxygen unloading in tissues.
- Facilitates oxygen loading in lungs.

3. Describe the various methods of carbondioxide (CO2) transport in blood. Add a note on chloride shift.

Answer

Transport of carbon dioxide in blood

Carbon dioxide is transported in three forms:

1. Dissolved form

- About 7% of carbon dioxide is transported dissolved in plasma.

2. As bicarbonate ions

- About 70% is transported as bicarbonate.

- Inside red blood cells, carbon dioxide combines with water to form carbonic acid.
- Reaction is catalysed by carbonic anhydrase.
- Carbonic acid dissociates into hydrogen and bicarbonate ions.
- Bicarbonate diffuses into plasma.

Reaction:

$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$

3. As carbamino compounds

- About 23% combines with proteins and haemoglobin.
- Forms carbaminohaemoglobin.

Chloride shift

Chloride shift is exchange of bicarbonate ions and chloride ions across red blood cell membrane.

Mechanism

- In tissues, bicarbonate leaves red blood cells.
- Chloride enters red blood cells to maintain electrical neutrality.
- In lungs, reverse process occurs.

Significance

- Helps transport of carbon dioxide as bicarbonate.
- Maintains ionic balance.
- Increases carbon dioxide carrying capacity of blood.

4. Describe carbon dioxide transport in the blood

Answer

Carbon dioxide is transported in blood in three forms:

1. Dissolved form

- About 7% dissolved in plasma.

2. As bicarbonate ions

- Major form (about 70%).
- In red blood cells:

$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$

- Catalysed by carbonic anhydrase.
- Bicarbonate diffuses into plasma.
- Chloride shift maintains ionic balance.

3. As carbamino compounds

- About 23% transported combined with haemoglobin.
- Forms carbaminohaemoglobin.

Significance

- Efficient transport of carbon dioxide from tissues to lungs.
- Helps acid-base balance.

5. O_2 transport in blood

Answer

Oxygen is transported in blood in two forms:

1. Dissolved oxygen

- About 3% transported dissolved in plasma.
- Determines PO_2 of blood.

2. Combined with haemoglobin

- About 97% transported as oxyhaemoglobin.
- 1 gram haemoglobin carries 1.34 mL oxygen.
- Oxygen carrying capacity is about 20 mL oxygen/100 mL blood.

Oxygen-haemoglobin dissociation curve

- Sigmoid in shape.
- Shows relation between PO2 and haemoglobin saturation.

Factors affecting oxygen transport

Right shift

- Increased PCO2
- Increased temperature
- Increased H+
- Increased 2,3-DPG

Left shift

- Opposite changes
- Foetal haemoglobin
- Carbon monoxide poisoning

6. Describe the mechanisms of oxygen diffusion across lung

Answer

Oxygen diffuses from alveoli to pulmonary capillary blood due to pressure gradient.

Mechanism

- Alveolar PO2 is about 104 mmHg.
- Pulmonary capillary PO2 is about 40 mmHg.
- Oxygen diffuses across respiratory membrane from high pressure to low pressure.

Layers of respiratory membrane

1. Alveolar fluid layer
2. Alveolar epithelium
3. Basement membrane
4. Interstitial space
5. Capillary basement membrane
6. Capillary endothelium

Factors affecting diffusion

According to Fick's law:

- Directly proportional to:
  - Surface area
  - Pressure gradient
  - Diffusion coefficient
- Inversely proportional to:
  - Thickness of membrane

Diffusing capacity

- Normal diffusing capacity for oxygen is about 21 mL/min/mmHg.
- Increases during exercise.

SHORT ANSWERS

7. Sigmoid shape of the Oxygen Dissociation curve

Answer

- Oxygen-haemoglobin dissociation curve is sigmoid or S-shaped.
- Due to cooperative binding of oxygen with haemoglobin.
- Binding of one oxygen molecule increases affinity for next oxygen molecule.

Significance

- Flat upper part helps oxygen loading in lungs.
- Steep lower part helps oxygen unloading in tissues.

8. Oxygen hemoglobin dissociation curve

Answer

Oxygen-haemoglobin dissociation curve shows relationship between PO2 and percentage saturation of haemoglobin.

Features

- Sigmoid in shape.
- At PO2 of 100 mmHg, haemoglobin saturation is about 97%.
- At PO2 of 40 mmHg, saturation is about 75%.

Right shift

- Increased PCO2
- Increased H+
- Increased temperature
- Increased 2,3-DPG

Left shift

- Opposite changes
- Foetal haemoglobin
- Carbon monoxide poisoning

Significance

- Helps oxygen loading and unloading.

9. Draw and label : Oxygen hemoglobin dissociation curve

REFER DIAGRAM SECTION

10. Transport of CO2 in blood

Answer

Carbon dioxide is transported in blood in three forms:

1. Dissolved in plasma – 7%
2. As bicarbonate ions – 70%
3. As carbamino compounds – 23%

Important points

- Carbonic anhydrase catalyses bicarbonate formation.
- Chloride shift maintains ionic balance.
- Haemoglobin buffers hydrogen ions.

11. Oxygen debt

Answer

Oxygen debt is extra oxygen consumed after exercise to restore body to resting state.

Uses of oxygen debt

- Replenishment of ATP and creatine phosphate
- Conversion of lactic acid to glucose
- Reoxygenation of myoglobin
- Restoration of normal metabolism

12. Draw and label : Effect of pH on the oxygen-haemoglobin dissociation curve

REFER DIAGRAM SECTION

13. Draw and label : The effect of temperature and pH on oxygen dissociation curve

REFER DIAGRAM SECTION

REGULATION OF RESPIRATION

LONG ESSAYS

1. Mention the location of neural centers that regulate respiration. Describe the interaction between the various neural centers in regulation of respiration.

Explain the effect of the transection at different levels in the brainstem.

Answer

Neural centres regulating respiration

Location

Medullary centres

1. Dorsal respiratory group (DRG)
    - Located in nucleus tractus solitarius of medulla.
    - Mainly inspiratory neurons.
2. Ventral respiratory group (VRG)
    - Located in ventrolateral medulla.
    - Contains inspiratory and expiratory neurons.

Pontine centres

1. Pneumotaxic centre
    - Located in upper pons.
    - Limits inspiration.
2. Apneustic centre
    - Located in lower pons.
    - Stimulates inspiration.

Interaction between respiratory centres

Dorsal respiratory group

- Generates basic inspiratory rhythm.
- Sends impulses to diaphragm through phrenic nerve.

Ventral respiratory group

- Functions during forceful breathing.
- Controls inspiratory and expiratory muscles.

Pneumotaxic centre

- Switches off inspiration.
- Regulates rate and depth of breathing.
- Strong stimulation → rapid shallow breathing.

Apneustic centre

- Prolongs inspiration.
- Produces deep breathing.

Overall regulation

- Normal respiration depends on coordinated action of medullary and pontine centres.

Effects of transection at different levels

Above pons

- Respiration remains almost normal.

Between upper and lower pons

- Apneustic breathing occurs.
- Prolonged inspiratory spasms.

Below medulla

- Respiration stops.
- Due to destruction of medullary respiratory centres.

2. Name the respiratory centres. Describe the neural regulation of respiration. Add a note on periodic breathing.

Answer

Respiratory centres

Medullary centres

1. Dorsal respiratory group
2. Ventral respiratory group

Pontine centres

1. Pneumotaxic centre
2. Apneustic centre

Neural regulation of respiration

Dorsal respiratory group

- Main inspiratory centre.
- Produces inspiratory ramp signals.

Ventral respiratory group

- Active during forceful breathing.
- Controls accessory muscles.

Pneumotaxic centre

- Inhibits inspiration.
- Controls respiratory rate.

Apneustic centre

- Stimulates inspiration.
- Produces prolonged inspiration.

Reflex regulation

Hering-Breuer reflex

- Stretch receptors in lungs inhibit inspiration.
- Prevents overinflation.

Higher centres

- Cerebral cortex controls voluntary respiration.
- Hypothalamus affects respiration during emotions.

Periodic breathing

Periodic breathing is cyclic variation in respiration with periods of hyperpnoea and apnoea.

Types

1. Cheyne-Stokes breathing
2. Biot's breathing

Causes

- Congestive cardiac failure
- Brain injury
- High altitude

3.

• Name the location of the respiratory centres.
• Explain their role in the regulation of respiration.
• Describe the mechanisms of periodic breathing.

Answer

Location of respiratory centres

Medulla

- Dorsal respiratory group
- Ventral respiratory group

Pons

- Pneumotaxic centre
- Apneustic centre

Role in regulation of respiration

Dorsal respiratory group

- Generates inspiratory rhythm.

Ventral respiratory group

- Active during forced respiration.

Pneumotaxic centre

- Terminates inspiration.
- Controls respiratory rate.

Apneustic centre

- Stimulates inspiration.
- Increases depth of respiration.

Mechanism of periodic breathing

Periodic breathing occurs due to delayed response of respiratory centres to changes in blood gases.

Cheyne-Stokes breathing

- Alternating periods of hyperventilation and apnoea.
- Due to delayed circulation time and altered sensitivity of respiratory centre.

Mechanism

1. Apnoea increases PCO2.
2. Respiratory centre stimulated.
3. Hyperventilation occurs.
4. Excess CO2 washed out.
5. Respiratory centre depressed.
6. Apnoea recurs.

4. A 20 year old boy climbing a mountain suffered from shortness of breath after reaching about 3200m from sea level.Answer the following :

- **Define hypoxia .**
- **Probable cause of hypoxia in this case .**
- **Characteristic features of different types of hypoxia .**
- **Treatment of hypoxia ?**

• Different types of cyanosis and their causes .

• Define hypoxia .

Hypoxia is a condition in which there is inadequate supply of oxygen to the tissues resulting in deficient tissue oxygenation.

• Probable cause of hypoxia in this case .

The probable cause is **high altitude hypoxia (hypoxic hypoxia)** due to decreased atmospheric pressure at high altitude leading to reduced partial pressure of oxygen in inspired air.

• Characteristic features of different types of hypoxia .

Type of hypoxia	Cause	Arterial PO_2	Venous PO_2	Cyanosis	Examples
Hypoxic hypoxia	Decreased oxygenation of blood	↓ Decreased	↓ Decreased	Present	High altitude, respiratory diseases
Anaemic hypoxia	Reduced oxygen carrying capacity of blood	Normal	↓ Decreased	Usually absent	Anaemia, carbon monoxide poisoning
Stagnant (circulatory) hypoxia	Reduced blood flow to tissues	Normal	Markedly ↓	Present	Heart failure, shock
Histoto	Inabilit	Norm	↑	Abse	Cyani

Type of hypoxia	Cause	Arterial PO_2	Venous PO_2	Cyanosis	Examples
xic hypoxia	y of tissues to utilize oxygen	al	Increased	nt	de poisoning

• Treatment of hypoxia ?

1. Removal of cause.
2. Administration of oxygen therapy.
3. Artificial ventilation if necessary.
4. Blood transfusion in anaemia.
5. Improvement of circulation in circulatory failure.
6. Treatment of poisoning in histotoxic hypoxia.
7. Descent to lower altitude in mountain sickness.

• Different types of cyanosis and their causes .

1. Central cyanosis

Bluish discoloration due to increased reduced haemoglobin in arterial blood.

Causes:

- Respiratory diseases
- Congenital heart diseases
- High altitude hypoxia
- Right to left cardiac shunt

2. Peripheral cyanosis

Bluish discoloration due to excessive oxygen extraction in peripheral tissues because of slow circulation.

Causes:

- Heart failure
- Shock
- Exposure to cold
- Peripheral vascular disease

5. A 30 years old woman presented with history of cough and breathlessness that got worse during the winter months every year. She also complained of occasional whistling sounds arising from the chest during breathing.

Answer the following:

• What is the most likely clinical diagnosis of her condition?

Diagnosis: Bronchial asthma.

• What major findings would her pulmonary function tests show?

Pulmonary function tests in bronchial asthma show:

- Decreased Forced Expiratory Volume in one second (FEV1)
- Decreased FEV1/FVC ratio
- Increased residual volume due to air trapping
- Increased airway resistance
- Reduced peak expiratory flow rate
- Improvement after bronchodilator administration (reversible airway obstruction)

• What kind of medication would she likely benefit from?

The patient benefits from:

- Bronchodilators
  - β2 agonists such as Salbutamol
- Anti-inflammatory drugs
  - Corticosteroids

- Leukotriene antagonists
- Mast cell stabilizers

• Depict the different lung volumes and capacities with the help of a neatly labelled diagram.

Lung Volumes

1. Tidal Volume (TV) – Volume inspired or expired during normal breathing (~500 mL)
2. Inspiratory Reserve Volume (IRV) – Additional volume inspired after normal inspiration (~3000 mL)
3. Expiratory Reserve Volume (ERV) – Additional volume expired after normal expiration (~1100 mL)
4. Residual Volume (RV) – Volume remaining in lungs after forceful expiration (~1200 mL)

Lung Capacities

1. Inspiratory Capacity (IC) = TV + IRV
2. Functional Residual Capacity (FRC) = ERV + RV
3. Vital Capacity (VC) = IRV + TV + ERV
4. Total Lung Capacity (TLC) = VC + RV

Diagram of Lung Volumes and Capacities

REFER DIAGRAM SECTION

6. A 40 years old man was admitted to hospital with complaints of difficulty in breathing and was shortness of breath following a head injury.

Answer the following.

• With the help of diagram describe the two types of periodic breathing in such a patient.

Types of periodic breathing

1. Cheyne–Stokes breathing

Characterized by:

- Gradual increase in depth and rate of breathing
- Followed by gradual decrease
- Followed by apnea
- Cycle repeats regularly

Diagram

REFER DIAGRAM SECTION

Causes

- Heart failure
- Brain injury
- Increased intracranial pressure
- During sleep at high altitude

2. Biot's breathing (Ataxic breathing)

Characterized by:

- Completely irregular breathing
- Irregular periods of apnea
- No rhythmic pattern

Diagram

REFER DIAGRAM SECTION

Causes

- Medullary damage
- Meningitis
- Severe head injury

• Explain the physiological basis for the changes in periodic breathing pattern.

Physiological basis

- Respiratory centers become less sensitive or damaged.
- Delay in circulation between lungs and respiratory center causes delayed feedback.
- Carbon dioxide tension rises during apnea.
- Increased carbon dioxide strongly stimulates respiratory center.
- Hyperventilation occurs leading to excessive removal of carbon dioxide.
- Carbon dioxide falls below threshold leading to apnea again.
- This cycle repeats producing periodic breathing.

• Describe the role of peripheral chemoreceptors in regulation of normal respiration.

Peripheral chemoreceptors

Location

- Carotid bodies at bifurcation of common carotid arteries
- Aortic bodies in arch of aorta

Stimuli

- Decreased arterial oxygen tension (most powerful stimulus)
- Increased arterial carbon dioxide tension
- Increased hydrogen ion concentration

Mechanism

- Chemoreceptors are stimulated by hypoxia.
- Impulses travel through:
  - Glossopharyngeal nerve from carotid body
  - Vagus nerve from aortic body
- Signals reach respiratory center in medulla.
- Ventilation increases.

Functions

- Maintain normal arterial oxygen level
- Increase respiration during hypoxia
- Important in chronic lung disease

7. A road traffic accident victim was found to be unconscious and breathing in an irregular rhythm. From your knowledge of physiology answer the following :

• Name two types of periodic breathing.

1. Cheyne–Stokes breathing
2. Biot's breathing

• Explain the neural regulation of respiration.

Neural regulation of respiration

Respiration is regulated by respiratory centers situated in medulla and pons.

1. Medullary centers

a) Dorsal respiratory group (DRG)

- Situated in nucleus tractus solitarius
- Mainly inspiratory neurons
- Produces normal quiet inspiration

b) Ventral respiratory group (VRG)

- Contains inspiratory and expiratory neurons

- Active during forceful breathing

2. Pontine centers

a) Pneumotaxic center

- Located in upper pons
- Inhibits inspiration
- Regulates respiratory rate and depth

b) Apneustic center

- Located in lower pons
- Stimulates inspiration
- Produces prolonged inspiration

3. Higher centers

- Cerebral cortex permits voluntary control
- Hypothalamus and limbic system affect respiration during emotions

4. Reflex regulation

Hering–Breuer inflation reflex

- Stretch receptors in lungs stimulated during inflation
- Impulses pass through vagus nerve
- Inhibits inspiration and prevents overinflation

• What is the mechanism of function of medullary chemoreceptors?

Medullary chemoreceptors

Location

- Ventrolateral surface of medulla

Stimulus

- Increased hydrogen ion concentration in cerebrospinal fluid produced by carbon dioxide

Mechanism

- Carbon dioxide diffuses across blood brain barrier.
- In cerebrospinal fluid it forms carbonic acid.
- Carbonic acid dissociates into hydrogen ions.
- Hydrogen ions stimulate medullary chemoreceptors.
- Respiratory center is stimulated.
- Ventilation increases.
- Excess carbon dioxide is removed.

Importance

- Major regulator of respiration
- Responsible for approximately 70% stimulation of ventilation by carbon dioxide

SHORT ESSAYS

8. Draw and label the respiratory centers. Describe Hering-Breuer inflation reflex.

Respiratory centers

Medullary centers

1. Dorsal respiratory group (Inspiratory center)
2. Ventral respiratory group

Pontine centers

1. Pneumotaxic center
2. Apneustic center

Diagram

REFER DIAGRAM SECTION

Hering–Breuer inflation reflex

Definition

Reflex inhibition of inspiration produced by overdistension of lungs.

Receptors

Stretch receptors in smooth muscle of bronchi and bronchioles.

Pathway

- Afferent pathway: Vagus nerve
- Center: Medulla
- Efferent pathway: Respiratory muscles

Mechanism

- Lung inflation stimulates stretch receptors.
- Impulses pass via vagus nerve to inspiratory center.
- Inspiratory neurons are inhibited.
- Inspiration stops and expiration begins.

Functions

- Prevents overinflation of lungs
- Protects lung tissue
- More important in infants and during exercise

9. Where are the chemoreceptors situated. How do they regulate respiration.

Chemoreceptors

1. Central chemoreceptors

Situation

- Ventrolateral surface of medulla

Stimulus

- Increased hydrogen ion concentration in cerebrospinal fluid

Action

- Stimulate respiratory center
- Increase ventilation

2. Peripheral chemoreceptors

Situation

1. Carotid bodies at bifurcation of common carotid arteries
2. Aortic bodies in arch of aorta

Stimuli

- Decreased oxygen tension
- Increased carbon dioxide tension
- Increased hydrogen ion concentration

Regulation of respiration

- Chemoreceptors send impulses to medullary respiratory center.
- Ventilation increases.
- Helps maintain normal oxygen and carbon dioxide levels.

10. Chemical regulation of respiration

Chemical regulation of respiration

Respiration is regulated mainly by:

1. Carbon dioxide
2. Hydrogen ions
3. Oxygen

1. Regulation by carbon dioxide

- Most important chemical regulator
- Increased carbon dioxide stimulates medullary chemoreceptors indirectly.
- Ventilation increases.

Mechanism

Carbon dioxide + Water → Carbonic acid → Hydrogen ions

Hydrogen ions stimulate respiratory center.

2. Regulation by hydrogen ions

- Increased hydrogen ion concentration stimulates respiration.
- Important in metabolic acidosis.

3. Regulation by oxygen

- Decreased arterial oxygen tension stimulates peripheral chemoreceptors.
- Ventilation increases.
- Significant when arterial oxygen pressure falls below 60 mm Hg.

Importance

- Maintains acid–base balance
- Maintains normal oxygen and carbon dioxide levels

11. Explain the neural regulation of respiration

Neural regulation of respiration

Respiratory centers

1. Medullary centers

a) Dorsal respiratory group

- Inspiratory center
- Generates normal rhythm of breathing

b) Ventral respiratory group

- Contains inspiratory and expiratory neurons
- Active during forceful respiration

2. Pontine centers

a) Pneumotaxic center

- Limits inspiration
- Increases respiratory rate

b) Apneustic center

- Stimulates inspiration
- Produces prolonged inspiration

Reflex control

Hering–Breuer reflex

- Prevents overinflation of lungs

Irritant receptor reflex

- Causes cough and bronchoconstriction

J receptor reflex

- Causes rapid shallow breathing

Higher control

- Cerebral cortex: voluntary control
- Hypothalamus: emotional influence

12. Describe the neural control of respiration and add a note on Cheyne-stokes breathing

Neural control of respiration

Respiratory centers

1. Dorsal respiratory group
2. Ventral respiratory group
3. Pneumotaxic center
4. Apneustic center

Functions

- Maintain rhythmic respiration
- Regulate depth and rate of breathing

Reflexes

- Hering–Breuer reflex
- Irritant receptor reflex
- Proprioceptor reflex

Cheyne–Stokes breathing

Definition

Periodic breathing characterized by alternating periods of hyperpnea and apnea.

Features

- Gradual increase in respiration
- Gradual decrease in respiration
- Followed by apnea

Causes

- Congestive heart failure
- Brain injury
- High altitude
- Deep sleep

Mechanism

Delayed response of respiratory center to changes in carbon dioxide tension causes oscillation in breathing pattern.

13. Explain the neural regulation of respiration

Neural regulation of respiration

Respiratory centers

Medullary centers

- Dorsal respiratory group
- Ventral respiratory group

Pontine centers

- Pneumotaxic center
- Apneustic center

Functions

- Generate rhythmic respiration
- Control inspiration and expiration
- Modify respiratory rate and depth

Reflexes regulating respiration

1. Hering–Breuer reflex
2. Irritant receptor reflex
3. J receptor reflex
4. Proprioceptor reflex

Higher centers

- Cerebral cortex controls voluntary respiration.
- Hypothalamus affects respiration during emotions.

14. Describe the role of chemo-receptors in regulation of respiration

Chemoreceptors in regulation of respiration

Types

1. Central chemoreceptors

2. Peripheral chemoreceptors

Central chemoreceptors

Location

- Ventrolateral medulla

Stimulus

- Increased hydrogen ion concentration in cerebrospinal fluid

Action

- Increase pulmonary ventilation

Peripheral chemoreceptors

Location

- Carotid bodies
- Aortic bodies

Stimuli

- Hypoxia
- Hypercapnia
- Increased hydrogen ion concentration

Pathway

- Glossopharyngeal and vagus nerves carry impulses to medulla.

Functions

- Rapid adjustment of respiration
- Important in hypoxia
- Maintain arterial blood gases

SHORT ANSWERS

15. write the physiological basis of infant distress respiratory syndrome

Infant respiratory distress syndrome

Physiological basis

- Occurs mainly in premature infants.
- Due to deficiency of pulmonary surfactant.
- Surfactant is produced by type II alveolar cells.
- Absence of surfactant increases surface tension.
- Alveoli collapse during expiration (atelectasis).
- Lung compliance decreases.
- Work of breathing increases.
- Severe hypoxia develops.

Clinical features

- Dyspnea
- Cyanosis
- Respiratory failure

16. Hering – Breuer reflex

Definition

Reflex inhibition of inspiration due to overdistension of lungs.

Receptors

Stretch receptors in lungs.

Pathway

- Afferent: Vagus nerve
- Center: Medulla
- Efferent: Respiratory muscles

Mechanism

- Inflation of lungs stimulates stretch receptors.
- Inspiratory center inhibited.
- Expiration starts.

Functions

- Prevents overinflation
- Protects lungs

17. How is hypoxia classified. Explain any one in detail.

Classification of hypoxia

1. Hypoxic hypoxia

- Due to low arterial oxygen tension

2. Anemic hypoxia

- Due to decreased oxygen carrying capacity of blood

3. Stagnant (circulatory) hypoxia

- Due to reduced blood flow

4. Histotoxic hypoxia

- Due to inability of tissues to utilize oxygen

Hypoxic hypoxia in detail

Definition

Deficiency of oxygen at tissue level due to reduced arterial oxygen tension.

Causes

- High altitude
- Respiratory diseases
- Hypoventilation
- Diffusion defects

Features

- Cyanosis
- Dyspnea
- Tachycardia
- Mental confusion

Compensation

- Hyperventilation
- Increased erythropoietin secretion
- Polycythemia

Treatment

- Oxygen therapy
- Treat underlying cause

18. Cyanosis

Definition

Bluish discoloration of skin and mucous membrane due to increased reduced hemoglobin in blood above 5 g/dL.

Types

1. Central cyanosis

- Due to decreased arterial oxygen saturation.
- Seen in respiratory and cardiac diseases.

2. Peripheral cyanosis

- Due to sluggish blood flow and increased oxygen extraction.
- Seen in circulatory failure and exposure to cold.

Causes

- Hypoxia
- Congenital heart disease
- Respiratory diseases
- Circulatory failure

19. Cheyne-stokes breathing

Definition

A type of periodic breathing characterized by alternating phases of apnea and hyperpnea with waxing and waning respiration.

Causes

- Congestive cardiac failure
- Cerebral lesions
- Increased intracranial pressure
- Uremia
- During sleep in elderly persons

Mechanism

Delayed transport of blood gases to respiratory center causes instability of respiratory control.

20. Explain the physiological basis of Chvostek's sign

Chvostek's sign

Twitching of facial muscles produced by tapping over facial nerve in front of ear.

Physiological basis

- Seen in hypocalcemia.
- Low calcium increases neuromuscular excitability.
- Facial nerve becomes hyperexcitable.
- Tapping the nerve produces contraction of facial muscles.

21. Draw and label Physiological organisation of respiratory centres

Physiological organisation of respiratory centres

Medullary centers

1. Dorsal respiratory group

- Present in nucleus tractus solitarius.
- Mainly inspiratory neurons.
- Responsible for normal quiet breathing.

2. Ventral respiratory group

- Present in ventrolateral medulla.
- Contains inspiratory and expiratory neurons.
- Active during forced breathing.

Pontine centers

1. Pneumotaxic center

- Present in upper pons.
- Inhibits inspiration.
- Regulates respiratory rate.

2. Apneustic center

- Present in lower pons.
- Stimulates inspiration.
- Produces prolonged inspiration.

Diagram

REFER DIAGRAM SECTION

22. Respiratory rhythm

Definition

Regular rhythmic alternation of inspiration and expiration.

Mechanism

- Generated mainly by dorsal respiratory group in medulla.
- Inspiratory neurons show ramp signals.

- Inspiration occurs due to inspiratory discharge.
- Expiration is passive during quiet breathing.
- Pontine centers modify rhythm.
- Chemoreceptors and higher centers influence rhythm.

23. Peripheral chemo receptors

Definition

Chemoreceptors located outside central nervous system sensitive to changes in blood gases.

Types

1. Carotid bodies

- Located at bifurcation of common carotid artery.

2. Aortic bodies

- Located in arch of aorta.

Stimuli

- Decreased oxygen tension
- Increased carbon dioxide tension
- Increased hydrogen ion concentration

Functions

- Stimulate respiration during hypoxia.
- Important in regulation of ventilation.

24. Dyspnoeic index

Definition

Ratio between pulmonary ventilation and maximum breathing capacity expressed in percentage.

Formula

$$\textbf{Dyspnoeic index} = \frac{\textbf{Pulmonary ventilation}}{\textbf{Maximum breathing capacity}} \times 100$$

Significance

- Indicates respiratory reserve.
- Increased in respiratory diseases.
- Dyspnea occurs when dyspnoeic index exceeds about 50%.

25. Periodic breathing

Definition

Breathing pattern characterized by alternating periods of apnea and hyperpnea.

Types

- Cheyne-Stokes breathing
- Biot breathing

Causes

- Heart failure
- Brain damage
- High altitude
- Drug depression

Mechanism

Instability of respiratory center due to delayed chemical regulation of breathing.

ENVIRONMENTAL PHYSIOLOGY

LONG ESSAYS

1. Eighteen hours after arrival at an altitude of 12000 feet, a man has headache, irritability, insomnia, breathlessness, nausea and vomiting.

Answer the following :

• What is he suffering from ?
• What are the changes taking place in the body systems during acclimatization to high altitude ?
• Explain the physiological basis of these changes .

Diagnosis : Altitude sickness (Acute mountain sickness)

Definition

A condition occurring in non-acclimatized persons after rapid ascent to high altitude due to hypoxia.

Symptoms

- Headache
- Irritability
- Insomnia
- Breathlessness
- Nausea and vomiting
- Fatigue
- Dizziness

Changes taking place in the body systems during acclimatization to high altitude

1. Respiratory system

- Hyperventilation occurs.
- Pulmonary diffusion capacity increases.
- Vital capacity increases slightly.

2. Blood

- Polycythemia develops.
- Hemoglobin percentage increases.
- Hematocrit increases.
- Red blood cell count increases.
- 2,3-Diphosphoglycerate level increases.

3. Cardiovascular system

- Heart rate increases initially.
- Cardiac output increases initially.
- Later cardiac output returns near normal.
- Systemic blood pressure changes little.

4. Renal system

- Increased bicarbonate excretion.
- Diuresis occurs.
- Correction of respiratory alkalosis.

5. Tissue changes

- Increased capillary density.
- Increased mitochondria.
- Increased oxidative enzymes.
- Better oxygen utilization by tissues.

6. Central nervous system

- Chemoreceptor sensitivity increases.
- Respiratory center becomes more responsive to hypoxia.

Physiological basis of these changes

1. Hyperventilation

Hypoxia stimulates peripheral chemoreceptors in carotid and aortic bodies leading to increased ventilation.

2. Increased red blood cell production

Hypoxia stimulates erythropoietin secretion from kidneys causing polycythemia and increased oxygen carrying capacity.

3. Increased 2,3-Diphosphoglycerate

Shifts oxyhemoglobin dissociation curve to the right facilitating oxygen unloading to tissues.

4. Increased pulmonary diffusion capacity

Due to increased pulmonary blood flow and better alveolar expansion.

5. Renal compensation

Hyperventilation causes respiratory alkalosis. Kidneys excrete bicarbonate to restore acid-base balance.

6. Increased tissue efficiency

Increase in capillary density, mitochondria and oxidative enzymes improves tissue oxygen utilization.

Conclusion

Acclimatization is the adaptive response of the body to chronic hypoxia at high altitude.

SHORT ESSAYS

2. Describe the respiratory adjustments in isotonic exercise. Why isometric exercise is not advised in cardiac patients

Respiratory adjustments in isotonic exercise

1. Increased pulmonary ventilation

- Both rate and depth of respiration increase.
- Minute ventilation increases.

2. Increased oxygen consumption

- Oxygen uptake by muscles increases.

3. Increased carbon dioxide output

- Due to increased metabolism.

4. Increased alveolar ventilation

- Better gas exchange occurs.

5. Increased pulmonary blood flow

- Improves oxygen transport.

6. Mechanism

- Stimulation of motor cortex.
- Proprioceptor stimulation from muscles and joints.
- Increased carbon dioxide and hydrogen ions stimulate respiratory center.

Why isometric exercise is not advised in cardiac patients

- Isometric exercise causes sustained muscle contraction.
- Peripheral resistance increases markedly.
- Both systolic and diastolic blood pressure rise.
- Cardiac workload and myocardial oxygen demand increase.
- May precipitate angina, arrhythmia or cardiac failure.

3. Describe the pathophysiology of nitrogen narcosis. Add a note on its management

Nitrogen narcosis

Definition

A condition occurring in deep sea divers due to increased partial pressure of nitrogen at high atmospheric pressure.

Pathophysiology

- At high pressure, excess nitrogen dissolves in body tissues.
- Nitrogen especially dissolves in lipid rich nervous tissue.
- It depresses neuronal activity similar to anesthetic agents.
- Causes altered synaptic transmission in brain.

Features

- Euphoria
- Impaired judgment
- Confusion
- Drowsiness
- Incoordination
- Hallucinations
- Loss of consciousness in severe cases

Management

- Ascend slowly to lower pressure.
- Use helium-oxygen mixture instead of nitrogen-oxygen mixture.
- Avoid deep dives.
- Proper diver training.

4. Describe the cardio-respiratory adjustments in high altitude.

Respiratory adjustments

1. Hyperventilation

Due to stimulation of peripheral chemoreceptors by hypoxia.

2. Increased pulmonary diffusion capacity

Improves oxygen transfer.

3. Increased vital capacity

Occurs gradually.

4. Increased sensitivity of respiratory center

Enhances ventilation.

Cardiovascular adjustments

1. Increased heart rate

Occurs initially.

2. Increased cardiac output

Improves oxygen delivery.

3. Increased pulmonary arterial pressure

Due to hypoxic pulmonary vasoconstriction.

4. Increased red blood cell production

Due to erythropoietin secretion.

5. Increased capillary density

Improves tissue oxygenation.

5. Discuss the compensatory changes at high altitude.

Compensatory changes at high altitude

Respiratory changes

- Hyperventilation
- Increased pulmonary diffusion capacity
- Increased respiratory center sensitivity

Hematological changes

- Polycythemia
- Increased hemoglobin
- Increased hematocrit
- Increased 2,3-Diphosphoglycerate

Cardiovascular changes

- Increased cardiac output initially
- Increased heart rate
- Increased capillary density

Renal changes

- Increased bicarbonate excretion
- Diuresis

Tissue changes

- Increased mitochondria
- Increased oxidative enzymes
- Improved oxygen utilization

6. Discuss the cause and clinical features and treatment of dysbarism

Dysbarism

Definition

Disorders caused by changes in atmospheric pressure.

Causes

- Rapid ascent from deep sea.
- Rapid ascent to high altitude.
- Failure of pressure equalization.

Clinical features

Decompression sickness

- Joint pain
- Muscle pain
- Breathlessness
- Paralysis
- Giddiness
- Shock

Barotrauma

- Ear pain
- Sinus pain
- Lung injury

Treatment

- Recompression therapy in hyperbaric chamber.
- Slow decompression.
- Oxygen administration.
- Adequate hydration.

SHORT ANSWERS

7. Caisson disease or decompression sickness

Definition

Condition occurring due to rapid decompression after exposure to high pressure.

Cause

Rapid reduction in pressure causes dissolved nitrogen to come out as bubbles.

Effects

- Joint pain (bends)
- Choking
- Paralysis
- Embolism

Treatment

- Recompression therapy
- Oxygen administration

- Slow decompression

8. Describe physiological mechanisms to reduce the effects of hypoxia in natives of high altitude.

Mechanisms

- Hyperventilation
- Polycythemia
- Increased hemoglobin
- Increased capillary density
- Increased pulmonary diffusion capacity
- Increased 2,3-Diphosphoglycerate
- Increased oxidative enzymes
- Better tissue oxygen utilization

9. Explain the physiological basis of symptoms in decompression sickness.

Physiological basis

- At high pressure, nitrogen dissolves in tissues.
- Rapid decompression forms nitrogen bubbles.
- Bubbles obstruct blood vessels causing ischemia.
- Joint pain occurs due to bubbles in joints.
- Neurological symptoms occur due to embolism in nervous tissue.
- Pulmonary symptoms occur due to obstruction of pulmonary vessels.

10. Dysbarism

Definition

Physiological disturbances produced by changes in atmospheric pressure.

Types

- Decompression sickness
- Barotrauma
- Altitude sickness

Features

- Joint pain
- Breathlessness
- Ear pain
- Giddiness

Prevention

- Slow decompression
- Use of pressure chambers

11. Acute respiratory distress syndrome is seen in premature infants. Why?

- Premature infants lack sufficient surfactant.
- Surfactant is produced by type II alveolar cells.
- Deficiency increases surface tension.
- Alveoli collapse leading to respiratory distress.
- Condition is called hyaline membrane disease.

12. Hyperventilation is seen when low landers travel to high altitude. Why?

- High altitude causes hypoxia due to low partial pressure of oxygen.
- Hypoxia stimulates carotid and aortic body chemoreceptors.
- Respiratory center is stimulated.
- Ventilation increases causing hyperventilation.

13. Decompression sickness

Definition

Condition caused by rapid reduction of atmospheric pressure after exposure to high pressure.

Cause

Formation of nitrogen bubbles in tissues and blood.

Features

- Bends
- Chokes
- Paralysis

Treatment

- Hyperbaric oxygen therapy
- Slow decompression

14. Prolonged stay at high altitude increases the hematocrit. Why?

- High altitude causes hypoxia.
- Hypoxia stimulates erythropoietin secretion from kidneys.
- Erythropoietin increases red blood cell production.
- Hematocrit and hemoglobin increase.

15. Hypoxic hypoxia

Definition

A type of hypoxia in which arterial oxygen tension is reduced.

Causes

- High altitude
- Respiratory diseases
- Hypoventilation

Features

- Cyanosis
- Dyspnea
- Tachycardia

Treatment

- Oxygen therapy
- Treatment of underlying cause

16. Acclimatization in high altitude

Definition

Adaptive changes occurring in the body on prolonged exposure to high altitude.

Changes

- Hyperventilation
- Polycythemia
- Increased cardiac output initially
- Increased capillary density
- Increased pulmonary diffusion capacity
- Increased tissue oxidative capacity

ARTIFICIAL RESPIRATION

SHORT ANSWERS

1. Mouth to mouth respiration is the best form of artificial respiration

Reasons

- Expired air contains about 16% oxygen.
- Adequate ventilation can be provided.
- Simple and rapid method.
- No equipment required.
- Effective in emergency situations.

GASTROINTESTINAL SYSTEM

INTRODUCTION

SHORT ESSAYS

1. Describe the mechanisms of digestion and absorption of fat along the gastrointestine

Digestion of fat

In mouth

- Minimal digestion by lingual lipase.

In stomach

- Gastric lipase causes slight fat digestion.

In small intestine

Main site of fat digestion.

Role of bile salts

- Emulsification of fats.
- Breaks large fat globules into small droplets.
- Increases surface area for enzyme action.

Pancreatic enzymes

Pancreatic lipase

- Converts triglycerides into monoglycerides and fatty acids.

Cholesterol esterase

- Digests cholesterol esters.

Phospholipase

- Digests phospholipids.

Absorption of fat

Formation of micelles

- Fatty acids and monoglycerides combine with bile salts to form micelles.
- Micelles transport lipids to intestinal mucosa.

Absorption into intestinal cells

- Fatty acids and monoglycerides diffuse into mucosal cells.

Re-esterification

- Triglycerides are reformed inside mucosal cells.

Chylomicron formation

- Triglycerides combine with proteins to form chylomicrons.

Transport

- Chylomicrons enter lacteals.
- Transported through lymphatics to blood.

Absorption of short chain fatty acids

- Directly absorbed into portal blood.

Functions of bile salts in fat absorption

- Emulsification
- Micelle formation
- Facilitate absorption of fat soluble vitamins A, D, E and K.

2.Describe the enteric nervous system.

Definition

Enteric nervous system is the intrinsic nervous system of the gastrointestinal tract present in the wall of the gut extending from esophagus to anus.

Components

1. **Myenteric plexus (Auerbach's plexus)**
    - Present between longitudinal and circular muscle layers.
    - Controls gastrointestinal motility.
2. **Submucosal plexus (Meissner's plexus)**
    - Present in submucosa.
    - Controls secretion and local blood flow.

Neurotransmitters

- Acetylcholine
- Noradrenaline
- Serotonin
- Dopamine
- Nitric oxide
- Vasoactive intestinal peptide
- Substance P

Functions

1. Controls gastrointestinal motility.
2. Regulates secretion.
3. Coordinates peristalsis.
4. Regulates local blood flow.
5. Mediates local reflexes.

Applied aspect

Absence of enteric ganglion cells causes Hirschsprung disease.

Write the physiological basis for achalasia cardia.

Definition

Achalasia cardia is a motor disorder of the esophagus characterized by failure of relaxation of lower esophageal sphincter.

Physiological basis

1. Degeneration of myenteric plexus in lower esophagus.
2. Loss of inhibitory neurons secreting nitric oxide and vasoactive intestinal peptide.
3. Failure of relaxation of lower esophageal sphincter during swallowing.
4. Absence of normal peristalsis in lower esophagus.
5. Food accumulates causing dilatation of esophagus.

Clinical features

- Dysphagia
- Regurgitation
- Chest pain

SALIVARY GLANDS AND ESOPHAGUS

SHORT ESSAYS

1.Components and functions of saliva

Definition

Saliva is a mixed secretion produced by salivary glands.

Composition of saliva

1. Water

- About 99.5%

2. Organic constituents

- Ptyalin (salivary amylase)
- Lingual lipase
- Mucin
- Lysozyme
- Immunoglobulin A

- Urea and uric acid

3. Inorganic constituents

- Sodium
- Potassium
- Chloride
- Bicarbonate
- Phosphate
- Calcium

Properties

- Daily secretion: 1000–1500 mL/day
- pH: 6.0–7.4
- Hypotonic to plasma

Functions of saliva

Digestive functions

1. Ptyalin digests starch.
2. Lingual lipase digests fat.

Lubricating function

3. Mucin lubricates food and aids swallowing.

Protective functions

4. Cleans oral cavity.
5. Antibacterial action by lysozyme and IgA.
6. Prevents dental caries.

Taste sensation

7. Dissolves substances for taste perception.

Speech

8. Facilitates speech.

Excretory function

9. Excretes urea, uric acid and some drugs.

Buffering action

10. Bicarbonate buffers acids.

Applied aspect

Dry mouth is called xerostomia.

SHORT ANSWERS

2.Describe the pathophysiology in achalasia cardia

Pathophysiology

1. Degeneration of ganglion cells in myenteric plexus.
2. Loss of inhibitory neurotransmitters like nitric oxide and vasoactive intestinal peptide.
3. Failure of lower esophageal sphincter relaxation.
4. Absence of normal peristaltic waves.
5. Progressive dilatation of esophagus.
6. Food stasis produces dysphagia and regurgitation.

3.Composition and functions of saliva

Composition

Water

- 99.5%

Organic substances

- Ptyalin
- Mucin
- Lysozyme
- Immunoglobulin A
- Lingual lipase

Inorganic substances

- Sodium
- Potassium
- Chloride
- Bicarbonate
- Phosphate

Functions

1. Digestion of starch by ptyalin.
2. Lubrication of food.
3. Helps swallowing.
4. Cleans oral cavity.
5. Antibacterial action.
6. Facilitates taste sensation.
7. Buffers acids.
8. Helps speech.

4.Stages of deglutition

Definition

Deglutition means swallowing.

Stages

1. Oral stage (voluntary)

- Food bolus pushed into pharynx by tongue.

2. Pharyngeal stage (involuntary)

- Soft palate closes nasopharynx.
- Vocal cords close.
- Epiglottis closes laryngeal opening.
- Upper esophageal sphincter relaxes.

3. Esophageal stage (involuntary)

- Peristaltic waves propel food through esophagus.
- Lower esophageal sphincter relaxes.

5.Functions of saliva

1. Digestion of starch by salivary amylase.
2. Lubrication of food.
3. Facilitates swallowing.
4. Cleans mouth.
5. Antibacterial action.
6. Helps in taste sensation.
7. Buffers acids.
8. Protects teeth from caries.
9. Facilitates speech.
10. Excretion of certain substances.

STOMACH

LONG ESSAYS

1.Describe the composition and functions of gastric juice. Describe various phases and regulation of gastric secretion.

Gastric juice

Gastric juice is the secretion of gastric glands.

Composition of gastric juice

Inorganic constituents

- Hydrochloric acid
- Sodium chloride
- Potassium chloride
- Bicarbonate

Organic constituents

1. Pepsinogen
2. Gastric lipase
3. Rennin (in infants)
4. Intrinsic factor
5. Mucus

Functions of gastric juice

Functions of hydrochloric acid

1. Activates pepsinogen into pepsin.
2. Provides acidic pH.
3. Bactericidal action.
4. Helps iron absorption.

Functions of pepsin

5. Digests proteins into peptides.

Functions of rennin

6. Coagulates milk in infants.

Functions of gastric lipase

7. Digests fats slightly.

Functions of intrinsic factor

8. Necessary for vitamin B12 absorption.

Functions of mucus

9. Protects gastric mucosa.

Phases of gastric secretion

1. Cephalic phase

- Stimulated by sight, smell, taste and thought of food.
- Mediated through vagus nerve.
- Contributes about 30% of secretion.

2. Gastric phase

- Stimulated by food in stomach.
- Gastric distension activates local and vagovagal reflexes.
- Proteins stimulate gastrin release.
- Contributes about 60% of secretion.

3. Intestinal phase

- Small amount of secretion due to intestinal gastrin.
- Later inhibited by enterogastric reflex.
- Contributes about 10%.

Regulation of gastric secretion

Neural regulation

- Vagus nerve stimulates secretion.
- Acetylcholine acts on parietal and chief cells.

Hormonal regulation

1. Gastrin stimulates acid secretion.
2. Histamine stimulates HCl secretion.
3. Secretin inhibits gastric secretion.
4. Gastric inhibitory peptide inhibits secretion.

Mechanism of inhibition

- Low pH inhibits gastrin release.
- Fat in intestine inhibits gastric secretion.

2.List the cells and secretion from the Oxyntic gland of the stomach.

• With the help of a diagram explain the mechanism of gastric acid secretion
• Explain the phases of gastric acid secretion

Cells of oxyntic gland and their secretions

Cells	Secretion
Parietal cells	Hydrochloric acid and intrinsic factor
Chief cells	Pepsinogen
Mucous neck cells	Mucus
Enterochromaffin like cells	Histamine

Mechanism of gastric acid secretion

Mechanism

1. Carbon dioxide combines with water inside parietal cell.
2. Carbonic anhydrase forms carbonic acid.
3. Carbonic acid dissociates into hydrogen and bicarbonate ions.
4. Hydrogen ions are secreted into canaliculus by H+-K+ ATPase pump.
5. Chloride ions diffuse into canaliculus.
6. Hydrogen and chloride form hydrochloric acid.
7. Bicarbonate enters blood causing alkaline tide.

Regulation

1. Acetylcholine stimulates parietal cells.
2. Gastrin stimulates acid secretion.
3. Histamine acts through H2 receptors.

Phases of gastric acid secretion

1. Cephalic phase

- Stimulated by sight, smell and taste of food.
- Mediated by vagus nerve.

2. Gastric phase

- Due to gastric distension and gastrin release.
- Major phase of secretion.

3. Intestinal phase

- Mild stimulation followed by inhibition.

SHORT ESSAYS

3.Describe the mechanism of secretion of HCl. Add note on management of peptic ulcer.

Mechanism of HCl secretion

1. Carbon dioxide combines with water.
2. Carbonic acid formed by carbonic anhydrase.
3. Carbonic acid dissociates into hydrogen and bicarbonate ions.
4. Hydrogen ions secreted by proton pump.
5. Chloride ions secreted into lumen.
6. Hydrochloric acid formed in canaliculi.

Stimulators

- Acetylcholine
- Gastrin
- Histamine

Management of peptic ulcer

General measures

1. Avoid smoking and alcohol.
2. Avoid spicy food.
3. Reduce stress.

Drugs

1. Proton pump inhibitors.
2. H2 receptor blockers.
3. Antacids.
4. Antibiotics for Helicobacter pylori.

Surgery

- Vagotomy in resistant cases.

4.Explain the factors regulating gastric emptying.

Gastric factors promoting emptying

1. Gastric distension increases motility.
2. Gastrin stimulates gastric contractions.

Duodenal factors inhibiting emptying

1. Fat in duodenum.
2. Acidic chyme.
3. Hyperosmolar chyme.
4. Distension of duodenum.

Mechanism

- Enterogastric reflex inhibits gastric motility.
- Hormones like secretin and cholecystokinin inhibit emptying.

5.Describe the regulation of the different phases of gastric secretion.

1. Cephalic phase

Stimuli

- Sight, smell, taste and thought of food.

Pathway

- Mediated through vagus nerve.

Mechanism

- Acetylcholine stimulates parietal and chief cells.

2. Gastric phase

Stimuli

- Distension of stomach.
- Presence of proteins.

Mechanism

- Local reflexes.
- Vagovagal reflex.
- Gastrin secretion.

3. Intestinal phase

Early phase

- Intestinal gastrin causes mild stimulation.

Late phase

- Enterogastric reflex inhibits secretion.
- Secretin and cholecystokinin inhibit gastric secretion.

6.Describe the phases of deglutition. Add a note on Achalasia cardia

Phases of deglutition

1. Oral stage

- Voluntary stage.
- Tongue pushes food into pharynx.

2. Pharyngeal stage

- Involuntary stage.
- Soft palate closes nasopharynx.
- Epiglottis closes larynx.
- Upper esophageal sphincter relaxes.

3. Esophageal stage

- Peristaltic waves move food.
- Lower esophageal sphincter relaxes.

Achalasia cardia

Definition

Failure of relaxation of lower esophageal sphincter.

Cause

Degeneration of myenteric plexus.

Features

- Dysphagia
- Regurgitation
- Dilated esophagus

7.Describe the phases of gastric secretion. How is it regulated.

Phases of gastric secretion

1. Cephalic phase

- Stimulated by sight, smell and taste of food.
- Mediated by vagus nerve.

2. Gastric phase

- Due to gastric distension and gastrin release.

3. Intestinal phase

- Mild stimulation followed by inhibition.

Regulation

Neural factors

- Vagus nerve
- Enteric nervous system

Hormonal factors

Stimulatory

- Gastrin
- Histamine

Inhibitory

- Secretin
- Gastric inhibitory peptide
- Cholecystokinin

8.Explain the regulation of gastric juice secretion in different phases

Cephalic phase

- Triggered by sight, smell, taste and thought of food.
- Vagal stimulation causes secretion.

Gastric phase

- Gastric distension stimulates secretion.
- Gastrin released by G cells.

Intestinal phase

- Initially slight stimulation.
- Later inhibition by enterogastric reflex and intestinal hormones.

9.Describe the mechanism of gastric acid secretion

1. Carbon dioxide and water form carbonic acid.
2. Carbonic anhydrase catalyzes the reaction.
3. Carbonic acid dissociates into hydrogen and bicarbonate ions.
4. Hydrogen ions secreted by H+-K+ ATPase.
5. Chloride ions diffuse into lumen.
6. Hydrochloric acid formed in canaliculus.
7. Bicarbonate enters blood causing alkaline tide.

Stimulators

- Acetylcholine
- Gastrin
- Histamine

10.Describe the functions and regulation of hydrochloric acid secretion

Functions of hydrochloric acid

1. Activates pepsinogen.
2. Provides acidic pH for pepsin.
3. Bactericidal action.
4. Helps absorption of iron.
5. Prevents bacterial overgrowth.

Regulation of hydrochloric acid secretion

Neural regulation

- Vagus nerve through acetylcholine.

Hormonal regulation

1. Gastrin stimulates parietal cells.
2. Histamine stimulates H2 receptors.

Inhibition

1. Secretin inhibits secretion.
2. Gastric inhibitory peptide inhibits secretion.
3. Low pH inhibits gastrin release.

SHORT ANSWERS

11.Explain the physiologic basis of vagotomy in the treatment of peptic ulcer.

Physiological basis

1. Vagus nerve stimulates gastric acid secretion.
2. Vagotomy cuts vagal supply to stomach.
3. Decreases hydrochloric acid secretion.
4. Promotes healing of peptic ulcer.

12.Draw and label: HCl secretion by parietal cells

REFER DIAGRAM SECTION

13.Alkaline tide after a meal.

Definition

Temporary rise in blood pH after meals due to entry of bicarbonate into blood during gastric acid secretion.

Mechanism

1. Carbonic acid dissociates into hydrogen and bicarbonate ions.
2. Hydrogen ions secreted into stomach.
3. Bicarbonate enters blood.
4. Blood becomes temporarily alkaline.

14.Describe the importance of dietary fiber

Importance

1. Increases bulk of stool.
2. Prevents constipation.
3. Reduces risk of colon cancer.
4. Lowers blood cholesterol.
5. Slows glucose absorption.
6. Prevents obesity.

Sources

- Vegetables
- Fruits
- Cereals

15.Use of Oral Rehydration Solution (ORS) in treatment of diarrhea.

Principle

Glucose enhances sodium and water absorption in intestine.

Composition of ORS

- Glucose
- Sodium chloride
- Potassium chloride
- Sodium citrate

Uses

1. Prevents dehydration.
2. Replaces water and electrolytes.
3. Reduces mortality in diarrhea.

16.Use of H2 receptor blockers in peptic ulcer.

Examples

- Ranitidine
- Famotidine

Mechanism

1. Block H2 receptors on parietal cells.
2. Decrease gastric acid secretion.
3. Promote ulcer healing.

17.Regulation of gastric secretion

Neural factors

- Vagus nerve
- Enteric nervous system

Hormonal factors

Stimulatory

- Gastrin
- Histamine

Inhibitory

- Secretin
- Gastric inhibitory peptide

18.Post prandial alkaline tide

Definition

Temporary increase in blood alkalinity after meals.

Cause

Entry of bicarbonate into blood during hydrochloric acid secretion.

Significance

Urine becomes alkaline after meals.

19.Use of proton pump inhibitors in peptic ulcer

Examples

- Omeprazole
- Pantoprazole

Mechanism

1. Inhibit H+-K+ ATPase pump.
2. Reduce gastric acid secretion.
3. Promote ulcer healing.

20.Draw and label :Mechanism of gastric HCl secretion

REFER DIAGRAM SECTION

21.Gastric mucosa is resistant to auto-digestion

Reasons

1. Presence of mucus barrier.

2. Bicarbonate secretion neutralizes acid.
3. Tight junctions prevent back diffusion.
4. Rapid regeneration of mucosal cells.
5. Adequate blood supply.

22.Mucosal barrier and peptic ulcer

Mucosal barrier

Consists of mucus, bicarbonate and epithelial cells protecting stomach from acid and pepsin.

Breakdown of barrier causes peptic ulcer

Causes

1. Helicobacter pylori infection.
2. Non steroidal anti inflammatory drugs.
3. Excess acid secretion.
4. Stress.

Result

Autodigestion of mucosa leading to ulcer.

23.Cephalic phase of gastric juice secretion

Definition

Phase of gastric secretion occurring before food enters stomach.

Stimuli

- Sight
- Smell
- Taste
- Thought of food

Mechanism

1. Mediated through vagus nerve.
2. Acetylcholine stimulates gastric glands.
3. Produces about 30% of gastric secretion.

Importance

Prepares stomach for digestion.

24. Draw and label : Mechanism of gastric hydrochloric acid secretion

Mechanism of Gastric Hydrochloric Acid Secretion

Hydrochloric acid is secreted by parietal (oxyntic) cells of gastric glands.

Steps

1. Inside parietal cell, carbon dioxide combines with water in presence of carbonic anhydrase.

   $CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$

2. Hydrogen ions are actively secreted into canaliculi by H^+-K^+ ATPase pump.
3. Potassium ions enter the cell and are recycled.
4. Chloride ions enter the cell in exchange for bicarbonate ions.
5. Chloride ions diffuse into canaliculi.
6. Hydrogen ions combine with chloride ions to form hydrochloric acid.
7. Bicarbonate enters blood causing postprandial alkaline tide.

REFER DIAGRAM SECTION

25. Control of gastric secretion

Control of Gastric Secretion

Gastric secretion is controlled by neural and hormonal mechanisms.

Phases of Gastric Secretion

1. Cephalic phase

- Occurs before food enters stomach.
- Mediated by vagus nerve.
- Stimuli:
  - Sight of food
  - Smell of food
  - Taste of food
  - Thought of food
- Accounts for about 30% secretion.

2. Gastric phase

- Begins when food enters stomach.
- Accounts for about 60% secretion.

Stimuli

- Gastric distension
- Presence of peptides and amino acids

Mechanism

- Local enteric reflexes
- Vago-vagal reflexes
- Gastrin secretion from G cells

3. Intestinal phase

- Begins when chyme enters intestine.
- Small stimulatory effect initially.
- Later inhibitory.

Inhibitory factors

- Enterogastric reflex
- Secretin
- Cholecystokinin
- Gastric inhibitory peptide

Factors stimulating gastric secretion

- Acetylcholine
- Gastrin
- Histamine

Factors inhibiting gastric secretion

- Secretin
- Cholecystokinin
- Somatostatin
- Low gastric pH

26. Postprandial alkaline tide

Postprandial Alkaline Tide

Definition

Increase in blood bicarbonate concentration and alkalinity after meals due to gastric hydrochloric acid secretion.

Mechanism

1. In parietal cells:

   $CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$

2. H^+ is secreted into stomach lumen as hydrochloric acid.
3. HCO_3^- enters blood.
4. Blood becomes temporarily alkaline.

Features

- Occurs after meals.
- Urine becomes alkaline.
- Compensated by pancreatic bicarbonate secretion.

27. Gastrectomy produces pernicious anemia. Why?

Gastrectomy produces pernicious anemia. Why?

Answer

- Intrinsic factor is secreted by parietal cells of stomach.
- Intrinsic factor is essential for absorption of vitamin B12 in ileum.
- After gastrectomy, intrinsic factor secretion is absent.
- Vitamin B12 absorption decreases.
- Megaloblastic anemia develops.
- This is called pernicious anemia.

28. Mechanism of gastric hydrochloric acid secretion

Mechanism of Gastric Hydrochloric Acid Secretion

Hydrochloric acid is secreted by parietal cells.

Mechanism

1. Carbon dioxide combines with water in presence of carbonic anhydrase.

   $CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$

2. H^+ ions are secreted into lumen by H^+-K^+ ATPase pump.
3. Chloride enters cell in exchange for bicarbonate.
4. Chloride diffuses into canaliculi.
5. H^+ and Cl^- combine to form hydrochloric acid.
6. Bicarbonate enters blood producing alkaline tide.

Regulation

Stimulators

- Acetylcholine
- Gastrin
- Histamine

Inhibitors

- Secretin
- Somatostatin
- Prostaglandins

29. Gastric emptying time

Gastric Emptying Time

Definition

Time taken for stomach contents to pass into duodenum.

Normal gastric emptying time

- Mixed meal: 2–4 hours.
- Liquids empty faster than solids.

Factors affecting gastric emptying

Factors increasing emptying

- Gastrin
- Increased gastric motility
- Liquid food

Factors delaying emptying

- Fatty meals
- Hypertonic chyme
- Acidic chyme in duodenum
- Enterogastric reflex
- Secretin and cholecystokinin

30. Pathophysiology of peptic ulcer

Pathophysiology of Peptic Ulcer

Definition

Ulceration in stomach or duodenum due to digestion by acid and pepsin.

Etiology

- Helicobacter pylori infection
- Excess acid secretion
- Nonsteroidal anti-inflammatory drugs
- Stress
- Smoking

Pathogenesis

1. Imbalance between aggressive and defensive factors.

Aggressive factors

- Hydrochloric acid
- Pepsin
- Helicobacter pylori

Defensive factors

- Mucus barrier
- Bicarbonate secretion
- Mucosal blood flow
- Prostaglandins

2. Mucosal damage occurs.
3. Ulcer formation develops.

Complications

- Bleeding
- Perforation
- Gastric outlet obstruction

31. Peptic ulcer

Peptic Ulcer

Definition

A break in gastric or duodenal mucosa caused by acid-pepsin digestion.

Types

- Gastric ulcer
- Duodenal ulcer

Causes

- Helicobacter pylori
- Hyperacidity
- Stress
- Smoking
- NSAIDs

Clinical features

- Epigastric pain
- Nausea
- Vomiting
- Bleeding

Complications

- Hemorrhage
- Perforation
- Obstruction

PANCREAS

SHORT ESSAYS

1. Describe the composition and regulation of pancreatic juice secretion

Composition of Pancreatic Juice

Volume

- About 1200–1500 mL/day.

Nature

- Clear, colorless and alkaline.
- pH: 7.8–8.4.

Composition

1. Water

- Major constituent.

2. Electrolytes

- Sodium
- Potassium
- Chloride
- Bicarbonate

3. Enzymes

Proteolytic enzymes

- Trypsinogen
- Chymotrypsinogen
- Procarboxypeptidase

Amylolytic enzyme

- Pancreatic amylase

Lipolytic enzymes

- Pancreatic lipase
- Phospholipase
- Cholesterol esterase

Nucleases

- Ribonuclease
- Deoxyribonuclease

Regulation of Pancreatic Secretion

Neural regulation

- Vagus nerve stimulates secretion.

Hormonal regulation

Secretin

- Secreted from S cells of duodenum.
- Stimulated by acid in duodenum.
- Increases bicarbonate-rich secretion.

Cholecystokinin

- Secreted from I cells.
- Stimulated by fats and proteins.
- Increases enzyme-rich secretion.

Phases

Cephalic phase

- Vagal stimulation.

Gastric phase

- Gastrin and vagal stimulation.

Intestinal phase

- Most important phase.
- Secretin and cholecystokinin act.

2. Regulation of pancreatic exocrine secretion

Regulation of Pancreatic Exocrine Secretion

Pancreatic secretion is regulated by neural and hormonal mechanisms.

Neural regulation

Vagus nerve

- Stimulates enzyme-rich secretion.
- Acts through acetylcholine.

Hormonal regulation

Secretin

- Released from S cells of duodenum.

- Stimulus: Acidic chyme.
- Action: Increases bicarbonate secretion.

Cholecystokinin

- Released from I cells.
- Stimulus: Fatty acids and amino acids.
- Action: Increases enzyme secretion.

Phases of secretion

1. Cephalic phase

- Mediated by vagus nerve.
- About 20% secretion.

2. Gastric phase

- Due to gastrin and vagal reflexes.

3. Intestinal phase

- Most important.
- Secretin and cholecystokinin produce maximum secretion.

3. Describe the functions & regulations of pancreatic juice secretion

Functions of Pancreatic Juice

Digestive functions

Digestion of proteins

- Trypsin and chymotrypsin digest proteins.

Digestion of carbohydrates

- Pancreatic amylase converts starch to maltose.

Digestion of fats

- Pancreatic lipase digests triglycerides.

Digestion of nucleic acids

- Nucleases digest nucleic acids.

Neutralization of acid

- Bicarbonate neutralizes acidic chyme.
- Provides alkaline medium for enzyme action.

Regulation of Pancreatic Juice Secretion

Neural regulation

- Vagus nerve stimulates secretion.

Hormonal regulation

Secretin

- Stimulates bicarbonate secretion.

Cholecystokinin

- Stimulates enzyme secretion.

Phases

- Cephalic phase
- Gastric phase
- Intestinal phase

SHORT ANSWERS

4. Proteolytic pancreatic enzymes

Proteolytic Pancreatic Enzymes

Enzymes

- Trypsinogen
- Chymotrypsinogen

- Procarboxypeptidase
- Proelastase

Activation

- Enterokinase converts trypsinogen to trypsin.
- Trypsin activates other enzymes.

Functions

- Digest proteins into peptides and amino acids.

5. Physiological basis for steatorrhoea in exocrine pancreatic deficiency.

Physiological basis for steatorrhoea in exocrine pancreatic deficiency

Answer

- Pancreatic lipase is essential for fat digestion.
- In exocrine pancreatic deficiency, lipase secretion decreases.
- Fat digestion and absorption are impaired.
- Excess fat is excreted in stools.
- Stools become bulky, greasy and foul smelling.
- This condition is called steatorrhoea.

6. Steatorrhoea following pancreatectomy. Why?

Steatorrhoea following pancreatectomy. Why?

Answer

- Pancreatectomy removes pancreas.
- Pancreatic lipase secretion becomes absent.
- Fat digestion decreases markedly.
- Undigested fat is excreted in feces.
- Hence steatorrhoea occurs.

7. Pancreatic juice composition

Pancreatic Juice Composition

Water

- Major constituent.

Electrolytes

- Sodium
- Potassium
- Chloride
- Bicarbonate

Enzymes

Proteolytic enzymes

- Trypsinogen
- Chymotrypsinogen
- Procarboxypeptidase

Amylolytic enzyme

- Pancreatic amylase

Lipolytic enzymes

- Lipase
- Phospholipase
- Cholesterol esterase

Nucleases

- Ribonuclease
- Deoxyribonuclease

8. Steatorrhoea in diseases that destroy exocrine pancreas. Why?

Answer

- Diseases destroying exocrine pancreas reduce pancreatic enzyme secretion.
- Lipase deficiency causes defective fat digestion.
- Unabsorbed fat passes in stools.
- Therefore steatorrhoea develops.

9. Steatorrhoea occurs after pancreatectomy. Why?

Steatorrhoea occurs after pancreatectomy. Why?

Answer

- Pancreatectomy removes source of pancreatic lipase.
- Fat digestion becomes defective.
- Fat absorption decreases.
- Excess fat appears in stools causing steatorrhoea.

10. Steatorrhoea in acute pancreatitis. Why?

Steatorrhoea in acute pancreatitis. Why?

Answer

- Acute pancreatitis damages pancreatic acinar cells.
- Pancreatic lipase secretion decreases.
- Digestion and absorption of fats are impaired.
- Excess fat is excreted in stools.
- Hence steatorrhoea occurs.

LIVER AND BILIARY SYSTEM

SHORT ESSAYS

1. Enumerate the plasma proteins along with their site of production. Describe their functions. (3+5)

Plasma Proteins and Site of Production

Albumin

- Site: Liver.

Globulins

- Alpha and beta globulins: Liver.
- Gamma globulins: Plasma cells.

Fibrinogen

- Site: Liver.

Functions of Plasma Proteins

1. Maintain colloidal osmotic pressure

- Mainly by albumin.

2. Transport function

- Carry hormones, bilirubin, calcium, iron and drugs.

3. Blood coagulation

- Fibrinogen helps clotting.

4. Buffer action

- Maintain acid-base balance.

5. Defense function

- Gamma globulins act as antibodies.

6. Nutritional function

- Source of amino acids.

7. Maintain blood viscosity

- Help maintain normal circulation.

SHORT ANSWERS

2. Write the physiological basis of pale coloured stools in jaundice.

Physiological basis of pale coloured stools in jaundice

Answer

- In obstructive jaundice, bile does not enter intestine.
- Bilirubin is not converted to stercobilin.
- Stercobilin gives brown color to stools.
- Absence of stercobilin causes pale or clay colored stools.

3. What is jaundice. What are its types. What is the cause for clay colored stools in obstructive jaundice.

Jaundice

Definition

Yellow discoloration of skin, sclera and mucous membrane due to increased bilirubin in blood.

Types

1. Hemolytic jaundice
2. Hepatocellular jaundice
3. Obstructive jaundice

Cause for clay colored stools in obstructive jaundice

- Bile does not reach intestine.
- Stercobilin formation decreases.
- Stools become clay colored.

4. Enumerate plasma proteins. Describe the functions of plasma protein.

Plasma Proteins

Types

1. Albumin
2. Globulins
    - Alpha globulin
    - Beta globulin
    - Gamma globulin
3. Fibrinogen

Functions of Plasma Proteins

1. Maintain colloidal osmotic pressure

2. Transport substances

- Hormones
- Lipids
- Drugs
- Bilirubin

3. Blood coagulation

- Fibrinogen helps clotting.

4. Immunity

- Gamma globulins act as antibodies.

5. Buffer action

- Maintain acid-base balance.

6. Nutritional function

- Protein reserve.

5. Enumerate the functions of the Liver.

Functions of the Liver

1. Metabolic functions

- Carbohydrate metabolism
- Protein metabolism

- Fat metabolism

2. Secretory function

- Formation and secretion of bile.

3. Storage function

- Glycogen
- Iron
- Vitamins

4. Detoxification

- Detoxifies drugs and toxins.

5. Hematological function

- Synthesis of clotting factors.

6. Excretory function

- Excretion of bilirubin.

7. Immune function

- Kupffer cells perform phagocytosis.

6. Plasma proteins

Plasma Proteins

Definition

Proteins present in plasma.

Types

1. Albumin
2. Globulins
3. Fibrinogen

Functions

- Maintain oncotic pressure.
- Transport substances.
- Blood clotting.
- Immunity.
- Buffer action.

7. Define and classify jaundice

Define and classify jaundice

Definition

Jaundice is yellow discoloration of tissues due to elevated bilirubin levels.

Classification

1. Hemolytic jaundice

- Due to excessive hemolysis.

2. Hepatocellular jaundice

- Due to liver cell damage.

3. Obstructive jaundice

- Due to obstruction to bile flow.

8. Movements of small intestine

Movements of Small Intestine

1. Segmentation movements

- Mixing movements.
- Help digestion and absorption.

2. Peristaltic movements

- Propulsive movements.
- Propel chyme forward.

3. Pendular movements

- To and fro movements.

4. Peristaltic rush

- Powerful peristalsis in irritation.

5. Movements of villi

- Increase absorption.

9. Functions of bile

Functions of Bile

1. Digestion and absorption of fats

- Bile salts emulsify fats.

2. Absorption of fat soluble vitamins

- Vitamins A, D, E and K.

3. Neutralization of acid

- Bile is alkaline.

4. Excretory function

- Excretes bilirubin and cholesterol.

5. Stimulates intestinal motility.

6. Prevents putrefaction.

10. Jaundice

Jaundice

Definition

Yellow discoloration of skin and sclera due to increased bilirubin in blood.

Types

1. Hemolytic jaundice
2. Hepatocellular jaundice
3. Obstructive jaundice

Features

- Yellow sclera
- Dark urine
- Pale stools in obstructive jaundice

11. Steatorrhoea

Steatorrhoea

Definition

Excretion of excess fat in feces.

Causes

- Pancreatic insufficiency
- Bile salt deficiency
- Intestinal malabsorption

Features

- Bulky stools
- Greasy stools
- Foul smelling stools

12. Entero-hepatic circulation

Entero-hepatic circulation

Definition

Circulation of bile salts from liver to intestine and back to liver.

Mechanism

1. Liver secretes bile salts into bile.
2. Bile enters intestine.
3. Bile salts aid fat digestion.
4. About 95% bile salts are reabsorbed from terminal ileum.
5. Reabsorbed bile salts return to liver through portal circulation.
6. Liver resecretes them.

Importance

- Conserves bile salts.
- Essential for fat digestion and absorption.
- Stimulates bile secretion.

SMALL INTESTINE

SHORT ANSWERS

1. Small intestinal movements

Small intestinal movements are of two types:

A. Mixing movements

1. **Segmentation movements**
   - Most common movement in small intestine.
   - Produced by circular muscle contractions.
   - Divide intestine into segments.
   - Help mixing of chyme with digestive juices.
   - Facilitate absorption by repeated contact with mucosa.
2. **Pendular movements**
   - Due to contraction of longitudinal muscles.
   - Cause back and forth movement of intestinal contents.
   - Help in mixing.
3. **Villus movements**
   - Caused by contraction of muscularis mucosa.
   - Improve lymphatic and blood flow.
   - Aid absorption.

B. Propulsive movements

1. **Peristaltic movements**
   - Propel intestinal contents towards large intestine.
   - Controlled by myenteric plexus.
2. **Peristaltic rush**
   - Powerful rapid peristalsis.
   - Seen in irritation and infection.
   - Causes diarrhea.

Functions

- Mixing of food with digestive juices.
- Propulsion of chyme.
- Facilitation of digestion and absorption.

2. Small intestinal hormones

Hormones secreted by small intestine are:

Hormone	Site of secretion	Functions
Secretin	S cells of duodenum	Stimulates bicarbonate secretion from pancreas and bile ducts
Cholecystokinin (CCK)	I cells of duodenum and jejunum	Stimulates pancreatic enzyme secretion and gall bladder contraction
Gastric inhibitory peptide (GIP)	K cells	Inhibits gastric secretion and motility; stimulates insulin secretion
Motilin	M cells	Initiates migrating motor complex
Vasoactive intestinal	Enteric neurons	Causes intestinal

Hormone	Site of secretion	Functions
peptide (VIP)		secretion and smooth muscle relaxation
Enteroglucagon	Intestinal mucosa	Slows gastric motility
Somatostatin	D cells	Inhibits gastrointestinal secretions

3. Law of intestine

The law of intestine states that:

"Peristaltic contraction occurs above the point of stimulation and relaxation occurs below the point of stimulation, causing movement of contents in aboral direction."

This is also called **myenteric reflex**.

Mechanism

- Distension of intestine stimulates enteric nervous system.
- Circular muscle contracts above stimulus.
- Circular muscle relaxes below stimulus.
- Chyme moves downward.

Significance

- Produces forward movement of intestinal contents.
- Prevents backward movement.

LARGE INTESTINE

SHORT ESSAYS

1. Describe the functions of large intestine and add a note on cause and pathophysiology of Megacolon (Hirschsprung's disease)

Functions of large intestine

1. Absorption

- Absorbs water and electrolytes.
- Sodium absorption is active.
- Chloride follows sodium.
- Water follows osmotically.

2. Formation and storage of feces

- Converts liquid chyme into semisolid feces.
- Stores feces in sigmoid colon and rectum.

3. Secretion

- Secretes mucus.
- Mucus lubricates feces and protects mucosa.

4. Bacterial action

Colonic bacteria:

- Synthesize vitamin K and some B vitamins.
- Ferment undigested carbohydrates.
- Produce gases.

5. Defecation

- Expulsion of feces through defecation reflex.

Megacolon (Hirschsprung's disease)

Cause

- Congenital absence of ganglion cells in:
  - Myenteric plexus (Auerbach plexus)
  - Submucosal plexus (Meissner plexus)
- Usually affects rectosigmoid region.

Pathophysiology

- Aganglionic segment cannot relax.
- Functional obstruction occurs.
- Feces accumulate proximal to obstruction.
- Proximal colon becomes markedly dilated → megacolon.

Features

- Severe constipation.
- Abdominal distension.
- Failure to pass meconium in newborn.

Complications

- Intestinal obstruction.
- Enterocolitis.

SHORT ANSWERS

2. Describe the role of colonic bacteria

Role of colonic bacteria

1. Synthesize vitamin K.
2. Synthesize B complex vitamins.
3. Ferment undigested carbohydrates.
4. Produce short chain fatty acids.
5. Convert bilirubin into stercobilin.
6. Prevent growth of harmful organisms.
7. Produce intestinal gases.

Harmful effects

- Excess gas formation.
- Infection if bacteria enter blood.

3. Mass peristalsis

Mass peristalsis is a powerful propulsive movement occurring in large intestine.

Features

- Occurs 1–3 times daily.
- Usually after meals due to gastrocolic reflex.
- Propels fecal matter towards rectum.

Mechanism

- Strong contractions move contents over long distances.
- Distension of rectum initiates defecation reflex.

Functions

- Movement of feces.
- Initiation of defecation.

MOVEMENTS OF GASTROINTESTINAL TRACT

SHORT ESSAYS

1. Name the types of intestinal movements and explain their functions.

Types of intestinal movements

Intestinal movements are divided into:

A. Movements of small intestine

1. Mixing movements

a. Segmentation movements

- Rhythmic contractions of circular muscle.
- Divide intestine into segments.
- Mix chyme with digestive juices.
- Facilitate absorption.

b. Pendular movements

- Due to longitudinal muscle contractions.
- Produce to and fro movement.
- Help mixing.

c. Villus movements

- Caused by muscularis mucosa.
- Increase contact with mucosa.
- Aid absorption.

2. Propulsive movements

a. Peristalsis

- Waves of contraction moving towards anus.
- Propel intestinal contents.

b. Peristaltic rush

- Strong rapid peristalsis.
- Occurs in irritation and infection.
- Causes diarrhea.

B. Movements of large intestine

1. Haustral contractions

- Mixing movements.
- Help absorption of water and salts.

2. Peristaltic movements

- Propel feces slowly.

3. Mass peristalsis

- Powerful propulsive movement.
- Pushes feces into rectum.

Functions of intestinal movements

1. Mixing food with digestive juices.
2. Propulsion of intestinal contents.
3. Facilitation of digestion.
4. Facilitation of absorption.
5. Expulsion of feces.

2. Stages of deglutition

Deglutition means swallowing.

It occurs in three stages:

1. Oral stage (voluntary stage)

- Food bolus is pushed into pharynx by tongue.
- Voluntary stage.

2. Pharyngeal stage (involuntary stage)

- Reflex stage.
- Soft palate closes nasopharynx.
- Vocal cords close.
- Epiglottis closes laryngeal opening.
- Respiration temporarily stops (deglutition apnoea).
- Upper esophageal sphincter relaxes.
- Bolus enters esophagus.

3. Esophageal stage

- Peristaltic waves propel bolus through esophagus.
- Lower esophageal sphincter relaxes.
- Food enters stomach.

Deglutition center

- Located in medulla oblongata.

3. Name the components of the enteric nervous system and outline its functions

Components of enteric nervous system

1. Myenteric plexus (Auerbach plexus)

- Located between longitudinal and circular muscle layers.
- Controls gastrointestinal motility.

2. Submucosal plexus (Meissner plexus)

- Located in submucosa.
- Controls secretion and blood flow.

Functions of enteric nervous system

1. Regulation of motility

- Controls peristalsis.
- Controls segmentation movements.
- Regulates tone of gut.

2. Regulation of secretion

- Controls secretion of digestive juices.
- Controls mucus secretion.

3. Regulation of blood flow

- Regulates local circulation.

4. Coordination of gastrointestinal reflexes

- Gastrocolic reflex.
- Enterogastric reflex.
- Peristaltic reflex.

5. Independent activity

- Can function independently of central nervous system.

SHORT ANSWERS

4. Types of movements in large intestine

Types

1. Haustral contractions.
2. Peristaltic movements.
3. Mass peristalsis.
4. Antiperistalsis.

Functions

- Mixing of contents.
- Absorption of water and electrolytes.
- Propulsion of feces.

5. Defecation reflex

Defecation reflex is a reflex causing expulsion of feces from rectum.

Mechanism

1. Feces enter rectum.
2. Rectal distension stimulates stretch receptors.
3. Reflex contractions of rectum occur.
4. Internal anal sphincter relaxes.
5. Voluntary relaxation of external anal sphincter causes defecation.

Types

1. Intrinsic defecation reflex.
2. Parasympathetic defecation reflex.

Center

- Sacral spinal cord segments S2–S4.

6. Second stage of deglutition

Second stage of deglutition is the **pharyngeal stage**.

Features

- Involuntary reflex stage.
- Soft palate closes nasopharynx.
- Vocal cords adduct.
- Epiglottis closes laryngeal opening.
- Respiration stops temporarily (deglutition apnoea).
- Upper esophageal sphincter relaxes.
- Food enters esophagus.

Center

- Medulla oblongata.

7. Peristaltic movements

Peristaltic movements are wave-like contractions of gastrointestinal smooth muscle that propel contents forward.

Mechanism

- Circular muscle contracts behind bolus.
- Circular muscle relaxes ahead of bolus.
- Content moves in aboral direction.

Functions

- Propulsion of food.
- Movement of intestinal contents.
- Expulsion of feces.

8. Deglutition reflex

Deglutition reflex is the involuntary reflex responsible for swallowing.

Mechanism

1. Food reaches pharynx.
2. Sensory impulses pass through glossopharyngeal and vagus nerves.
3. Deglutition center in medulla is stimulated.
4. Motor impulses coordinate swallowing.

Features

- Protects airway.
- Moves food into stomach.

9. Receptive relaxation

Receptive relaxation is relaxation of stomach wall occurring during swallowing.

Mechanism

- Mediated by vagovagal reflex.
- Fundus and body of stomach relax.

Functions

- Accommodates food without rise in intragastric pressure.

10. Law of intestines

The law of intestine states that:

"Contraction occurs above the point of stimulation and relaxation occurs below the point of stimulation causing propulsion of contents downward."

Significance

- Produces peristalsis.
- Ensures forward movement.

11. Deglutition apnoea

Deglutition apnoea is temporary cessation of respiration during swallowing.

Mechanism

- Occurs during pharyngeal stage of deglutition.
- Respiratory center is inhibited.
- Glottis closes to prevent aspiration.

Significance

- Prevents food entry into respiratory tract.

12. Phases of deglutition

The phases of deglutition are:

1. Oral phase – voluntary.
2. Pharyngeal phase – involuntary.
3. Esophageal phase – involuntary.

RENAL PHYSIOLOGY

FUNCTIONAL ANATOMY OF KIDNEY

SHORT ANSWERS

1. Draw and label the juxta-glomerular apparatus. Describe the physiological basis for renal splay

REFER DIAGRAM SECTION

Juxtaglomerular apparatus

Components

1. Juxtaglomerular cells.
2. Macula densa.
3. Lacis cells (extraglomerular mesangial cells).

Functions

- Secretion of renin.
- Regulation of glomerular filtration rate.
- Regulation of blood pressure.

Physiological basis for renal splay

Definition

Renal splay is the curved portion of glucose titration curve between threshold and transport maximum.

Causes

1. Different nephrons have different transport maximum values.
2. Not all nephrons excrete glucose at same plasma level.
3. Gradual saturation of tubular transporters.

Significance

- Explains gradual appearance of glucose in urine.

2. Draw and label : Nephron

REFER DIAGRAM SECTION

3. Juxtaglomerular apparatus

Juxtaglomerular apparatus is a specialized structure formed where distal convoluted tubule comes in contact with afferent arteriole.

Components

1. Juxtaglomerular cells.
2. Macula densa.
3. Lacis cells.

Functions

1. Renin secretion.
2. Regulation of blood pressure.
3. Regulation of glomerular filtration rate.
4. Tubuloglomerular feedback.

4. Draw and label: Juxtaglomerular apparatus

REFER DIAGRAM SECTION

5. Renin anemia

Renin is an enzyme secreted by juxtaglomerular cells.

Actions

- Converts angiotensinogen into angiotensin I.
- Helps formation of angiotensin II.
- Causes vasoconstriction.
- Stimulates aldosterone secretion.

Functions

- Regulation of blood pressure.
- Regulation of sodium and water balance.

6. Non renal functions of kidney

Endocrine functions

1. Secretion of erythropoietin.
2. Secretion of renin.
3. Activation of vitamin D.
4. Secretion of prostaglandins.

Metabolic functions

1. Gluconeogenesis.
2. Protein metabolism.
3. Degradation of hormones.

7. Anemia is seen in patients with renal disease. Why?

Causes

1. Decreased erythropoietin production by diseased kidneys.
2. Reduced red blood cell production in bone marrow.
3. Shortened lifespan of red blood cells.

Result

- Normocytic normochromic anemia develops.

MECHANISM OF FORMATION OF URINE

LONG ESSAYS

1. Describe the role of counter current multiplier and exchanger system in the concentration of urine. Add a note on renal failure and artificial kidney.

Counter current mechanism

Counter current mechanism helps in concentration of urine.

It consists of:

1. Counter current multiplier – Loop of Henle.
2. Counter current exchanger – Vasa recta.

Counter current multiplier

Site

- Loop of Henle of juxtamedullary nephrons.

Principle

- Fluid flows in opposite directions in descending and ascending limbs.

Properties

Descending limb

- Highly permeable to water.
- Less permeable to sodium chloride.

Ascending limb

- Impermeable to water.
- Actively transports sodium and chloride.

Mechanism

1. Sodium chloride pumped out from ascending limb.
2. Medullary interstitial osmolarity increases.
3. Water moves out from descending limb.
4. Tubular fluid becomes concentrated in descending limb.
5. Repetition along loop multiplies osmotic gradient.

Result

- Hyperosmotic renal medulla is formed.

Counter current exchanger

Site

- Vasa recta.

Function

- Maintains medullary osmotic gradient.

Mechanism

- Blood flows in opposite directions.
- Solute enters descending vasa recta and leaves ascending vasa recta.
- Water movement occurs in opposite direction.
- Prevents washout of medullary gradient.

Role in concentration of urine

1. Hyperosmotic medulla formed.
2. Antidiuretic hormone increases water permeability of collecting ducts.
3. Water moves out of collecting ducts.
4. Concentrated urine is formed.

Renal failure

Definition

Renal failure is inability of kidneys to perform normal functions.

Types

1. Acute renal failure.
2. Chronic renal failure.

Features

- Oliguria.
- Edema.
- Uremia.
- Electrolyte imbalance.
- Hypertension.

Artificial kidney (Hemodialysis)

Principle

- Diffusion across semipermeable membrane.

Procedure

- Blood passed through dialyzer.
- Waste products diffuse into dialysing fluid.
- Purified blood returned to patient.

Uses

- Renal failure.
- Poisoning.
- Severe electrolyte imbalance.

Complications

- Hypotension.
- Infection.
- Clotting.

2. A 48 year old man suffering from diabetes mellitus had increased frequency of micturition
• What is the physiological basis of the polyuria?
• What are the mechanisms operating in the nephron for the concentration of urine?
• Add a note on free water clearance.

• What is the physiological basis of the polyuria?

Polyuria in diabetes mellitus occurs due to **osmotic diuresis**.

Mechanism:

1. In diabetes mellitus, blood glucose level increases.
2. When blood glucose exceeds the **renal threshold** (about 180 milligrams per deciliter), glucose appears in urine (**glycosuria**).
3. Glucose in renal tubules increases the osmotic pressure of tubular fluid.
4. Water reabsorption from proximal tubule and loop of Henle decreases.
5. Excess water is excreted in urine causing:
    - Increased urine volume (polyuria)
    - Increased frequency of micturition

Additional points:

- Loss of water leads to dehydration.
- Dehydration stimulates thirst causing polydipsia

• What are the mechanisms operating in the nephron for the concentration of urine?

Urine concentration depends on:

1. Hyperosmotic renal medulla
2. Antidiuretic hormone
3. Counter current mechanism

1. Counter current multiplier system

Occurs in the **Loop of Henle**.

Descending limb:

- Highly permeable to water
- Less permeable to sodium chloride
- Water moves out → tubular fluid becomes concentrated

Ascending limb:

- Impermeable to water
- Sodium and chloride actively reabsorbed
- Tubular fluid becomes dilute

This creates a hyperosmotic medullary interstitium.

2. Counter current exchanger

Occurs in **Vasa recta**.

Functions:

- Maintains medullary osmotic gradient
- Prevents washout of solutes

3. Role of Antidiuretic Hormone

Antidiuretic hormone increases water permeability of:

- Distal convoluted tubule
- Collecting duct

Water moves into hyperosmotic medulla causing:

- Water conservation
- Formation of concentrated urine

4. Role of urea recycling

- Urea diffuses from collecting duct into medulla
- Helps maintain high medullary osmolarity
- Assists urine concentration

• Add a note on free water clearance.

Free water clearance is the amount of solute-free water excreted by kidneys per minute.

Definition:

It is the volume of plasma cleared of solute-free water per minute.

Formula:

$$C_{H_2O} = V - C_{osm}$$

Where:

- C_{H_2O}= Free water clearance
- V= Urine flow rate
- C_{osm}= Osmolar clearance

Significance:

Positive free water clearance:

- Dilute urine formed
- Excess water excreted
- Occurs when Antidiuretic hormone secretion is low

Negative free water clearance:

- Concentrated urine formed
- Water conserved
- Occurs when Antidiuretic hormone secretion is high

Normal value:

- Approximately zero during normal hydration.

SHORT ESSAYS

3. Explain the renal tubular handling of water. Add a note on diuresis.

Renal Tubular Handling of Water

About 180 L of water is filtered daily through the glomeruli. Around 178–179 L is reabsorbed and only 1–2 L is excreted as urine.

Water reabsorption in different parts of nephron

1. Proximal Convoluted Tubule (PCT)

- About 65–70% of filtered water is reabsorbed.
- Reabsorption is obligatory and iso-osmotic.
- Water follows sodium by osmosis.
- Highly permeable due to aquaporin-1 channels.

2. Loop of Henle

Descending limb

- Highly permeable to water.
- About 15% water reabsorbed.
- Tubular fluid becomes hyperosmotic.

Ascending limb

- Impermeable to water.
- Sodium, potassium and chloride are reabsorbed.
- Tubular fluid becomes dilute.

3. Distal Convoluted Tubule (DCT)

- Early DCT is impermeable to water.
- Late DCT reabsorbs water under influence of antidiuretic hormone.

4. Collecting Duct

- Water permeability depends on antidiuretic hormone.
- Presence of antidiuretic hormone increases aquaporin-2 channels.
- Water moves into hyperosmotic medullary interstitium.
- Concentrated urine is formed.

Factors affecting water reabsorption

- Antidiuretic hormone
- Medullary osmotic gradient
- Glomerular filtration rate
- Renal blood flow

Note on Diuresis

Diuresis means increased urine output.

Types

1. Water diuresis

- Due to excess water intake.
- Antidiuretic hormone secretion decreases.
- Large volume of dilute urine formed.

2. Osmotic diuresis

- Due to presence of non-reabsorbed solutes in tubules.
- Example: glucose in diabetes mellitus.
- Solutes retain water in tubules.

Causes of diuresis

- Excess water intake
- Diabetes mellitus
- Diabetes insipidus
- Diuretic drugs
- High salt intake

4. Compare the water reabsorption in proximal and distal parts of the nephrons.

Feature	Proximal nephron	Distal nephron
Site	PCT and descending loop	DCT and collecting duct
Amount reabsorbed	About 65–85%	About 10–15%
Type	Obligatory	Facultative
Hormonal control	Independent of antidiuretic hormone	Dependent on antidiuretic hormone
Osmolarity	Iso-osmotic reabsorption	Variable
Permeability	Highly permeable	Variable permeability
Mechanism	Water follows sodium	Aquaporin insertion by antidiuretic hormone
Function	Bulk	Fine regulation

Feature	Proximal nephron	Distal nephron
	reabsorption	of water balance

5. Describe water reabsorption in the different parts of nephron. Explain the role of hormones in water reabsorption.

Water Reabsorption in Different Parts of Nephron

1. Proximal Convoluted Tubule

- Reabsorbs 65–70% of filtered water.
- Iso-osmotic reabsorption.
- Water follows sodium passively.

2. Descending Limb of Loop of Henle

- Permeable to water.
- About 15% water reabsorbed.
- Tubular fluid becomes concentrated.

3. Ascending Limb of Loop of Henle

- Impermeable to water.
- Solute reabsorption occurs.
- Diluting segment.

4. Distal Convoluted Tubule

- Early DCT impermeable to water.
- Late DCT becomes permeable in presence of antidiuretic hormone.

5. Collecting Duct

- Water permeability depends on antidiuretic hormone.
- Final concentration of urine occurs here.

Role of Hormones in Water Reabsorption

1. Antidiuretic Hormone

- Secreted from posterior pituitary.
- Increases water permeability of late DCT and collecting ducts.
- Inserts aquaporin-2 channels.
- Produces concentrated urine.

2. Aldosterone

- Increases sodium reabsorption in distal nephron.
- Water follows sodium secondarily.

3. Atrial Natriuretic Peptide

- Inhibits sodium and water reabsorption.
- Increases urine output.

4. Angiotensin II

- Increases sodium and water reabsorption in proximal tubule.

Conclusion

Water reabsorption occurs throughout the nephron and is regulated mainly by antidiuretic hormone.

6. Describe the mechanism of water reabsorption from the renal tubules. Add a note on anuria.

Mechanism of Water Reabsorption

Water reabsorption occurs mainly by osmosis.

Steps

1. Sodium is actively reabsorbed from tubular lumen.
2. Osmotic gradient develops.
3. Water follows sodium passively through aquaporins and tight junctions.

4. Water enters peritubular capillaries.

Sites

- PCT: obligatory reabsorption
- Descending loop: passive water reabsorption
- DCT and collecting duct: antidiuretic hormone dependent

Role of Antidiuretic Hormone

- Increases permeability of distal nephron.
- Inserts aquaporin-2 channels.
- Enhances facultative water reabsorption.

Note on Anuria

Anuria means urine output less than 100 mL/day.

Causes

1. Prerenal causes

- Shock
- Severe dehydration
- Hemorrhage

2. Renal causes

- Acute renal failure
- Glomerulonephritis

3. Postrenal causes

- Urinary tract obstruction
- Enlarged prostate

Significance

- Indicates severe renal dysfunction.
- Requires immediate management.

7. With the aid of a diagram, explain the mechanism of Micturition.

Micturition

Micturition is the process of emptying the urinary bladder.

Nerve Supply

- Parasympathetic: pelvic nerves (S2–S4)
- Sympathetic: hypogastric nerves
- Somatic: pudendal nerve

Mechanism

1. Filling phase

- Bladder fills progressively.
- Intravesical pressure rises slightly.
- Internal and external sphincters remain contracted.

2. Micturition reflex

- Stretch receptors in bladder wall are stimulated.
- Impulses pass through pelvic nerves to sacral spinal cord.
- Parasympathetic impulses return to bladder.
- Detrusor muscle contracts.
- Internal sphincter relaxes.

3. Voluntary control

- External sphincter controlled by pudendal nerve.
- Relaxation leads to urination.

Higher Centres

- Pontine micturition centre facilitates reflex.

- Cerebral cortex exerts voluntary control.

Diagram

.REFER DIAGRAM SECTION

8. Counter current mechanism

Definition

Counter current mechanism is the mechanism by which hyperosmolarity of renal medulla is maintained for concentration of urine.

Components

1. Counter current multiplier – Loop of Henle
2. Counter current exchanger – Vasa recta
3. Urea recycling

Counter Current Multiplier

Descending limb

- Permeable to water.
- Water moves out.
- Tubular fluid becomes concentrated.

Ascending limb

- Impermeable to water.
- Active sodium chloride reabsorption.
- Interstitium becomes hyperosmotic.

Single Effect

- Difference of about 200 mOsm/L produced.

Counter Current Exchange by Vasa Recta

- Prevents washout of medullary gradient.
- Maintains hyperosmolarity.

Role of Urea

- Recycled from collecting ducts.
- Contributes to medullary osmolarity.

Functions

- Formation of concentrated urine.
- Conservation of water.

Conclusion

Counter current mechanism is essential for urine concentration.

9. Factors influencing glomerular filtration

Definition

Glomerular filtration is the filtration of plasma from glomerular capillaries into Bowman's capsule.

Factors Influencing Glomerular Filtration

1. Glomerular capillary hydrostatic pressure

- Main force favoring filtration.
- Normal value: about 60 mm Hg.

2. Bowman's capsule hydrostatic pressure

- Opposes filtration.
- Normal value: about 18 mm Hg.

3. Plasma colloid osmotic pressure

- Opposes filtration.
- Due to plasma proteins.

- Normal value: about 32 mm Hg.

4. Filtration coefficient

- Depends on permeability and surface area.

5. Renal blood flow

- Increased blood flow increases filtration.

6. Afferent and efferent arteriolar tone

- Afferent constriction decreases glomerular filtration rate.
- Mild efferent constriction increases glomerular filtration rate.

7. Sympathetic stimulation

- Causes vasoconstriction.
- Reduces glomerular filtration rate.

Net Filtration Pressure

Net filtration pressure = 60 – (32 + 18) = 10 mm Hg

Conclusion

Glomerular filtration depends on Starling forces and renal hemodynamics.

10. Explain the mechanism of maintaining osmatic gradient in renal medullary interstitium

Definition

Hyperosmotic medullary interstitium is maintained by counter current mechanism.

Mechanism

1. Active sodium chloride transport

- Thick ascending limb actively transports sodium chloride.
- Impermeable to water.
- Interstitial osmolarity increases.

2. Water movement from descending limb

- Descending limb permeable to water.
- Water moves out into hyperosmotic interstitium.

3. Counter current multiplication

- Repeated flow multiplies osmotic gradient.
- Osmolarity increases from cortex to papilla.

4. Urea recycling

- Urea diffuses from collecting ducts.
- Adds to medullary osmolarity.

5. Vasa recta

- Acts as counter current exchanger.
- Prevents washout of gradient.

Importance

- Essential for concentration of urine.
- Helps conserve water.

11. Explain the mechanisms of water re-absorption in renal tubule

Mechanism

Water is reabsorbed mainly by osmosis.

Steps

1. Active sodium reabsorption creates osmotic gradient.
2. Water moves passively through tubular epithelium.

3. Water enters interstitium and peritubular capillaries.

In Different Parts

Proximal tubule

- Obligatory reabsorption.
- Iso-osmotic.

Descending limb

- Permeable to water.

Ascending limb

- Impermeable to water.

Distal tubule and collecting duct

- Facultative reabsorption.
- Controlled by antidiuretic hormone.

Role of Antidiuretic Hormone

- Inserts aquaporin-2 channels.
- Increases water permeability.

Conclusion

Water reabsorption maintains body fluid volume and osmolarity.

12. Describe the counter current multiplier in the kidney

Definition

Counter current multiplier is the mechanism by which Loop of Henle creates medullary osmotic gradient.

Requirements

- Long loops of Henle
- Differential permeability
- Active sodium transport

Mechanism

Descending limb

- Permeable to water.
- Water leaves tubule.
- Fluid becomes concentrated.

Ascending limb

- Impermeable to water.
- Active sodium chloride reabsorption.
- Interstitium becomes hyperosmotic.

Single Effect

- About 200 mOsm/L gradient established.

Multiplication Process

- Continuous tubular flow multiplies gradient.
- Osmolarity rises progressively towards papilla.

Role of Urea

- Enhances medullary hyperosmolarity.

Importance

- Formation of concentrated urine.
- Conservation of water.

SHORT ANSWERS

13. Physiological basis for the renal counter current mechanism

Basis

1. Opposite flow in descending and ascending limbs.
2. Descending limb permeable to water.
3. Ascending limb impermeable to water.
4. Active sodium chloride transport in ascending limb.
5. Vasa recta acts as counter current exchanger.
6. Urea recycling contributes to medullary osmolarity.

Function

Maintains medullary osmotic gradient and concentrates urine.

14. Physiological basis for alkaline urine in high altitude

Cause

At high altitude, hypoxia causes hyperventilation.

Mechanism

- Excess carbon dioxide is lost.
- Respiratory alkalosis develops.
- Kidneys excrete more bicarbonate.
- Urine becomes alkaline.

15. Draw a neat labelled diagram showing the structure of the renal filtration membrane

REFER DIAGRAM SECTION

16. Explain the role of 'Vasa Recta' in renal function.

Role of Vasa Recta

1. Acts as counter current exchanger.
2. Maintains medullary osmotic gradient.
3. Prevents washout of solutes from medulla.
4. Supplies nutrients and oxygen to medulla.
5. Helps in concentration of urine.

Mechanism

- Descending vasa recta gains solutes and loses water.
- Ascending vasa recta loses solutes and gains water.

17. What is autoregulation of renal blood flow. What is its importance.

Definition

Autoregulation is the maintenance of nearly constant renal blood flow despite changes in arterial pressure.

Mechanisms

1. Myogenic mechanism
2. Tubuloglomerular feedback

Importance

1. Maintains stable glomerular filtration rate.
2. Prevents damage to glomeruli.
3. Maintains excretion of waste products.
4. Helps maintain fluid and electrolyte balance.

18. Describe the mechanisms regulating glomerular filtration rate.

Mechanisms Regulating Glomerular Filtration Rate

1. Autoregulation

Myogenic mechanism

- Stretch of afferent arteriole causes constriction.

Tubuloglomerular feedback

- Macula densa senses sodium chloride delivery.
- Adjusts afferent arteriolar tone.

2. Neural regulation

- Sympathetic stimulation causes vasoconstriction.
- Reduces glomerular filtration rate.

3. Hormonal regulation

- Angiotensin II constricts efferent arteriole.
- Atrial natriuretic peptide increases glomerular filtration rate.

19. Describe the physiological basis for renal splay.

Definition

Splay is the gradual appearance of glucose in urine before tubular maximum is reached.

Physiological Basis

1. Not all nephrons have identical tubular maximum.
2. Some nephrons reach transport maximum earlier.
3. Carrier systems become saturated gradually.
4. Hence glucose appears in urine progressively.

20. Tubulo glomerular feed back

Definition

Tubuloglomerular feedback is an autoregulatory mechanism by which macula densa regulates glomerular filtration rate.

Mechanism

1. Increased glomerular filtration rate increases sodium chloride delivery to macula densa.
2. Macula densa releases vasoactive substances.
3. Afferent arteriole constricts.
4. Glomerular filtration rate decreases.

Importance

- Maintains stable glomerular filtration rate.
- Prevents excessive loss of fluid.

21. In humans effective renal plasma flow is

Effective Renal Plasma Flow

- Normal value: about 650 mL/min.
- Measured by para aminohippuric acid clearance.

22. Urine output is decreased in summer season because

Causes

1. Increased sweating causes water loss.
2. Antidiuretic hormone secretion increases.
3. More water is reabsorbed from kidneys.
4. Urine volume decreases.

23. Draw and label : juxta glomerular apparatus

REFER DIAGRAM SECTION

24. Splay

Definition

Splay is the difference between renal threshold and tubular maximum.

Cause

- Due to variability in nephron transport capacity.

Significance

- Causes gradual appearance of glucose in urine.

25. Explain the physiological basis of glycosuria

Definition

Presence of glucose in urine is called glycosuria.

Physiological Basis

1. Normally glucose is completely reabsorbed in proximal tubule.
2. When blood glucose exceeds renal threshold (about 180 mg/dL), transport maximum is exceeded.
3. Excess glucose remains in tubular fluid.
4. Glucose appears in urine.

Causes

- Diabetes mellitus
- Renal glycosuria

26. Glomerular filtration rate

Definition

Glomerular filtration rate is the volume of filtrate formed by both kidneys per minute.

Normal Value

- About 125 mL/min.
- About 180 L/day.

Measurement

- Inulin clearance.
- Creatinine clearance.

Factors affecting glomerular filtration rate

- Renal blood flow
- Filtration pressure
- Filtration coefficient

Importance

- Indicator of renal function.

27. Describe the role of bicarbonate buffer system in aid-base balance

Bicarbonate Buffer System

Reaction

$H2CO3 \rightleftharpoons H+ + HCO3-$

Role in Acid-Base Balance

1. Important extracellular buffer.
2. Carbonic acid acts as weak acid.
3. Bicarbonate acts as base.
4. Lungs regulate carbon dioxide.
5. Kidneys regulate bicarbonate concentration.
6. Maintains blood pH around 7.4.

28. Factors affecting glomerular filtration rate

Factors

1. Glomerular capillary pressure
2. Plasma colloid osmotic pressure
3. Bowman's capsule pressure
4. Renal blood flow
5. Filtration coefficient
6. Afferent and efferent arteriolar tone
7. Sympathetic stimulation
8. Hormones like angiotensin II and atrial natriuretic peptide

29. Counter current exchange mechanism

Definition

Counter current exchange is the mechanism by which vasa recta maintains medullary osmotic gradient.

Mechanism

Descending vasa recta

- Gains sodium chloride.
- Loses water.

Ascending vasa recta

- Loses sodium chloride.
- Gains water.

Importance

- Prevents washout of medullary gradient.
- Helps concentration of urine.

30. Glomerulo-tubular feedback

Definition

Glomerulotubular balance is the phenomenon in which a constant fraction of filtered sodium and water is reabsorbed by proximal tubule despite changes in glomerular filtration rate.

Mechanism

- Increased filtration increases proximal tubular reabsorption.
- Due to Starling forces in peritubular capillaries.

Importance

- Prevents overloading of distal nephron.

31. Tubular maximum for glucose

Definition

Tubular maximum is the maximum amount of glucose reabsorbed per minute.

Normal Value

- About 375 mg/min in males.
- About 300 mg/min in females.

Significance

- Above tubular maximum, glucose appears in urine.

32. Proteinuria occurs in renal diseases. Why?

Cause

1. Damage to glomerular filtration membrane increases permeability.
2. Plasma proteins pass into filtrate.
3. Proteins appear in urine.

Conditions

- Glomerulonephritis
- Nephrotic syndrome

- Hypertension

33. Urine output is decreased in summer season. Why?

Reason

1. Excess sweating causes water loss.
2. Plasma osmolarity increases.
3. Antidiuretic hormone secretion increases.
4. Increased water reabsorption occurs in kidneys.
5. Urine volume decreases.

34. Water re-absorption by renal tubules

Definition

Water reabsorption is the process by which filtered water is returned from renal tubules to blood.

Normal Value

About 99% of filtered water is reabsorbed.

Sites of Water Reabsorption

1. Proximal convoluted tubule – 65%
2. Loop of Henle – 15%
3. Distal convoluted tubule – 10%
4. Collecting duct – 9%

Mechanism

1. Obligatory water reabsorption

- Occurs in proximal convoluted tubule and descending limb of loop of Henle.
- Water follows solute passively by osmosis.
- Not dependent on antidiuretic hormone.

2. Facultative water reabsorption

- Occurs in distal convoluted tubule and collecting duct.
- Depends on antidiuretic hormone.
- Antidiuretic hormone increases permeability of tubules by insertion of aquaporin channels.

Factors affecting water reabsorption

1. Antidiuretic hormone
2. Osmotic gradient in medulla
3. Blood volume
4. Blood pressure

Applied Physiology

- Deficiency of antidiuretic hormone causes diabetes insipidus.

35. Renal clearance

Definition

Renal clearance is the volume of plasma completely cleared of a substance by kidneys per minute.

Formula

$C = UV/P$

Where:

- C = Clearance
- U = Urinary concentration
- V = Urine flow per minute
- P = Plasma concentration

Types

1. Inulin clearance

- Measures glomerular filtration rate.
- Normal value: 125 mL/min.

2. Para amino hippuric acid clearance

- Measures renal plasma flow.
- Normal value: 650 mL/min.

3. Creatinine clearance

- Used clinically to estimate glomerular filtration rate.

Significance

1. Measures kidney function
2. Assesses glomerular filtration rate
3. Assesses renal plasma flow
4. Detects renal disease

36. Filtration pressure in glomerulus

Definition

Net filtration pressure is the pressure responsible for ultrafiltration across glomerular membrane.

Forces involved

Forces favoring filtration

1. Glomerular capillary hydrostatic pressure = 60 mm Hg

Forces opposing filtration

1. Colloid osmotic pressure of plasma proteins = 32 mm Hg
2. Capsular hydrostatic pressure = 18 mm Hg

Calculation

Net filtration pressure = 60 – (32 + 18) = 10 mm Hg

Significance

- Maintains glomerular filtration.

37. Nephrotic syndrome

Definition

Nephrotic syndrome is characterized by massive proteinuria, hypoalbuminemia, edema and hyperlipidemia.

Causes

1. Glomerulonephritis
2. Diabetes mellitus
3. Minimal change disease
4. Amyloidosis

Features

1. Massive proteinuria
2. Hypoalbuminemia
3. Generalized edema
4. Hyperlipidemia
5. Lipiduria

Mechanism of edema

- Loss of plasma proteins decreases plasma colloid osmotic pressure.
- Fluid moves from blood to tissues causing edema.

Complications

1. Infection
2. Thrombosis
3. Renal failure

38. Splay in renal glucose reabsorption curve

Definition

Splay is the rounded portion of glucose titration curve between renal threshold and transport maximum.

Cause

1. Different nephrons have different transport maximum.
2. Glucose carriers become saturated gradually.

Significance

- Small amount of glucose appears in urine before transport maximum is reached.

39. Auto regulation of glomerular filtration rate

Definition

Autoregulation is the intrinsic ability of kidneys to maintain constant renal blood flow and glomerular filtration rate despite changes in arterial pressure.

Mechanisms

1. Myogenic mechanism

- Stretch of afferent arteriole causes constriction.
- Prevents increase in glomerular filtration rate.

2. Tubuloglomerular feedback

- Macula densa senses sodium chloride delivery.
- Signals afferent arteriole constriction or dilation.

Significance

1. Maintains constant glomerular filtration rate.
2. Prevents renal damage.
3. Maintains fluid and electrolyte balance.

40. Draw and label : Splay

REFER DIAGRAM SECTION

Definition

Splay is the curved portion of glucose titration curve between renal threshold and transport maximum.

41. Role of juxta glomerular apparatus in the regulation of ECF volume

Juxtaglomerular apparatus

It is formed by:

1. Macula densa
2. Juxtaglomerular cells
3. Lacis cells

Role in extracellular fluid volume regulation

1. Fall in extracellular fluid volume

- Decreases renal perfusion.
- Stimulates juxtaglomerular cells.
- Renin is released.

2. Renin angiotensin aldosterone system activation

- Renin converts angiotensinogen to angiotensin I.
- Angiotensin converting enzyme converts it to angiotensin II.

3. Actions of angiotensin II

1. Vasoconstriction
2. Stimulates aldosterone secretion
3. Increases sodium and water reabsorption
4. Increases thirst

Result

- Extracellular fluid volume increases.

42. Renal plasma clearance values for inulin, PAH and glucose their significance

Substance	Clearance value	Significance
Inulin	125 mL/min	Measures glomerular filtration rate
PAH	650 mL/min	Measures renal plasma flow
Glucose	Zero	Completely reabsorbed normally

43. Draw and label : Counter current multiplier and exchange system in renal tubules

REFER DIAGRAM SECTION

LOWER URINARY TRACT

SHORT ESSAYS

1. Describe the physiological basis of cystometrogram with a graph

Definition

Cystometrogram is the graphical recording of intravesical pressure during filling of urinary bladder.

Physiological basis

1. Initial stage

- Small rise in pressure with initial filling.

2. Tone adaptation

- Pressure remains nearly constant despite increase in volume due to stress relaxation.

3. Micturition waves

- Sudden rise in pressure due to micturition reflex.

4. Further filling

- Marked rise in pressure after bladder capacity is exceeded.

Normal bladder capacity

- About 300–400 mL.

Graph labels

REFER DIAGRAM SECTION

Significance

1. Assesses bladder function
2. Detects neurogenic bladder disorders

2. With a neat labelled diagram describe the micturition reflex. Add a note on autoregulation of renal blood flow.

Micturition reflex

Definition

Micturition reflex is a spinal reflex responsible for emptying of urinary bladder.

Receptors

- Stretch receptors in bladder wall.

Afferent pathway

- Pelvic nerves to sacral spinal cord segments S2–S4.

Centre

- Sacral micturition centre.
- Facilitated or inhibited by cerebral cortex and pontine centre.

Efferent pathway

- Parasympathetic fibers through pelvic nerves.

Mechanism

1. Bladder filling stretches wall.
2. Stretch receptors stimulated.
3. Impulses reach sacral spinal cord.
4. Parasympathetic nerves cause detrusor contraction.
5. Internal sphincter relaxes.
6. External sphincter relaxes voluntarily.
7. Urine is expelled.

Diagram labels

REFER DIAGRAM SECTION

Note on autoregulation of renal blood flow

Definition

Maintenance of constant renal blood flow despite changes in arterial pressure.

Mechanisms

1. Myogenic mechanism
2. Tubuloglomerular feedback

Importance

- Maintains stable glomerular filtration rate.

3. Describe the mechanism of micturition reflex

Definition

Micturition reflex is a spinal reflex causing bladder emptying.

Mechanism

1. Urine fills bladder.
2. Stretch receptors in bladder wall are stimulated.
3. Afferent impulses pass through pelvic nerves to sacral spinal cord.
4. Parasympathetic efferent fibers return through pelvic nerves.
5. Detrusor muscle contracts.
6. Internal urethral sphincter relaxes.
7. External urethral sphincter relaxes voluntarily.
8. Urine is expelled.

Higher control

- Cerebral cortex can facilitate or inhibit reflex.

SHORT ANSWERS

4. Draw and label a normal cystometrogram

REFER DIAGRAM SECTION

5. Draw and label: nerve supply of the urinary bladder and sphincters.

REFER DIAGRAM SECTION

6. Micturition reflex

Definition

Micturition reflex is a spinal reflex that empties urinary bladder.

Pathway

1. Stretch receptors in bladder
2. Pelvic nerve afferents
3. Sacral spinal cord
4. Parasympathetic efferents
5. Detrusor contraction

Result

- Relaxation of sphincters and passage of urine.

7. Osmotic and pressure diuresis

Osmotic diuresis

Increase in urine output due to presence of nonreabsorbable solutes in renal tubules.

Causes

1. Diabetes mellitus
2. Mannitol administration

Mechanism

- Solutes retain water in tubules.

Pressure diuresis

Increase in urine output due to rise in arterial pressure.

Mechanism

- Increased blood pressure decreases tubular reabsorption.

Significance

- Helps regulate body fluid volume and blood pressure.

8. Change in bladder function in spinal shock. Why?

Changes

- Bladder becomes atonic and distended.
- Urinary retention occurs.
- Overflow incontinence may occur.

Cause

- Temporary suppression of spinal reflexes after spinal cord injury.
- Micturition reflex is absent.

9. Atonic bladder

Definition

Atonic bladder is a flaccid bladder due to loss of sensory input or reflex activity.

Causes

1. Damage to sensory nerves
2. Tabes dorsalis
3. Diabetes mellitus

Features

1. Large distended bladder
2. Urinary retention
3. Overflow incontinence

10. Filling and emptying of urinary bladder

Filling

- Sympathetic nerves relax detrusor muscle.
- Internal sphincter contracts.
- External sphincter remains contracted.

Emptying

- Parasympathetic stimulation contracts detrusor muscle.
- Internal sphincter relaxes.
- External sphincter relaxes voluntarily.

SKIN & TEMPERATURE REGULATION

SHORT ESSAYS

1. Explain the mechanism of temperature regulation in a cold environment

Definition

Temperature regulation is maintenance of normal body temperature around 37°C.

Receptors

- Cold receptors in skin and hypothalamus.

Centre

- Posterior hypothalamus.

Mechanisms conserving heat

1. Cutaneous vasoconstriction

- Reduces heat loss.

2. Piloerection

- Traps insulating air layer.

3. Decreased sweating

- Reduces evaporative heat loss.

Mechanisms increasing heat production

1. Shivering

- Increases muscle heat production.

2. Nonshivering thermogenesis

- Increased sympathetic activity and thyroxine secretion.

3. Increased metabolism

- Raises heat production.

Result

- Body temperature maintained.

2. Briefly describe the thermoregulatory mechanisms in human body.

Thermoregulatory centre

- Hypothalamus acts as thermostat.

Mechanisms of heat loss

1. Radiation
2. Conduction
3. Convection
4. Evaporation

Mechanisms activated in heat exposure

1. Vasodilation
2. Sweating
3. Decreased heat production

Mechanisms activated in cold exposure

1. Vasoconstriction
2. Shivering
3. Increased metabolism

Importance

- Maintains constant body temperature.

3. Describe the regulation of body temperature during hot climate

Mechanisms of heat loss

1. Vasodilation

- Increases blood flow to skin.

2. Sweating

- Evaporation causes cooling.

3. Decreased heat production

- Reduced muscle activity and metabolism.

Role of hypothalamus

- Anterior hypothalamus activates heat loss mechanisms.

Acclimatization to hot climate

1. Increased sweating
2. Reduced salt loss in sweat
3. Improved tolerance to heat

SHORT ANSWERS

4. Describe heat stroke and the role of hypothalamus in causing heat loss

Heat stroke

Heat stroke is rise in body temperature above 40°C due to failure of thermoregulatory mechanisms.

Features

1. Hot dry skin
2. High fever
3. Delirium
4. Coma

Role of hypothalamus in heat loss

- Anterior hypothalamus activates:

1. Sweating
2. Vasodilation
3. Decreased heat production

5. What is Hypothermia. Write one clinical application for hypothermia.

Definition

Hypothermia is fall in body temperature below normal.

Causes

1. Cold exposure
2. Shock
3. Hypothyroidism

Effects

1. Shivering
2. Reduced metabolism
3. Bradycardia

Clinical application

- Used during cardiac surgery to reduce metabolic rate.

6. Describe the role of hypothalamus in temperature regulation

Anterior hypothalamus

- Heat loss centre.
- Causes sweating and vasodilation.

Posterior hypothalamus

- Heat gain centre.
- Causes vasoconstriction and shivering.

Functions

1. Receives thermal signals.
2. Maintains body temperature.
3. Coordinates autonomic responses.

7. Describe various physiological mechanisms that operate in response to heat

Mechanisms

1. Cutaneous vasodilation
2. Sweating
3. Increased evaporation
4. Decreased muscle activity
5. Decreased metabolic rate

Centre involved

- Anterior hypothalamus.

Importance

- Promotes heat loss and maintains body temperature.

8. Explain the role of skin in regulating body temperature.

Functions of skin in temperature regulation

1. Vasodilation

- Increases heat loss.

2. Vasoconstriction

- Conserves heat.

3. Sweating

- Causes evaporative cooling.

4. Insulation

- Subcutaneous fat reduces heat loss.

5. Piloerection

- Conserves heat.

9. Shivering is a thermoregulatory response. Why?

Reason

- Shivering consists of involuntary rhythmic muscle contractions.
- Increases heat production during cold exposure.

Centre

- Controlled by posterior hypothalamus.

10. Mechanism of heat loss by body

Modes of heat loss

1. Radiation

- Transfer of heat without contact.

2. Conduction

- Transfer of heat by direct contact.

3. Convection

- Heat loss by moving air or fluid.

4. Evaporation

- Heat loss by conversion of water to vapor.

Importance

- Maintains normal body temperature.

11. Hypothermia

Definition

Hypothermia is reduction of body temperature below normal.

Causes

1. Exposure to cold
2. Endocrine disorders
3. Shock

Features

1. Shivering
2. Slow pulse
3. Reduced metabolism
4. Confusion

Treatment

- Gradual warming.

12. Skin as thermostat

Explanation

Skin contains temperature receptors that detect environmental temperature changes.

Functions

1. Detects heat and cold.
2. Initiates reflex responses.
3. Helps maintain body temperature.

Mechanisms

1. Sweating
2. Vasodilation
3. Vasoconstriction
4. Piloerection

13. Physiological basis of Hyperthermia

Definition:
Hyperthermia is an abnormal rise in body temperature due to failure of heat regulating mechanisms, where heat gain exceeds heat loss and hypothalamic set point remains normal.

Physiological basis

1. **Excess heat production**
   - Heavy muscular exercise
   - Convulsions
   - Hyperthyroidism
   - Increased metabolic activity
2. **Decreased heat loss**
   - Exposure to hot and humid environment
   - Impaired sweating
   - Dehydration
   - Tight clothing
3. **Failure of thermoregulatory mechanisms**
   - Damage to hypothalamic heat loss center
   - Heat stroke
4. **Mechanism**
   - Body temperature rises above normal
   - Sweating becomes inadequate
   - Peripheral vasodilatation occurs
   - If severe → cellular damage, dehydration and circulatory collapse

14. Physiological basis of non shivering thermogenesis

Non-shivering thermogenesis is heat production without muscular shivering.

Physiological basis

1. Exposure to cold stimulates hypothalamus.
2. Sympathetic nervous system is activated.
3. Catecholamines increase metabolic rate.
4. Thyroxine secretion increases and raises cellular metabolism.
5. Brown adipose tissue produces heat by oxidation of fatty acids.

Importance

- Important in newborns.
- Helps maintain body temperature during cold exposure.

15. Reactive hyperthermia

Definition:
Rise in body temperature due to increased metabolic activity following sympathetic discharge.

Causes

- Emotional stress
- Exercise
- Increased catecholamine secretion

Mechanism

1. Sympathetic stimulation increases metabolic rate.
2. Increased oxidation in tissues produces excess heat.
3. Heat production exceeds heat loss temporarily.
4. Body temperature rises slightly.

Features

- Temporary increase in temperature
- Usually mild
- Returns to normal after removal of stimulus

16. Brown fat

Brown fat is a specialized adipose tissue rich in mitochondria concerned with heat production.

Features

- Brown color due to cytochromes and rich blood supply
- Rich sympathetic innervation
- Contains abundant mitochondria

Functions

1. Produces heat by non-shivering thermogenesis.
2. Important in newborns for temperature regulation.

Mechanism

- Norepinephrine stimulates lipolysis.
- Fatty acid oxidation occurs.
- Uncoupling protein (thermogenin) causes heat production instead of ATP formation.

Sites

- Interscapular region
- Around neck
- Around kidneys

17. Hyperthermia

Definition:
Hyperthermia is elevation of body temperature due to excessive heat production or inadequate heat loss without change in hypothalamic set point.

Causes

1. High environmental temperature
2. Heavy exercise
3. Dehydration
4. Heat stroke
5. Hyperthyroidism

Manifestations

- Increased body temperature
- Sweating
- Tachycardia
- Weakness
- Headache

Effects

- Enzyme dysfunction
- Dehydration
- Circulatory failure
- CNS disturbances

Management

- Cooling measures
- Fluid replacement
- Treatment of cause

18. Body temperature is slightly elevated during ovulation. Why?

Reason

- After ovulation, progesterone secretion from corpus luteum increases.
- Progesterone acts on hypothalamic thermoregulatory center.
- It increases basal body temperature by about 0.3–0.5°C.

Importance

- Rise in basal body temperature indicates ovulation.
- Used in fertility assessment.

19. Fever during infection

Definition:
Fever is rise in body temperature due to increase in hypothalamic set point caused by pyrogens.

Mechanism

1. Infection produces exogenous pyrogens.
2. Leukocytes release endogenous pyrogens such as interleukin-1.
3. Pyrogens stimulate prostaglandin E_2 synthesis in hypothalamus.
4. Hypothalamic set point increases.
5. Heat conservation and heat production mechanisms are activated:
    - Vasoconstriction
    - Shivering
6. Body temperature rises producing fever.

Importance

- Enhances immune response
- Inhibits growth of microorganisms

GENERAL QUESTIONS

SHORT ESSAYS

1. Explain the barriers that can affect the communication process in a healthcare set-up

Introduction

Communication is the exchange of information between healthcare workers and patients. Effective communication is essential for proper patient care.

Barriers affecting communication

1. Physical barriers

- Noise
- Lack of privacy
- Poor lighting
- Distance between patient and doctor

2. Language barriers

- Different languages
- Use of medical jargon
- Illiteracy

3. Psychological barriers

- Anxiety
- Fear
- Depression
- Anger

4. Cultural and social barriers

- Differences in beliefs and customs
- Religious factors
- Social stigma

5. Physiological barriers

- Hearing impairment
- Speech defects
- Visual impairment
- Pain and fatigue

6. Attitudinal barriers

- Lack of empathy
- Negative attitude
- Poor listening skills

7. Organizational barriers

- Time constraints
- Heavy workload
- Improper coordination among staff

Measures to overcome barriers

- Use simple language
- Ensure privacy
- Active listening
- Empathy and respect
- Use interpreters if needed

2. Discuss the aspects of verbal and non-verbal communication during patient encounters.

Introduction

Communication during patient encounters may be verbal or non-verbal. Both are essential for effective patient care.

Verbal communication

Features

- Use of spoken or written words
- Clear and simple language
- Appropriate tone and pace

Important aspects

1. Greeting the patient politely
2. Introducing oneself
3. Asking open-ended questions
4. Active listening
5. Giving clear explanations
6. Confirming patient understanding
7. Maintaining confidentiality

Advantages

- Helps obtain history
- Builds trust
- Improves compliance

Non-verbal communication

Definition

Communication without words through gestures and expressions.

Types

1. Facial expressions
2. Eye contact
3. Posture
4. Gestures
5. Touch
6. Body language
7. Silence

Importance

- Reflects empathy and concern
- Improves patient confidence
- Helps understand patient emotions

Conclusion

Effective verbal and non-verbal communication improves diagnosis, treatment and doctor-patient relationship.

SHORT ANSWERS

3. What is empathy. Explain its importance in patient care

Definition

Empathy is the ability to understand and share the feelings of another person.

Importance in patient care

1. Builds trust between doctor and patient
2. Improves communication
3. Reduces patient anxiety
4. Increases treatment compliance
5. Improves patient satisfaction
6. Helps better clinical outcomes

4. Describe the professional qualities of doctor

Professional qualities of a doctor

1. Competence and knowledge
2. Good communication skills
3. Empathy and compassion
4. Honesty and integrity
5. Responsibility and accountability
6. Respect for patients
7. Confidentiality
8. Ethical practice
9. Patience and dedication
10. Teamwork and leadership

5. Enumerate the critical components of the doctor-patient relationship.

Critical components

1. Trust
2. Good communication
3. Respect
4. Empathy
5. Confidentiality
6. Informed consent
7. Professional competence
8. Shared decision making
9. Continuity of care
10. Ethical behavior

GENERAL PHYSIOLOGY

CELL

SHORT ESSAYS

1. Explain the different transport mechanisms across a cell membrane.

Introduction

Transport across the cell membrane is essential for maintenance of intracellular environment, nutrition, excretion and homeostasis.

Classification of transport mechanisms

1. Passive transport
2. Active transport
3. Vesicular transport

1. Passive transport

Movement of substances across the membrane without expenditure of energy and along the concentration or electrochemical gradient.

Types

A. Simple diffusion

Movement of molecules from higher concentration to lower concentration directly through membrane.

Features

- No carrier protein required
- No ATP required
- Non-saturable

Examples

- Oxygen
- Carbon dioxide
- Lipid soluble substances

B. Facilitated diffusion

Movement through carrier proteins.

Features

- Carrier mediated
- No ATP required

- Saturable
- Specific

Examples

- Glucose transport by GLUT transporters
- Urea transport

C. Osmosis

Movement of water through semipermeable membrane from low solute concentration to high solute concentration.

Example

- Water movement through aquaporins

D. Filtration

Movement of fluid and solutes due to hydrostatic pressure difference.

Example

- Glomerular filtration in kidney

2. Active transport

Movement of substances against concentration gradient with expenditure of energy.

Types

A. Primary active transport

Energy derived directly from ATP hydrolysis.

Examples

- Sodium-potassium pump
- Calcium pump
- Hydrogen-potassium ATPase

B. Secondary active transport

Uses energy stored in ionic gradient, usually sodium gradient.

Types

1. Symport (co-transport)
2. Antiport (counter-transport)

Examples

- Sodium-glucose co-transport
- Sodium-calcium exchange

3. Vesicular transport

Transport by formation of vesicles.

Types

A. Endocytosis

Entry of substances into cell.

Types

- Phagocytosis
- Pinocytosis
- Receptor mediated endocytosis

B. Exocytosis

Release of substances outside cell.

Examples

- Neurotransmitter release
- Hormone secretion

C. Transcytosis

Transport across the cell through vesicles.

2. Explain the different types of intercellular connections.

Introduction

Intercellular junctions are specialized structures connecting adjacent cells and maintaining tissue integrity and communication.

Types of intercellular junctions

1. Tight junctions (Zonula occludens)

Structure

- Adjacent membranes fuse at certain points.
- Seal intercellular space.

Functions

- Prevent passage of substances between cells
- Maintain cell polarity

Example

- Intestinal epithelium

2. Adherens junctions (Zonula adherens)

Structure

- Connected to actin filaments
- Mediated by cadherins

Functions

- Provide mechanical attachment
- Maintain tissue architecture

3. Desmosomes (Macula adherens)

Structure

- Spot-like adhesions
- Attached to intermediate filaments

Functions

- Provide tensile strength
- Resist mechanical stress

Example

- Skin
- Cardiac muscle

4. Hemidesmosomes

Structure

- Attach cell to basement membrane

Functions

- Anchor epithelial cells

5. Gap junctions

Structure

- Formed by connexons
- Create communicating channels between cells

Functions

- Passage of ions and small molecules
- Electrical coupling between cells

Example

- Cardiac muscle
- Smooth muscle

3. Inter-cellular communication

Definition

Intercellular communication is the transfer of information between cells to coordinate body functions.

Types

1. Direct intercellular communication

Occurs through gap junctions.

Features

- Direct transfer of ions and small molecules
- Rapid communication

Examples

- Cardiac muscle
- Smooth muscle

2. Chemical communication

Occurs through chemical messengers.

Types

A. Autocrine communication

Chemical acts on same cell.

Example

- Growth factors

B. Paracrine communication

Chemical acts on nearby cells.

Example

- Histamine

C. Endocrine communication

Hormones carried through blood.

Example

- Insulin

D. Synaptic communication

Neurotransmitters released at synapse.

Example

- Acetylcholine

E. Neuroendocrine communication

Neuron releases hormone into blood.

Example

- ADH release from hypothalamus

Mechanism

1. Synthesis of signaling molecule
2. Release from cell
3. Binding to receptor
4. Signal transduction
5. Cellular response

Importance

- Coordination of body functions
- Growth and development
- Homeostasis

SHORT ANSWERS

4. Draw and label sodium-potassium ATPase.

Sodium-potassium ATPase

Diagram

REFER DIAGRAM SECTION

Functions

- Maintains resting membrane potential
- Maintains cell volume

- Essential for secondary active transport

5. Depict the types of active transport with suitable examples.

Active transport

Movement of substances against concentration gradient with expenditure of energy.

Types

1. Primary active transport

Uses ATP directly.

Examples

- Sodium-potassium pump
- Calcium pump
- Hydrogen-potassium ATPase

2. Secondary active transport

Uses energy stored in ionic gradient.

Types

A. Symport (Co-transport)

Two substances move in same direction.

Examples

- Sodium-glucose co-transport
- Sodium-amino acid transport

B. Antiport (Counter-transport)

Substances move in opposite directions.

Examples

- Sodium-calcium exchange
- Sodium-hydrogen exchange

6. Describe secondary active transport using an example.

Definition

Secondary active transport is transport in which energy derived from ionic gradient is used to move another substance against its concentration gradient.

Mechanism

- Sodium-potassium pump creates sodium gradient.
- Sodium enters cell down gradient.
- Another substance is transported against gradient.

Types

1. Symport
2. Antiport

Example: Sodium-glucose co-transport

- Occurs in intestinal mucosa and renal tubules.
- Sodium and glucose enter together through carrier protein.
- Sodium moves along gradient.
- Glucose moves against gradient.
- Energy indirectly derived from ATP through sodium-potassium pump.

Importance

- Absorption of glucose from intestine
- Reabsorption of glucose in kidney

7. Draw, label and explain the sodium-potassium pump. What happens if it stops functioning.

Sodium-potassium pump

Definition

It is a primary active transport mechanism that transports sodium out of cell and potassium into cell using ATP.

Diagram

REFER DIAGRAM SECTION

Mechanism

1. Three sodium ions bind inside cell.
2. ATP is hydrolysed.
3. Sodium expelled outside.
4. Two potassium ions bind externally.
5. Potassium released inside.

Functions

- Maintains resting membrane potential
- Maintains osmotic balance and cell volume
- Helps secondary active transport
- Maintains intracellular potassium concentration

What happens if it stops functioning

- Sodium accumulates inside cell.
- Potassium decreases inside cell.
- Water enters cell causing swelling.
- Cell membrane potential is lost.
- Cellular functions fail.
- Cell may undergo death.

8. Active transport

Definition

Movement of substances against concentration gradient using energy.

Features

- Requires ATP
- Carrier mediated
- Specific
- Saturable
- Against electrochemical gradient

Types

1. Primary active transport
2. Secondary active transport

Examples

- Sodium-potassium pump
- Calcium pump
- Sodium-glucose transport

Importance

- Absorption of nutrients
- Maintenance of ionic gradients
- Maintenance of membrane potential

9. Primary active transport

Definition

Transport in which energy derived directly from ATP hydrolysis is used to move substances against gradient.

Features

- Direct use of ATP
- Carrier mediated
- Specific and saturable

Examples

- Sodium-potassium ATPase
- Calcium ATPase
- Hydrogen-potassium ATPase

Functions

- Maintains ionic gradients

- Maintains resting membrane potential
- Regulates intracellular calcium

10. Administration of sodium and glucose together in oral dehydration. Why?

Reason

Sodium and glucose are absorbed together by sodium-glucose co-transport mechanism in intestinal mucosa.

Mechanism

- Sodium enters intestinal cells along concentration gradient.
- Glucose is co-transported with sodium.
- Water follows osmotically.

Importance in oral rehydration therapy

- Enhances sodium absorption
- Enhances water absorption
- Corrects dehydration effectively

BODY FLUID COMPARTMENTS AND HOMEOSTASIS

SHORT ANSWERS

1. Describe the mechanisms of Homeostasis with suitable examples.

Definition

Homeostasis is maintenance of constant internal environment of body.

Components of homeostatic mechanism

1. Receptor
2. Control center
3. Effector

Mechanisms

1. Negative feedback mechanism

Response opposes initial change.

Examples

- Regulation of body temperature
- Blood glucose regulation
- Blood pressure regulation

2. Positive feedback mechanism

Response amplifies initial change.

Examples

- Blood clotting
- Parturition
- Action potential generation

Importance

- Maintains optimal cellular function
- Maintains internal environment stability

2. With the help of a neat, labelled diagram depict the factors that prevent accumulation of excess fluid in the interstitium.

Factors preventing edema

1. Low compliance of interstitial space

- Increase in interstitial pressure limits filtration.

2. Increased lymphatic drainage

- Removes excess fluid and proteins.

3. Washdown of interstitial proteins

- Decreases interstitial colloid osmotic pressure.

4. Safety factor due to low interstitial pressure

- Negative pressure opposes fluid accumulation.

Diagram labels

- Capillary hydrostatic pressure
- Plasma colloid osmotic pressure
- Interstitial hydrostatic pressure
- Lymphatic drainage

3. Sodium-potassium pump is essential for homeostasis – why?

Reasons

- Maintains intracellular and extracellular ionic composition.
- Maintains resting membrane potential.
- Regulates cell volume.
- Prevents cellular swelling.
- Essential for nerve and muscle excitability.
- Helps secondary active transport.

Conclusion

Hence sodium-potassium pump is essential for maintenance of cellular homeostasis.

4. Describe how edema is prevented in a normal body.

Prevention of edema

1. Low capillary hydrostatic pressure

Reduces excessive filtration.

2. Plasma proteins

Maintain plasma colloid osmotic pressure and promote reabsorption.

3. Efficient lymphatic drainage

Removes excess interstitial fluid and proteins.

4. Low interstitial compliance

Rise in interstitial pressure limits fluid accumulation.

5. Intact capillary membrane

Prevents leakage of proteins.

5. What is secondary active transport. Explain the types with examples.

Definition

Secondary active transport is transport in which energy stored in ionic gradient is used to move another substance against gradient.

Types

1. Symport (Co-transport)

Two substances move in same direction.

Examples

- Sodium-glucose co-transport
- Sodium-amino acid transport

2. Antiport (Counter-transport)

Substances move in opposite directions.

Examples

- Sodium-calcium exchange
- Sodium-hydrogen exchange

Importance

- Absorption of nutrients
- Regulation of intracellular ions

6. Physiological basis of Saturation of transportation of substances in facilitated diffusion.

Physiological basis

Facilitated diffusion depends on carrier proteins present in membrane.

Mechanism of saturation

- Carrier proteins are limited in number.
- At low concentration, transport increases with concentration.
- At high concentration, all carriers become occupied.
- Transport rate reaches maximum called Transport maximum (Tm).

Examples

- Glucose transport
- Amino acid transport

7. Edema in hypoproteinemia. Why?

Cause

Hypoproteinemia decreases plasma colloid osmotic pressure.

Mechanism

- Reduced plasma proteins especially albumin
- Decreased reabsorption at venous end of capillary
- Excess fluid accumulates in interstitial space
- Causes edema

Examples

- Nephrotic syndrome
- Liver disease
- Protein malnutrition

NERVE PHYSIOLOGY AND SKELETAL MUSCLE PHYSIOLOGY

LONG ESSAYS

1. Define synapse. Depict the mechanism of synaptic transmission using a flow chart. Describe the post-synaptic inhibition. Add a note on synaptic plasticity.

Definition

A synapse is the junction between two neurons or between a neuron and an effector organ through which nerve impulses are transmitted.

Mechanism of synaptic transmission

Flow chart

Action potential reaches presynaptic terminal
↓
Opening of voltage gated calcium channels
↓
Calcium influx into presynaptic terminal
↓
Fusion of synaptic vesicles with presynaptic membrane
↓
Release of neurotransmitter into synaptic cleft
↓
Binding of neurotransmitter to postsynaptic receptors
↓
Opening or closing of ion channels
↓

Generation of excitatory or inhibitory postsynaptic potential
↓
Postsynaptic response

Explanation

1. Arrival of action potential depolarizes presynaptic membrane.
2. Voltage gated calcium channels open.
3. Calcium enters presynaptic terminal.
4. Synaptic vesicles release neurotransmitter by exocytosis.
5. Neurotransmitter diffuses across synaptic cleft.
6. Neurotransmitter binds to receptors on postsynaptic membrane.
7. Ion channels open or close causing depolarization or hyperpolarization.
8. Neurotransmitter is removed by enzymatic degradation, diffusion or reuptake.

Post-synaptic inhibition

Definition

Postsynaptic inhibition is inhibition produced by hyperpolarization of postsynaptic membrane.

Mechanism

1. Inhibitory neurotransmitter such as GABA or glycine is released.
2. Neurotransmitter binds to inhibitory receptors.
3. Chloride channels open causing chloride influx or potassium channels open causing potassium efflux.
4. Postsynaptic membrane becomes hyperpolarized.
5. Generation of action potential is inhibited.

Inhibitory postsynaptic potential (IPSP)

Hyperpolarization produced in postsynaptic membrane is called IPSP.

Functions

- Prevents excessive neuronal discharge
- Coordinates motor activity
- Maintains balance between excitation and inhibition

Synaptic plasticity

Definition

Synaptic plasticity is the ability of synapses to undergo functional and structural changes in response to activity.

Types

1. Short term plasticity

- Facilitation
- Post tetanic potentiation

2. Long term plasticity

- Long term potentiation (LTP)
- Long term depression (LTD)

Mechanisms

- Increased neurotransmitter release
- Increased receptor sensitivity
- Structural changes in synapse

Importance

- Learning
- Memory
- Adaptation

2. A young female exhibits abnormal fatigability of muscles. Muscular movements, though initially strong, rapidly tire as the day advances or after a vigorous exercise. The symptoms to appear are ptosis, weakness of chewing, swallowing and speaking. She was unable to undertake work above the level of the shoulder. The symptoms showed a remitting course and often were precipitated by emotions, infections and pregnancy. Remarkable recovery was seen after injection of neostigmine intramuscularly.

• What is your diagnosis ?
• Name the structure involved in this disease.
• Describe the structure involved and the normal physiological mechanism of it .
• What is the main cause for this condition?
• Name any other condition that can affect this structure .
• How does injection of neostigmine improve the condition.
Describe other drugs which can act at this site.

• What is your diagnosis ?

Diagnosis:
Myasthenia Gravis

• Name the structure involved in this disease.

Structure involved:
Neuromuscular junction (motor end plate).

• Describe the structure involved and the normal physiological mechanism of it .

Neuromuscular Junction

The neuromuscular junction is the synapse between the terminal of a motor neuron and the skeletal muscle fiber.

Structure

1. **Presynaptic terminal**
   - Terminal part of motor neuron.
   - Contains synaptic vesicles filled with acetylcholine.
   - Contains mitochondria.
2. **Synaptic cleft**
   - Space between nerve ending and muscle membrane.
   - Contains acetylcholinesterase enzyme.
3. **Postsynaptic membrane (motor end plate)**
   - Part of muscle membrane with junctional folds.
   - Contains nicotinic acetylcholine receptors.

Normal Physiological Mechanism

1. Nerve impulse reaches motor nerve terminal.
2. Voltage-gated calcium channels open.
3. Calcium enters nerve terminal.
4. Acetylcholine is released into synaptic cleft.
5. Acetylcholine binds to nicotinic receptors on motor end plate.
6. Sodium influx causes end plate potential.
7. Muscle action potential is generated.
8. Muscle contraction occurs.
9. Acetylcholine is rapidly destroyed by acetylcholinesterase.

• What is the main cause for this condition?

Main Cause

- Autoimmune destruction of nicotinic acetylcholine receptors at the postsynaptic membrane.
- Antibodies reduce the number of functional receptors.
- Neuromuscular transmission becomes defective causing muscle weakness and fatigability.

• Name any other condition that can affect this structure .

Other conditions affecting neuromuscular junction:

1. Lambert-Eaton Myasthenic Syndrome
2. Botulism
3. Curare poisoning.

• How does injection of neostigmine improve the condition.

Action of Neostigmine

Neostigmine inhibits acetylcholinesterase enzyme.

Therefore:

- Breakdown of acetylcholine is prevented.
- Acetylcholine concentration at neuromuscular junction increases.
- Remaining receptors are stimulated effectively.
- Neuromuscular transmission improves.
- Muscle strength increases.

• Describe other drugs which can act at this site.

Drugs Acting at Neuromuscular Junction

1. Anticholinesterase drugs

- Neostigmine
- Physostigmine
- Pyridostigmine

Action: Increase acetylcholine at neuromuscular junction.

2. Neuromuscular blocking drugs

Non-depolarizing blockers

- Curare
- Pancuronium

Action: Compete with acetylcholine at receptors and prevent muscle contraction.

Depolarizing blockers

- Succinylcholine

Action: Causes persistent depolarization and paralysis.

3. Drugs affecting acetylcholine release

- Botulinum toxin inhibits acetylcholine release.
- Magnesium decreases acetylcholine release.

3. A 43-year-old woman complaining of double vision especially for the last 3 months. She has noticed difficulty holding her head up especially in the evenings. Her family noticed that her voice has become quieter. She has lost about 3kg in weight in the past 6 months. The woman had no significant previous medical illnesses.

• What is the diagnosis?

• What is your plan for investigation and management of this patient?

• Draw and label neuromuscular junction and describe the neuromuscular transmission.

ANSWER

Diagnosis

The diagnosis is **Myasthenia gravis**.

It is an autoimmune disorder affecting the neuromuscular junction characterized by fatigability and weakness of skeletal muscles due to antibodies against nicotinic acetylcholine receptors.

Investigations

1. Clinical Tests

Ice pack test

Improvement of ptosis after application of ice.

Fatigability test

Weakness increases on repeated muscle activity.

2. Pharmacological Test

Neostigmine test

Improvement in muscle power after administration of neostigmine.

3. Serological Tests

- Anti-acetylcholine receptor antibodies
- Anti-MuSK antibodies

4. Electrophysiological Tests

Repetitive nerve stimulation

Shows decremental response.

Single fiber electromyography

Shows increased jitter.

5. Imaging

Computed tomography or Magnetic resonance imaging of mediastinum

To detect thymoma or thymic hyperplasia.

Management

1. Anticholinesterase Drugs

- Neostigmine
- Pyridostigmine

These drugs increase acetylcholine concentration at neuromuscular junction.

2. Immunosuppressive Therapy

- Corticosteroids
- Azathioprine
- Cyclosporine

3. Thymectomy

Done in thymoma and generalized myasthenia gravis.

4. Plasmapheresis

Removes circulating antibodies.

5. Intravenous Immunoglobulin

Used in severe cases.

Neuromuscular Junction

Definition

Neuromuscular junction is the junction between terminal branch of motor neuron and skeletal muscle fiber.

Parts of Neuromuscular Junction

1. Presynaptic terminal

- Contains synaptic vesicles filled with acetylcholine
- Contains mitochondria
- Voltage gated calcium channels present

2. Synaptic cleft

- Space between nerve terminal and muscle membrane
- Contains acetylcholinesterase

3. Postsynaptic membrane (Motor end plate)

- Junctional folds present
- Nicotinic acetylcholine receptors present

Neuromuscular Transmission

1. Arrival of nerve impulse

Action potential reaches motor nerve terminal.

2. Calcium influx

Voltage gated calcium channels open and calcium enters nerve terminal.

3. Release of acetylcholine

Synaptic vesicles fuse with membrane and acetylcholine is released by exocytosis.

4. Binding of acetylcholine

Acetylcholine binds to nicotinic receptors on motor end plate.

5. End plate potential

Opening of sodium channels causes depolarization called end plate potential.

6. Muscle action potential

If threshold is reached, muscle action potential develops.

7. Muscle contraction

Action potential spreads along sarcolemma and T tubules causing calcium release from sarcoplasmic reticulum leading to contraction.

8. Destruction of acetylcholine

Acetylcholine is rapidly hydrolysed by acetylcholinesterase into acetate and choline.

9. Reuptake of choline

Choline is taken back into nerve terminal for resynthesis of acetylcholine.

Diagram of Neuromuscular Junction

REFER DIAGRAM SECTION

SHORT ESSAYS

4. Excitation –contraction coupling

ANSWER

Definition

Excitation contraction coupling is the process by which electrical excitation of

muscle membrane leads to muscle contraction.

Steps of Excitation–Contraction Coupling

1. Generation of muscle action potential

Action potential spreads over sarcolemma.

2. Spread through T tubules

Impulse enters transverse tubules.

3. Activation of dihydropyridine receptors

Voltage sensitive receptors in T tubules are activated.

4. Opening of ryanodine receptors

Ryanodine receptors in sarcoplasmic reticulum open.

5. Release of calcium

Calcium released from terminal cisternae into sarcoplasm.

6. Binding of calcium to troponin C

Troponin changes configuration.

7. Exposure of active sites

Tropomyosin shifts exposing active sites on actin.

8. Formation of cross bridges

Myosin heads bind with actin.

9. Sliding of filaments

Actin filaments slide over myosin producing contraction.

10. Relaxation

Calcium pumped back into sarcoplasmic reticulum by calcium ATPase pump.

Importance

Links electrical events with mechanical contraction.

5. Describe how impulse travel across the neuromuscular junction. Add a note on neuromuscular blockers.

ANSWER

Neuromuscular Transmission

1. Arrival of nerve impulse

Action potential reaches presynaptic terminal.

2. Opening of calcium channels

Voltage gated calcium channels open.

3. Calcium entry

Calcium enters nerve terminal.

4. Release of acetylcholine

Acetylcholine released by exocytosis.

5. Action on receptors

Acetylcholine binds nicotinic receptors.

6. End plate potential

Sodium influx causes depolarization.

7. Muscle action potential

Action potential generated in muscle.

8. Muscle contraction

Excitation contraction coupling occurs.

9. Destruction of acetylcholine

Acetylcholinesterase hydrolyses acetylcholine.

Neuromuscular Blockers

Definition

Drugs which block neuromuscular transmission.

Types

1. Non depolarizing blockers

Examples:

- Tubocurarine
- Pancuronium

Mechanism

Compete with acetylcholine for nicotinic receptors.

Effect

Prevent depolarization and cause paralysis.

2. Depolarizing blockers

Example:

- Succinylcholine

Mechanism

Produces persistent depolarization.

Effect

Initial fasciculation followed by paralysis.

Uses

- Surgical muscle relaxation
- Endotracheal intubation

6. Describe the excitation-contraction coupling in skeletal muscles

ANSWER

Definition

Excitation contraction coupling is the sequence of events by which excitation of muscle fiber causes contraction.

Mechanism

1. Muscle action potential generated

Impulse spreads along sarcolemma.

2. Impulse enters T tubules

Depolarization reaches triads.

3. Activation of dihydropyridine receptors

Acts as voltage sensor.

4. Opening of ryanodine receptors

Calcium released from sarcoplasmic reticulum.

5. Increase in intracellular calcium

Calcium binds troponin C.

6. Movement of tropomyosin

Active sites on actin exposed.

7. Cross bridge formation

Myosin binds actin.

8. Power stroke

Actin filaments slide producing contraction.

9. Relaxation

Calcium pumped back into sarcoplasmic reticulum.

Role of ATP

- Detachment of cross bridges
- Calcium pumping
- Energizing myosin heads

7. Describe the steps in transmission of impulse across a chemical synapse.

ANSWER

Definition

Chemical synapse is a junction where transmission occurs by neurotransmitter.

Steps in Synaptic Transmission

1. Arrival of action potential

Impulse reaches presynaptic terminal.

2. Opening of calcium channels

Voltage gated calcium channels open.

3. Calcium influx

Calcium enters presynaptic terminal.

4. Release of neurotransmitter

Synaptic vesicles fuse with membrane and release neurotransmitter.

5. Diffusion across synaptic cleft

Neurotransmitter diffuses to postsynaptic membrane.

6. Binding to receptors

Neurotransmitter binds receptors.

7. Postsynaptic potential generation

Excitatory or inhibitory postsynaptic potential produced.

8. Termination of action

Neurotransmitter removed by:

- Enzymatic destruction
- Reuptake
- Diffusion

Properties of Chemical Synapse

- One way conduction
- Synaptic delay
- Summation
- Facilitation
- Fatigue

8. Describe the molecular basis of skeletal muscle contraction.

ANSWER

Sliding Filament Theory

Contraction occurs by sliding of actin over myosin without change in filament length.

Molecular Basis

1. Resting state

Tropomyosin covers active sites on actin.

2. Calcium release

Calcium released from sarcoplasmic reticulum.

3. Binding to troponin C

Conformational change occurs.

4. Exposure of active sites

Tropomyosin moves away.

5. Cross bridge formation

Myosin head binds actin.

6. Power stroke

Myosin head bends and pulls actin.

7. ATP binding

ATP binds myosin causing detachment.

8. Reactivation of myosin head

ATP hydrolysis energizes myosin head.

9. Repetition of cycle

Cross bridge cycling continues till calcium remains elevated.

Changes during contraction

- I band shortens
- H zone disappears
- A band remains constant
- Sarcomere shortens

9. Describe the functions of sarcotubular system.

ANSWER

Sarcotubular System

It includes:

- T tubules
- Sarcoplasmic reticulum

Functions of T Tubules

1. Rapid conduction of impulse

Carry action potential deep into muscle fiber.

2. Excitation contraction coupling

Transmit depolarization to sarcoplasmic reticulum.

3. Synchronous contraction

Ensure simultaneous contraction of myofibrils.

Functions of Sarcoplasmic Reticulum

1. Storage of calcium

Stores calcium ions.

2. Release of calcium

Releases calcium during contraction.

3. Reuptake of calcium

Pumps calcium back during relaxation.

4. Regulation of intracellular calcium

Maintains low cytosolic calcium at rest.

Triad

A T tubule with two terminal cisternae forms triad.

10. Discuss the ionic basis for action potential of a nerve fiber

ANSWER

Resting Membrane Potential

Resting membrane potential of nerve fiber is about –70 millivolts.

Ionic Basis of Resting Membrane Potential

1. Potassium diffusion

High permeability to potassium causes potassium efflux.

2. Sodium potassium pump

Pumps 3 sodium out and 2 potassium in.

3. Impermeable intracellular anions

Negatively charged proteins remain inside.

Action Potential

1. Depolarization

Voltage gated sodium channels open.

Sodium influx

Rapid entry of sodium causes membrane potential to become positive.

2. Overshoot

Membrane potential reaches about +35 millivolts.

3. Repolarization

Sodium channels close and potassium channels open.

Potassium efflux

Potassium leaves cell restoring negativity.

4. After hyperpolarization

Continued potassium efflux makes membrane more negative.

Refractory Periods

Absolute refractory period

No second action potential can be generated.

Relative refractory period

Stronger stimulus required.

11. Explain neuromuscular transmission in response to an adequate stimulus to the motor nerve.

ANSWER

Definition

Neuromuscular transmission is transmission of impulse from motor nerve to skeletal muscle fiber.

Mechanism

1. Adequate stimulus to motor nerve

Action potential generated in motor nerve.

2. Arrival at nerve terminal

Impulse reaches presynaptic terminal.

3. Opening of calcium channels

Voltage gated calcium channels open.

4. Calcium influx

Calcium enters nerve terminal.

5. Release of acetylcholine

Acetylcholine released by exocytosis.

6. Diffusion across synaptic cleft

Acetylcholine reaches motor end plate.

7. Binding to nicotinic receptors

Ligand gated sodium channels open.

8. End plate potential

Local depolarization produced.

9. Muscle action potential

Threshold reached and action potential generated.

10. Muscle contraction

Impulse spreads through T tubules causing calcium release and contraction.

11. Destruction of acetylcholine

Acetylcholinesterase hydrolyses acetylcholine.

Features of Neuromuscular Transmission

- One to one transmission
- Always excitatory
- Safety factor present

12. Describe the molecular basis of skeletal muscle contraction. Add a note on rigor mortis

ANSWER

Molecular Basis of Skeletal Muscle Contraction

Sliding filament theory

Actin slides over myosin producing contraction.

Steps

1. Calcium release

Calcium released from sarcoplasmic reticulum.

2. Calcium binds troponin C

Conformational change occurs.

3. Tropomyosin shifts

Active sites exposed.

4. Cross bridge formation

Myosin binds actin.

5. Power stroke

Myosin pulls actin filament.

6. ATP mediated detachment

ATP causes separation of actin and myosin.

7. Reactivation of myosin head

ATP hydrolysis energizes myosin.

8. Repetition of cycle

Continues till calcium level falls.

Rigor Mortis

Definition

Stiffening of muscles after death is called rigor mortis.

Cause

Due to depletion of ATP after death.

Without ATP, actin and myosin cannot separate.

Features

- Begins within 1 to 2 hours
- Complete by 12 hours
- Disappears in 24 to 48 hours due to autolysis

13. Explain the stretch reflex with the aid of a diagram of the muscle spindle.

ANSWER

REFER DIAGRAM SECTION

Stretch Reflex

Stretch reflex is contraction of muscle in response to stretch.

Example:

- Knee jerk reflex

Receptor

Muscle spindle.

Structure of Muscle Spindle

Components

- Intrafusal fibers
- Nuclear bag fibers
- Nuclear chain fibers
- Sensory endings
- Gamma motor nerve endings

Pathway of Stretch Reflex

1. Stretch of muscle

Muscle spindle stimulated.

2. Activation of sensory fibers

Group Ia afferent fibers carry impulses.

3. Synapse in spinal cord

Direct monosynaptic connection with alpha motor neuron.

4. Motor response

Alpha motor neuron stimulates same muscle.

5. Muscle contraction

Muscle contracts opposing stretch.

Functions

- Maintains muscle tone
- Maintains posture
- Prevents overstretching

14. Diagram of neuromuscular junction. Add a note on neuromuscular blocking drugs.

ANSWER

REFER DIAGRAM SECTION

Neuromuscular Junction

Definition

Specialized synapse between motor nerve and skeletal muscle.

Parts

1. Presynaptic terminal

Contains acetylcholine vesicles.

2. Synaptic cleft

Contains acetylcholinesterase.

3. Postsynaptic membrane

Contains nicotinic receptors.

Neuromuscular Blocking Drugs

Types

1. Non depolarizing blockers

Examples:

- Tubocurarine
- Pancuronium

Mechanism

Competitive blockade of acetylcholine receptors.

Effect

Flaccid paralysis.

2. Depolarizing blockers

Example:

- Succinylcholine

Mechanism

Persistent depolarization of motor end plate.

Effect

Initial fasciculation followed by paralysis.

Clinical Uses

- Muscle relaxation during surgery
- Endotracheal intubation

15. Explain chronaxie, rheobase and strength duration curve

ANSWER

Rheobase

Minimum strength of electrical stimulus of long duration required to excite a tissue.

Chronaxie

Minimum time required for a current of double rheobase strength to excite tissue.

Strength Duration Curve

Graph showing relation between strength of stimulus and duration required for excitation.

Features of Curve

- Inverse relation between stimulus strength and duration
- Stronger stimulus requires shorter duration

Significance

- Determines excitability of nerve and muscle
- Used in diagnosis of nerve injury

16. Resting membrane potential in a neuron and its ionic basis.

ANSWER

Resting Membrane Potential

Difference in electrical potential across neuronal membrane at rest.

Value:
Approximately –70 millivolts.

Ionic Basis

1. Potassium diffusion

Membrane highly permeable to potassium. Potassium diffuses out producing negativity inside.

2. Sodium potassium pump

Pumps:

- 3 sodium ions out
- 2 potassium ions in

Maintains ionic gradient.

3. Impermeable intracellular proteins

Negatively charged proteins remain inside.

4. Selective membrane permeability

More permeable to potassium than sodium.

Significance

- Maintains excitability
- Essential for action potential generation

17. Define chronaxie, rheobase and utilization time. Draw a strength duration curve

ANSWER

Rheobase

Minimum current strength of long duration required to stimulate excitable tissue.

Chronaxie

Minimum time required for stimulus of double rheobase strength to excite tissue.

Utilization Time

Minimum time required for a rheobasic current to stimulate tissue.

Strength Duration Curve

Graph between stimulus strength and duration.

Features

- Hyperbolic curve
- As stimulus strength increases, required duration decreases.

Significance

- Measures excitability
- Useful in electrodiagnosis

REFER DIAGRAM SECTION

17. Explain the steps of neuromuscular transmission

Definition

Neuromuscular transmission is the process by which the nerve impulse is transmitted from motor nerve terminal to skeletal muscle fiber at the neuromuscular junction.

Steps of Neuromuscular Transmission

1. Arrival of nerve impulse

- Action potential reaches the terminal of alpha motor neuron.

2. Opening of calcium channels

- Depolarization opens voltage gated calcium channels.
- Calcium enters nerve terminal.

3. Release of acetylcholine

- Calcium facilitates fusion of acetylcholine vesicles with presynaptic membrane.
- Acetylcholine is released by exocytosis.

4. Binding of acetylcholine to receptors

- Acetylcholine diffuses across synaptic cleft.
- Binds to nicotinic acetylcholine receptors on motor end plate.

5. Formation of end plate potential

- Receptor channels open.
- Sodium enters muscle fiber and potassium leaves.
- End plate potential develops.

6. Generation of muscle action potential

- If threshold is reached, voltage gated sodium channels open.
- Muscle action potential is generated.

7. Spread of action potential

- Action potential spreads along sarcolemma and T tubules.

8. Muscle contraction

- Calcium released from sarcoplasmic reticulum initiates actin myosin interaction.
- Muscle contracts.

9. Destruction of acetylcholine

- Acetylcholine is hydrolyzed by acetylcholinesterase into acetate and choline.
- Choline is reuptaken into nerve terminal.

Diagram

REFER DIAGRAM SECTION

18. Events during neuromuscular transmission of impulse in skeletal muscle

1. Arrival of nerve impulse at motor nerve terminal.
2. Opening of voltage gated calcium channels.
3. Calcium influx into nerve terminal.
4. Exocytosis of acetylcholine vesicles.
5. Release of acetylcholine into synaptic cleft.
6. Binding of acetylcholine to nicotinic receptors.
7. Opening of ligand gated sodium channels.
8. Development of end plate potential.
9. Generation of muscle action potential.
10. Spread of impulse through sarcolemma and T tubules.
11. Release of calcium from sarcoplasmic reticulum.
12. Actin myosin interaction causing contraction.
13. Hydrolysis of acetylcholine by acetylcholinesterase.

19. Denervation hypersensitivity

Definition

Denervation hypersensitivity is increased sensitivity of effector organ to a chemical transmitter after loss of nerve supply.

Mechanism

- Increased number of receptors on postsynaptic membrane.
- Spread of receptors beyond junctional area.
- Increased responsiveness of receptors.
- Reduced destruction of neurotransmitter.

Examples

- Skeletal muscle after denervation.
- Supersensitivity of autonomic effector organs.

Importance

- Explains exaggerated response after nerve injury.

20. Draw and label a muscle spindle and list its functions

Muscle Spindle

Muscle spindle is a sensory receptor present within skeletal muscle.

REFER DIAGRAM SECTION

Functions

1. Maintains muscle tone.
2. Helps in stretch reflex.
3. Maintains posture.
4. Detects muscle length.
5. Prevents overstretching.
6. Coordinates voluntary movements.

21. Ionic basis of skeletal muscle action potential.

Resting membrane potential

- About –90 mV.

Depolarization

- Opening of voltage gated sodium channels.
- Rapid sodium influx.
- Membrane potential becomes positive.

Repolarization

- Closure of sodium channels.
- Opening of potassium channels.
- Potassium efflux occurs.

After hyperpolarization

- Continued potassium efflux causes transient hyperpolarization.

Diagram

REFER DIAGRAM SECTION

22. What are preload and after load in the skeletal muscle and give an example for preload condition in skeletal muscle

Preload

Load applied on muscle before contraction begins.

Example

- Weight attached to muscle before stimulation.

Afterload

Load applied after muscle contraction has started.

Example

- Muscle lifts weight only after beginning contraction.

Example for preload condition

- Holding a weight in hand before lifting it.

23. Write the mechanism of action of FOUR chemicals blocking the neuromuscular junction

1. Curare

- Competes with acetylcholine for nicotinic receptors.
- Prevents end plate potential.
- Causes flaccid paralysis.

2. Botulinum toxin

- Prevents release of acetylcholine from nerve terminal.
- Causes paralysis.

3. Organophosphorus compounds

- Inhibit acetylcholinesterase.
- Acetylcholine accumulates.
- Causes continuous stimulation followed by paralysis.

4. Succinylcholine

- Persistent depolarization of motor end plate.
- Produces depolarizing block.

24. Explain the molecular mechanism of skeletal muscle contraction.

Sliding filament theory

Muscle contraction occurs by sliding of actin filaments over myosin filaments.

Steps

1. Excitation

- Muscle action potential reaches T tubules.

2. Calcium release

- Sarcoplasmic reticulum releases calcium.

3. Binding of calcium

- Calcium binds to troponin C.

4. Exposure of active sites

- Tropomyosin shifts exposing active sites on actin.

5. Cross bridge formation

- Energized myosin head binds with actin.

6. Power stroke

- Myosin head bends.
- Actin filament slides inward.
- Adenosine triphosphate is split.

7. Detachment

- Fresh adenosine triphosphate binds to myosin.
- Cross bridge breaks.

8. Re-cocking

- Hydrolysis of adenosine triphosphate reenergizes myosin head.

9. Relaxation

- Calcium pumped back into sarcoplasmic reticulum.
- Tropomyosin covers active sites.

Changes during contraction

- I band decreases.
- H zone decreases.
- A band remains constant.
- Sarcomere shortens.

25. Describe the length – tension relationship in skeletal muscles

Definition

Relationship between initial length of muscle fiber and force of contraction produced.

Features

- Maximum tension develops at optimal length.
- At optimal length there is maximum overlap between actin and myosin.
- Very short muscle length decreases tension due to excessive overlap.
- Excessive stretching decreases tension due to less overlap.

Types of tension

1. Active tension.
2. Passive tension.
3. Total tension.

Importance

- Explains efficiency of skeletal muscle contraction.

Diagram

REFER DIAGRAM SECTION

26. Discuss the differences between red and white muscle fibres

Feature	Red Muscle Fibres	White Muscle Fibres
Color	Red	Pale
Myoglobin	More	Less
Mitochondria	Numerous	Few
Blood supply	Rich	Poor
Diameter	Small	Large
Contraction	Slow	Rapid
Fatigue	Resistant	Fatigues easily
Metabolism	Oxidative	Glycolytic
Glycogen	Less	More
Example	Soleus	Gastrocnemius

27. Physiological basis for myasthenia gravis

Definition

Myasthenia gravis is an autoimmune disorder affecting neuromuscular transmission.

Physiological basis

- Autoantibodies are formed against nicotinic acetylcholine receptors.
- Number of functional receptors decreases.
- End plate potential becomes inadequate.
- Muscle action potential fails.
- Leads to muscle weakness and fatigability.

Features

- Ptosis.
- Diplopia.
- Difficulty in swallowing.
- Muscle weakness increases with activity.

Treatment basis

- Anticholinesterase drugs improve neuromuscular transmission.

28. Physiological basis of muscle weakness in myasthenia gravis

- Autoimmune destruction of nicotinic acetylcholine receptors.
- Reduced end plate potential.
- Failure to reach threshold for muscle action potential.
- Repeated stimulation causes progressive weakness.
- Neuromuscular transmission becomes defective.

29. Draw and label muscle spindle

REFER DIAGRAM SECTION

30. Excitation contraction coupling.

Definition

Process by which muscle action potential causes muscle contraction.

Steps

1. Action potential spreads through sarcolemma.
2. Impulse travels along T tubules.
3. Dihydropyridine receptors activated.
4. Ryanodine receptors open.
5. Calcium released from sarcoplasmic reticulum.
6. Calcium binds troponin C.
7. Active sites on actin exposed.
8. Cross bridge cycling begins.
9. Muscle contracts.
10. Calcium pumped back into sarcoplasmic reticulum causing relaxation.

31. Explain the physiological basis of myasthenia gravis

Physiological basis

- Autoimmune disease involving neuromuscular junction.
- Antibodies destroy acetylcholine receptors.
- End plate potential decreases.
- Neuromuscular transmission fails.
- Skeletal muscle weakness develops.
- Weakness worsens with repeated activity.

Symptoms

- Ptosis.
- Diplopia.
- Fatigue.
- Dysphagia.

Treatment

- Anticholinesterase drugs.
- Immunosuppressive therapy.

32. Define chronaxie and rheobase Explain strength duration curve with the help of a diagram

Rheobase

Minimum strength of stimulus of long duration required to excite a tissue.

Chronaxie

Minimum time required for a stimulus of double rheobase strength to excite tissue.

Strength duration curve

- Graph between stimulus strength and duration.
- Stronger stimulus requires shorter duration.
- Weaker stimulus requires longer duration.

Importance

- Used to assess excitability of nerve and muscle.
- Increased chronaxie indicates reduced excitability.

Diagram

REFER DIAGRAM SECTION

33. Myelinated nerves have higher velocity of conduction compared to unmyelinated nerves why?

Reasons

1. Saltatory conduction occurs.
2. Impulse jumps from one node of Ranvier to another.
3. Myelin sheath acts as electrical insulator.
4. Less ion leakage.
5. Lower membrane capacitance.
6. Faster depolarization.

Result

- Conduction velocity is much higher in myelinated nerves.

34. Draw and label : stretch reflex

REFER DIAGRAM SECTION

35. With the aid of a diagram explain resting membrane potential.

Definition

Resting membrane potential is the potential difference across cell membrane during resting state.

Value

- Nerve fiber: about –70 mV.
- Skeletal muscle: about –90 mV.

Basis

1. Unequal distribution of ions

- Potassium high inside.
- Sodium high outside.

2. Selective permeability

- Membrane more permeable to potassium.
- Potassium diffuses outward.

3. Sodium potassium pump

- Pumps 3 sodium ions out and 2 potassium ions in.

4. Intracellular anions

- Negatively charged proteins remain inside.

Diagram

REFER DIAGRAM SECTION

36. Classify synapse. Write about the properties of synapses.

Classification of synapse

According to mode of transmission

1. Chemical synapse.

2. Electrical synapse.

According to site

1. Axodendritic.
2. Axosomatic.
3. Axoaxonic.

Properties of synapses

1. One way conduction.
2. Synaptic delay.
3. Summation.
4. Facilitation.
5. Occlusion.
6. Subliminal fringe.
7. Fatigue.
8. Convergence.
9. Divergence.
10. Plasticity.

37. Explain the ionic basis of resting membrane potential of a nerve fiber.

Ionic basis

1. Unequal ionic distribution

- Potassium concentration high inside.
- Sodium concentration high outside.

2. Potassium diffusion

- Membrane highly permeable to potassium.
- Potassium diffuses outward causing negativity inside.

3. Sodium diffusion

- Small sodium influx occurs.

4. Sodium potassium pump

- Pumps sodium out and potassium in.
- Maintains ionic gradient.

5. Intracellular anions

- Negatively charged proteins remain inside.

Resting membrane potential

- About –70 mV in nerve fiber.

38. Long term memory is a function of synapse

Explanation

Long term memory depends on synaptic plasticity.

Mechanism

1. Repeated stimulation strengthens synapses.
2. Increased neurotransmitter release.
3. Formation of new synaptic connections.
4. Increased receptor sensitivity.
5. Protein synthesis occurs.

Long term potentiation

- Persistent increase in synaptic transmission.
- Important mechanism for memory.

Conclusion

- Memory storage occurs due to structural and functional changes in synapses.

39. Draw and label : action potential in nerve

REFER DIAGRAM SECTION

40. Describe the properties of skeletal muscle.

Properties

1. Excitability

Ability to respond to stimulus.

2. Conductivity

Ability to conduct impulse.

3. Contractility

Ability to shorten and produce force.

4. Extensibility

Ability to be stretched.

5. Elasticity

Ability to regain original length.

6. Tonicity

Ability to maintain slight contraction.

7. Fatigability

Ability to get fatigued after repeated activity.

41. Draw and label a skeletal muscle action potential and indicate the ionic basis of each part.

REFER DIAGRAM SECTION

42. Physiological basis of myasthenia gravis

Physiological basis

- Autoantibodies against acetylcholine receptors.
- Reduced receptor number.
- Reduced end plate potential.
- Failure of neuromuscular transmission.
- Muscle weakness and fatigue.

43. Physiological basis of Rigor Mortis

Definition

Rigor mortis is stiffening of muscles after death.

Physiological basis

1. Adenosine triphosphate production stops after death.
2. Calcium leaks from sarcoplasmic reticulum.
3. Actin myosin cross bridges form.
4. Absence of adenosine triphosphate prevents detachment.
5. Muscles become rigid.

Disappearance

- Due to autolysis and putrefaction.

44. Sodium-potassium pump helps to maintain RMP in a neuron .How?

Mechanism

- Sodium potassium pump actively transports ions.
- Pumps 3 sodium ions outside.
- Pumps 2 potassium ions inside.
- Maintains concentration gradient.
- Maintains negativity inside neuron.
- Electrogenic nature contributes to resting membrane potential.

45. Draw and label : Sarcomere in skeletal muscle

REFER DIAGRAM SECTION

46. Re-polarization phase of action potential

Definition

Phase during which membrane potential returns toward resting level after depolarization.

Mechanism

1. Sodium channels close.
2. Potassium channels open.
3. Potassium efflux occurs.
4. Membrane becomes negative again.

Importance

- Restores resting membrane potential.

47. Neuromuscular hyper excitability in tetany.Why?

Cause

- Decreased ionized calcium in extracellular fluid.

Mechanism

- Low calcium increases sodium permeability.
- Threshold for excitation decreases.
- Nerves become hyperexcitable.
- Repeated spontaneous discharges occur.

Manifestations

- Carpopedal spasm.
- Laryngospasm.
- Muscle cramps.

48. Neuromuscular junction in skeletal muscle

Definition

Specialized junction between motor nerve terminal and skeletal muscle fiber.

Parts

1. Presynaptic terminal.
2. Synaptic cleft.
3. Postsynaptic membrane or motor end plate.

Features

- Neurotransmitter is acetylcholine.
- Transmission is always excitatory.
- Synaptic delay is present.

Functions

- Transmission of nerve impulse to muscle.

49. Absolute refractory period

Definition

Period during which second action potential cannot be produced irrespective of stimulus strength.

Cause

- Inactivation of voltage gated sodium channels.

Importance

1. Prevents repeated firing.
2. Ensures one way conduction.
3. Limits maximum frequency of impulses.

50. Draw and label :Neuron

REFER DIAGRAM SECTION

51. Tetany

Definition

Condition characterized by increased neuromuscular excitability causing muscle spasms.

Causes

1. Hypocalcemia.
2. Hypoparathyroidism.
3. Vitamin D deficiency.
4. Alkalosis.

Features

- Carpopedal spasm.
- Laryngospasm.
- Tingling sensation.
- Positive Chvostek sign.
- Positive Trousseau sign.

Mechanism

- Low calcium lowers threshold for nerve excitation.

52. End plate potential

Definition

Local non propagated depolarization occurring at motor end plate due to acetylcholine.

Mechanism

1. Acetylcholine binds nicotinic receptors.
2. Sodium channels open.
3. Sodium influx exceeds potassium efflux.
4. Depolarization occurs.
5. If threshold reached, muscle action potential develops.

Features

- Graded response.
- Not all or none.
- Local potential.

53. Excitation –contraction coupling

Definition

Process linking excitation of muscle fiber to contraction.

Steps

1. Action potential spreads along sarcolemma.
2. Impulse travels through T tubules.
3. Calcium released from sarcoplasmic reticulum.
4. Calcium binds troponin C.
5. Active sites on actin exposed.
6. Cross bridge cycling occurs.
7. Muscle contracts.
8. Calcium reuptake causes relaxation.

54. Draw and label :Length-tension relationship in skeletal muscle

REFER DIAGRAM SECTION

CARDIAC MUSCLE

SHORT ESSAYS

1. Enumerate and explain the properties of cardiac muscle

Properties of Cardiac Muscle

Automaticity (Autorhythmicity)

Property by which the heart generates impulses automatically without external stimulus.

Seen mainly in sinoatrial node.

Due to unstable resting membrane potential and pacemaker potential.

Rhythmicity

Ability of cardiac muscle to generate impulses at regular intervals.

Maintains regular rhythm of heartbeat.

Excitability (Irritability)

Ability of cardiac muscle to respond to a stimulus and produce an action potential.

Adequate stimulus is required.

Conductivity

Ability to conduct impulses from one part of the heart to another.

Conducting system includes sinoatrial node, atrioventricular node, bundle of His and Purkinje fibres.

Contractility

Ability of cardiac muscle to contract when stimulated.

Depends upon intracellular calcium concentration.

All-or-None Law

Cardiac muscle responds maximally once threshold stimulus is reached.

Whole myocardium contracts as a syncytium.

Refractory Period

Cardiac muscle has a long refractory period.

Includes:

Absolute refractory period

Relative refractory period

Prevents tetanization.

Staircase Phenomenon (Treppe)

Successive contractions increase in strength when stimuli are given after rest.

Due to accumulation of calcium ions.

Fatigue Resistance

Cardiac muscle does not fatigue easily.

Rich blood supply and abundant mitochondria.

Functional Syncytium

Cardiac muscle fibres act as a single unit because of gap junctions.

Atria form one syncytium and ventricles another.

Length-Tension Relationship (Frank-Starling Law)

Force of contraction increases with increase in initial muscle fibre length.

Basis of Frank-Starling mechanism of the heart.

2. Explain the ionic basis of pacemaker potential with the aid of labelled diagram.

Mention the changes during sympathetic stimulation

Pacemaker Potential

Pacemaker potential is the slow spontaneous depolarization occurring in pacemaker cells of sinoatrial node during diastole.

Ionic Basis of Pacemaker Potential

Phase 4 – Slow Diastolic Depolarization

Due to:

Decreased outward potassium current

Opening of funny sodium channels causing slow sodium influx

Entry of calcium through transient (T-type) calcium channels

Membrane potential gradually becomes less negative.

Phase 0 – Depolarization

Occurs when threshold potential is reached.

Due to opening of long-lasting (L-type) calcium channels.

Rapid calcium influx causes depolarization.

Phase 3 – Repolarization

Due to closure of calcium channels and opening of potassium channels.

Potassium efflux causes repolarization.

Labelled Diagram of Pacemaker Potential

REFER DIAGRAM SECTION

Changes During Sympathetic Stimulation

Sympathetic stimulation acts through beta-1 receptors.

Increases cyclic adenosine monophosphate.

Increases funny sodium current and calcium influx.

Slope of pacemaker potential increases.

Threshold is reached earlier.

Heart rate increases (positive chronotropic effect).

SHORT ANSWERS

3. Cardiac muscle cannot be tetanized. Why?

Cardiac muscle has a prolonged refractory period.

Refractory period almost coincides with duration of contraction.

Second stimulus cannot excite the muscle during systole.

Therefore summation and tetanus cannot occur.

This helps proper alternate systole and diastole for pumping function.

4. Prolonged action potential in cardiac muscle. Why?

Due to prolonged plateau phase.

Causes:

Slow calcium influx through L-type calcium channels.

Decreased potassium permeability reducing potassium efflux.

Plateau prolongs depolarization.

Duration of cardiac action potential is about 200–300 milliseconds.

5. Cardiac muscle action potential

Phases of Ventricular Muscle Action Potential

Phase 0 – Rapid Depolarization

Rapid sodium influx through fast sodium channels.

Phase 1 – Initial Repolarization

Closure of sodium channels and transient potassium efflux.

Phase 2 – Plateau Phase

Calcium influx through L-type calcium channels.

Decreased potassium efflux.

Phase 3 – Repolarization

Closure of calcium channels.

Increased potassium efflux.

Phase 4 – Resting Membrane Potential

Stable resting membrane potential around –90 millivolts.

6. Draw and label : Pacemaker potential

REFER DIAGRAM SECTION

SMOOTH MUSCLE

SHORT ANSWERS

1. Latch – Bridge hypothesis

Proposed to explain sustained contraction in smooth muscle with low energy expenditure.

After contraction, myosin heads remain attached to actin for prolonged periods.

Detachment and reattachment rates become slow.

This maintains muscle tension with minimal adenosine triphosphate consumption.

Important in visceral smooth muscles and vascular smooth muscles.

Significance

Maintains prolonged contraction economically.

Helps maintain vascular tone.

Reduces energy requirement.

ENDOCRINE SYSTEM

INTRODUCTION

SHORT ESSAYS

1. Describe the neuroendocrine reflex and physiological basis for onset of puberty

Neuroendocrine Reflex

Neuroendocrine reflex is a reflex in which afferent neural impulses stimulate release of hormones.

Components

- Receptor
- Afferent pathway
- Hypothalamus
- Endocrine gland
- Hormone release
- Target organ response

Examples

1. Milk Ejection Reflex

- Suckling stimulates nipple receptors.
- Impulses reach hypothalamus.
- Oxytocin released from posterior pituitary.
- Causes contraction of myoepithelial cells and milk ejection.

2. Parturition Reflex

- Stretch of cervix stimulates hypothalamus.
- Oxytocin secretion increases.
- Causes uterine contractions.

Physiological Basis for Onset of Puberty

Puberty is the period during which secondary sexual characters develop and reproductive capacity is attained.

Mechanism

- Hypothalamic maturation occurs.
- Pulsatile secretion of gonadotropin-releasing hormone increases.
- Anterior pituitary secretes follicle stimulating hormone and luteinizing hormone.
- Gonads enlarge and become active.
- Increased secretion of sex hormones:
  - Testosterone in males
  - Estrogen in females
- Development of secondary sexual characters occurs.
- Growth spurt occurs due to growth hormone and sex hormones.

Factors Influencing Puberty

- Genetic factors
- Nutritional status
- Environmental factors
- Body fat and leptin

2. Negative feedback mechanisms of hormonal control

Negative Feedback Mechanism

Negative feedback is a regulatory mechanism in which increased hormone level inhibits further secretion of the same hormone.

Types

1. Long-loop Feedback

Hormone from target gland inhibits hypothalamus and pituitary.

Example:

Cortisol inhibits adrenocorticotropic hormone and corticotropin-releasing hormone.

2. Short-loop Feedback

Pituitary hormone inhibits hypothalamic secretion.

Example:

Growth hormone inhibits growth hormone releasing hormone.

3. Ultra-short Feedback

Hormone inhibits its own secretion.

Example:

Gonadotropin-releasing hormone inhibits its own release.

Importance

Maintains hormonal balance.

Prevents over-secretion.

Maintains homeostasis.

SHORT ANSWERS

3. What are positive and negative feedback mechanisms. Give examples of each.

Negative Feedback Mechanism

Increased hormone secretion inhibits further secretion.

Maintains homeostasis.

Examples

Cortisol inhibits adrenocorticotropic hormone secretion.

Thyroxine inhibits thyroid stimulating hormone secretion.

Positive Feedback Mechanism

Hormone action increases further secretion.

Usually self-limiting.

Examples

Oxytocin during parturition.

Estrogen causing luteinizing hormone surge before ovulation.

4. Mention all the hormones that promote growth of the human body and short answers on each

Hormones Promoting Growth

1. Growth Hormone

Secreted by anterior pituitary.

Stimulates protein synthesis and bone growth.

Acts through somatomedins.

2. Thyroid Hormones

Essential for normal growth and development.

Promote skeletal growth and brain development.

3. Insulin

Promotes protein synthesis.

Facilitates cellular uptake of glucose and amino acids.

4. Sex Hormones

Testosterone

Increases protein synthesis and muscle growth.

Causes pubertal growth spurt.

Estrogen

Promotes skeletal growth.

Causes epiphyseal closure.

5. Glucocorticoids

Small amounts necessary for normal growth.

Excess inhibits growth.

6. Somatomedins (Insulin-like Growth Factors)

Produced mainly in liver.

Mediate actions of growth hormone.

Promote cartilage and bone growth.

5. Permissive action of hormone

Permissive action means one hormone enhances the action of another hormone.

First hormone itself may not produce major effect.

Examples

Thyroid hormone enhances action of catecholamines.

Cortisol permits vasoconstrictor action of catecholamines.

Estrogen increases uterine response to oxytocin.

6. c-AMP as a second messenger

Cyclic Adenosine Monophosphate as Second Messenger

Mechanism

Hormone binds to membrane receptor.

G protein is activated.

Adenylate cyclase is stimulated.

Adenosine triphosphate converted to cyclic adenosine monophosphate.

Cyclic adenosine monophosphate activates protein kinase.

Cellular response occurs through protein phosphorylation.

Hormones Acting Through Cyclic Adenosine Monophosphate

Adrenocorticotropic hormone

Thyroid stimulating hormone

Follicle stimulating hormone

Luteinizing hormone

Glucagon

Parathyroid hormone

7. Classify hormones.

Classification of Hormones

According to Chemical Nature

1. Peptide and Protein Hormones

Insulin

Growth hormone

Parathyroid hormone

2. Steroid Hormones

Cortisol

Aldosterone

Testosterone

Estrogen

3. Amino Acid Derivatives

Thyroxine

Adrenaline

Noradrenaline

According to Solubility

Water Soluble Hormones

Peptide hormones

Catecholamines

Lipid Soluble Hormones

Steroid hormones

Thyroid hormones

8. Explain positive feedback.

Positive feedback is a mechanism in which hormone action stimulates further secretion of the same hormone.

It amplifies the response.

Usually temporary and self-limiting.

Examples

Oxytocin secretion during labour.

Estrogen-induced luteinizing hormone surge before ovulation.

Blood clotting cascade.

9. Cyclic GMP acts as second messenger

Cyclic Guanosine Monophosphate as Second Messenger

Mechanism

Hormone binds to receptor.

Guanylate cyclase activated.

Guanosine triphosphate converted to cyclic guanosine monophosphate.

Protein kinase activation occurs.

Cellular response produced.

Hormones Acting Through Cyclic Guanosine Monophosphate

Atrial natriuretic peptide

Nitric oxide

Functions

Vasodilatation

Smooth muscle relaxation

10. Mode of action of peptide hormone

Mode of Action of Peptide Hormones

Peptide hormone binds to cell membrane receptor.

Receptor activates G protein.

Second messenger system activated.

Protein kinases activated.

Cellular proteins phosphorylated.

Physiological response produced.

Second Messengers

Cyclic adenosine monophosphate

Cyclic guanosine monophosphate

Inositol triphosphate

Diacylglycerol

Calcium ions

Features

Rapid onset of action.

Short duration of action.

11.c-AMP as a second messenger

Cyclic adenosine monophosphate is an intracellular second messenger formed from adenosine triphosphate by the action of adenylate cyclase.

Mechanism

Hormone (first messenger) binds to membrane receptor.

Receptor activates G protein.

G protein activates adenylate cyclase.

Adenylate cyclase converts adenosine triphosphate into cyclic adenosine monophosphate.

Cyclic adenosine monophosphate activates protein kinase A.

Protein phosphorylation occurs.

Cellular response is produced.

Diagrammatic Sequence

Hormone → Receptor → G protein → Adenylate cyclase → c-AMP → Protein kinase activation → Cellular response

Hormones Acting Through c-AMP

Adrenocorticotropic hormone

Thyroid stimulating hormone

Follicle stimulating hormone

Luteinizing hormone

Glucagon

Parathyroid hormone

Calcitonin

Antidiuretic hormone (V2 receptor)

Functions of c-AMP

Mediates action of many peptide hormones.

Activates intracellular enzymes.

Produces rapid cellular response.

Amplifies hormonal action.

Features

Acts as a second messenger inside the cell.

Rapid onset and short duration of action.

PITUITARY GLAND

LONG ESSAYS

1. A 55-year-old man came to the medicine department with complaints of headache. On examination he had coarse facial features, enlarged hands and feet and hepatosplenomegaly. His blood sugar was elevated

• Name the most probable clinical condition

• Physiological basis for his enlarged hands and for the elevated blood sugar

• What type of visual field defect can occur in this patient. Give its physiological basis

• Add a note on somatomedins

Most Probable Clinical Condition

The patient is suffering from **Acromegaly**.

Cause

Excess secretion of growth hormone after epiphyseal closure.

Usually due to pituitary adenoma.

Physiological Basis for Enlarged Hands and Feet

Excess growth hormone stimulates protein synthesis and growth of soft tissues.

Growth hormone acts through somatomedins.

Causes periosteal bone growth and soft tissue proliferation.

Results in enlargement of hands, feet and coarse facial features.

Physiological Basis for Elevated Blood Sugar

Growth hormone has diabetogenic action.

Mechanism

Decreases glucose uptake by tissues.

Increases gluconeogenesis in liver.

Increases lipolysis.

Produces insulin resistance.

Leads to hyperglycemia.

Visual Field Defect and Physiological Basis

Visual Field Defect

Bitemporal hemianopia.

Physiological Basis

Enlarged pituitary tumour compresses optic chiasma.

Crossing nasal fibres are affected.

Temporal visual fields are lost in both eyes.

Somatomedins

Somatomedins are insulin-like growth factors produced mainly in liver under the influence of growth hormone.

Types

Insulin-like growth factor-1 (Somatomedin C)

Insulin-like growth factor-2

Actions

Stimulate cartilage growth.

Increase protein synthesis.

Promote bone growth.

Increase cell proliferation.

Mediate growth-promoting effects of growth hormone.

Mechanism of Action

Bind to membrane receptors with tyrosine kinase activity.

Stimulate deoxyribonucleic acid and ribonucleic acid synthesis.

Functions

Essential for longitudinal bone growth.

Important in tissue growth and repair.

Clinical Importance

Decreased in growth hormone deficiency.

Increased in gigantism and acromegaly.

2. List the hormones of the anterior pituitary gland. Describe the actions and control of growth hormone. Explain the consequences of its hyper and hypo secretion.

Hormones of Anterior Pituitary Gland

Growth hormone (GH) / Somatotropic hormone

Thyroid stimulating hormone (TSH)

Adrenocorticotropic hormone (ACTH)

Follicle stimulating hormone (FSH)

Luteinizing hormone (LH)

Prolactin (PRL)

Growth Hormone

Actions of Growth Hormone

1. Effects on Protein Metabolism

- Increases protein synthesis
- Increases amino acid uptake by cells
- Decreases protein breakdown
- Produces positive nitrogen balance
- Promotes growth of soft tissues and bones

2. Effects on Fat Metabolism

- Increases lipolysis
- Mobilizes fat from adipose tissue
- Increases free fatty acids in blood
- Fat is used for energy production
- Excess causes ketosis

3. Effects on Carbohydrate Metabolism

- Decreases glucose uptake by tissues
- Increases blood glucose level
- Increases gluconeogenesis
- Produces insulin resistance
- Hence called diabetogenic hormone

4. Effects on Growth

A. Effects on Bone

- Stimulates epiphyseal cartilage growth
- Increases length of long bones
- Increases osteoblastic activity
- Increases bone thickness

B. Effects on Soft Tissue

- Enlargement of viscera
- Increased muscle mass
- Increased connective tissue growth

5. Effects through Somatomedins (IGF-1)

- Most growth promoting actions are mediated through insulin-like growth factors produced mainly by liver

Control of Growth Hormone Secretion

Hypothalamic Regulation

1. Growth Hormone Releasing Hormone (GHRH)

- Stimulates GH secretion

2. Growth Hormone Inhibiting Hormone (Somatostatin)

- Inhibits GH secretion

Factors Increasing GH Secretion

- Deep sleep
- Exercise
- Stress
- Hypoglycemia
- Starvation
- High protein diet

Puberty

Factors Decreasing GH Secretion

Hyperglycemia

Obesity

Aging

Increased free fatty acids

Feedback Regulation

IGF-1 inhibits GH secretion by negative feedback

Hypersecretion of Growth Hormone

1. Gigantism

Cause

Excess GH secretion before closure of epiphysis

Features

Excessive height

Increased growth of long bones

Hyperglycemia

Muscle weakness

2. Acromegaly

Cause

Excess GH secretion after closure of epiphysis

Features

Enlargement of hands and feet

Prognathism

Thickened skin

Enlargement of tongue

Kyphosis

Diabetes mellitus

Hypertension

Visual defects due to pituitary tumor

Hyposecretion of Growth Hormone

Pituitary Dwarfism

Cause

Deficiency of GH during childhood

Features

Stunted growth

Short stature

Normal body proportions

Delayed puberty

Normal intelligence

Adult GH Deficiency

Reduced muscle mass

Weakness

Increased fat deposition

SHORT ESSAYS

3. Describe the actions and regulation of anti- diuretic hormone

Anti-diuretic Hormone (ADH) / Vasopressin

Actions of ADH

1. Anti-diuretic Action

Increases water reabsorption from distal convoluted tubule and collecting duct

Acts through V2 receptors

Increases permeability by insertion of aquaporin-2 channels

Concentrates urine

Decreases urine output

2. Vasoconstrictor Action

Causes constriction of blood vessels through V1 receptors

Increases blood pressure

3. Other Actions

Maintains plasma osmolarity

Helps maintain blood volume

Regulation of ADH Secretion

1. Osmotic Regulation

Increased plasma osmolarity

Stimulates osmoreceptors in hypothalamus

Increases ADH secretion

Decreased plasma osmolarity

Inhibits ADH secretion

2. Volume Regulation

Decreased blood volume or blood pressure

Stimulates baroreceptors

Increases ADH secretion

Increased blood volume

Decreases ADH secretion

3. Other Stimuli Increasing ADH

Pain

Stress

Exercise

Nicotine

Morphine

Factors Decreasing ADH

Alcohol

4. Describe the abnormalities of growth hormone secretion.

Abnormalities of Growth Hormone Secretion

Hypersecretion of GH

1. Gigantism

Occurs before epiphyseal closure

Excessive longitudinal growth

Very tall stature

Hyperglycemia may occur

2. Acromegaly

Occurs after epiphyseal closure

Enlargement of membranous bones and soft tissues

Features

Large hands and feet

Prognathism

Thick lips

Enlarged tongue

Kyphosis

Diabetes mellitus

Hypertension

Visual field defects

Hyposecretion of GH

Pituitary Dwarfism

Deficiency during childhood

Features

Short stature

Proportionate body

Delayed puberty

Normal intelligence

Adult GH Deficiency

Weakness

Reduced muscle mass

Increased fat deposition

5. Discuss the hormones influencing growth and the uses of growth chart in assessing progress of growth in different age groups(3+3)

Hormones Influencing Growth

Growth hormone

Stimulates protein synthesis and bone growth

Thyroid hormones

Essential for normal growth and maturation

Insulin

Promotes protein synthesis

Sex hormones

Cause pubertal growth spurt

Glucocorticoids

Excess inhibits growth

Somatomedins (IGF)

Mediate actions of GH

Uses of Growth Chart

Assessment of normal growth pattern

Detection of growth retardation

Identification of malnutrition

Monitoring growth in children

Assessment of effectiveness of treatment

Comparison with standard growth values in different age groups

6. Actions of hormones of posterior pituitary

Hormones of Posterior Pituitary

Anti-diuretic hormone (ADH)

Oxytocin

Actions of ADH

Increases water reabsorption from kidney

Concentrates urine

Decreases urine output

Causes vasoconstriction

Increases blood pressure

Actions of Oxytocin

Causes contraction of pregnant uterus during labor

Causes milk ejection from mammary glands

Helps postpartum uterine involution

7. Actions of growth hormone

Actions of Growth Hormone

On Protein Metabolism

Increases protein synthesis

Increases amino acid uptake

Positive nitrogen balance

On Fat Metabolism

Increases lipolysis

Mobilizes fat stores

On Carbohydrate Metabolism

Increases blood glucose

Decreases glucose utilization

Diabetogenic effect

On Growth

Increases growth of bones and soft tissues

Stimulates epiphyseal cartilage

Increases cell division

8. Effects of hyposecretion of growth hormone

Effects of Hyposecretion of Growth Hormone

In Children – Pituitary Dwarfism

Short stature

Stunted growth

Delayed puberty

Normal intelligence

Proportionate body

In Adults

Weakness

Reduced muscle mass

Increased fat deposition

Reduced work capacity

SHORT ANSWERS

9. Insulin –like growth factors

Insulin-like Growth Factors (IGF)

Definition

Polypeptides produced mainly by liver under influence of GH.

Types

IGF-1 (Somatomedin C)

IGF-2

Actions

Mediate growth-promoting actions of GH

Stimulate cartilage and bone growth

Increase protein synthesis

Promote cell division

Functions

Essential for normal body growth

Negative feedback inhibition of GH secretion

10. Physiological basis of onset of puberty

Physiological Basis of Onset of Puberty

Activation of hypothalamo-pituitary-gonadal axis

Increased GnRH secretion from hypothalamus

Increased secretion of FSH and LH

Increased secretion of sex hormones

Development of secondary sexual characters

Pubertal growth spurt occurs

11. Describe the actions of vasopressin and add a note on Diabetes Insipidus

Actions of Vasopressin (ADH)

Increases water reabsorption from kidney

Decreases urine output

Concentrates urine

Causes vasoconstriction

Maintains plasma osmolarity and blood volume

Diabetes Insipidus

Definition

Condition due to deficiency of ADH or failure of kidney to respond to ADH.

Types

Central diabetes insipidus

Nephrogenic diabetes insipidus

Features

Polyuria

Polydipsia

Dilute urine

Dehydration

Treatment

Desmopressin in central diabetes insipidus

12. Diabetogenic effect of human growth hormone

Diabetogenic Effect of Human Growth Hormone

GH decreases glucose uptake by tissues

Increases gluconeogenesis

Causes insulin resistance

Raises blood glucose level

Excess GH may produce diabetes mellitus

13. Describe features of acromegaly

Features of Acromegaly

Enlargement of hands and feet

Prognathism

Thickened lips and nose

Enlarged tongue

Thick skin

Kyphosis

Hypertension

Diabetes mellitus

Headache and visual defects

14. Deficiency of somatomedins in human beings may result in Dwarfism. Why?

Deficiency of Somatomedins may Result in Dwarfism – Why?

Somatomedins (IGF-1) mediate growth-promoting actions of GH

They stimulate cartilage and bone growth

Deficiency causes failure of normal skeletal growth

Leads to dwarfism despite normal GH levels

15. Patients with acromegaly have visual field defects. Why?

Cause of Visual Field Defects in Acromegaly

Acromegaly usually occurs due to pituitary adenoma

Enlarged tumor compresses optic chiasma

Produces bitemporal hemianopia

Hence visual field defects occur

16. Pituitary dwarfism

Pituitary Dwarfism

Definition

Condition due to deficiency of GH during childhood.

Features

- Short stature
- Stunted growth
- Delayed puberty
- Proportionate body
- Normal intelligence

Cause

- GH deficiency due to pituitary disorder

17. Milk ejection reflex

Milk Ejection Reflex

Definition

Reflex expulsion of milk from mammary glands.

Mechanism

- Suckling stimulates nipple receptors
- Impulses pass to hypothalamus
- Posterior pituitary releases oxytocin
- Oxytocin contracts myoepithelial cells
- Milk is ejected from alveoli into ducts

18. Hyper secretion of growth hormone

Hypersecretion of Growth Hormone

Before Puberty – Gigantism

- Excessive increase in height
- Long bone overgrowth

After Puberty – Acromegaly

- Enlargement of hands and feet
- Prognathism
- Thickened soft tissues
- Diabetes mellitus may occur

19. Functions of GH

Functions of GH

- Increases protein synthesis
- Stimulates bone and tissue growth
- Increases lipolysis
- Raises blood glucose level
- Increases cell division
- Produces positive nitrogen balance

20. Physiological actions of growth hormones

Physiological Actions of Growth Hormone

Protein Metabolism

- Increases protein synthesis

Fat Metabolism

- Increases lipolysis

Carbohydrate Metabolism

Causes hyperglycemia

Growth

Increases growth of bones and soft tissues

21. Patients with acromegaly may develop diabetes. Why?

Why Patients with Acromegaly Develop Diabetes?

Excess GH has diabetogenic action

GH decreases glucose uptake by tissues

Increases gluconeogenesis

Causes insulin resistance

Leads to hyperglycemia and diabetes mellitus

THYROID GLAND

LONG ESSAYS

1. A 45-year-old female patient was presented with palpitations, loss of weight in spite of good appetite and intolerance to heat. On examination she had fine tremors, thyroid nodule and mild exophthalmos. Blood report showed decreased TSH and elevated T3, T4 levels

a) Name the most probable clinical condition

b) Describe the actions of the affected hormone

c) Physiological basis for palpitation and exophthalmos in this patient

a) Most Probable Clinical Condition

Graves' disease / Hyperthyroidism

b) Actions of Thyroid Hormones

1. Calorigenic Action

Increases basal metabolic rate

Increases oxygen consumption

Increases heat production

2. Effect on Carbohydrate Metabolism

Increases glucose absorption

Increases glycogenolysis

Increases gluconeogenesis

3. Effect on Fat Metabolism

Increases lipolysis

Decreases body weight

4. Effect on Protein Metabolism

Normal level promotes protein synthesis

Excess causes protein breakdown

5. Cardiovascular Effects

Increases heart rate

Increases cardiac output

Increases force of contraction

6. Effect on Nervous System

Essential for brain development

Increases alertness and excitability

7. Effect on Growth

Essential for normal growth and skeletal maturation

c) Physiological Basis for Palpitation and Exophthalmos

Palpitation

Thyroid hormones increase sensitivity of heart to catecholamines

Increase heart rate and force of contraction

Causes tachycardia and palpitation

Exophthalmos

Autoimmune inflammation in orbital tissues

Edema and infiltration behind eyeball

Protrusion of eyeball occurs

Graves Disease

Definition

Autoimmune hyperthyroidism caused by thyroid stimulating immunoglobulins.

Features

Weight loss

Heat intolerance

Tremors

Tachycardia

Exophthalmos

Increased T3 and T4

Decreased TSH

2. A 45 year old female presents to the outpatient department with complaints of increase in body weight by more than 10kgs, dry coarse skin, hoarseness of voice, increase in sleep duration and loss of appetite.
a) What is this condition
b) Describe the functions of thyroid hormone
c) Physiological basis for cretinism

a) What is this condition

The condition is **Hypothyroidism (Myxedema in adults).**

Features suggestive of hypothyroidism:

Weight gain

Dry coarse skin

Hoarseness of voice

Excessive sleepiness

Loss of appetite

Mental and physical sluggishness

b) Describe the functions of thyroid hormone

Functions of Thyroid Hormones

1. Actions on Basal Metabolic Rate (BMR)

Increases BMR

Increases oxygen consumption of tissues

Increases heat production (calorigenic action)

2. Actions on Carbohydrate Metabolism

Increases intestinal absorption of glucose

Increases glycogenolysis

Increases gluconeogenesis

Increases utilization of glucose by cells

3. Actions on Fat Metabolism

Increases lipolysis

Decreases fat stores

Lowers blood cholesterol level

Increases free fatty acids in blood

4. Actions on Protein Metabolism

Physiological levels increase protein synthesis and growth

Excess thyroid hormone causes protein breakdown and muscle wasting

5. Actions on Growth

Essential for normal growth in children

Promotes skeletal growth and maturation

Acts synergistically with growth hormone

6. Actions on Central Nervous System

Essential for normal brain development

Maintains normal mental activity

Deficiency in infancy causes mental retardation

7. Cardiovascular Actions

Increases heart rate

Increases force of cardiac contraction

Increases cardiac output

Causes vasodilatation

8. Respiratory Actions

Increases rate and depth of respiration due to increased metabolic demand

9. Gastrointestinal Actions

Increases appetite

Increases gastrointestinal motility and secretions

10. Actions on Muscles

Maintains normal muscle tone and activity

Excess causes tremors

Deficiency causes muscle weakness

11. Actions on Reproductive System

Necessary for normal reproductive functions in both sexes

c) Physiological basis for cretinism

Cretinism

Cretinism is caused by **hypothyroidism during infancy or childhood** due to deficiency of thyroid hormones.

Physiological Basis

Thyroid hormones are essential for normal growth and development of the brain and body.

Deficiency during early life leads to:

Impaired brain development

Reduced neuronal growth and myelination

Retardation of skeletal growth

Delayed maturation of tissues

Features of Cretinism

Severe mental retardation

Stunted growth (dwarfism)

Pot belly

Protruded tongue

Dry skin

Delayed eruption of teeth

Delayed sexual maturation

Prevention

Early diagnosis and treatment with thyroid hormone

Adequate iodine intake during pregnancy and childhood

3. A 52-year-old housewife complains of progressive weight gain of 10 kg in 1 year, fatigue, loss of memory, slow speech, deepening of her voice, dry skin, constipation, and cold intolerance. On examination her pulse was 58 beats/min, she was moderately obese with a puffy face, non-pitting edema on the lower limbs, the Thyroid gland appeared enlarged, and deep tendon reflexes were delayed.

• What is the patient suffering from

The patient is suffering from **Hypothyroidism (Myxedema)**.

• What blood investigations should be done to confirm the diagnosis

Serum Thyroid Stimulating Hormone (TSH) – increased in primary hypothyroidism

Serum T3 – decreased

Serum T4 (thyroxine) – decreased

Anti-thyroid antibodies – positive in autoimmune thyroiditis

Serum cholesterol – increased

Radioactive iodine uptake – decreased

• Describe the biosynthesis and functions of the hormone causing this disorder

Biosynthesis of Thyroid Hormones

Thyroid hormones are **T3 (triiodothyronine)** and **T4 (thyroxine)**.

Steps

Synthesis of thyroglobulin

Produced by follicular cells and secreted into colloid.

Iodide trapping

Iodide actively transported into follicular cells by sodium-iodide symporter.

Oxidation of iodide

Iodide converted to active iodine by thyroid peroxidase.

Organification

Iodination of tyrosine residues in thyroglobulin.

Forms:

Monoiodotyrosine (MIT)

Diiodotyrosine (DIT)

Coupling reaction

MIT + DIT → T3

DIT + DIT → T4

Storage

Stored in colloid as thyroglobulin.

Release

Colloid endocytosed.

Proteolysis releases T3 and T4 into blood.

Transport

Mainly bound to thyroid-binding globulin.

Functions of Thyroid Hormones

1. Calorigenic and metabolic actions

Increase basal metabolic rate

Increase oxygen consumption

Increase heat production

2. Protein metabolism

Physiological levels: protein synthesis

Excess: protein breakdown

3. Carbohydrate metabolism

Increase glucose absorption

Increase glycogenolysis

Increase gluconeogenesis

4. Fat metabolism

Increase lipolysis

Decrease plasma cholesterol

5. Cardiovascular system

Increase heart rate

Increase cardiac output

Increase sensitivity to catecholamines

6. Growth and development

Essential for normal physical growth

Necessary for skeletal maturation

7. Central nervous system

Essential for brain development in fetus and child

Maintain normal mental activity in adults

8. Gastrointestinal tract

Increase appetite and intestinal motility

9. Neuromuscular system

Maintain normal reflexes and muscle tone

10. Hemopoietic system

Increase erythropoiesis

11. Reproductive system

Necessary for normal fertility and reproductive function

4. A patient with parathyroid hormone deficiency 10 days after inadvertent damage to parathyroid glands during thyroid surgery. Answer the following questions

• Explain the mechanisms underlying two clinical signs of parathyroid hormone deficiency

Parathyroid hormone deficiency causes **hypocalcemia**, leading to increased neuromuscular excitability.

1. Tetany

Mechanism

Low extracellular calcium increases sodium permeability of nerve membrane.

Nerves become hyperexcitable.

Repeated spontaneous action potentials occur.

Produces painful tonic muscle spasms.

2. Chvostek sign

Mechanism

Tapping facial nerve causes facial muscle contraction due to increased neuromuscular excitability from hypocalcemia.

3. Trousseau sign

Mechanism

Inflation of blood pressure cuff causes carpal spasm because ischemia further increases nerve excitability in hypocalcemia.

• Describe the physiological actions of parathyroid hormone

Actions of Parathyroid Hormone (PTH)

1. On bone

Stimulates bone resorption

Releases calcium and phosphate into blood

Activates osteoclasts indirectly

2. On kidney

Increases calcium reabsorption

Decreases phosphate reabsorption

Increases phosphate excretion

Stimulates formation of calcitriol

3. On intestine

Indirectly increases calcium and phosphate absorption through calcitriol

Overall effect

Increases plasma calcium

Decreases plasma phosphate

• Mention the normal blood calcium level and add a note on significance of intracellular calcium

Normal Blood Calcium Level

Total plasma calcium: **9–11 mg/dL**

Significance of Intracellular Calcium

Intracellular calcium acts as an important **second messenger**.

Functions

Muscle contraction

Neurotransmitter release

Hormone secretion

Activation of enzymes

Blood coagulation

Cell division and growth

Fertilization

Glycogen metabolism

Regulation of membrane permeability

5. A 50 years old lady was suffering from excess of sleep and tiredness, loss of appetite, hoarseness of voice for the last six months. On examination, she had non pitting edema, dry scaly skin and prolonged reflex time. Answer the following questions based on your knowledge in physiology

• What is your clinical diagnosis?

Hypothyroidism (Myxedema)

• What will be the TSH, T3 and T4 levels ?

TSH – increased

T3 – decreased

T4 – decreased

• What is the cause of low BMR?

Low basal metabolic rate occurs due to:

Decreased cellular metabolism

Reduced oxygen consumption

Reduced heat production

Decreased activity of metabolic enzymes due to deficiency of thyroid hormones

• How can you treat the subject?

Thyroid hormone replacement therapy

Levothyroxine administration

Adequate iodine intake if deficiency exists

• What will be the resting pulse rate and ECG wave complex?

Resting pulse rate

Decreased (Bradycardia)

ECG changes

Low voltage complexes

Sinus bradycardia

Flattened or inverted T wave

• Explain the action of thyroxin on the three metabolisms and CNS.

Action of Thyroxin on Metabolism

1. Carbohydrate metabolism

Increases glucose absorption

Increases glycogenolysis

Increases gluconeogenesis

2. Protein metabolism

Physiological level increases protein synthesis

Excess causes protein catabolism

3. Fat metabolism

Increases lipolysis

Increases fatty acid oxidation

Decreases plasma cholesterol

Action on Central Nervous System (CNS)

Essential for normal brain development

Promotes mental alertness

Maintains normal reflex activity

Deficiency in infancy causes cretinism

Deficiency in adults causes mental slowing and lethargy

6. A young woman has puffy skin and hoarseness of voice. Her plasma TSH concentration is low. Answer the following questions based on your knowledge in physiology:

• Explain the physiological basis of her symptoms.

The woman is suffering from **hypothyroidism**.

Physiological basis

Puffy skin

Accumulation of mucopolysaccharides in subcutaneous tissue

Causes non-pitting edema (myxedema)

Hoarseness of voice

Edema of vocal cords and laryngeal tissues

• Describe the mechanism of action of thyroid hormones.

Mechanism of Action of Thyroid Hormones

T4 converted to T3 inside cells

T3 enters nucleus

Binds to thyroid hormone receptor

Hormone-receptor complex binds to DNA

Activates transcription

Increases messenger ribonucleic acid and protein synthesis

Produces metabolic effects

• Explain the regulation of its synthesis.

Regulation of Thyroid Hormone Synthesis

Hypothalamo-pituitary-thyroid axis

Hypothalamus secretes Thyrotropin Releasing Hormone (TRH)

TRH stimulates anterior pituitary

Pituitary secretes Thyroid Stimulating Hormone (TSH)

TSH stimulates thyroid gland to synthesize and release T3 and T4

Negative feedback

Increased T3 and T4 inhibit:

TSH secretion

TRH secretion

Other factors

Cold stimulates secretion

Stress inhibits secretion

• What are its effects on nervous system?

Effects of Thyroid Hormones on Nervous System

Essential for growth and maturation of brain

Maintain normal mental activity

Increase alertness and responsiveness

Increase speed of reflexes

Deficiency causes:

Mental retardation in children

Sluggishness and slow reflexes in adults

Excess causes:

Nervousness

Irritability

Tremors

7.A 30 years female with features of increased weight, menstrual abnormalities, cold intolerance. Answer the following questions based on your knowledge in physiology:
• Name the probable condition with its cause.
• What are the physiological actions of hormone related to this condition?
• Mention the tests for diagnosing this condition.

• Name the probable condition with its cause.

Probable condition:
Hypothyroidism (Myxedema in adults)

Cause:
Deficiency of thyroid hormones —

Thyroxine (T4) and Triiodothyronine (T3) due to decreased activity of thyroid gland. Common causes include:

- Iodine deficiency
- Autoimmune destruction of thyroid gland (Hashimoto thyroiditis)
- Thyroidectomy
- Pituitary or hypothalamic disorders

• What are the physiological actions of hormone related to this condition?

Physiological actions of thyroid hormones:

On metabolism

- Increases Basal Metabolic Rate (BMR)
- Increases oxygen consumption
- Increases heat production (calorigenic action)

On carbohydrate metabolism

- Increases glucose absorption
- Increases glycogenolysis and gluconeogenesis

On protein metabolism

- Promotes protein synthesis and growth

On fat metabolism

- Increases lipolysis
- Reduces blood cholesterol level

On growth

- Essential for normal physical growth and skeletal development

On nervous system

- Necessary for normal mental development and alertness

On cardiovascular system

- Increases heart rate and cardiac output

On reproductive system

- Necessary for normal menstrual cycle and fertility

• Mention the tests for diagnosing this condition.

Tests for diagnosis of hypothyroidism:

Serum Thyroid Stimulating Hormone (TSH) estimation

- Increased in primary hypothyroidism

Serum T3 and T4 estimation

- Decreased levels

Basal Metabolic Rate (BMR)

- Decreased

Protein Bound Iodine (PBI) test

- Decreased

Radioactive iodine uptake test

Decreased uptake

Thyroid antibody tests

Useful in autoimmune thyroiditis

SHORT ESSAYS

8. Describe the functions of Thyroid hormone. Write the physiological basis for cretinism.

Functions of Thyroid Hormone

1. Actions on Metabolism

Carbohydrate metabolism

Increases intestinal absorption of glucose.

Increases glycogenolysis.

Increases gluconeogenesis.

Increases utilization of glucose by tissues.

Fat metabolism

Increases lipolysis.

Decreases body fat stores.

Lowers plasma cholesterol and triglycerides.

Protein metabolism

Physiological levels increase protein synthesis.

Excess causes protein catabolism.

2. Calorigenic Action

Increases basal metabolic rate.

Increases oxygen consumption.

Increases heat production.

3. Actions on Growth

Essential for normal growth and development.

Promotes skeletal growth.

Necessary for maturation of bones.

4. Actions on Nervous System

Essential for normal development and maturation of central nervous system.

Maintains normal mental activity.

5. Cardiovascular Actions

Increases heart rate.

Increases cardiac output.

Increases blood flow.

6. Respiratory Actions

Increases rate and depth of respiration.

7. Gastrointestinal Actions

Increases appetite.

Increases gastrointestinal motility and secretion.

8. Actions on Muscles

Maintains normal muscle tone.

Increases muscle activity.

9. Actions on Blood

Stimulates erythropoiesis.

10. Actions on Reproductive System

Necessary for normal reproductive function.

Physiological Basis for Cretinism

Cretinism is congenital hypothyroidism occurring due to deficiency of thyroid hormone during fetal or early neonatal life.

Causes

Congenital absence of thyroid gland.

Defective thyroid hormone synthesis.

Iodine deficiency.

Physiological Basis

Deficiency of thyroid hormone causes defective development and maturation of brain.

Impaired myelination and neuronal development lead to mental retardation.

Reduced protein synthesis and skeletal growth lead to dwarfism.

Delayed ossification causes stunted growth.

Decreased metabolic activity produces lethargy and cold intolerance.

Clinical Features

Mental retardation.

Dwarfism.

Pot belly.

Protruded tongue.

Dry skin.

Delayed milestones.

9. Describe the synthesis of thyroid hormones. Explain their physiological actions and add a note on hypo secretion of thyroid hormones.

Synthesis of Thyroid Hormones

1. Iodide Trapping

Follicular cells actively trap iodide from blood by sodium iodide symporter.

2. Oxidation of Iodide

Iodide is oxidized to active iodine by thyroid peroxidase.

3. Organification

Active iodine binds with tyrosine residues of thyroglobulin.

Monoiodotyrosine and diiodotyrosine are formed.

4. Coupling Reaction

Monoiodotyrosine + diiodotyrosine → Triiodothyronine.

Diiodotyrosine + diiodotyrosine → Thyroxine.

5. Storage

Thyroid hormones remain stored in colloid as thyroglobulin.

6. Release of Hormones

Colloid undergoes endocytosis.

Proteolysis releases thyroxine and triiodothyronine into blood.

Physiological Actions of Thyroid Hormones

Metabolic Actions

Increase basal metabolic rate.

Increase oxygen consumption.

Increase heat production.

Increase carbohydrate, fat and protein metabolism.

Growth Promoting Actions

Essential for normal physical growth.

Essential for skeletal maturation.

Actions on Nervous System

Necessary for development and maturation of central nervous system.

Cardiovascular Actions

Increase heart rate and cardiac output.

Gastrointestinal Actions

Increase appetite and motility.

Respiratory Actions

Increase respiration.

Hemopoietic Actions

Stimulate erythropoiesis.

Hypo Secretion of Thyroid Hormones

Definition

Deficiency of thyroid hormone secretion is called hypothyroidism.

Causes

Iodine deficiency.

Autoimmune thyroiditis.

Thyroidectomy.

Pituitary failure.

Types

In children

Cretinism.

In adults

Myxedema.

Clinical Features

Increased body weight.

Cold intolerance.

Bradycardia.

Dry skin.

Puffy face.

Constipation.

Mental sluggishness.

Decreased basal metabolic rate.

Investigations

Low serum thyroxine and triiodothyronine.

Increased thyroid stimulating hormone in primary hypothyroidism.

10. Actions of parathormone.

Actions of Parathormone

1. Actions on Bone

Stimulates osteoclastic activity indirectly.

Increases bone resorption.

Releases calcium and phosphate into blood.

2. Actions on Kidney

Increases calcium reabsorption.

Decreases phosphate reabsorption.

Increases phosphate excretion.

Stimulates formation of calcitriol.

3. Actions on Intestine

Indirectly increases intestinal absorption of calcium through calcitriol.

Overall Effects

Increases serum calcium level.

Decreases serum phosphate level.

11. Graves disease

Graves Disease

Definition

Graves disease is an autoimmune disorder causing hypersecretion of thyroid hormones.

Cause

Thyroid stimulating immunoglobulins stimulate thyroid gland.

Clinical Features

Weight loss.

Heat intolerance.

Tachycardia.

Nervousness.

Increased appetite.

Tremors.

Exophthalmos.

Goitre.

Physiological Basis

Excess thyroid hormones increase basal metabolic rate.

Increased sympathetic activity causes tachycardia and tremors.

Autoimmune inflammation behind eyeball causes exophthalmos.

Investigations

Increased serum thyroxine and triiodothyronine.

Decreased thyroid stimulating hormone.

Increased radioactive iodine uptake.

SHORT ANSWERS

12. Describe the physiological basis of cretinism.

Cretinism is congenital hypothyroidism due to deficiency of thyroid hormone during fetal or neonatal life.

Thyroid hormone deficiency impairs development and maturation of central nervous system.

Defective myelination and neuronal growth cause mental retardation.

Decreased protein synthesis and skeletal growth cause dwarfism.

Delayed ossification results in stunted growth.

Decreased metabolic activity causes lethargy and cold intolerance.

13. Physiological basis of Mental retardation in cretinism

Thyroid hormones are essential for normal brain development.

Deficiency during fetal and neonatal life impairs neuronal multiplication and differentiation.

Defective myelination and synapse formation occur.

Cerebral development becomes incomplete.

This leads to irreversible mental retardation.

14. Any two characteristic features and their physiological basis of hypothyroidism in a 30- year old woman

1. Increased Body Weight

Physiological Basis

Decreased basal metabolic rate causes reduced energy expenditure and fat accumulation.

2. Cold Intolerance

Physiological Basis

Reduced calorigenic action decreases heat production.

(Other acceptable points: Bradycardia, constipation, dry skin, menstrual abnormalities.)

15. Calorigenic action of thyroxin

Thyroxine increases basal metabolic rate.

Increases oxygen consumption in tissues.

Increases activity of sodium potassium adenosine triphosphatase pump.

Enhances cellular metabolism.

Produces excess heat in body.

This heat producing effect is called calorigenic action.

16. Cretinism

Definition

Cretinism is congenital hypothyroidism occurring in infancy or childhood.

Causes

Congenital absence of thyroid gland.

Defective thyroid hormone synthesis.

Iodine deficiency.

Clinical Features

Mental retardation.

Dwarfism.

Pot belly.

Protruded tongue.

Dry skin.

Delayed milestones.

17. Physiological basis of goitre

Goitre means enlargement of thyroid gland.

Iodine deficiency decreases thyroid hormone synthesis.

Reduced thyroxine decreases negative feedback on anterior pituitary.

Increased thyroid stimulating hormone secretion occurs.

Thyroid stimulating hormone causes hypertrophy and hyperplasia of thyroid gland.

This leads to goitre.

18. List clinical features of cretinism

Mental retardation.

Dwarfism.

Pot belly.

Protruded tongue.

Dry coarse skin.

Delayed skeletal growth.

Delayed milestones.

Puffy face.

Hoarse cry.

19. Steps of thyroid hormone synthesis

Iodide trapping.

Oxidation of iodide.

Organification.

Coupling reaction.

Storage in colloid.

Release of hormones.

20. Draw and label :Feedback regulation of thyroid hormone secretion

REFER DIAGRAM SECTION

21. Feedback regulation of thyroid hormone secretion

Hypothalamus secretes thyrotropin releasing hormone.

Thyrotropin releasing hormone stimulates anterior pituitary.

Anterior pituitary secretes thyroid stimulating hormone.

Thyroid stimulating hormone stimulates thyroid gland to secrete thyroxine and triiodothyronine.

Increased thyroid hormones inhibit hypothalamus and anterior pituitary by negative feedback.

22. Draw and label :Mechanism of action of thyroid hormone on intracellular receptor

REFER DIAGRAM SECTION

CALCIUM AND PHOSPHATE HOMEOSTASIS

LONG ESSAYS

1. What is the normal serum calcium level. Describe the calcium homeostasis in our body. Describe the physiological basis for tetany.

Normal Serum Calcium Level

Total serum calcium : 9 – 11 milligram per deciliter.

Ionized calcium : 4.5 – 5.5 milligram per deciliter.

Calcium Homeostasis

Hormones Regulating Calcium Homeostasis

Parathormone.

Calcitriol.

Calcitonin.

Role of Parathormone

Bone

Increases bone resorption.

Releases calcium into blood.

Kidney

Increases calcium reabsorption.

Increases phosphate excretion.

Activates vitamin D.

Intestine

Indirectly increases calcium absorption through calcitriol.

Role of Calcitriol

Intestine

Increases absorption of calcium and phosphate.

Bone

Helps mineralization.

Kidney

Increases calcium reabsorption.

Role of Calcitonin

Decreases bone resorption.

Lowers serum calcium level.

Physiological Basis for Tetany

Tetany occurs in hypocalcemia.

Low ionized calcium increases permeability of neuronal membrane to sodium.

Nerves become hyperexcitable.

Repeated spontaneous action potentials occur.

This causes muscle spasms and carpopedal spasm.

2. Describe the regulation of serum calcium with the mechanisms involved. Write the physiological basis of tetany in hypocalemia. List the causes and clinical features of hypercalcemia.

Regulation of Serum Calcium

Parathormone

Mechanism

Secreted in response to low serum calcium.

Increases bone resorption.

Increases renal calcium reabsorption.

Increases activation of vitamin D.

Increases intestinal calcium absorption indirectly.

Calcitriol

Mechanism

Increases intestinal absorption of calcium.

Increases renal calcium reabsorption.

Helps bone mineralization.

Calcitonin

Mechanism

Secreted in response to increased serum calcium.

Inhibits osteoclastic activity.

Decreases bone resorption.

Physiological Basis of Tetany in Hypocalemia

Hypocalcemia increases neuromuscular excitability.

Increased sodium permeability leads to spontaneous nerve discharge.

Repeated skeletal muscle contractions occur.

Manifestations include muscle spasm and convulsions.

Causes of Hypercalcemia

Hyperparathyroidism.

Excess vitamin D.

Bone tumors.

Prolonged immobilization.

Excess calcium intake.

Clinical Features of Hypercalcemia

Muscle weakness.

Constipation.

Polyuria.

Kidney stones.

Cardiac arrhythmias.

Mental confusion.

SHORT ESSAYS

3. Name the hormones which affect serum calcium level. Describe their mode of action

Hormones Affecting Serum Calcium Level

Parathormone.

Calcitriol.

Calcitonin.

Parathormone

Mode of Action

Increases bone resorption.

Increases renal calcium reabsorption.

Decreases phosphate reabsorption.

Increases calcitriol formation.

Calcitriol

Mode of Action

Increases intestinal absorption of calcium and phosphate.

Increases renal calcium reabsorption.

Helps bone mineralization.

Calcitonin

Mode of Action

Inhibits osteoclastic activity.

Decreases bone resorption.

Lowers serum calcium.

SHORT ANSWERS

4. Describe regulation of blood calcium level

Blood calcium is regulated mainly by parathormone, calcitriol and calcitonin.

Low calcium stimulates parathormone secretion.

Parathormone increases bone resorption and renal calcium reabsorption.

Calcitriol increases intestinal calcium absorption.

Increased calcium stimulates calcitonin secretion.

Calcitonin decreases bone resorption.

These mechanisms maintain normal serum calcium level.

5. Hormones regulating calcium homeostasis

Parathormone.

Calcitriol.

Calcitonin.

Functions

Parathormone

Increases serum calcium.

Calcitriol

Increases intestinal calcium absorption.

Calcitonin

Decreases serum calcium.

ADRENAL GLAND

LONG ESSAYS

1. A 35-year-old female presents with weight gain, especially around her abdomen and face, fragile skin, easy bruising, acne, fatigue, mood swings, and irregular periods over the past 6 months. She also reports increased thirst and frequent urination. Examination reveals high blood pressure, a moon-shaped face, buffalo hump, purple striae, and thin, easily bruised skin.

• Name the most probable clinical condition and mention its cause.
• Describe the physiological action of cortisol.
• Explain the physiological basis of clinical features observed in the above case.

Answer

Most probable clinical condition and cause

Condition: Cushing syndrome

Cause: Excess secretion of cortisol due to:

Pituitary ACTH secreting adenoma (Cushing disease)

Adrenal cortical tumor

Excess glucocorticoid therapy

Ectopic ACTH secretion

Physiological actions of cortisol

1. Actions on carbohydrate metabolism

Increases gluconeogenesis

Decreases peripheral utilization of glucose

Increases blood glucose level

Anti-insulin effect

2. Actions on protein metabolism

Increases protein catabolism

Decreases protein synthesis

Causes muscle wasting and thinning of skin

3. Actions on fat metabolism

Increases lipolysis

Redistribution of fat to face, neck and trunk

4. Anti-inflammatory action

Stabilizes lysosomal membrane

Decreases capillary permeability

Inhibits inflammatory mediators

5. Immunosuppressive action

Decreases lymphocytes and eosinophils

Suppresses antibody formation

6. Actions on cardiovascular system

Maintains vascular responsiveness to catecholamines

Increases blood pressure

7. Actions on blood cells

Increases neutrophils and RBCs

Decreases eosinophils and lymphocytes

8. Actions on bone

Decreases bone formation

Causes osteoporosis

9. Actions on CNS

Produces mood changes and emotional disturbances

Physiological basis of clinical features

Clinical feature	Physiological basis
Central obesity	Fat redistribution due to excess cortisol
Moon face	Fat deposition over face
Buffalo hump	Fat deposition over upper back
Purple striae	Breakdown of collagen and thinning of skin
Easy bruising	Fragile capillaries and protein catabolism
Thin skin	Loss of collagen
Hypertension	Increased vascular sensitivity to catecholamines
Muscle weakness/fatigue	Protein catabolism and muscle wasting
Acne	Increased adrenal androgen secretion
Irregular menstruation	Suppression of gonadotropin secretion
Polyuria and polydipsia	Hyperglycemia causing osmotic diuresis
Mood swings	Effect of cortisol on CNS

2. A 42-year-old female patient presented with hirsutism, purple striae on the skin, buffalo hump and visual field defect. Her serum cortisol was elevated.

• Name the most probable clinical condition
• Describe the regulation of cortisol
• What type of visual field defect occurs in this patient and why
• Describe the physiological basis for the buffalo hump and striae.

Answer

Most probable clinical condition

Cushing disease

Regulation of cortisol

Hypothalamo–pituitary–adrenal axis

Hypothalamus secretes:

Corticotropin releasing hormone

Anterior pituitary secretes:

ACTH

ACTH stimulates adrenal cortex (zona fasciculata) to secrete cortisol.

Feedback regulation

Increased cortisol inhibits:

Corticotropin releasing hormone secretion

ACTH secretion

Other factors influencing secretion

Stress increases cortisol secretion

Circadian rhythm:

Highest in early morning

Lowest at midnight

Type of visual field defect and reason

Defect:

Bitemporal hemianopia

Reason:

Pituitary adenoma compresses the optic chiasma causing damage to crossing nasal fibers of optic nerve.

Physiological basis of buffalo hump and striae

Buffalo hump

Excess cortisol causes redistribution of fat to upper back and neck region.

Purple striae

Protein catabolism causes loss of collagen fibers

Skin becomes thin and stretched

Subcutaneous blood vessels become visible producing purple striae

3. A 40-year old female patient reported that she was feeling very weak. Her legs were thin but abdomen, upper back and face were full with deposition of fat.She had also noticed that minor injuries were resulting in bruises and taking a long time to heal. Reddish purple striations were seen in the skin of her abdomen. Her blood pressure was 180/100 mmHg, pulse rate was 99/min

• Identify the condition.
• Discuss the physiological basis for the above condition
• Discuss the physiological and pharmacological actions of glucocorticoids

Answer

Identification of condition

Cushing syndrome

Physiological basis for the condition

Feature	Basis
Thin legs	Protein catabolism and muscle wasting
Central obesity	Redistribution of fat
Moon face	Fat deposition over face
Buffalo hump	Fat deposition over upper back
Bruising	Fragile capillaries and thin skin
Delayed wound healing	Inhibition of fibroblast activity
Purple striae	Breakdown of collagen
Hypertension	Increased vascular responsiveness and sodium retention
Weakness	Muscle protein breakdown

Physiological and pharmacological actions of glucocorticoids

Physiological actions

On carbohydrate metabolism

Increase gluconeogenesis

Increase blood glucose

On protein metabolism

Increase protein breakdown

Decrease protein synthesis

On fat metabolism

Lipolysis and fat redistribution

Anti-inflammatory action

Reduce inflammatory response

Immunosuppressive action

Decrease lymphocyte activity

On CVS

Maintain blood pressure

On blood cells

Increase neutrophils

Decrease eosinophils

On bone

Osteoporosis

Pharmacological actions

1. Anti-inflammatory

Used in asthma, arthritis and allergies

2. Immunosuppressive

Used in organ transplantation and autoimmune diseases

3. Anti-allergic

Suppress hypersensitivity reactions

4. Anti-shock effect

Useful in septic shock

5. Lympholytic action

Used in leukemia and lymphoma

4. A 33 years old woman complained of weight gain. Round face, thinning of her limbs and increased bruising of skin with discoloration on her prominent abdomen.Answer the following questions based on your knowledge in physiology:

• What is the probable endocrinological disorder?
• What investigations are needed for confirmation of the diagnosis and follow up ?
• Mention the major manifestations and their physiological basis.

Answer

Probable endocrinological disorder

Cushing syndrome

Investigations for confirmation and follow up

Screening tests

Plasma cortisol estimation

24-hour urinary free cortisol

Low dose dexamethasone suppression test

Midnight salivary cortisol

Tests for cause

Plasma ACTH estimation

CT/MRI of pituitary and adrenal gland

Follow up

Serial cortisol estimation

Blood glucose monitoring

Blood pressure monitoring

Major manifestations and physiological basis

Manifestation	Physiological basis
Weight gain	Fat redistribution
Moon face	Fat deposition over face
Thin limbs	Protein catabolism
Purple striae	Loss of collagen
Easy bruising	Fragile capillaries
Hypertension	Increased catecholamine sensitivity
Muscle weakness	Muscle protein breakdown
Hyperglycemia	Increased gluconeogenesis
Osteoporosis	Bone protein breakdown

SHORT ESSAYS

5. Describe the physiological actions of glucocorticoids. List the features of Cushing's syndrome

Answer

Physiological actions of glucocorticoids

1. Carbohydrate metabolism

Increase gluconeogenesis

Increase blood glucose

Decrease glucose utilization

2. Protein metabolism

Increase protein catabolism

Decrease protein synthesis

3. Fat metabolism

Lipolysis

Redistribution of fat

4. Anti-inflammatory action

Inhibit inflammatory mediators

Stabilize lysosomal membrane

5. Immunosuppressive action

Reduce lymphocyte function

6. Cardiovascular action

Maintain blood pressure

7. Hematological action

Increase neutrophils and RBCs

Decrease eosinophils

8. Bone action

Osteoporosis

9. CNS action

Mood and behavioral changes

Features of Cushing's syndrome

Central obesity

Moon face

Buffalo hump

Thin limbs

Muscle wasting

Purple striae

Hypertension

Hyperglycemia

Osteoporosis

Hirsutism

Acne

Easy bruising

Delayed wound healing

Menstrual disturbances

6. Explain the anti-inflammatory and immunosuppressive actions of cortisol.Add a note on cushings syndrome

Answer

Anti-inflammatory actions of cortisol

Stabilizes lysosomal membrane

Decreases capillary permeability

Inhibits prostaglandin and leukotriene synthesis

Decreases migration of leukocytes

Suppresses inflammatory mediators

Immunosuppressive actions of cortisol

Decreases lymphocyte proliferation

Suppresses T-cell function

Decreases antibody production

Reduces eosinophils and basophils

Note on Cushing's syndrome

Definition

Condition due to excess glucocorticoids.

Causes

Pituitary adenoma

Adrenal tumor

Prolonged steroid therapy

Ectopic ACTH secretion

Features

Central obesity

Moon face

Buffalo hump

Hypertension

Hyperglycemia

Purple striae

Muscle wasting

Osteoporosis

7. Describe the functions of aldosterone. Explain aldosterone escape.Add a note on Conn's syndrome.

Answer

Functions of aldosterone

On kidney

Increases sodium reabsorption

Increases water reabsorption

Increases potassium secretion

Increases hydrogen ion secretion

Site of action

Distal convoluted tubule

Collecting duct

Effects

Increases extracellular fluid volume

Increases blood pressure

Aldosterone escape

Definition

Despite continued excess aldosterone secretion, edema does not continue indefinitely.

Mechanism

Increased extracellular fluid volume raises arterial pressure

Increased renal perfusion causes pressure diuresis and natriuresis

Excess sodium and water are excreted

Conn's syndrome

Definition

Primary hyperaldosteronism due to adrenal adenoma or hyperplasia.

Features

Hypertension

Hypokalemia

Muscle weakness

Metabolic alkalosis

Polyuria and polydipsia

8. Role of mineralocorticoids in salt and water balance

Answer

Mineralocorticoids

Main mineralocorticoid is **aldosterone** secreted from zona glomerulosa of adrenal cortex.

Role in salt and water balance

1. Sodium retention

Increases sodium reabsorption from distal tubules and collecting ducts.

2. Water retention

Water follows sodium osmotically.

Increases extracellular fluid volume.

3. Potassium excretion

Enhances potassium secretion in urine.

4. Hydrogen ion secretion

Maintains acid–base balance.

5. Maintenance of blood pressure

By increasing blood volume and cardiac output.

Regulation of aldosterone secretion

Renin–angiotensin system

Plasma potassium level

ACTH (minor role)

Disorders

Hypersecretion

Conn's syndrome

Hyposecretion

Addison disease

9. Describe the regulation of secretion of cortisol and its physiological role

Regulation of secretion of cortisol

Cortisol secretion is regulated by the hypothalamo–pituitary–adrenal axis.

1. Role of hypothalamus

Hypothalamus secretes Corticotropin Releasing Hormone (CRH).

CRH stimulates anterior pituitary to secrete Adrenocorticotropic Hormone (ACTH).

2. Role of ACTH

ACTH acts on zona fasciculata of adrenal cortex.

Stimulates synthesis and secretion of cortisol.

3. Negative feedback regulation

Increased cortisol inhibits secretion of:

CRH from hypothalamus

ACTH from anterior pituitary.

4. Diurnal rhythm

Cortisol secretion shows circadian rhythm.

Highest in early morning.

Lowest around midnight.

5. Stress

Stress increases cortisol secretion.
Examples:

Trauma

Surgery

Infection

Hypoglycemia

Emotional stress

Physiological actions of cortisol

1. Actions on carbohydrate metabolism

Increases gluconeogenesis.

Increases blood glucose.

Decreases peripheral utilization of glucose.

2. Actions on protein metabolism

Increases protein catabolism.

Decreases protein synthesis.

Causes muscle wasting.

3. Actions on fat metabolism

Increases lipolysis.

Mobilizes fatty acids.

4. Anti-inflammatory action

Suppresses inflammatory response.

Stabilizes lysosomal membrane.

Decreases capillary permeability.

5. Immunosuppressive action

Decreases lymphocytes and eosinophils.

Suppresses immune reactions.

6. Permissive action

Essential for normal action of catecholamines.

Maintains vascular responsiveness.

7. Hematological effects

Increases red blood cells and neutrophils.

8. Role in stress

Helps body adapt to stress.

10. Role of aldosterone in maintaining ECF sodium concentration

Aldosterone is the principal mineralocorticoid secreted by zona glomerulosa of adrenal cortex.

Actions

On kidney

Acts mainly on distal convoluted tubule and collecting duct.

Functions

Increases sodium reabsorption.

Increases water retention secondary to sodium retention.

Increases potassium excretion.

Increases hydrogen ion secretion.

Role in maintaining extracellular fluid sodium concentration

Conserves sodium in the body.

Maintains extracellular fluid volume.

Maintains blood pressure.

Prevents excessive sodium loss in urine.

Mechanism

Stimulates synthesis of sodium channels and Na+-K+ ATPase.

Enhances sodium transport from tubular lumen to blood.

SHORT ANSWERS

11. Fight-flight reaction

Fight or flight reaction is the emergency response produced by sympathetic stimulation and adrenal medullary secretion.

Features

Tachycardia

Increased blood pressure

Bronchodilation

Dilatation of pupil

Increased blood glucose

Increased sweating

Increased cardiac output

Diversion of blood to skeletal muscle

Increased mental alertness

Significance

Helps the body to face emergency situations.

12. Soldiers do not feel the pain of their injury until the battle is over – why?

During stress and emotional excitement, endogenous opioids such as endorphins and enkephalins are released.

Mechanism

These substances inhibit pain pathways in the central nervous system.

Sympathetic discharge and adrenal catecholamine secretion also suppress pain perception.

Result

Pain sensation is reduced temporarily during battle or severe stress.

13. Edema is not a feature of primary hyper aldosteronism. Why

In primary hyperaldosteronism, sodium and water retention initially occur.

However, edema does not develop due to:

Aldosterone escape phenomenon.

Increased glomerular filtration rate.

Pressure natriuresis causing excretion of excess sodium and water.

Hence extracellular fluid volume increases only slightly without edema.

14. Compare and contrast the functions of epinephrine and nor-epinephrine. Add a note on pheochromocytomy

Differences between epinephrine and norepinephrine

Epinephrine	Norepinephrine
Secreted mainly by adrenal medulla	Secreted mainly by sympathetic nerve

Epinephrine	Norepinephrine
	endings
Acts on alpha and beta receptors	Mainly acts on alpha receptors
Increases heart rate markedly	Slight increase or decrease in heart rate
Causes bronchodilation	Minimal bronchodilation
Increases metabolic rate	Less effect on metabolism
Increases glycogenolysis	Mild effect
Increases systolic blood pressure	Increases both systolic and diastolic pressure

Pheochromocytoma

Pheochromocytoma is a tumor of adrenal medulla causing excess catecholamine secretion.

Features

- Hypertension
- Tachycardia
- Headache
- Sweating
- Palpitations
- Hyperglycemia

Diagnosis

- Increased urinary catecholamines and vanillylmandelic acid.

15. Mechanism of action of steroid hormone

Steroid hormones act through intracellular receptors.

Mechanism

- Steroid hormone diffuses through cell membrane.
- Binds with cytoplasmic or nuclear receptor.
- Hormone–receptor complex enters nucleus.
- Binds to hormone response element on DNA.
- Activates transcription.
- Messenger ribonucleic acid synthesis occurs.
- Protein synthesis increases.
- Physiological response is produced.

Features

- Slow onset of action.
- Long duration of action.

16. Name the glucocorticoids and mention its functions

Glucocorticoids

- Cortisol (Hydrocortisone)
- Corticosterone
- Cortisone

Functions

1. Carbohydrate metabolism

Increases gluconeogenesis.

Raises blood glucose.

2. Protein metabolism

Increases protein breakdown.

3. Fat metabolism

Increases lipolysis.

4. Anti-inflammatory action

Suppresses inflammation.

5. Immunosuppressive action

Decreases immune response.

6. Stress adaptation

Helps body withstand stress.

7. Permissive action

Maintains vascular responsiveness to catecholamines.

17. Permissive action of glucocorticoids

Permissive action means glucocorticoids are essential for full expression of actions of other hormones.

Examples

Necessary for vasoconstrictor action of catecholamines.

Maintains normal blood pressure.

Necessary for glucagon and adrenaline induced glycogenolysis.

18. Action of ADH

Antidiuretic Hormone (ADH) is secreted from posterior pituitary.

Actions

1. Antidiuretic action

Increases water reabsorption in distal tubule and collecting duct.

Decreases urine volume.

Concentrates urine.

2. Vasopressor action

Causes vasoconstriction.

Raises blood pressure.

3. Maintains osmolarity

Maintains body water balance and plasma osmolarity.

19. Aldosterone escape phenomenon

Despite continued excess aldosterone secretion, severe edema usually does not occur.

Mechanism

Sodium and water retention increase extracellular fluid volume.

Blood pressure and glomerular filtration rate increase.

Increased sodium excretion occurs by pressure natriuresis.

Thus further sodium retention is prevented.

This phenomenon is called aldosterone escape.

20. Adrenogenital syndrome

Adrenogenital syndrome is due to excess secretion of adrenal androgens.

Causes

Congenital adrenal hyperplasia.

Adrenal tumors.

Features

In females

Virilism

Hirsutism

Deep voice

Amenorrhea

In males

Precocious puberty.

In children

Early development of secondary sexual characters.

21. Difference between adrenaline and nor adrenaline

Adrenaline	Noradrenaline
Secreted mainly from adrenal medulla	Secreted mainly from sympathetic nerve endings
Acts on alpha and beta receptors	Mainly alpha action
Increases heart rate markedly	Reflex bradycardia may occur
Causes bronchodilation	Minimal bronchodilation
Increases metabolic rate	Less metabolic effect
Increases systolic pressure mainly	Increases both systolic and diastolic pressure
More potent on beta receptors	More potent on alpha receptors

22. Pigmentation in Addison's disease .Why?

In Addison's disease, cortisol secretion decreases.

Mechanism

Reduced cortisol removes negative feedback on pituitary.

ACTH secretion increases.

ACTH contains melanocyte stimulating activity.

Stimulates melanin production.

Result

Hyperpigmentation of skin and mucous membrane occurs.

23. Cushing's syndrome

Cushing's syndrome is the clinical condition caused by excess glucocorticoids.

Causes

Adrenal cortical tumor.

Excess ACTH secretion.

Prolonged steroid therapy.

Features

Moon face

Truncal obesity

Buffalo hump

Hyperglycemia

Hypertension

Muscle wasting

Thin skin

Osteoporosis

Purple striae

24. Glucocorticoids in stress .Why?

Stress increases ACTH secretion which stimulates glucocorticoid secretion.

Importance of glucocorticoids in stress

Maintains blood glucose by gluconeogenesis.

Mobilizes amino acids and fatty acids.

Maintains vascular responsiveness.

Helps body resist stress.

Essential for survival during stress.

ENDOCRINE PANCREAS

LONG ESSAYS

1. A 55 year old women comes to the medicine department with history of increased frequency of nocturnal urination with increased thirst and hunger , investigation revealed her HbA1c to be 8 and fasting blood sugar was 280mg/dl

• What is your probable diagnosis
• Discuss the physiological basis of her complaints
• List all the hormones responsible for glucose homeostasis

Probable diagnosis

The probable diagnosis is Diabetes Mellitus, most likely Type 2 Diabetes Mellitus.

Physiological basis of her complaints

1. Polyuria (Increased urination)

Blood glucose exceeds renal threshold (about 180 mg/dL).

Glucose appears in urine (glycosuria).

Glucose causes osmotic diuresis.

Increased urine output occurs.

2. Nocturia

Excess urine formation continues during night.

Causes frequent nighttime urination.

3. Polydipsia (Increased thirst)

Excess water loss through urine causes dehydration.

Increased plasma osmolarity stimulates thirst center.

Patient drinks excess water.

4. Polyphagia (Increased hunger)

Glucose cannot enter cells properly due to insulin deficiency/resistance.

Cells undergo intracellular starvation.

Hunger center is stimulated.

5. Raised HbA1c

HbA1c reflects long term blood glucose level.

HbA1c of 8% indicates poor glycemic control.

6. Hyperglycemia

Due to decreased glucose uptake.

Increased hepatic glucose production.

Insulin resistance.

Hormones responsible for glucose homeostasis

Hypoglycemic hormone

Insulin.

Hyperglycemic hormones

Glucagon

Epinephrine

Cortisol

Growth hormone

Thyroxine

2. A 45-year-old casual labourer comes to the OPD with complaints of excessive thirst, urination , hunger and weakness, Of two weeks' duration with your knowledge of physiology, answer the following.

- What is the most likely condition.
- What tests would you suggest to confirm.
- How can you explain his symptoms.
- What are the dietary and lifestyle modifications you would suggest for this man.

Most likely condition

Diabetes Mellitus.

Tests to confirm diagnosis

1. Fasting blood sugar

≥126 mg/dL indicates diabetes mellitus.

2. Postprandial blood sugar

≥200 mg/dL suggests diabetes mellitus.

3. Oral glucose tolerance test

Two hour plasma glucose ≥200 mg/dL confirms diabetes mellitus.

4. HbA1c estimation

HbA1c ≥6.5% indicates diabetes mellitus.

5. Urine examination

Glycosuria may be present.

Explanation of symptoms

1. Polyuria

Hyperglycemia causes glycosuria.

Glucose in urine causes osmotic diuresis.

2. Polydipsia

Excess urine loss causes dehydration.

Thirst center is stimulated.

3. Polyphagia

Glucose cannot be utilized properly by cells.

Cellular starvation stimulates appetite.

4. Weakness

Defective glucose utilization.

Increased protein breakdown.

Dehydration.

Dietary and lifestyle modifications

Dietary modifications

Restrict refined carbohydrates and sugars.

Balanced diet with high fiber.

Reduce saturated fat intake.

Calorie restriction in obesity.

Small frequent meals.

Lifestyle modifications

Regular exercise.

Weight reduction.

Avoid smoking and alcohol.

Regular blood sugar monitoring.

Adequate sleep and stress reduction.

3. A 50 year old diabetic was brought to the hospital complaining of severe breathlessness. His breath had a fruity odour and respiratory rate was 30 per minute. His blood sugar was 375 mg% and plasma pH was 7.2. Answer the following questions based in your knowledge in physiology.

• What is the most likely diagnosis?
• What is the most important medication that should be given?

Most likely diagnosis

Diabetic ketoacidosis.

Basis of diagnosis

Severe hyperglycemia.

Ketone body formation.

Fruity odour of breath due to acetone.

Metabolic acidosis with low plasma pH.

Kussmaul breathing causing severe breathlessness.

Most important medicine to be administered immediately

Insulin (preferably intravenous regular insulin)
Insulin

Two abnormal substances present in urine

Glucose (glycosuria)

Ketone bodies (ketonuria)

Physiological explanation for low plasma pH and fruity odour of breath

Low plasma pH

Due to **accumulation of ketone bodies** such as:

Acetoacetic acid

Beta-hydroxybutyric acid

Insulin deficiency causes increased fat breakdown and excessive ketogenesis in liver.

Excess ketoacids produce **metabolic acidosis**, thereby decreasing plasma pH.

Fruity odour of breath

Due to increased formation of **acetone**, a volatile ketone body.

Acetone is excreted through lungs, producing characteristic **fruity or sweet odour** of breath.

4. A 50 years old person complaints of increased appetite, increased thirst and increased frequency of urination, the blood glucose was found to be 180mg/dl.Answer the following questions based on your knowledge in physiology:

• What is your probable diagnosis?

Diagnosis: Diabetes mellitus.

• Which hormone is affected?

Hormone affected: Insulin.

• What are the physiological effects of this hormone in the body?

Physiological effects of insulin

1. Effects on carbohydrate metabolism

Increases glucose uptake by muscle and adipose tissue.

Increases glycogenesis.

Decreases glycogenolysis.

Decreases gluconeogenesis.

Lowers blood glucose level.

2. Effects on fat metabolism

Increases lipogenesis.

Inhibits lipolysis.

Promotes storage of triglycerides.

Prevents ketosis.

3. Effects on protein metabolism

Increases amino acid uptake.

Increases protein synthesis.

Decreases protein breakdown.

Promotes growth.

4. Effects on electrolytes

Increases entry of potassium into cells.

• Enumerate the other hormones involved in the regulation of blood glucose.

Hormones regulating blood glucose

Hypoglycemic hormone

Insulin.

Hyperglycemic hormones

Glucagon.

Adrenaline (epinephrine).

Cortisol.

Growth hormone.

Thyroxine.

SHORT ESSAYS

5. Describe the actions of insulin. Write the physiological basis for polyphagia, polydipsia and polyuria in diabetes mellitus.

Actions of insulin

1. Actions on carbohydrate metabolism

Increases uptake of glucose by muscle and adipose tissue.

Increases glycogenesis in liver and muscle.

Decreases glycogenolysis.

Decreases gluconeogenesis.

Decreases blood glucose concentration.

2. Actions on fat metabolism

Increases synthesis of fatty acids and triglycerides.

Increases fat storage.

Inhibits lipolysis.

Decreases free fatty acids in blood.

Prevents ketone body formation.

3. Actions on protein metabolism

Increases amino acid uptake by cells.

Increases protein synthesis.

Decreases proteolysis.

Promotes growth and tissue repair.

4. Actions on electrolytes

Increases intracellular potassium.

Increases phosphate uptake.

Physiological basis of symptoms in diabetes mellitus

1. Polyphagia

Due to inability of glucose to enter cells because of insulin deficiency.

Cells undergo intracellular starvation.

Hunger center in hypothalamus is stimulated causing excessive appetite.

2. Polyuria

Blood glucose exceeds renal threshold (about 180 mg/dL).

Glucose appears in urine (glycosuria).

Glucose causes osmotic diuresis.

Large amount of water is lost in urine causing excessive urination.

3. Polydipsia

Excessive water loss due to polyuria causes dehydration.

Increased plasma osmolarity stimulates thirst center.

Results in excessive thirst.

6. Describe the mechanism of action of insulin and its functions. Add a note on clinical signs and symptoms of diabetes mellitus. Explain glucose tolerance test curve.

Mechanism of action of insulin

Insulin acts through membrane receptor having alpha and beta subunits.

Alpha subunit binds insulin.

Beta subunit has tyrosine kinase activity.

Binding of insulin activates tyrosine kinase.

Causes phosphorylation of intracellular proteins.

Leads to activation of glucose transporters (GLUT-4).

Increases glucose uptake into muscle and adipose tissue.

Produces metabolic effects of insulin.

Functions of insulin

1. On carbohydrate metabolism

Increases glucose uptake.

Increases glycogenesis.

Decreases gluconeogenesis.

Decreases glycogenolysis.

Lowers blood glucose.

2. On fat metabolism

Increases lipogenesis.

Decreases lipolysis.

Prevents ketosis.

3. On protein metabolism

Increases protein synthesis.

Decreases protein breakdown.

Promotes growth.

4. On electrolytes

Increases intracellular potassium.

Clinical signs and symptoms of diabetes mellitus

Cardinal symptoms

Polyuria.

Polydipsia.

Polyphagia.

Other symptoms

Weight loss.

Weakness and fatigue.

Glycosuria.

Blurring of vision.

Pruritus.

Recurrent infections.

Delayed wound healing.

Severe manifestations

Ketoacidosis.

Coma.

Glucose tolerance test (GTT)

Definition

It is a test used to assess the ability of the body to metabolize glucose.

Procedure

Subject fasts overnight.

Fasting blood glucose is measured.

75 g oral glucose is given.

Blood samples are taken at intervals for 2 hours.

Normal glucose tolerance curve

Fasting blood glucose: 70–110 mg/dL.

Blood glucose rises after glucose intake.

Peak occurs within 1 hour.

Returns to normal within 2 hours.

No glucose in urine.

Diabetic curve

Fasting blood glucose increased.

Higher peak after glucose load.

Delayed return to normal.

Glycosuria may be present.

7. Metabolic effects of insulin

Metabolic effects of insulin

1. Effects on carbohydrate metabolism

Increases cellular uptake of glucose.

Increases glycogenesis.

Decreases glycogenolysis.

Decreases gluconeogenesis.

Lowers blood glucose level.

2. Effects on fat metabolism

Increases fatty acid synthesis.

Increases triglyceride storage.

Inhibits lipolysis.

Decreases ketogenesis.

3. Effects on protein metabolism

Increases amino acid uptake.

Increases protein synthesis.

Decreases proteolysis.

Promotes growth.

SHORT ANSWERS

8. Physiological basis of polyuria and polydipsia in diabetes mellitus

Polyuria

Hyperglycemia exceeds renal threshold.

Glucose appears in urine.

Glucose causes osmotic diuresis.

Excess water loss leads to polyuria.

Polydipsia

Excessive water loss causes dehydration.

Plasma osmolarity increases.

Thirst center is stimulated.

Leads to excessive thirst.

9. Renal threshold for glucose and glycosuria in diabetes mellitus

Renal threshold for glucose

It is the blood glucose level above which glucose appears in urine.

Normal renal threshold is about 180 mg/dL.

Glycosuria in diabetes mellitus

In diabetes mellitus blood glucose rises above renal threshold.

Renal tubules cannot reabsorb all filtered glucose.

Glucose appears in urine causing glycosuria.

10. Physiological basis of polyuria in diabetes mellitus

Hyperglycemia exceeds renal threshold.

Glucose appears in urine.

Glucose exerts osmotic effect in renal tubules.

Water reabsorption decreases.

Increased urine output occurs producing polyuria.

11. Diabetes insipidus

Definition

Diabetes insipidus is a disorder characterized by passage of large volumes of dilute urine due to deficiency of antidiuretic hormone or renal unresponsiveness to it.

Types

Central diabetes insipidus.

Nephrogenic diabetes insipidus.

Features

Polyuria.

Polydipsia.

Dilute urine.

Increased plasma osmolarity.

12. Polyphagia of diabetes mellitus

Insulin deficiency decreases glucose utilization by cells.

Cells undergo starvation despite hyperglycemia.

Hunger center in hypothalamus is stimulated.

Causes excessive appetite called polyphagia.

13. Polyuria and polydipsia in diabetes insipidus

Polyuria

Deficiency of antidiuretic hormone decreases water reabsorption in distal tubules and collecting ducts.

Large quantity of dilute urine is excreted.

Polydipsia

Excessive water loss increases plasma osmolarity.

Thirst center is stimulated causing excessive thirst.

14. Composition of pancreatic juice

Water

Major component.

Electrolytes

Sodium.

Potassium.

Calcium.

Chloride.

Bicarbonate.

Enzymes

Proteolytic enzymes

Trypsinogen.

Chymotrypsinogen.

Procarboxypeptidase.

Amylolytic enzyme

Pancreatic amylase.

Lipolytic enzymes

Pancreatic lipase.

Phospholipase.

Nucleases

Ribonuclease.

Deoxyribonuclease.

15. Functions of glucagon

Increases glycogenolysis.

Increases gluconeogenesis.

Raises blood glucose level.

Increases lipolysis.

Increases ketogenesis.

Stimulates protein catabolism.

16. Presence of insulin is needed for glucose entry into the skeletal muscle. Why?

Skeletal muscle contains insulin-dependent GLUT-4 transporters.

Insulin increases translocation of GLUT-4 to cell membrane.

This facilitates entry of glucose into skeletal muscle cells.

17. Physiological actions of glucagon on carbohydrate metabolism

Stimulates glycogenolysis in liver.

Stimulates gluconeogenesis.

Inhibits glycogenesis.

Increases blood glucose concentration.

REPRODUCTIVE SYSTEM

SEXUAL DEVELOPMENT IN EMBRYO

SHORT ANSWERS

1. Differentiate between turner's syndrome and Klinefelter's syndrome

Feature	Turner's syndrome	Klinefelter's syndrome
Chromosomal pattern	45, XO	47, XXY
Sex affected	Female	Male
Gonads	Streak ovaries	Small testes
Stature	Short stature	Tall stature
Secondary sexual characters	Poorly developed	Poorly developed male characters
Menstruation	Primary amenorrhea	Absent fertility
Fertility	Sterile	Sterile
Body features	Webbed neck, shield chest	Gynecomastia, eunuchoid body
Intelligence	Usually normal	Mild mental retardation may occur

MALE REPRODUCTIVE SYSTEM

SHORT ESSAYS

1. Explain the functions of testosterone during fetal period, puberty and in adults

Functions of testosterone

1. During fetal life

Development of male reproductive organs.

Differentiation of Wolffian ducts into:

Epididymis.

Vas deferens.

Seminal vesicles.

Development of external genitalia.

Descent of testes.

Masculinization of fetus.

2. During puberty

Effect on reproductive organs

Enlargement of testes, penis and accessory sex organs.

Initiation of spermatogenesis.

Development of secondary sexual characters

Growth of beard and moustache.

Male pattern body hair distribution.

Enlargement of larynx.

Deepening of voice.

Effect on body build

Increased muscle mass.

Broadening of shoulders.

Increased bone growth.

Effect on skin

Increased sebaceous gland activity.

Acne may occur.

Behavioral effects

Increased libido and aggressive behavior.

3. Functions in adults

Reproductive functions

Maintains spermatogenesis.

Maintains accessory sex organs.

Metabolic effects

Anabolic effect on protein metabolism.

Increases muscle mass.

Promotes bone growth and calcium retention.

Hematopoietic effect

Stimulates erythropoiesis.

Sexual function

Maintains libido and male sexual behavior.

2. Describe the physiological actions and control of testosterone secretion

Testosterone

Principal male sex hormone secreted by Leydig cells of testes.

Small amount is secreted by adrenal cortex.

Physiological actions of testosterone

1. Actions on foetus

Development of male genital organs.

Descent of testes into scrotum.

Development of male internal genitalia.

2. Actions at puberty

Enlargement of testes, penis and scrotum.

Development of secondary sexual characters.

Growth of beard, moustache and body hair.

Male pattern of pubic hair distribution.

Enlargement of larynx and deepening of voice.

Increased sebaceous gland secretion.

Thickening of skin.

3. Actions on reproductive system

Essential for spermatogenesis.

Maintains accessory sex organs.

Increases secretions of seminal vesicles and prostate.

Increases libido.

4. Actions on protein metabolism

Anabolic action.

Increases protein synthesis.

Increases muscle mass and strength.

5. Actions on bone

Stimulates bone growth.

Causes epiphyseal closure.

Increases bone thickness.

6. Actions on blood

Stimulates erythropoiesis.

Increases haemoglobin concentration.

7. Metabolic actions

Mild increase in basal metabolic rate.

Sodium and water retention.

Control of testosterone secretion

Hypothalamo–pituitary–testicular axis

Hypothalamus secretes Gonadotropin Releasing Hormone.

Gonadotropin Releasing Hormone stimulates anterior pituitary.

Anterior pituitary secretes Luteinizing Hormone.

Luteinizing Hormone stimulates Leydig cells.

Leydig cells secrete testosterone.

Feedback regulation

Testosterone inhibits Gonadotropin Releasing Hormone secretion from hypothalamus.

Testosterone inhibits Luteinizing Hormone secretion from pituitary.

Diagrammatic flow

Hypothalamus → Gonadotropin Releasing Hormone → Anterior pituitary → Luteinizing Hormone → Leydig cells → Testosterone

Negative feedback by testosterone on hypothalamus and pituitary.

3. Describe the functions of testosterone in foetal and adult life. What is cryptorchidism.

Functions of testosterone in foetal life

Development of male genital tract.

Differentiation of Wolffian ducts into male internal genitalia.

Development of penis and scrotum.

Descent of testes.

Masculinization of foetus.

Functions of testosterone in adult life

1. Reproductive functions

Essential for spermatogenesis.

Maintains accessory sex organs.

Maintains libido.

2. Secondary sexual characters

Beard and moustache growth.

Male pattern hair distribution.

Deep voice.

Thick skin.

3. Anabolic actions

Increased protein synthesis.

Increased muscle mass.

Increased body growth.

4. Skeletal actions

Bone growth and epiphyseal closure.

Increased bone density.

5. Haematopoietic action

Increased erythropoiesis.

Cryptorchidism

Cryptorchidism means failure of descent of testes into scrotum.

Causes

Hormonal deficiency.

Mechanical obstruction.

Effects

Testes remain in abdominal cavity.

Increased temperature damages seminiferous tubules.

Spermatogenesis decreases markedly.

Sterility may occur.

Treatment

Hormonal therapy.

Orchidopexy.

4. Describe about spermatogenesis and the hormonal factors regulating it

Definition

Spermatogenesis is the process by which sperms are formed from spermatogonia in seminiferous tubules.

Stages of spermatogenesis

1. Multiplication phase

Spermatogonia divide by mitosis.

Type A spermatogonia act as stem cells.

Type B spermatogonia form primary spermatocytes.

2. Growth phase

Primary spermatocytes enlarge.

3. Maturation phase

Primary spermatocyte undergoes first meiotic division to form secondary spermatocytes.

Secondary spermatocytes undergo second meiotic division to form spermatids.

4. Spermiogenesis

Spermatids transform into spermatozoa.

Formation of head, middle piece and tail occurs.

Hormonal regulation of spermatogenesis

1. Follicle Stimulating Hormone

Acts on Sertoli cells.

Essential for initiation of spermatogenesis.

2. Testosterone

Secreted by Leydig cells.

Essential for maturation of sperms.

3. Luteinizing Hormone

Stimulates Leydig cells to secrete testosterone.

4. Oestrogen

Formed by Sertoli cells.

Helps spermiogenesis.

5. Growth hormone

Required for metabolic functions of testes.

Functions of Sertoli cells in spermatogenesis

Nourish developing sperms.

Form blood testis barrier.

Secrete androgen binding protein.

Secrete inhibin.

SHORT ANSWERS

5. Functions of Sertoli cells

Support and nourish developing germ cells.

Form blood testis barrier.

Secrete androgen binding protein.

Secrete inhibin.

Phagocytose residual cytoplasm.

Help spermiogenesis.

Produce testicular fluid.

Convert testosterone to oestrogen.

6. Hormonal and ovarian changes in the Menstrual cycle

Hormonal changes

Follicular phase

Follicle Stimulating Hormone stimulates follicular growth.

Oestrogen secretion increases.

Ovulation

Midcycle surge of Luteinizing Hormone causes ovulation.

Luteal phase

Corpus luteum secretes progesterone.

Progesterone level increases.

Ovarian changes

Growth of primordial follicles.

Formation of Graafian follicle.

Ovulation around 14th day.

Formation of corpus luteum.

Degeneration into corpus albicans if pregnancy does not occur.

7. Define menarche and menopause.

Menarche

Menarche is the first menstrual bleeding occurring at puberty.

Usually occurs between 11–14 years.

Menopause

Menopause is the permanent cessation of menstruation due to loss of ovarian activity.

Usually occurs between 45–50 years.

8. Steps of spermatogenesis

Multiplication phase.

Growth phase.

Maturation phase.

Spermiogenesis.

9. Enumerate the functions of androgens during puberty.

Enlargement of testes and penis.

Development of accessory sex organs.

Growth of beard and moustache.

Male pattern pubic hair distribution.

Deepening of voice.

Increased muscle mass.

Increased bone growth.

Increased libido.

Increased sebaceous secretion.

10. What is testosterone. Describe two important actions of this hormone.

Testosterone

Testosterone is the principal male sex hormone secreted by Leydig cells of testes.

Two important actions

1. On reproductive system

Essential for spermatogenesis.

Maintains accessory sex organs.

2. On secondary sexual characters

Beard and moustache growth.

Deepening of voice.

11. Sterility in man working in hot surroundings Why?

Spermatogenesis requires temperature 2–3°C below body temperature.

Exposure to high temperature increases testicular temperature.

Increased temperature damages seminiferous epithelium.

Spermatogenesis decreases leading to temporary sterility.

12. Anemia in hypogonadism of male. Why?

Testosterone stimulates erythropoiesis.

In hypogonadism testosterone level decreases.

Red blood cell production decreases.

Hence anaemia occurs.

13. Capacitation of sperms

Capacitation is the functional maturation of sperms occurring in female genital tract.

Changes during capacitation

Removal of glycoprotein coat.

Increased motility.

Increased permeability to calcium ions.

Sperm acquires ability to fertilize ovum.

Site

Occurs mainly in uterus and fallopian tubes.

14. Spermatogenesis is markedly reduced in undescended testis . Why?

Undescended testis remains in abdominal cavity.

Abdominal temperature is higher than scrotal temperature.

High temperature damages seminiferous tubules.

Spermatogenesis decreases markedly.

15. Physiological basis of blood testis barrier

Blood testis barrier is formed by tight junctions between Sertoli cells.

Functions

Prevents entry of harmful substances.

Protects germ cells from immune reactions.

Maintains suitable environment for spermatogenesis.

16. Castration before puberty .Why?

Effects of castration before puberty

Failure of development of secondary sexual characters.

High pitched voice.

Sparse body hair.

Small genital organs.

Decreased muscle mass.

Eunuchoid body proportions.

Reason

Absence of testosterone secretion.

17. Undescended tests

Definition

Failure of descent of testes into scrotum.

Causes

Hormonal deficiency.

Mechanical factors.

Effects

Reduced spermatogenesis.

Sterility.

Treatment

Orchidopexy.

18. Testosterone

Testosterone is the principal male sex hormone.

Secreted by Leydig cells of testes.

Functions

Essential for spermatogenesis.

Development of male secondary sexual characters.

Anabolic effects.

Increases erythropoiesis.

19. Functions of testosterone

Development of male genital organs.

Essential for spermatogenesis.

Development of secondary sexual characters.

Increases protein synthesis.

Increases muscle mass.

Stimulates erythropoiesis.

Bone growth and epiphyseal closure.

Increases libido.

20. Steps of spermatogenesis and list the hormones involved

Steps

Multiplication phase.

Growth phase.

Maturation phase.

Spermiogenesis.

Hormones involved

Follicle Stimulating Hormone.

Luteinizing Hormone.

Testosterone.

Oestrogen.

Growth hormone.

21. Hormones regulating spermatogenesis

Follicle Stimulating Hormone.

Luteinizing Hormone.

Testosterone.

Oestrogen.

Growth hormone.

Inhibin.

Functions

Follicle Stimulating Hormone acts on Sertoli cells.

Luteinizing Hormone stimulates testosterone secretion.

Testosterone is essential for spermatogenesis.

Inhibin inhibits Follicle Stimulating Hormone secretion.

FEMALE REPRODUCTIVE SYSTEM

SHORT ESSAYS

1. Describe the actions of estrogen in various tissues

Actions on female reproductive organs

Growth of uterus, fallopian tubes and vagina.

Proliferation of endometrium.

Increases uterine motility.

Growth of breast ducts.

Actions on secondary sexual characters

Female body contour.

Female pattern fat distribution.

Soft and smooth skin.

Growth of pubic and axillary hair.

Actions on bone

Stimulates bone growth.

Causes epiphyseal closure.

Prevents osteoporosis.

Actions on metabolism

Mild anabolic effect.

Sodium and water retention.

Actions on cardiovascular system

Increases High Density Lipoprotein.

Decreases Low Density Lipoprotein.

Actions on central nervous system

Influences behaviour and libido.

2. Describe the changes that occur in the uterine endometrium during the menstrual cycle with the hormonal basis

Menstrual cycle

Average duration is 28 days.

Phases of endometrial cycle

1. Menstrual phase (1–5 days)

Shedding of superficial layer of endometrium.

Bleeding occurs.

Hormonal basis

Due to fall in oestrogen and progesterone.

2. Proliferative phase (6–14 days)

Endometrial regeneration occurs.

Endometrial glands become straight.

Increased vascularity.

Hormonal basis

Due to oestrogen secretion from developing follicles.

3. Secretory phase (15–28 days)

Endometrium becomes thick and oedematous.

Glands become tortuous and secrete glycogen.

Spiral arteries become coiled.

Hormonal basis

Due to progesterone secreted by corpus luteum.

If fertilization does not occur

Corpus luteum degenerates.

Oestrogen and progesterone decrease.

Menstruation occurs.

3. Describe the ovarian changes in menstrual cycle and the hormones regulating it

Ovarian cycle

1. Follicular phase

Growth of primordial follicles.

Formation of primary and secondary follicles.

Formation of Graafian follicle.

Hormonal regulation

Follicle Stimulating Hormone stimulates follicular growth.

Oestrogen secretion increases.

2. Ovulation

Rupture of Graafian follicle and release of ovum.

Occurs around 14th day.

Hormonal regulation

Midcycle surge of Luteinizing Hormone causes ovulation.

3. Luteal phase

Formation of corpus luteum.

Corpus luteum secretes progesterone.

Hormonal regulation

Luteinizing Hormone maintains corpus luteum.

If fertilization does not occur

Corpus luteum degenerates into corpus albicans.

Hormone levels fall.

Menstruation occurs.

4. Describe endometrial changes that occur during a normal menstrual cycle. Name the hormone responsible for each phase.

1. Menstrual phase

Shedding of superficial endometrium.

Bleeding occurs.

Hormonal basis

Fall in oestrogen and progesterone.

2. Proliferative phase

Regeneration of endometrium.

Glands become straight.

Increased stromal growth.

Hormone responsible

Oestrogen.

3. Secretory phase

Endometrium thick and vascular.

Glands become tortuous.

Increased glycogen secretion.

Hormone responsible

Progesterone.

5. Describe the hormonal regulation of menstrual cycle. Add a note on menopause

Hormonal regulation of menstrual cycle

Hypothalamus

Secretes Gonadotropin Releasing Hormone.

Pituitary hormones

Follicle Stimulating Hormone

Stimulates follicular growth.

Luteinizing Hormone

Causes ovulation.

Maintains corpus luteum.

Ovarian hormones

Oestrogen

Causes proliferative changes in endometrium.

Progesterone

Causes secretory changes in endometrium.

Feedback mechanism

Oestrogen and progesterone exert feedback on hypothalamus and pituitary.

Midcycle positive feedback of oestrogen produces Luteinizing Hormone surge.

Menopause

Definition

Permanent cessation of menstruation.

Age

Usually between 45–50 years.

Cause

Exhaustion of ovarian follicles.

Hormonal changes

Decrease in oestrogen and progesterone.

Increase in Follicle Stimulating Hormone and Luteinizing Hormone.

Symptoms

Hot flushes.

Irritability.

Osteoporosis

6. Describe any five functions of oestrogen

Growth of uterus and fallopian tubes.

Proliferation of endometrium.

Development of secondary sexual characters.

Growth of breast ducts.

Bone growth and epiphyseal closure.

Female pattern fat distribution.

Increases High Density Lipoprotein.

7. Describe hormonal and endometrial changes during menstrual cycle

Hormonal changes

Follicular phase

Follicle Stimulating Hormone stimulates follicular growth.

Oestrogen secretion increases.

Ovulation

Luteinizing Hormone surge occurs.

Luteal phase

Corpus luteum secretes progesterone.

Endometrial changes

Menstrual phase

Shedding of endometrium.

Proliferative phase

Regeneration and proliferation of endometrium.

Secretory phase

Thick, vascular and secretory endometrium.

8. Ovarian changes during a normal menstrual cycle

Follicular phase

Growth of follicles.

Formation of Graafian follicle.

Ovulation

Rupture of Graafian follicle.

Release of ovum.

Luteal phase

Formation of corpus luteum.

Secretion of progesterone.

If fertilization does not occur

Corpus luteum degenerates into corpus albicans.

9. Ovarian cycle

Definition

Cyclic changes occurring in ovary during menstrual cycle.

Phases

1. Follicular phase

Follicular growth and maturation.

2. Ovulation

Release of ovum.

3. Luteal phase

Formation and function of corpus luteum.

Hormonal control

Follicle Stimulating Hormone and Luteinizing Hormone regulate ovarian cycle.

10. Tests for ovulation

Basal body temperature rise.

Detection of Luteinizing Hormone surge.

Cervical mucus changes.

Endometrial biopsy.

Ultrasonography.

Mittelschmerz.

Increased serum progesterone.

SHORT ANSWERS

11. Physiological basis of menopause

Ovarian follicles become depleted.

Oestrogen and progesterone secretion decrease.

Negative feedback on pituitary decreases.

Follicle Stimulating Hormone and Luteinizing Hormone increase.

Menstruation ceases.

12. Draw and label : Hormonal and uterine changes in menstrual cycle

REFER DIAGRAM SECTION

13. Describe secondary sexual characteristics in females

Development of breasts.

Female pattern fat distribution.

Broadening of pelvis.

Growth of pubic and axillary hair.

Soft and smooth skin.

Higher pitched voice.

Rounded body contour.

14. Menstrual blood does not clot. Why?

Menstrual blood normally does not clot because:

Presence of fibrinolysin released from the endometrium dissolves fibrin and prevents clot formation.

Menstrual blood contains **less fibrinogen**.

Continuous shedding and flow of blood prevent stagnation and clotting.

15. Physiological basis of menopause

Menopause is the permanent cessation of menstruation due to loss of ovarian activity.

Physiological basis:

Depletion of ovarian follicles occurs with age.

Ovaries become less responsive to Follicle Stimulating Hormone and Luteinizing Hormone.

Estrogen and progesterone secretion decreases markedly.

Absence of ovulation and corpus luteum formation.

Due to loss of negative feedback, Follicle Stimulating Hormone and Luteinizing Hormone levels increase.

Effects:

Irregular menstruation followed by amenorrhea

Hot flushes

Mood changes

Vaginal dryness

Osteoporosis

16. Draw and label : Hormonal changes during a normal menstrual cycle

REFER DIAGRAM SECTION

17. Functions of progesterone

Functions of progesterone

Actions on uterus

Converts proliferative endometrium into secretory endometrium.

Prepares uterus for implantation.

Decreases uterine contractions during pregnancy.

Actions on fallopian tube

Increases nutritive secretion for ovum.

Actions on breast

Promotes growth of lobules and alveoli.

Actions on cervix

Makes cervical mucus thick and viscid.

Metabolic actions

Slight rise in body temperature.

Promotes fat deposition.

During pregnancy

Maintains pregnancy.

18. Corpus luteum of menstruation and pregnancy

Corpus luteum of menstruation

Formed after ovulation.

Secretes progesterone and small amount of estrogen.

If fertilization does not occur, it degenerates after about 14 days.

It becomes corpus albicans.

Corpus luteum of pregnancy

If fertilization occurs, Human Chorionic Gonadotropin maintains corpus luteum.

Continues secretion of progesterone and estrogen.

Essential for maintenance of pregnancy during early months.

Persists until placenta becomes functional.

19. Ovarian cycle

Ovarian cycle consists of cyclic changes occurring in ovary every month.

Phases

1. Follicular phase

Primordial follicles develop into Graafian follicle under Follicle Stimulating Hormone.

Estrogen secretion increases.

2. Ovulation

Rupture of mature Graafian follicle and release of ovum.

Triggered by Luteinizing Hormone surge.

3. Luteal phase

Ruptured follicle becomes corpus luteum.

Corpus luteum secretes progesterone.

If fertilization does not occur, degeneration occurs.

20. Functions of oestrogen

Functions of estrogen

On female reproductive organs

Growth of uterus, fallopian tubes and vagina.

Proliferation of endometrium.

Increases uterine motility.

Secondary sexual characters

Development of breasts.

Female body configuration.

Female pattern of hair distribution.

On bones

Promotes bone growth and epiphyseal closure.

Metabolic actions

Mild anabolic effect.

Fat deposition in hips and thighs.

On cardiovascular system

Increases High Density Lipoprotein and decreases Low Density Lipoprotein.

FERTILIZATION AND PREGNANCY

LONG ESSAYS

1. A married female aged 25 years has history of amenorrhea for 3 months, she has morning sickness.

• What is your diagnosis?
• Describe one test to confirm your diagnosis.
• Describe the relevant changes that occur to this female.
• Add a note on feto-placental unit.

Diagnosis : Pregnancy

Definition

Pregnancy is the condition in which developing embryo or fetus is present in the uterus.

Test to confirm diagnosis

Immunological pregnancy test

Principle

Human Chorionic Gonadotropin hormone is detected in urine or serum.

Procedure

Early morning urine sample is collected.

Urine is tested with Human Chorionic Gonadotropin antibodies.

Agglutination inhibition or strip method is used.

Result

Positive test indicates pregnancy.

Basis

Human Chorionic Gonadotropin is secreted by syncytiotrophoblast after implantation.

Relevant changes occurring during pregnancy

Changes in reproductive system

Enlargement of uterus

Increased vascularity

Breast enlargement

Pigmentation of areola

Hormonal changes

Increased estrogen and progesterone

Increased Human Chorionic Gonadotropin

Increased prolactin

Cardiovascular changes

Increased cardiac output

Increased blood volume

Respiratory changes

Increased ventilation

Gastrointestinal changes

Morning sickness

Constipation

Renal changes

Increased glomerular filtration rate

Frequency of micturition

Metabolic changes

Weight gain

Increased Basal Metabolic Rate

Feto-placental unit

Definition

Fetus and placenta function together as an integrated endocrine unit called feto-placental unit.

Components

Fetal adrenal cortex

Fetal liver

Placenta

Functions

Synthesis of estrogen especially estriol

Maintenance of pregnancy

Exchange of gases and nutrients

Hormonal support for fetal growth

Significance

Essential for normal fetal development.

Placental estrogen production depends on fetal precursors.

SHORT ESSAYS

2. Functions of placenta

Placenta is a temporary fetomaternal organ connecting fetus and mother.

Functions of placenta

Respiratory function

Exchange of oxygen and carbon dioxide.

Nutritive function

Transfer of glucose, amino acids, fatty acids, vitamins and minerals.

Excretory function

Removal of fetal waste products.

Storage function

Stores glycogen, iron and vitamins.

Protective function

Placental barrier prevents entry of some harmful substances.

Transfer of maternal antibodies provides passive immunity.

Endocrine function

Secretes:

Human Chorionic Gonadotropin

Human Placental Lactogen

Estrogen

Progesterone

Relaxin

SHORT ANSWERS

3. Draw and label the feto-placental unit. Describe its significance.

REFER DIAGRAM SECTION

Significance

Placenta and fetus act as one endocrine unit.

Important for estrogen synthesis.

Maintains pregnancy.

Supports fetal growth and development.

4. Describe parturition

Parturition is the process of expulsion of fetus from uterus at term.

Mechanism

Increased estrogen-progesterone ratio

Increased uterine excitability

Oxytocin release

Prostaglandin formation

Stretch reflex from cervix

Stages

First stage

Dilatation of cervix

Second stage

Expulsion of fetus

Third stage

Expulsion of placenta

5. Functions of hCG

Functions of Human Chorionic Gonadotropin

Maintains corpus luteum during early pregnancy.

Stimulates secretion of progesterone and estrogen.

Prevents menstruation during pregnancy.

Stimulates fetal Leydig cells for testosterone secretion.

Basis of pregnancy tests.

6. Immunological test of pregnancy

Principle

Detection of Human Chorionic Gonadotropin in urine or serum.

Types

Latex agglutination test

Strip test

Significance

Early diagnosis of pregnancy.

7. Physiological basis of pregnancy tests

Syncytiotrophoblast secretes Human Chorionic Gonadotropin after implantation.

Human Chorionic Gonadotropin appears in maternal blood and urine.

Pregnancy tests detect this hormone.

Positive test confirms pregnancy.

8. Functions of placenta

Functions

Respiratory

Nutritive

Excretory

Endocrine

Protective

Storage function

9. Tests of ovulation

Tests of ovulation

Basal body temperature rise

Cervical mucus test

Vaginal cytology

Endometrial biopsy

Ultrasonography

Detection of Luteinizing Hormone surge

Progesterone estimation

LACTATION

SHORT ANSWERS

1. Milk ejection reflex

Milk ejection reflex is the reflex expulsion of milk from mammary glands.

Mechanism

Suckling stimulates nipple receptors.

Impulses pass to hypothalamus.

Posterior pituitary releases oxytocin.

Oxytocin causes contraction of myoepithelial cells.

Milk is ejected from alveoli into ducts.

CONTRACEPTION AND INFERTILITY

SHORT ESSAYS

1. Describe temporary and permanent methods of contraception in females.

Temporary methods

Natural methods

Safe period

Coitus interruptus

Lactational amenorrhea

Barrier methods

Condom

Diaphragm

Cervical cap

Hormonal methods

Oral contraceptive pills

Injectable contraceptives

Intrauterine contraceptive devices

Copper-T

Hormone releasing intrauterine contraceptive devices

Permanent methods

Female sterilization

Tubectomy

Tubal ligation

Male sterilization

Vasectomy

2. List the contraceptive methods in females. Describe the physiological basis for any two of them

Contraceptive methods in females

Natural methods

Barrier methods

Hormonal methods

Intrauterine contraceptive devices

Sterilization

Physiological basis

Oral contraceptive pills

Estrogen and progesterone inhibit Follicle Stimulating Hormone and Luteinizing Hormone secretion.

Ovulation is prevented.

Cervical mucus becomes thick.

Endometrium becomes unsuitable for implantation.

Intrauterine contraceptive devices

Causes local inflammatory reaction.

Interferes with sperm motility and fertilization.

Copper suppresses sperm activity.

Prevents implantation.

3. Female contraception

Female contraception refers to prevention of pregnancy by methods used in women.

Methods

Natural methods

Barrier methods

Hormonal methods

Intrauterine contraceptive devices

Surgical sterilization

SHORT ANSWERS

4. Physiological basis of intra uterine devices (IUCD)

Produces local inflammatory reaction in uterus.

Increases phagocytosis of sperms.

Copper decreases sperm motility and viability.

Prevents fertilization and implantation.

5. Physiological basis of Oral Contraceptives

Inhibits Follicle Stimulating Hormone and Luteinizing Hormone secretion.

Prevents ovulation.

Thickens cervical mucus.

Alters endometrium preventing implantation.

6. Methods of contraception in the woman

Natural methods

Barrier methods

Hormonal methods

Intrauterine contraceptive devices

Surgical methods

7. Safe period of family planning in females.

Safe period is the period during menstrual cycle when chances of conception are minimal.

Basis

Ovulation occurs around 14th day.

Sperms survive about 48 hours.

Ovum survives about 24 hours.

Safe period

First 7 days and last 7 days of menstrual cycle in a 28-day cycle.

8. Safe period

Safe period is the infertile period of menstrual cycle during which intercourse usually does not result in pregnancy.

Time

From day 1 to day 7

From day 21 to day 28 in a normal 28-day cycle.

9. Physiological basis of Copper-T

Definition

Copper-T is a copper containing intrauterine contraceptive device used for temporary contraception.

Physiological basis / Mechanism of action

1. Foreign body reaction

Copper-T acts as a foreign body in uterus.

Causes sterile inflammatory reaction in endometrium.

Increases leukocyte infiltration and phagocytosis of sperms.

2. Action of copper ions

Copper ions suppress sperm motility.

Decreases sperm viability and fertilizing capacity.

Interferes with sperm transport.

3. Effect on endometrium

Endometrium becomes unsuitable for implantation.

4. Effect on cervical mucus

Cervical mucus becomes hostile to sperms.

Advantages

Long acting

Reversible

Highly effective

Does not interfere with lactation

Side effects

Menorrhagia

Dysmenorrhea

Pelvic inflammatory disease

10. Contraception by oral contraceptive pills

Definition

Oral contraceptive pills are hormonal preparations used for prevention of pregnancy.

Types

Combined oral contraceptive pills

Estrogen + progesterone

Progesterone only pills

Mechanism of action

1. Inhibition of ovulation

Estrogen and progesterone inhibit secretion of follicle stimulating hormone and luteinizing hormone.

Ovulation is prevented.

2. Effect on cervical mucus

Cervical mucus becomes thick and viscid.

Prevents sperm penetration.

3. Effect on endometrium

Endometrium becomes unsuitable for implantation.

4. Effect on fallopian tubes

Alters tubal motility and ovum transport.

Advantages

Highly effective

Reversible

Reduces dysmenorrhea

Reduces risk of ovarian and endometrial carcinoma

Side effects

Nausea

Weight gain

Headache

Hypertension

Thromboembolism

Contraindications

Liver disease

Pregnancy

Hypertension

Thromboembolic disorders

11. Intra-uterine contraceptive devices preventing pregnancy

Definition

Intrauterine contraceptive devices are devices inserted into uterus to prevent pregnancy.

Types

1. Non-medicated devices

Lippes loop

2. Copper containing devices

Copper-T

Multiload

3. Hormone releasing devices

Levonorgestrel intrauterine system

Mechanism of action

1. Foreign body reaction

Produces sterile inflammatory response in uterus.

Increases phagocytosis of sperms.

2. Prevention of fertilization

Reduces sperm motility and viability.

3. Prevention of implantation

Endometrium becomes unsuitable for implantation.

4. Hormonal action

Hormone releasing devices thicken cervical mucus.

Advantages

Long acting

Reversible

Highly effective

Side effects

Bleeding

Pain

Infection

Uterine perforation

12. Lactation amenorrhea

Definition

Lactation amenorrhea is temporary absence of menstruation during lactation.

Physiological basis

1. Suckling reflex

Suckling stimulates hypothalamus.

Increases prolactin secretion from anterior pituitary.

2. Inhibition of gonadotropin releasing hormone

Increased prolactin inhibits gonadotropin releasing hormone secretion.

3. Decreased follicle stimulating hormone and luteinizing hormone

Ovulation is suppressed.

Menstruation does not occur.

Contraceptive effect

Prevents ovulation during exclusive breast feeding.

Effective mainly during first 6 months after delivery.

Conditions for effectiveness

Exclusive breast feeding

Amenorrhea present

Infant younger than 6 months

Advantages

Natural method

No cost

No drug side effects

Limitations

Less reliable after 6 months

Ineffective if supplementary feeding is started

NERVOUS SYSTEM

SHORT ESSAYS

1. Mechanism of synaptic transmission

Definition

Synaptic transmission is the process by which nerve impulses are transmitted from one neuron to another across a synapse.

Steps in synaptic transmission

1. Arrival of action potential

Action potential reaches the presynaptic terminal.

Presynaptic membrane gets depolarized.

2. Opening of calcium channels

Voltage-gated calcium channels open.

Calcium ions enter the presynaptic knob.

3. Release of neurotransmitter

Increased intracellular calcium causes synaptic vesicles to fuse with presynaptic membrane.

Neurotransmitter is released into synaptic cleft by exocytosis.

4. Diffusion across synaptic cleft

Neurotransmitter diffuses across the synaptic cleft.

5. Action on postsynaptic membrane

Neurotransmitter binds with specific receptors on postsynaptic membrane.

Ion channels open.

6. Postsynaptic potentials

Two types:

Excitatory postsynaptic potential (EPSP)

Sodium entry causes depolarization.

Increases excitability.

Inhibitory postsynaptic potential (IPSP)

Potassium exit or chloride entry causes hyperpolarization.

Decreases excitability.

7. Generation of action potential

If threshold is reached, action potential develops in postsynaptic neuron.

8. Removal of neurotransmitter

Neurotransmitter is removed by:

Enzymatic destruction

Reuptake into nerve terminal

Diffusion away from synapse

Properties of synaptic transmission

One way conduction

Synaptic delay

Fatigue

Summation

Facilitation

Inhibition

Synaptic delay

Time taken for transmission across synapse.

Approximately 0.5 milliseconds.

PHYSIOLOGY OF NERVOUS SYSTEM

SHORT ESSAYS

1. List the different types of inhibition. Explain Renshaw cell inhibition

Types of inhibition

A. Postsynaptic inhibition

Direct inhibition

Recurrent inhibition (Renshaw cell inhibition)

Reciprocal inhibition

Lateral inhibition

B. Presynaptic inhibition

Occurs at presynaptic terminal.

Renshaw cell inhibition

Definition

Renshaw cell inhibition is a recurrent inhibitory mechanism in spinal cord in which collateral branches from alpha motor neurons stimulate inhibitory interneurons called Renshaw cells.

Mechanism

Axon collateral from alpha motor neuron stimulates Renshaw cell.

Renshaw cell releases inhibitory neurotransmitter glycine.

Glycine inhibits the same motor neuron and neighboring motor neurons.

This produces recurrent inhibition.

Neurotransmitter

Glycine

Functions

Prevents excessive discharge of motor neurons.

Stabilizes motor activity.

Improves precision of movements.

Prevents spread of excitation.

Clinical importance

Strychnine blocks glycine action.

Causes severe muscle spasms and convulsions.

SHORT ANSWERS

2. Draw and label nerve action potential in relation to ionic fluxes

REFER DIAGRAM SECTION

3. Presynaptic inhibition

Definition

Presynaptic inhibition is inhibition occurring at presynaptic terminal resulting in decreased neurotransmitter release.

Mechanism

Inhibitory neuron forms axo-axonic synapse.

Gamma amino butyric acid (GABA) is released.

Chloride influx occurs into presynaptic terminal.

Reduced calcium entry into terminal.

Decreased neurotransmitter release.

Features

Reduces synaptic transmission.

Produces selective inhibition.

Importance

Controls sensory input.

Prevents excessive reflex activity.

4. Reciprocal innervations

Definition

Reciprocal innervation is simultaneous excitation of agonist muscles and inhibition of antagonist muscles.

Mechanism

Stretch receptor stimulates alpha motor neuron of agonist muscle.

Interneuron inhibits antagonist muscle motor neuron.

Example

During flexion of elbow:

Biceps contracts.

Triceps relaxes.

Significance

Produces smooth coordinated movements.

Essential for reflex actions.

5. Renshaw cell inhibition

Definition

Renshaw cell inhibition is recurrent inhibition mediated by inhibitory interneurons called Renshaw cells.

Mechanism

Axon collateral from alpha motor neuron excites Renshaw cell.

Renshaw cell releases glycine.

Glycine inhibits motor neurons.

Functions

Limits excessive motor discharge.

Coordinates muscle activity.

Clinical importance

Strychnine blocks glycine causing convulsions.

6. Draw and label: Neuromuscular junction in skeletal muscle

REFER DIAGRAM SECTION

REFLEX ACTION

SHORT ANSWERS

1. Draw the diagram of stretch reflex arc

REFER DIAGRAM SECTION

2. Draw the diagram of Inverse stretch reflex pathway

REFER DIAGRAM SECTION

3. Myotatic reflex

Definition

Myotatic reflex is contraction of a muscle in response to sudden stretch.

Receptor

Muscle spindle

Pathway

Ia afferent fiber → spinal cord → alpha motor neuron → muscle contraction

Example

Knee jerk reflex

Functions

Maintains posture

Maintains muscle tone

Prevents overstretching

4. Pyramidal tract lesions produces exaggerated deep tendon reflexes. Why ?

Reason

Pyramidal tract normally exerts inhibitory influence over spinal reflexes.

In pyramidal tract lesion

Loss of descending inhibitory control occurs.

Stretch reflex becomes hyperactive.

Deep tendon reflexes become exaggerated.

Associated features

Hyperreflexia

Spasticity

Babinski sign positive

5. Reciprocal innervation

Definition

Simultaneous contraction of agonist muscle with relaxation of antagonist muscle.

Mechanism

Excitatory impulses activate agonist.

Inhibitory interneurons suppress antagonist.

Importance

Smooth coordinated movements

Efficient reflex action

6. Draw and label: Muscle spindle

REFER DIAGRAM SECTION

7. Draw and label: Stretch reflex and inverse stretch reflex

REFER DIAGRAM SECTION

SENSORY DIVISIONS OF NERVOUS SYSTEM AND SENSORY PATHWAYS

LONG ESSAYS

1. Trace the pain pathway from (R) lower limb. Describe the analgesia system of the body

Pain pathway from right lower limb

Receptors

Free nerve endings present in skin and tissues.

First order neuron

Pain impulses carried by A delta and C fibers.

Cell body present in dorsal root ganglion.

Fibers enter spinal cord through dorsal root.

Second order neuron

Synapse occurs in substantia gelatinosa of posterior horn.

Fibers cross to opposite side through anterior white commissure.

Ascend in lateral spinothalamic tract.

Course in brain stem

Fibers ascend through:

Medulla

Pons

Midbrain

Third order neuron

Synapse in ventral posterolateral nucleus of thalamus.

Fibers project to sensory cortex.

Cortical area

Postcentral gyrus of parietal lobe.

Important feature

Pain from right lower limb ascends mainly in left lateral spinothalamic tract.

Analgesia system of the body

Definition

Analgesia system is an endogenous pain suppressing system present in nervous system.

Components

1. Periaqueductal gray matter

Present around cerebral aqueduct in midbrain.

2. Nucleus raphe magnus

Present in medulla.

3. Pain inhibitory complex in dorsal horn

Present in substantia gelatinosa.

Neurotransmitters

Enkephalins

Endorphins

Serotonin

Mechanism

Periaqueductal gray stimulates nucleus raphe magnus.

Descending fibers reach dorsal horn.

Enkephalins inhibit release of substance P.

Pain transmission is suppressed.

Functions

Reduces pain perception.

Important during stress and injury.

Clinical importance

Basis for action of opioid analgesics.

2. A 15 year old boy presents with sudden onset of severe pain around the umbilicus, radiating to the right iliac fossa. He also has fever and nausea.

a) Explain any two theories that explain the basis of this type of pain.

b) Explain the pathways of pain with a neat labelled diagram.

c) Explain the supraspinal analgesia mechanism that modulates pain perception

a) Explain any two theories that explain the basis of this type of pain

1. Specificity theory

Pain sensation is carried by specific pain receptors and specific pathways.

Pain fibers terminate in specific cortical area.

According to this theory, pain is a distinct sensation.

2. Gate control theory

Proposed by Melzack and Wall.

Substantia gelatinosa acts as a gate.

Large fibers close the gate and reduce pain.

Small fibers open the gate and increase pain.

Basis for pain relief by rubbing affected area.

b) Explain the pathways of pain with a neat labelled diagram

Lateral spinothalamic tract

Carries:

Fast pain

Sharp localized pain

Pathway

Receptor – Free nerve endings

First order neuron – Dorsal root ganglion

Synapse in posterior horn

Fibers cross opposite side

Ascend in lateral spinothalamic tract

Synapse in thalamus

Reach sensory cortex

Spinoreticular pathway

Carries:

Slow pain

Dull aching pain

Functions

Arousal

Emotional aspects of pain

Diagram

REFER DIAGRAM SECTION

c) Explain the supraspinal analgesia mechanism that modulates pain perception

Components

Periaqueductal gray matter

Nucleus raphe magnus

Dorsal horn inhibitory neurons

Neurotransmitters

Endorphins

Enkephalins

Serotonin

Mechanism

Periaqueductal gray activates raphe nucleus.

Descending serotonergic fibers reach spinal cord.

Enkephalin interneurons inhibit substance P release.

Pain transmission is blocked.

Functions

Suppresses pain sensation.

Important during stress and emotional states.

Clinical importance

Opioid analgesics act through this system.

3. An elderly man was admitted to the hospital with complaints of intense central chest pain with radiation to left arm. Answer the following questions based on your knowledge in physiology

What is the cause of the pain in the left arm and explain its mechanism?

Describe the pain pathway in detail.

Mention gate control theory of pain sensation.

DIAGNOSIS : REFERRED PAIN

Cause of pain in the left arm

Pain in the left arm during myocardial ischemia or myocardial infarction is due to referred pain.

Mechanism of referred pain

Pain fibers from the heart enter spinal cord through sympathetic nerves.

They enter spinal segments T1–T5.

Somatic sensory fibers from the left upper limb also enter the same spinal segments.

Visceral and somatic afferent fibers converge on the same second-order neurons.

Brain misinterprets visceral pain as arising from the somatic area supplied by the same spinal segments.

Hence pain is felt in the left arm, shoulder and chest.

Pain pathway

First-order neuron

Receptors: Free nerve endings.

Cell body: Dorsal root ganglion.

Fibers enter posterior horn of spinal cord.

Second-order neuron

Present in substantia gelatinosa and nucleus proprius.

Fibers cross to opposite side through anterior white commissure.

Ascend as lateral spinothalamic tract.

Third-order neuron

Synapse in ventral posterolateral nucleus of thalamus.

Fibers pass through internal capsule.

Reach sensory cortex (postcentral gyrus).

Gate control theory of pain sensation

Proposed by Melzack and Wall.

Theory

Substantia gelatinosa in dorsal horn acts as a gate.

Small pain fibers (A delta and C fibers) open the gate and transmit pain.

Large touch fibers (A beta fibers) close the gate by activating inhibitory interneurons.

Hence rubbing the affected part reduces pain.

Significance

Explains pain relief by rubbing and massage.

Basis of transcutaneous electrical nerve stimulation.

SHORT ESSAYS

4. Draw and label the pathway for fast pain from the right lower limb. Describe the supra spinal modulation of pain

REFER DIAGRAM SECTION

Supra spinal modulation of pain

Pain is inhibited by descending pathways from brain.

Sites involved

Periaqueductal gray matter

Nucleus raphe magnus

Reticular formation

Substantia gelatinosa

Mechanism

Descending fibers release serotonin and enkephalins.

These inhibit release of substance P.

Pain transmission in dorsal horn is suppressed.

Neurotransmitters

Enkephalin

Endorphin

Serotonin

Dynorphin

Functions

Produces analgesia.

Important in stress-induced analgesia.

5. With the aid of a diagram describe the pain pathway from right lower limb.

Pain pathway from right lower limb

Receptors

Free nerve endings.

First-order neuron

Peripheral process receives pain sensation.

Cell body in dorsal root ganglion.

Central process enters spinal cord.

Second-order neuron

Synapse in substantia gelatinosa.

Fibers cross to opposite side.

Ascend as lateral spinothalamic tract.

Third-order neuron

Synapse in ventral posterolateral nucleus of thalamus.

Fibers pass through internal capsule.

Terminate in sensory cortex.

Important points

Fast pain fibers: A delta fibers.

Slow pain fibers: C fibers.

Pain pathway is crossed.

Diagram

REFER DIAGRAM SECTION

6. Explain theories of pain and give two examples

Theories of pain

1. Specificity theory

Specific pain receptors and pathways exist.

Pain sensation is transmitted through dedicated pathways.

2. Pattern theory

Pain depends on pattern and intensity of stimulation.

Strong stimulation of receptors produces pain.

3. Gate control theory

Proposed by Melzack and Wall.

Substantia gelatinosa acts as a gate.

Large fibers inhibit pain transmission.

Examples

Rubbing painful area reduces pain.

Transcutaneous electrical nerve stimulation relieves pain.

7. Gate control theory of pain

Definition

Theory proposed by Melzack and Wall explaining modulation of pain at spinal cord level.

Mechanism

Substantia gelatinosa acts as gate.

Small fibers (A delta and C fibers) open gate.

Large fibers (A beta fibers) close gate.

Inhibitory interneurons suppress pain transmission.

Significance

Explains pain relief by rubbing.

Basis of acupuncture and transcutaneous electrical nerve stimulation.

SHORT ANSWERS

8. Physiological basis for phantom limb

Pain or sensation felt in amputated limb is called phantom limb.

Due to persistence of cortical representation of amputated part.

Irritation of severed nerve endings also contributes.

Brain continues to perceive sensations from missing limb.

9. Draw and label the Dorsal column pathway from right lower limb.

REFER DIAGRAM SECTION

10. Pain of Myocardial Infarction (MI) can be felt on the left upper arm. Why

It is due to referred pain.

Visceral pain fibers from heart enter spinal segments T1–T5.

Somatic sensory fibers from left upper limb also enter same segments.

Convergence occurs on same neurons.

Brain interprets pain as arising from left upper arm.

11. Two – point discrimination is better on the finger tips than on the back. Why

Fingertips have more sensory receptors.

Receptor fields are smaller.

Greater cortical representation in sensory cortex.

Lateral inhibition is more effective.

12. Draw and label: Pain pathway.

REFER DIAGRAM SECTION

13. One example for lateral inhibition.

Two-point discrimination on fingertips.

14. Explain the physiological basis of referred pain.

Visceral and somatic afferent fibers enter same spinal segment.

Both synapse on common second-order neurons.

Brain mistakes visceral pain for somatic pain.

Example: Cardiac pain referred to left arm.

15. Endogenous peptide produces analgesia

Endogenous analgesic peptides

Endorphins

Enkephalins

Dynorphins

Action

Inhibit release of substance P.

Suppress pain transmission in dorsal horn.

16. Draw and label: Lateral spinothalamic tract

REFER DIAGRAM SECTION

17. Physiological basis of referred pain

Referred pain occurs due to convergence of visceral and somatic afferent fibers.

Both enter same spinal segments.

Brain localizes pain to somatic structure.

18. Law of projection

Sensation is projected to the peripheral receptor even when pathway is stimulated at any point.

Example: Ulnar nerve stimulation causes sensation in little finger.

19. The pain of an injury is felt more after the game by a player. Why?

During stress and excitement, endogenous analgesic system is activated.

Endorphins and enkephalins suppress pain transmission.

After game, inhibition decreases and pain becomes prominent.

20. Referred pain

Definition

Pain felt at a site away from the site of origin.

Mechanism

Due to convergence of visceral and somatic afferents.

Examples

Cardiac pain felt in left arm.

Diaphragmatic pain felt at shoulder tip.

21. Supra spinal modulation of pain

Definition

Descending inhibitory control of pain from higher centers.

Centers involved

Periaqueductal gray matter

Nucleus raphe magnus

Reticular formation

Neurotransmitters

Serotonin

Enkephalin

Endorphin

Action

Inhibit pain transmission in dorsal horn.

22. Draw and label: Antero lateral system

REFER DIAGRAM SECTION

23. Draw and label: Pathway of crude touch

REFER DIAGRAM SECTION

24. Draw and label: Pain pathway from origin to termination

REFER DIAGRAM SECTION

25. Pain disappears by rubbing the affected area. Why?

Rubbing stimulates large A beta fibers.

These activate inhibitory interneurons in substantia gelatinosa.

Gate for pain transmission closes.

Pain sensation decreases.

26. Diaphragmatic pain is felt at the tip of the shoulder Why?

Diaphragm supplied by phrenic nerve (C3, C4, C5).

Shoulder skin supplied by cervical nerves of same segments.

Convergence of afferents causes referred pain at shoulder tip.

27. Patients with sensory ataxia lose balance on closing their eyes. Why?

Sensory ataxia occurs due to loss of proprioceptive sensations.

Patient depends on vision to maintain posture.

On closing eyes, visual compensation is lost.

Balance becomes impaired.

28. Draw and label: Posterior column tract

REFER DIAGRAM SECTION

THALAMUS

SHORT ESSAYS

1. Describe connections and functions of thalamus

Connections of thalamus

Afferent connections

Spinothalamic tract

Medial lemniscus

Trigeminothalamic tract

Cerebellothalamic fibers

Basal ganglia fibers

Optic tract to lateral geniculate body

Auditory pathway to medial geniculate body

Efferent connections

Sensory cortex

Motor cortex

Association cortex

Limbic system

Functions of thalamus

Relay station for sensory impulses except smell.

Crude perception of pain, touch and temperature.

Regulation of motor activity.

Role in consciousness and alertness.

Emotional behavior.

Memory and integration.

SHORT ANSWERS

2. Describe the physiological basis for thalamic phantom limb pain

Due to lesion or irritation of thalamic sensory nuclei.

Thalamus generates spontaneous pain sensations.

Pain is severe, persistent and poorly localized.

3. Functions of thalamus

Sensory relay center.

Crude perception of sensations.

Motor integration.

Regulation of consciousness.

Emotional functions.

Role in memory.

MOTOR DIVISIONS OF NERVOUS SYSTEM

LONG ESSAYS

1. A 65-year old male, known to have long-standing diabetes and hypertension, presents to the hospital with the sudden onset of paralysis affecting the right side of his body. There was no history of trauma. On examination, he is alert but unable to move his right arm and leg voluntarily.

a) Describe the origin, course, and termination of the pyramidal tract with a neat, labelled diagram

Physiological basis for hypertonia and Babinski sign in this patient

Answer

Pyramidal tract (Corticospinal tract)

Origin

Fibres arise from:

Primary motor cortex (Area 4) – mainly giant Betz cells

Premotor cortex (Area 6)

Somatosensory cortex (Areas 3, 1, 2)

Course

Corona radiata

Posterior limb of internal capsule

Middle 3/5th of crus cerebri in midbrain

Basis pontis of pons

Medullary pyramids

At lower medulla:

About 80% fibres cross to opposite side → lateral corticospinal tract

Remaining 20% descend uncrossed as anterior corticospinal tract and cross near termination.

Termination

Fibres terminate mainly on interneurons and anterior horn cells of spinal cord.

Lateral corticospinal tract → distal limb muscles.

Anterior corticospinal tract → axial and proximal muscles.

Functions of pyramidal tract

Voluntary skilled movements

Fine movements of distal limbs

Regulation of muscle tone

Inhibitory control over spinal reflexes

Flow chart

Motor cortex
↓
Corona radiata
↓
Internal capsule
↓
Crus cerebri
↓
Pons
↓
Medullary pyramids
↓
Pyramidal decussation
↓
Lateral corticospinal tract
↓
Anterior horn cells
↓
Skeletal muscles

Physiological basis for hypertonia

Upper motor neuron lesion removes inhibitory influence of cerebral cortex on spinal reflexes.

Gamma motor neuron activity becomes excessive.

Muscle spindle sensitivity increases.

Stretch reflex becomes exaggerated.

Hence muscle tone increases → spasticity/hypertonia.

Physiological basis for Babinski sign

In upper motor neuron lesion, corticospinal inhibition over spinal reflexes is lost.

Stroking sole causes dorsiflexion of great toe with fanning of other toes.

It indicates corticospinal tract damage.

2. A patient complains of difficulty in walking, talking and not able to perform rapid alternate movements. Answer the following questions based on your knowledge in physiology:

• Which part of brain is affected
• Enumerate the other manifestations of this lesion
• Describe the functional connections and functions of the part affected

Answer

Part of brain affected

The lesion is in the **cerebellum**.

Other manifestations of cerebellar lesion

Hypotonia

Ataxia

Intention tremor

Dysmetria (past pointing)

Dysdiadochokinesia

Nystagmus

Scanning speech

Rebound phenomenon

Broad-based gait

Functional connections of cerebellum

Afferent connections

Inputs received from:

Cerebral cortex through pontocerebellar fibres

Spinal cord through spinocerebellar tracts

Vestibular apparatus

Inferior olive

Reticular formation

Efferent connections

Outputs through cerebellar nuclei to:

Thalamus → motor cortex

Vestibular nuclei

Reticular formation

Red nucleus

Functions of cerebellum

Coordination of voluntary movements

Maintenance of posture and equilibrium

Regulation of muscle tone

Comparator function for smooth execution of movements

Maintenance of balance

Coordination of skilled movements

Motor learning

3. Describe the origin, course and termination and functions of cortico-spinal tract.

Add a note on hemiplegia.

List the differences between upper motor neuron and lower motor neuron lesions

Answer

Corticospinal tract

Origin

Primary motor cortex (Area 4)

Premotor cortex (Area 6)

Somatosensory cortex

Course

Corona radiata

Internal capsule

Crus cerebri

Pons

Medullary pyramids

Decussation

80% fibres cross → lateral corticospinal tract

20% fibres form anterior corticospinal tract

Termination

Fibres terminate on interneurons and anterior horn cells.

Functions

Voluntary skilled movement

Fine finger movements

Regulation of tone

Inhibition of spinal reflexes

Note on hemiplegia

Definition

Paralysis of one side of body due to corticospinal tract lesion.

Causes

Stroke

Hemorrhage

Tumour

Trauma

Features

Loss of voluntary movements

Hypertonia

Hyperreflexia

Clonus

Babinski sign positive

Loss of superficial reflexes

Differences between UMN and LMN lesions

Feature	UMN lesion	LMN lesion
Paralysis	Spastic	Flaccid
Muscle tone	Increased	Decreased
Deep reflexes	Exaggerated	Absent
Superficial reflexes	Lost	Lost
Babinski sign	Present	Absent
Muscle wasting	Mild	Marked
Fasciculation	Absent	Present
Clonus	Present	Absent

4. A 55 year old man, known hypertensive comes to emergency department with altered consciousness and weakness of right side of the body. On examination there is increased muscle tone in the right upper and lower limbs, exaggerated deep tendon reflexes and absent superficial reflexes.

• What is he suffering from ?

• What are the differences between UMN and LMN lesions ?

• What is Babinski's sign ?

• What are the physiological and pathological causes of Babinski's sign ?

Answer

Diagnosis

The patient is suffering from **Upper Motor Neuron lesion due to stroke** causing hemiplegia.

Differences between UMN and LMN lesions

Feature	UMN lesion	LMN lesion
Type of paralysis	Spastic	Flaccid
Tone	Increased	Decreased
Deep tendon reflexes	Exaggerated	Absent
Superficial reflexes	Absent	Absent
Babinski sign	Present	Absent
Muscle wasting	Mild	Severe
Fasciculations	Absent	Present
Clonus	Present	Absent

Babinski's sign

On stroking lateral border of sole, there is:

dorsiflexion of great toe

fanning of other toes.

It indicates corticospinal tract lesion.

Physiological causes of Babinski sign

Infants below 1 year due to incomplete myelination of corticospinal tract

During sleep

Deep anesthesia

Pathological causes of Babinski sign

Upper motor neuron lesion

Stroke

Multiple sclerosis

Spinal cord injury

Tumours involving corticospinal tract

5. A 60 years old hypertensive male is admitted with the complaints of sudden inability to use his right upper and lower limbs and inability to speak. On examination he has increased tone in some of the limb muscles loss of superficial reflexes and deep tendon reflexes are exaggerated. Answer the following questions based on your knowledge in physiology:

• What is this clinical condition?

• Draw the diagram of the tract involved

• Why there is an increase in the tone of the muscle?

• Why speech is lost in this condition?

Answer

Clinical condition

Upper motor neuron lesion due to stroke causing hemiplegia with aphasia.

Diagram of tract involved

REFER DIAGRAM SECTION

Why there is increase in muscle tone?

Loss of inhibitory corticospinal influence.

Increased gamma motor neuron discharge.

Muscle spindle sensitivity increases.

Stretch reflex becomes exaggerated.

Hence spasticity develops.

Why speech is lost in this condition?

Stroke affects dominant cerebral hemisphere.

Broca's speech area may be involved.

Motor aphasia occurs leading to inability to speak.

SHORT ESSAYS

6.Draw a diagram to show the origin, course and termination of Cortico spinal tract

Answer

REFER DIAGRAM SECTION

SHORT ANSWERS

7.Physiological basis for rigidity in UMN lesions

Answer

Loss of inhibitory cortical influence on spinal motor neurons

Increased gamma efferent discharge

Increased muscle spindle sensitivity

Exaggerated stretch reflex

Increased alpha motor neuron activity

Results in hypertonia/spastic rigidity in UMN lesions

7. Describe the degenerative changes that occur following peripheral nerve injury.

Degenerative changes following peripheral nerve injury

Peripheral nerve injury produces degeneration in the nerve fiber both distal and proximal to the site of injury.

1. Wallerian degeneration (Distal degeneration)

Occurs in the part of axon distal to the site of injury.

Begins within 24–48 hours after injury.

Axon swells and breaks into fragments.

Myelin sheath degenerates into droplets.

Macrophages remove debris.

Schwann cells proliferate and form columns called bands of Büngner.

These guide regenerating axons.

2. Retrograde degeneration (Proximal degeneration)

Occurs proximal to the site of injury up to the next node of Ranvier.

Cell body undergoes chromatolysis.

Changes in cell body:

Swelling of cell body.

Nucleus moves to periphery.

Nissl granules disappear.

Increased protein synthesis for regeneration.

3. Regeneration

If neurilemma is intact, regeneration occurs.

Axon sprouts arise from proximal stump.

Sprouts grow along Schwann cell tubes.

Growth rate is about 1–3 mm/day.

Functional recovery occurs if proper reinnervation takes place.

8. Draw and label Dorsal column pathway.

REFER DIAGRAM SECTION

9. Physiological basis of hypertonia in UMN lesion

Hypertonia in UMN lesion

Hypertonia means increased muscle tone seen in upper motor neuron lesion.

Physiological basis

Loss of inhibitory influence from cerebral cortex on spinal motor neurons.

Increased gamma motor neuron discharge.

Gamma efferents become overactive.

Muscle spindle sensitivity increases.

Stretch reflex becomes exaggerated.

Minor stretch produces excessive contraction.

Leads to spasticity.

Increased excitability of alpha motor neurons.

Reticulospinal and vestibulospinal facilitatory influences become unopposed.

Clasp-knife spasticity occurs due to exaggerated stretch reflex followed by sudden relaxation.

Features

Increased tone mainly in antigravity muscles.

Velocity-dependent resistance.

Associated with exaggerated tendon reflexes.

10. Compare the Upper Motor Neuron (UMN) and Lower Motor Neuron (LMN) lesions

Feature	UMN lesion	LMN lesion
Muscle tone	Increased (spasticity)	Decreased (flaccidity)
Muscle wasting	Mild/disuse atrophy	Marked atrophy
Deep reflexes	Exaggerated	Absent/decreased
Plantar reflex	Extensor (Babinski positive)	Flexor/absent
Fasciculations	Absent	Present
Paralysis	Spastic paralysis	Flaccid paralysis
Clonus	Present	Absent
Distribution	Groups of muscles	Individual muscles

11. Draw and label pyramidal tract

REFER DIAGRAM SECTION

12. Babinski sign

Definition

Babinski sign is extension (dorsiflexion) of great toe with fanning of other toes on stroking the lateral side of sole.

Method

Stroke lateral border of sole from heel to little toe and medially across forefoot.

Normal response

Plantar flexion of toes.

Positive Babinski sign

Dorsiflexion of great toe.

Fanning of other toes.

Cause

Upper motor neuron lesion.

Loss of corticospinal tract inhibition.

Seen in

UMN lesions

Infants (due to incomplete myelination)

Significance

Indicates pyramidal tract lesion.

13. Draw and label: Corticospinal tracts from its origin to termination

REFER DIAGRAM SECTION

LESIONS OF SPINAL CORD

LONG ESSAYS

1. A 35-year-old man was brought to the casualty after a stab injury to the left side of his back. Imaging study showed injury to left half of spinal cord in region of 9th and 10th thoracic vertebrae. Neurological examination showed that he was unable to move his left lower limb. Some sensations were absent on the left half of the body while some other sensations were absent on the right side. On the left

side the abdominal reflex was absent, but knee and ankle jerks were brisk.

Name the most probable clinical condition in this patient.

Explain the physiological basis for the typical sensory loss in this patient.

Describe the sensory and motor changes occurring at the level and below the level of injury in such cases.

Answer

Diagnosis

The patient is suffering from Brown-Sequard syndrome (hemisection of spinal cord).

Physiological basis for sensory loss

1. Ipsilateral loss of dorsal column sensations

Fine touch

Vibration

Position sense

Tactile discrimination

Reason

Dorsal column fibers ascend uncrossed in spinal cord.

Therefore lesion on left side causes loss on left side below lesion.

2. Contralateral loss of pain and temperature

Reason

Pain and temperature fibers cross within 1–2 segments through anterior white commissure.

Therefore left-sided lesion causes loss of pain and temperature on right side below lesion.

Motor and sensory changes

At the level of lesion

Motor changes

Destruction of lower motor neurons.

Ipsilateral flaccid paralysis.

Loss of segmental reflexes.

Abdominal reflex absent.

Sensory changes

Complete sensory loss at the affected segments.

Below the level of lesion

Ipsilateral changes

Motor

Spastic paralysis due to corticospinal tract damage.

Hypertonia.

Exaggerated knee and ankle jerks.

Babinski sign positive.

Sensory

Loss of fine touch.

Loss of vibration sense.

Loss of proprioception.

Contralateral changes

Loss of pain and temperature sensations below lesion.

Summary of Brown-Sequard syndrome

Side	Deficit
Ipsilateral	Spastic paralysis, loss of fine touch, vibration and proprioception
Contralateral	Loss of pain and temperature

2. Describe the theories of referred pain using an example explain the nervous system involvement in this disease

Referred pain

Definition

Referred pain is pain perceived at a site different from the site of origin.

Example

Pain of myocardial ischemia felt over left arm and shoulder.

Theories of referred pain

1. Convergence theory

Visceral and somatic afferent fibers converge on same second-order neuron in spinal cord.

Brain misinterprets visceral pain as somatic pain.

Most accepted theory.

2. Facilitation theory

Visceral impulses facilitate spinal neurons.

Mild somatic stimuli are perceived as pain.

3. Dermatomal rule

Referred pain occurs in dermatome supplied by same spinal segment as diseased organ.

Nervous system involvement

Pathway

Pain receptors in viscera stimulated.

Visceral afferent fibers travel with sympathetic nerves.

Enter spinal cord through dorsal roots.

Synapse in posterior horn.

Same neurons also receive somatic afferents.

Pain projected to somatic area.

Example: Cardiac pain

Heart supplied by T1–T5 spinal segments.

Pain referred to chest, left shoulder and medial side of left arm.

SHORT ESSAYS

3. Describe the effects of complete transverse section of spinal cord.

Effects of complete transverse section of spinal cord

Immediate effect – Spinal shock

Features

Loss of all sensations below lesion.

Flaccid paralysis.

Loss of all reflexes.

Hypotension.

Loss of bladder and bowel control.

Recovery phase

Reflexes return gradually

Deep reflexes become exaggerated.

Spasticity develops.

Babinski sign positive.

Autonomic effects

Automatic bladder develops.

Reflex bowel evacuation.

Permanent effects

Voluntary movements absent below lesion.

Sensory loss below lesion.

Spastic paralysis.

SHORT ANSWERS

4. Draw and label the dorsal column pathway

REFER DIAGRAM SECTION

5. Brown-Sequard syndrome

Definition

Hemisection of spinal cord.

Causes

Stab injury

Tumor

Compression

Features

Ipsilateral

Spastic paralysis

Loss of fine touch, vibration and proprioception

Contralateral

Loss of pain and temperature

Cause

Damage to corticospinal tract, dorsal columns and spinothalamic tract.

6. Upper motor neuron lesions produce hypertonia Why?

Causes of hypertonia in UMN lesion

Loss of inhibitory cortical influence.

Increased gamma motor neuron activity.

Increased muscle spindle sensitivity.

Exaggerated stretch reflex.

Increased alpha motor neuron excitability.

Result

Spasticity and exaggerated tendon reflexes.

7. Abnormal plantar reflex in neurological diseases Why?

Abnormal plantar reflex

Extensor plantar response (Babinski sign).

Cause

Lesion of corticospinal tract.

Loss of inhibitory influence of upper motor neurons.

Response

Dorsiflexion of great toe.

Fanning of toes.

8. Babinski's sign in new born. Why?

Reason

Corticospinal tract is not fully myelinated in newborns.

Inhibitory influence on spinal reflexes is absent.

Result

Extensor plantar response is normal in infants.

9. Lumbar puncture is done at L2-L3 level. Why?

Reason

Spinal cord ends at lower border of L1 vertebra in adults.

Below this level only cauda equina is present.

Nerve roots move away from needle, reducing risk of injury.

Therefore

Lumbar puncture is safely performed below L1 level.

BASAL GANGLIA OR BASAL NUCLEI

LONG ESSAYS

1. A 69-year-old man goes to consult his physician. As he sits in the waiting room, he is observed to have tremors in his hands and fingers. His face is unexpressive and he makes few movements. When he is invited to enter the physician's office, he walks slowly into the office, he has difficulty swinging his arms and does not swing appreciably. When he talks to the physician, his speech is monotonous but he shows no intellectual deficit. There was no sensory loss. The stretch reflexes were normal and the muscles exhibited rigidity.

- **What is your diagnosis**
- **Which part of the nervous system is involved in this disease**
- **Explain the connections and functions of the part of the nervous system involved.**
- **Why are the movements so few and slow**
- **What is the treatment**

• What is your diagnosis

Diagnosis:
The patient is suffering from **Parkinsonism (Parkinson's disease)**.

Features supporting diagnosis:

- Resting tremor ("pill-rolling tremor")
- Mask-like face
- Bradykinesia (slowness of movement)
- Rigidity
- Monotonous speech
- Loss of associated movements such as arm swinging
- Normal sensory system and reflexes

• Which part of the nervous system is involved in this disease

The part involved is the **Basal Ganglia (Extrapyramidal system)**, especially:

- **Substantia nigra pars compacta**
- **Corpus striatum (caudate nucleus and putamen)**

There is degeneration of dopaminergic neurons of substantia nigra leading to deficiency of dopamine in the basal ganglia.

• Explain the connections and functions of the part of the nervous system involved.

Basal Ganglia – Connections

Components

- Caudate nucleus
- Putamen
- Globus pallidus
- Substantia nigra
- Subthalamic nucleus

Connections

Afferent connections

Basal ganglia receive impulses from:

- Cerebral cortex
- Thalamus
- Substantia nigra

Efferent connections

Basal ganglia send impulses to:

- Thalamus
- Brainstem
- Motor cortex through thalamus

Functional pathways

There are two pathways:

1. Direct pathway

- Facilitates movement

2. Indirect pathway

- Inhibits unwanted movement

Dopamine from substantia nigra:

- Stimulates direct pathway via D1 receptors

Inhibits indirect pathway via D2 receptors

Thus dopamine promotes smooth voluntary movements.

Functions of Basal Ganglia

Regulation and coordination of voluntary movements

Initiation of desired movements

Suppression of unwanted movements

Regulation of muscle tone

Control of associated automatic movements

Maintenance of posture

Control of learned motor activities

• Why are the movements so few and slow

Movements are few and slow due to **loss of dopamine in basal ganglia**.

This causes:

Decreased activity of direct pathway

Increased activity of indirect pathway

As a result:

Motor cortex receives less excitatory input

Initiation of movements becomes difficult

Hence:

Bradykinesia

Akinesia

Reduced spontaneous movements occur

• What is the treatment

Treatment of Parkinsonism

Drug therapy

Levodopa

Precursor of dopamine

Most effective treatment

Levodopa + Carbidopa

Carbidopa prevents peripheral breakdown of levodopa

Dopamine agonists

Bromocriptine

Pramipexole

Anticholinergic drugs

Benzhexol

Benztropine

Monoamine oxidase-B inhibitors

Selegiline

Surgical treatment

Deep brain stimulation

Pallidotomy

Thalamotomy

Physiotherapy

Exercises to improve posture and movement

Speech therapy may help speech defects

2.A 69-year-old man went to consult his physician. He had tremors in his hands and fingers. His face was unexpressive. When he was invited to enter the physician's office, he had difficulty in standing up. He walked slowly into the office. There was no sensory loss. The stretch reflexes were normal and the muscles exhibited rigidity.

• Identify this condition
• Discuss the physiological basis of this condition
• Describe the connections of basal ganglia
• Discuss the functions of basal ganglia

Answer

Identification of condition

The condition is **Parkinsonism (Parkinson's disease).**

Physiological basis of Parkinsonism

Parkinsonism is caused by degeneration of dopaminergic neurons in the **substantia nigra pars compacta**.

This causes deficiency of dopamine in the corpus striatum.

Normally dopamine:

Excites direct pathway through D1 receptors

Inhibits indirect pathway through D2 receptors

Facilitates voluntary movements

Loss of dopamine leads to:

Increased inhibitory output from basal ganglia to thalamus

Reduced excitation of motor cortex

Decreased voluntary movements

Clinical features and physiological basis

Bradykinesia/Akinesia – due to decreased cortical motor activity

Rigidity – increased gamma motor neuron discharge

Resting tremor – due to oscillatory discharge in basal ganglia circuits

Mask-like face – reduced spontaneous facial movements

Shuffling gait – difficulty in initiating movement

Stooped posture – loss of postural reflexes

Connections of basal ganglia

Components

Caudate nucleus

Putamen

Globus pallidus

Substantia nigra

Subthalamic nucleus

Afferent connections

Cerebral cortex → striatum
(corticostriate fibers)

Thalamus → striatum

Substantia nigra → striatum
(nigrostriatal dopaminergic fibers)

Efferent connections

Striatum → globus pallidus

Globus pallidus → thalamus

Thalamus → motor cortex

Connections with brainstem nuclei

Functional pathways

Direct pathway

Facilitates movement.

Cortex → striatum → internal globus pallidus inhibited → thalamus disinhibited → motor cortex stimulated.

Indirect pathway

Inhibits unwanted movements.

Cortex → striatum → external globus pallidus → subthalamic nucleus → internal globus pallidus → thalamus inhibited.

Functions of basal ganglia

Regulation of voluntary movements

Initiation and planning of movements

Control of muscle tone

Regulation of posture and equilibrium

Suppression of unwanted movements

Automatic associated movements

Emotional motor expression

3.A 71 years old retired teacher presented with complaints of difficulty to start walking and tremor of hands. His wife often found his face "expressionless". Answer the following questions based on your knowledge in physiology:

• Name the commonest clinical condition causing the above complaints
• Diagrammatically represent the structure involved and its functional connections
• Enumerate its functions
• Briefly mention the physiological basis of treatment of this disease

Answer

Commonest clinical condition

Parkinsonism (Parkinson's disease).

Structure involved and functional connections

Structure involved

Basal ganglia.

Functional connections

Cerebral cortex sends impulses to striatum

Striatum projects to globus pallidus

Globus pallidus projects to thalamus

Thalamus projects back to motor cortex

Substantia nigra provides dopaminergic input to striatum

Subthalamic nucleus participates in indirect pathway

Functions of basal ganglia

Initiation of voluntary movement

Regulation of muscle tone

Coordination of learned motor activities

Control of posture

Automatic associated movements

Suppression of unwanted movements

Physiological basis of treatment

Levodopa therapy

Levodopa crosses blood-brain barrier

Converted to dopamine in brain

Restores dopamine deficiency

Carbidopa

Prevents peripheral conversion of levodopa

Increases availability to brain

Dopamine agonists

Stimulate dopamine receptors

Anticholinergic drugs

Reduce cholinergic overactivity

Deep brain stimulation

Reduces abnormal basal ganglia activity

4.Important findings on examination include decrease in power in all muscle groups. Tone, coordination, reflexes and sensation are normal. Bilateral ptosis is present and is exacerbated by prolonged upward gaze. Pupillary reflexes, eye movements and fundoscopy are normal. Speech becomes soft when the patient is tired. Symptoms are usually worse in the evenings and better in the mornings.

• What are the connections and functions of Basal ganglia?
• Add a note on Parkinsonism.

Answer

Connections of basal ganglia

Afferent connections

Cerebral cortex → striatum

Thalamus → striatum

Substantia nigra → striatum

Efferent connections

Striatum → globus pallidus

Globus pallidus → thalamus

Thalamus → motor cortex

Connections with brainstem nuclei

Functions of basal ganglia

Initiation of voluntary movement

Regulation of muscle tone

Control of posture

Coordination of automatic movements

Suppression of unwanted movements

Emotional expression in motor activity

Note on Parkinsonism

Definition

A degenerative disorder due to dopamine deficiency in basal ganglia.

Cause

Degeneration of substantia nigra pars compacta.

Features

Resting tremor

Rigidity

Bradykinesia

Mask-like face

Shuffling gait

Stooped posture

Physiological basis

Loss of dopamine increases inhibitory output from basal ganglia to thalamus, reducing cortical motor activity.

Treatment

Levodopa + carbidopa

Dopamine agonists

Anticholinergics

Deep brain stimulation

5.A 45 years old automobile mechanic is not able to perform his professional work and is complaining of tremor during rest and unable to initiate a movement. He always takes short quick steps while walking. Answer the following questions based on your knowledge in physiology:

• What can be the probable condition?
• Explain the pathophysiology underlying it.
• What are the functions of the structure affected?
• Suggest the probable methods of treatment for this condition.

Answer

Probable condition

Parkinsonism.

Pathophysiology

Degeneration of substantia nigra pars compacta

Dopamine deficiency in corpus striatum

Reduced activity of direct pathway

Increased activity of indirect pathway

Excess inhibition of thalamus

Reduced stimulation of motor cortex

This causes:

Bradykinesia

- Rigidity
- Resting tremor
- Difficulty in initiating movement

Functions of basal ganglia

- Planning and initiation of movement
- Control of muscle tone
- Coordination of learned motor activities
- Suppression of unwanted movements
- Regulation of posture
- Automatic associated movements

Methods of treatment

- Levodopa with carbidopa
- Dopamine agonists
- Monoamine oxidase inhibitors
- Anticholinergic drugs
- Physiotherapy
- Deep brain stimulation

SHORT ESSAYS

6. Connections and functions of basal ganglia

Connections of basal ganglia

Components

- Caudate nucleus
- Putamen
- Globus pallidus
- Substantia nigra
- Subthalamic nucleus

Afferent connections

- Corticostriate fibers from cerebral cortex
- Thalamostriate fibers from thalamus
- Nigrostriatal dopaminergic fibers

Efferent connections

- Striatopallidal fibers
- Pallidothalamic fibers
- Thalamocortical fibers
- Connections with reticular formation and brainstem

Functional circuits

Direct pathway

Facilitates movement.

Indirect pathway

Inhibits unwanted movements.

Functions of basal ganglia

- Initiation of voluntary movement
- Planning and programming of motor activity
- Control of muscle tone
- Regulation of posture and equilibrium

Automatic associated movements

Suppression of unwanted movements

Emotional motor behavior

7. Explain the basis of clinical features of Parkinsonism with the help of basal ganglia circuits.

Introduction

Parkinsonism is caused by degeneration of substantia nigra with dopamine deficiency in basal ganglia.

Basis of clinical features

1. Bradykinesia

Reduced activity of direct pathway decreases stimulation of motor cortex.

2. Rigidity

Increased gamma motor neuron activity increases muscle tone.

3. Resting tremor

Due to oscillatory activity in basal ganglia-thalamocortical circuits.

4. Difficulty in initiating movement

Excess inhibition of thalamus reduces cortical motor activation.

5. Mask-like face

Reduced spontaneous movements of facial muscles.

6. Shuffling gait

Impaired postural reflexes and reduced motor activity.

SHORT ANSWERS

8. Explain the physiological basis of Parkinson's disease.

Parkinson's disease occurs due to degeneration of dopaminergic neurons in substantia nigra pars compacta.

This causes dopamine deficiency in corpus striatum.

Consequences:

Reduced direct pathway activity

Increased indirect pathway activity

Excess inhibition of thalamus

Reduced motor cortex activity

Clinical features:

Bradykinesia

Rigidity

Resting tremor

Mask-like face

Shuffling gait

9. Short answer on Parkinsonism.

Definition

A degenerative disease of basal ganglia due to dopamine deficiency.

Cause

Degeneration of substantia nigra.

Features

- Resting tremor
- Rigidity
- Bradykinesia
- Mask-like face
- Shuffling gait

Treatment

- Levodopa + carbidopa
- Dopamine agonists
- Anticholinergic drugs

10. Administration of L-dopa in Parkinson's disease. Why?

L-dopa is administered because dopamine cannot cross the blood-brain barrier.

Levodopa crosses the blood-brain barrier and is converted into dopamine in the brain.

It restores dopamine deficiency in basal ganglia and improves motor symptoms.

Usually combined with carbidopa to reduce peripheral metabolism.

11. Cogwheel rigidity

Cogwheel rigidity is a type of rigidity seen in Parkinsonism where resistance to passive movement occurs in a jerky manner.

It is due to:

- Lead pipe rigidity combined with resting tremor.

12. A 50 year old lady finds difficulty in reading and doing close work. Why?

Difficulty in reading and doing close work occurs due to **presbyopia**.

Cause:

- Loss of elasticity of lens with age
- Decreased power of accommodation

Near point moves away from eye causing difficulty in near vision.

13. Clasp knife rigidity

Clasp knife rigidity is a feature of upper motor neuron lesion.

Initially there is resistance to passive movement followed by sudden release.

It occurs due to exaggerated stretch reflex and activation of Golgi tendon organ reflex.

14. Parkinsonism

Definition

A syndrome due to dopamine deficiency in basal ganglia.

Features

- Resting tremor
- Rigidity
- Bradykinesia
- Mask-like face

Shuffling gait

Cause

Degeneration of substantia nigra.

Treatment

Levodopa, dopamine agonists and physiotherapy.

CEREBELLUM

LONG ESSAYS

1. Explain the connections and functions of cerebellum. Add a note on clinical symptoms seen in cerebellar lesions.

Connections of cerebellum

Afferent connections

Spinocerebellar tracts

Vestibulocerebellar fibers

Corticopontocerebellar fibers

Olivocerebellar fibers

Efferent connections

Cerebellothalamic pathway

Cerebellorubral fibers

Cerebellovestibular fibers

Cerebelloreticular fibers

Functions of cerebellum

Maintenance of posture and equilibrium

Regulation of muscle tone

Coordination of voluntary movements

Planning and programming of movements

Maintenance of balance

Comparator function

Motor learning

Clinical symptoms of cerebellar lesions

Hypotonia

Ataxia

Intention tremor

Dysmetria

Dysdiadochokinesia

Nystagmus

Pendular knee jerk

Scanning speech

Broad-based gait

2. A 65 years old woman was admitted to the hospital with the complaints of intentional tremors in the left arm and missing the target when she attempted to do a work. On examination eye reveals nystagmus. Answer the following questions based on your knowledge in physiology:

• What is the diagnosis?
• Mention the characteristic of knee jerk in this patient.
• What is dysdiadochokinesia?
• Describe the gait in this patient giving the physiological basis.

• What happens when flocculonodular lobe is damaged?

Answer

Diagnosis

Cerebellar ataxia.

Characteristic of knee jerk

Pendular knee jerk is seen.

Cause:

Hypotonia due to cerebellar lesion.

Dysdiadochokinesia

Inability to perform rapid alternating movements.

Example:

Rapid pronation and supination of forearm cannot be performed properly.

Gait and physiological basis

Gait

Broad-based staggering gait

Patient walks like a drunken person

Physiological basis

Due to loss of coordination and impaired equilibrium caused by cerebellar dysfunction.

Damage to flocculonodular lobe

Disturbance of equilibrium

Truncal ataxia

Nystagmus

Falling towards side of lesion

SHORT ESSAYS

3. Describe the physiological basis for any three features of cerebellar disorders.

1. Intention tremor

Occurs during voluntary movement due to failure of comparator function.

2. Ataxia

Due to loss of coordination of muscle activity.

3. Hypotonia

Due to decreased facilitatory influence on gamma motor neurons.

4. Dysmetria

Inability to judge distance due to impaired control of movement range.

4. Describe the functions of cerebellum. List the clinical features of cerebellar dysfunction.

Functions of cerebellum

Coordination of voluntary movements

Maintenance of posture and equilibrium

Regulation of muscle tone

Planning and programming of movement

Comparator function

Motor learning

Clinical features of cerebellar dysfunction

Ataxia

Hypotonia

Intention tremor

Dysmetria

Dysdiadochokinesia

Nystagmus

Pendular knee jerk

Scanning speech

5. Connections and functions of cerebellum

Connections

Afferent

Spinocerebellar fibers

Vestibular fibers

Pontocerebellar fibers

Olivocerebellar fibers

Efferent

To thalamus

To red nucleus

To vestibular nuclei

To reticular formation

Functions

Coordination of voluntary movements

Maintenance of posture

Equilibrium

Muscle tone regulation

Motor learning

6. Draw the functional divisions of cerebellum. Explain the functions of these divisions with referring to their connections.

REFER DIAGRAM SECTION

Functions

Regulation of muscle tone

Control of posture

Cerebrocerebellum

Connections

Connected with cerebral cortex through pontine nuclei.

Functions

Planning and coordination of skilled voluntary movements

Motor learning

7. Functions of cerebellum

Coordination of voluntary movement

Maintenance of posture and equilibrium

Regulation of muscle tone

Comparator function

Planning and programming of movement

Motor learning

Coordination of eye movements

SHORT ANSWERS

8. Dysdiadochokinesia (Adiadochokinesia)

Inability to perform rapid alternating movements.

Seen in cerebellar lesions.

Example:
Rapid pronation and supination cannot be performed smoothly.

9. Functions of cerebellum

Coordination of movement

Maintenance of posture

Equilibrium

Muscle tone regulation

Motor learning

10. Cerebellum in voluntary activity

Cerebellum coordinates voluntary movements by comparing intended movement with actual performance.

It corrects errors and ensures smooth coordinated activity.

11. Role of the cerebellum in motor control

Coordination of voluntary movements

Maintenance of posture and balance

Regulation of muscle tone

Motor learning

Comparator function

12. Features of cerebellar lesions

Ataxia

Intention tremor

Dysmetria

Dysdiadochokinesia

Hypotonia

Nystagmus

Pendular knee jerk

Scanning speech

13. Broad based gait in cerebellar lesion. Why?

Due to loss of equilibrium and incoordination of muscles, the patient walks with feet placed widely apart to maintain balance.

VESTIBULAR APPARATUS

SHORT ANSWERS

1. Physiological basis of vestibulo ocular reflex

Vestibulo-ocular reflex maintains fixation of eyes during head movement.

Head movement stimulates semicircular canals.

Impulses pass through:

- Vestibular nerve
- Vestibular nuclei
- Medial longitudinal fasciculus
- Ocular motor nuclei

Eyes move in opposite direction to maintain fixation.

2. Nystagmus is observed in vestibular disease. Why?

Unequal vestibular discharge from two sides causes rhythmic involuntary eye movements.

Slow component is due to vestibular reflex and fast component is corrective cortical movement.

CEREBRAL CORTEX

LONG ESSAYS

1. A 61 year old Senior Lawyer (male) in a law firm, while eating breakfast experienced sudden onset slurring of speech, and had facial droop on his left-hand side with weakness in his left side upper and lower limbs. His wife spotted these sudden onsets of symptoms and immediately called for an ambulance, which arrived within 15 mins and rushed him to the Emergency room of a hospital.

a) What is the patient suffering from
b) What examination and investigations should be done to confirm the diagnosis
c) Describe the functions and connections of the pathway affected with a neat, labeled diagram

Answer

a) Diagnosis

Left sided hemiplegia due to stroke.

b) Examination and investigations

Examination

- Motor examination
- Cranial nerve examination
- Speech assessment
- Reflex examination
- Sensory examination

Investigations

- CT scan brain
- MRI brain
- Doppler study
- Electrocardiogram
- Blood investigations

c) Pathway affected – corticospinal tract

Connections

Origin

- Motor cortex
- Premotor cortex
- Somatosensory cortex

Course

Corona radiata

Internal capsule

Crus cerebri

Pons

Medullary pyramids

Decussation in medulla

Lateral corticospinal tract

Termination

Anterior horn cells of spinal cord.

Functions

Voluntary skilled movements

Fine movements of distal muscles

Regulation of muscle tone

Inhibitory control over reflexes

SHORT ANSWERS

2. Draw and label lateral view of cerebral hemisphere and mark the speech areas

REFER DIAGRAM SECTION

3. Functions of parietal lobe of brain

Somatic sensation perception

Sensory integration

Stereognosis

Spatial orientation

Language comprehension

4. Sensory homunculus

Sensory homunculus is the somatotopic representation of body parts in primary somatosensory cortex.

Areas with greater sensory acuity occupy larger cortical representation.

5. Aphasia

Aphasia is loss or impairment of speech due to cortical lesion.

Types

Broca's aphasia

Wernicke's aphasia

Global aphasia

6. Draw and label functional areas of cerebral cortex

REFER DIAGRAM SECTION

HYPOTHALAMUS

SHORT ESSAYS

1. Role of hypothalamus in feeding and satiety

Feeding center

Located in lateral hypothalamus.

Stimulation causes:

Hunger

Increased food intake

Satiety center

Located in ventromedial nucleus.

Stimulation causes:

- Satiety
- Decreased food intake

Regulation

Controlled by:

- Blood glucose level
- Leptin
- Ghrelin
- Gastrointestinal signals

2. Explain the role hypothalamus in regulation of water and food intake.

Regulation of food intake

Feeding center

Located in lateral hypothalamus.

Satiety center

Located in ventromedial nucleus.

Controlled by glucose, leptin and gastrointestinal hormones.

Regulation of water intake

Thirst center

Located in hypothalamus.

Stimulated by:

- Increased plasma osmolality
- Decreased blood volume

Osmoreceptors stimulate thirst and antidiuretic hormone secretion.

3. Explain the functions of the hypothalamus.

- Regulation of autonomic nervous system
- Regulation of body temperature
- Control of food and water intake
- Endocrine control through pituitary
- Sleep and circadian rhythm
- Emotional behavior
- Sexual functions
- Memory functions

4. Name the nuclei of hypothalamus. Enumerate the functions of hypothalamus and describe any one in detail.

Nuclei of hypothalamus

- Supraoptic nucleus
- Paraventricular nucleus
- Ventromedial nucleus
- Lateral nucleus
- Suprachiasmatic nucleus
- Mammillary nucleus

Functions of hypothalamus

- Autonomic regulation

Temperature regulation

Food intake regulation

Water balance

Endocrine regulation

Sleep and wakefulness

Emotional behavior

Temperature regulation in detail

Anterior hypothalamus acts as heat loss center.

Posterior hypothalamus acts as heat gain center.

Mechanisms include:

Sweating

Vasodilatation

Shivering

Vasoconstriction

5. Describe the role of hypothalamus in the regulation of food intake

Feeding center

Located in lateral hypothalamus.

Stimulates hunger.

Satiety center

Located in ventromedial nucleus.

Inhibits feeding.

Factors regulating food intake

Blood glucose

Leptin

Ghrelin

Gastrointestinal distension

SHORT ANSWERS

6. Explain the role of hypothalamus in regulation of food intake.

Hypothalamus regulates food intake through:

Feeding center in lateral hypothalamus

Satiety center in ventromedial nucleus

Leptin inhibits feeding while ghrelin stimulates hunger.

7. Functions of hypothalamus

Autonomic regulation

Temperature regulation

Water balance

Food intake regulation

Endocrine control

Emotional behavior

Sleep regulation

8. Hypothalamic disorders results in obesity. Why?

Damage to ventromedial nucleus destroys satiety center causing hyperphagia and obesity.

9. Role of hypothalamus in feeding behaviour

Lateral hypothalamus acts as feeding center while ventromedial nucleus acts as satiety center.

Together they regulate feeding behavior.

10. Role of hypothalamus in temperature regulation

Anterior hypothalamus regulates heat loss.

Posterior hypothalamus regulates heat production and conservation.

POSTURE AND EQUILIBRIUM

SHORT ANSWERS

1. Decerebrate rigidity

Definition

Increase in extensor muscle tone due to transection of brainstem below red nucleus.

Cause

Loss of inhibitory cortical influence with unopposed vestibulospinal and reticulospinal activity.

Features

- Extension of all limbs
- Hypertonia
- Exaggerated reflexes

LIMBIC SYSTEM

SHORT ANSWERS

1. Functions of limbic system

- Controls emotions – fear, anger, pleasure, affection.
- Regulates behaviour and motivation.
- Important in memory and learning.
- Controls autonomic responses associated with emotions.
- Regulates sexual behaviour.
- Maintains food intake and drinking behaviour.
- Involved in reward and punishment mechanisms.
- Influences endocrine functions through hypothalamus.

ELECTROENCEPHALOGRAPHY, SLEEP, YOGA AND MEDITATION

SHORT ANSWERS

1. Differentiate between REM and NREM sleep. Add a note on narcolepsy

Feature	REM sleep	NREM sleep
Also called	Paradoxical sleep	Slow wave sleep
EEG	Desynchronized	Synchronized
Eye movements	Rapid eye movements present	Absent
Muscle tone	Markedly decreased	Present
Dreaming	Vivid dreams	Less dreaming
Autonomic activity	Irregular	Regular

Feature	REM sleep	NREM sleep
Brain activity	Increased	Decreased
Occurrence	Cyclic, after NREM	Occupies major sleep period

Narcolepsy

Narcolepsy is a disorder characterized by sudden irresistible attacks of sleep during daytime.

Features

Excessive daytime sleepiness.

Sudden REM sleep.

Cataplexy – sudden loss of muscle tone.

Sleep paralysis.

Hypnagogic hallucinations.

Cause

Due to deficiency of hypocretin (orexin) neurons in hypothalamus.

2. Describe the waves and uses of Electroencephalogram (EEG)

EEG waves

Wave	Frequency	Features
Alpha	8–13 Hz	Seen in relaxed awake adults with eyes closed
Beta	14–30 Hz	Seen during alert mental activity
Theta	4–7 Hz	Seen in children and emotional stress
Delta	<4 Hz	Seen in deep sleep

Uses of EEG

Diagnosis of epilepsy.

Diagnosis of sleep disorders.

Detection of brain tumors.

Assessment of coma and brain death.

Study of sleep stages.

Detection of encephalopathies.

3. How does REM sleep differ from Non REM sleep

REM sleep	Non REM sleep
Rapid eye movements present	No rapid eye movements
Dreams common	Dreams less common
Muscle tone absent	Muscle tone maintained
EEG resembles awake state	EEG shows slow waves
Autonomic activity irregular	Autonomic activity regular
Brain metabolism increased	Brain metabolism decreased

4. Types of EEG wave forms

Alpha waves – 8–13 Hz.

Beta waves – 14–30 Hz.

Theta waves – 4–7 Hz.

Delta waves – less than 4 Hz.

5. Paradoxical sleep

Paradoxical sleep is another name for REM sleep.

Features

EEG resembles awake state.

Rapid eye movements present.

Skeletal muscle atonia occurs.

Dreaming is common.

Irregular pulse and respiration.

Increased brain activity.

6. Mention the stages of sleep

NREM sleep

Stage 1.

Stage 2.

Stage 3.

Stage 4.

REM sleep

REM stage.

CEREBROSPINAL FLUID

SHORT ESSAYS

1. Describe the production, circulation and functions of the cerebrospinal fluid

Cerebrospinal fluid (CSF)

CSF is a clear colourless fluid present in ventricles and subarachnoid space.

Production

Mainly produced by choroid plexus.

Small amount produced by ependymal cells and brain tissue.

Rate of formation – about 0.35 mL/minute.

Total volume – about 150 mL.

Circulation

Produced in lateral ventricles.

Passes through foramen of Monro to third ventricle.

Through aqueduct of Sylvius to fourth ventricle.

Leaves through foramina of Luschka and Magendie.

Enters subarachnoid space around brain and spinal cord.

Absorbed through arachnoid villi into dural venous sinuses.

Functions

Protects brain from injury.

Acts as shock absorber.

Maintains intracranial pressure.

Provides nutrition to nervous tissue.

Removes metabolic waste.

Maintains ionic environment.

Provides buoyancy to brain.

2. Cerebrospinal fluid

Definition

CSF is a clear colourless fluid present in ventricles and subarachnoid space.

Formation

Produced mainly by choroid plexus.

Normal volume

About 150 mL.

Normal pressure

60–150 mm CSF.

Composition

- Water.
- Glucose.
- Sodium.
- Chloride.
- Very little protein.
- Few lymphocytes.

Functions

- Protection of brain.
- Nutrition.
- Waste removal.
- Maintenance of ionic balance.

SHORT ANSWERS

3. Write a note on cerebrospinal fluid

- CSF is a clear colourless fluid.
- Produced mainly by choroid plexus.
- Total volume is about 150 mL.
- Present in ventricles and subarachnoid space.
- Functions:
  - Protection of brain.
  - Shock absorption.
  - Nutrition.
  - Removal of waste products.

4. Blood brain barrier

Definition

Blood brain barrier is a selective barrier between blood and brain tissue.

Components

- Capillary endothelial cells with tight junctions.
- Basement membrane.
- Astrocyte foot processes.

Functions

- Protects brain from toxins.
- Maintains stable environment.
- Regulates transport of substances.

Absent in

- Hypothalamus.
- Pineal gland.
- Area postrema.

5. Functions of CSF

Protection of brain.

Shock absorption.

Provides buoyancy.

Nutrition to CNS.

Removal of metabolic waste.

Maintains ionic balance.

Helps maintain intracranial pressure.

SPECIAL SENSES

VISION

SHORT ESSAYS

1. Describe the errors of refraction

Definition

Errors of refraction are conditions in which light rays are not focused properly on retina.

Types

1. Myopia

Image forms in front of retina.

Due to elongated eyeball or increased refractive power.

Corrected by concave lens.

2. Hypermetropia

Image forms behind retina.

Due to short eyeball or decreased refractive power.

Corrected by convex lens.

3. Astigmatism

Unequal curvature of cornea.

Rays focus at different points.

Corrected by cylindrical lens.

4. Presbyopia

Loss of accommodation with age.

Due to decreased elasticity of lens.

Corrected by convex lens.

2. Draw and label the visual pathway showing the effect of lesion at various levels. Add a note on presbyopia

REFER DIAGRAM SECTION

Effects of lesions

Optic nerve lesion – blindness in one eye.

Optic chiasma lesion – bitemporal hemianopia.

Optic tract lesion – homonymous hemianopia.

Optic radiation lesion – quadrantanopia.

Occipital cortex lesion – cortical blindness.

Presbyopia

Presbyopia is age related decrease in accommodation.

Cause

Loss of elasticity of lens.

Features

Difficulty in near vision.

Correction

Convex lenses.

3. Describe the visual pathway with the help of a neat labelled diagram and explain the effects of its lesion. Add a note on direct and indirect light reflex

Visual pathway

REFER DIAGRAM SECTION

Lesions

Optic nerve – monocular blindness.

Optic chiasma – bitemporal hemianopia.

Optic tract – homonymous hemianopia.

Visual cortex – cortical blindness.

Direct light reflex

Constriction of pupil in same eye when light falls on retina.

Indirect (consensual) light reflex

Constriction of opposite pupil when light is shone in one eye.

Reflex pathway

Afferent limb – optic nerve.

Efferent limb – oculomotor nerve.

4. Describe the different refractive errors in vision and methods of correcting them

Refractive error	Cause	Image formed	Correction
Myopia	Long eyeball	In front of retina	Concave lens
Hypermetropia	Short eyeball	Behind retina	Convex lens
Astigmatism	Unequal corneal curvature	Distorted	Cylindrical lens
Presbyopia	Loss of lens elasticity	Defective near vision	Convex lens

5. Draw the accommodation reflex pathway. Describe the changes occurring during accommodation

REFER DIAGRAM SECTION

Changes during accommodation

Contraction of ciliary muscle.

Lens becomes more convex.

Pupillary constriction.

Convergence of eyeballs.

6. Describe colour blindness

Definition

Colour blindness is inability to distinguish certain colours.

Types

Red-green colour blindness.

Total colour blindness.

Blue-yellow colour blindness.

Causes

Absence or defect of cones.

Tests

Ishihara chart.

Holmgren wool test.

7. Dark adaptation in human eye

Definition

Adjustment of eye to vision in dim light.

Mechanism

Increased sensitivity of rods.

Regeneration of rhodopsin.

Pupillary dilatation.

Importance

Improves night vision.

8. Describe the formation, composition and functions of aqueous humour

Formation

Produced by ciliary processes.

Circulation

Posterior chamber → pupil → anterior chamber → canal of Schlemm.

Composition

Water.

Sodium.

Chloride.

Glucose.

Low protein.

Functions

Maintains intraocular pressure.

Nutrition to cornea and lens.

Removes waste products.

Maintains shape of eyeball.

SHORT ANSWERS

9. Explain the pupillary light reflexes. Add a note on Argyll Robertson pupil

Pupillary light reflex

Constriction of pupil in response to light.

Direct reflex

Constriction in same eye.

Consensual reflex

Constriction in opposite eye.

Pathway

Afferent – optic nerve.

Efferent – oculomotor nerve.

Argyll Robertson pupil

Pupils do not react to light.

Accommodation reflex preserved.

Seen in neurosyphilis.

10. Accommodation reflex

Accommodation reflex is adjustment of eye for near vision.

Components

Increased curvature of lens.

Constriction of pupil.

Convergence of eyeballs.

Pathway

Visual cortex → Edinger-Westphal nucleus → oculomotor nerve.

11. Presbyopia and its correction

Presbyopia is defective near vision due to loss of elasticity of lens with age.

Features

Difficulty in reading near objects.

Correction

Convex lenses.

12. Physiological basis of night blindness

Night blindness occurs due to vitamin A deficiency causing defective rhodopsin formation in rods.

Features

Poor vision in dim light.

Delayed dark adaptation.

13. Draw a labelled diagram of visual pathway. Explain the physiological basis of macular sparing

REFER DIAGRAM SECTION

Macular sparing

Preservation of macular vision in occipital lobe lesions.

Causes

Dual blood supply from posterior and middle cerebral arteries.

Large cortical representation of macula.

14. What is presbyopia and how is it corrected

Presbyopia is age related decrease in accommodation due to reduced elasticity of lens.

Correction

Convex lenses.

15. Reading becomes progressively difficult with advancing age. Why?

Due to presbyopia caused by decreased elasticity of lens leading to reduced accommodation.

16. Light reflex

Constriction of pupil when light falls on retina.

Pathway

Retina → optic nerve → pretectal nucleus → Edinger-Westphal nucleus → oculomotor nerve → sphincter pupillae.

17. Draw and label : Visual pathway

REFER DIAGRAM SECTION

18. Physiological basis of hypermetropia and myopia

Hypermetropia

Image formed behind retina.

Due to short eyeball.

Myopia

Image formed in front of retina.

Due to elongated eyeball.

19. Cornea survives inspite of its avascularity. Why?

Receives oxygen from atmosphere.

Receives nutrition from aqueous humour and tears.

Waste products removed through aqueous humour.

20. Refractive errors

Myopia.

Hypermetropia.

Astigmatism.

Presbyopia.

21. Near response in normal eye

Accommodation.

Convergence.

Pupillary constriction.

22. Dark adaptation

Dark adaptation is increased sensitivity of eye in dim light due to regeneration of rhodopsin in rods.

23. Chorea

Chorea is characterized by involuntary rapid jerky movements.

Cause

Lesion of basal ganglia.

Example

Huntington chorea.

24. Bitemporal hemianopia

Loss of temporal visual fields of both eyes due to lesion at optic chiasma.

25. Hypermetropia

Hypermetropia is long sightedness in which image forms behind retina.

Correction

Convex lens.

26. Draw and label : Wald's visual cycle

REFER DIAGRAM SECTION

27. Visual pathway

Retina.

Optic nerve.

Optic chiasma.

Optic tract.

Lateral geniculate body.

Optic radiation.

Visual cortex.

28. Maximal visual acuity occurs at the fovea centralis. Why?

Only cones are present.

High density of cones.

One cone connected to one bipolar cell.

Minimal light scattering.

AUDITION

LONG ESSAYS

1. Draw and label the auditory pathway showing the receptors and the different synapses. Describe the different types of deafness with the tests used to differentiate them

REFER DIAGRAM SECTION

Types of deafness

1. Conductive deafness

Defect in external or middle ear.

Causes

Wax, otitis media, otosclerosis.

2. Sensorineural deafness

Defect in cochlea or auditory nerve.

Causes

Noise exposure, aging, nerve lesions.

Tests to differentiate

Rinne test

Normal: air conduction > bone conduction.

Conductive deafness: bone conduction > air conduction.

Weber test

Conductive deafness: sound lateralized to affected ear.

Sensorineural deafness: sound lateralized to normal ear.

Audiometry

Used to assess hearing threshold.

SHORT ESSAYS

2. Draw and label the auditory pathway. Describe impedance matching

REFER DIAGRAM SECTION

Impedance matching

Mechanism by which middle ear increases sound transmission from air to cochlear fluid.

Mechanisms

Lever action of ossicles.

Difference in area between tympanic membrane and oval window.

Importance

Prevents loss of sound energy.

3. Explain the functions of middle ear

Transmission of sound.

Impedance matching.

Protection by acoustic reflex.

Pressure equalization through Eustachian tube.

4. Depict the auditory transduction using a flow chart. Add a note on masking of sound

Auditory transduction

Sound waves → tympanic membrane vibration → ossicles → oval window → basilar membrane movement → bending of hair cells → receptor potential → auditory nerve impulses.

Masking of sound

One sound interferes with hearing of another sound.

Uses

Audiometry.

Prevention of crossover hearing.

5. Describe otolith organs and their functions

Otolith organs

Utricle.

Saccule.

Receptors

Maculae.

Functions

Detect linear acceleration.

Maintain posture.

Detect head position.

6. Describe the mechanism of appreciation of sound waves and explain the theories of hearing

Mechanism of hearing

Sound waves enter external ear.

Tympanic membrane vibrates.

Ossicles transmit vibrations.

Oval window vibrates.

Basilar membrane moves.

Hair cells stimulated.

Impulses carried through auditory pathway.

Theories of hearing

Place theory

Different frequencies stimulate different parts of basilar membrane.

Frequency theory

Frequency of impulses corresponds to sound frequency.

7. Explain impedance matching occurring in the ear and describes the tympanic reflex

Impedance matching

Lever action of ossicles.

Large tympanic membrane and small oval window increase pressure.

Tympanic reflex

Reflex contraction of stapedius and tensor tympani muscles in loud sounds.

Functions

Protects cochlea.

Reduces sound transmission.

8. Describe the auditory pathway. List the types of deafness with a note on audiometry

Auditory pathway

Organ of Corti.

Spiral ganglion.

Cochlear nuclei.

Superior olivary nucleus.

Inferior colliculus.

Medial geniculate body.

Auditory cortex.

Types of deafness

Conductive deafness.

Sensorineural deafness.

Audiometry

Method used to assess hearing acuity.

Types

Pure tone audiometry.

Speech audiometry.

SHORT ANSWERS

9. Give the physiological basis of impedance matching

Tympanic membrane area larger than oval window.

Lever action of ossicles.

Increases pressure at oval window.

10. Functions of middle ear

Sound transmission.

Impedance matching.

Acoustic protection.

Pressure equalization.

11. Explain the mechanism and importance of acoustic reflex in middle ear

Mechanism

Loud sound causes contraction of stapedius and tensor tympani muscles.

Importance

Protects cochlea.

Reduces excessive vibration.

12. Physiological basis of Hearing impairment due to advancing age

Presbycusis occurs due to degeneration of cochlear hair cells and auditory neurons with age.

13. Name the contents and describe the functions of middle ear

Contents

- Ossicles.
- Muscles.
- Eustachian tube.

Functions

- Sound transmission.
- Impedance matching.
- Pressure equalization.

14. Draw and label the Auditory pathway

REFER DIAGRAM SECTION

15. Presbyacusis

Age related sensorineural hearing loss due to degeneration of cochlear receptors.

16. Draw and label the audiogram in conductive deafness. Super impose a normal audiogram on it.

REFER DIAGRAM SECTION

17. Describe the role of basilar membrane in frequency discrimination

- Base responds to high frequency sounds.
- Apex responds to low frequency sounds.
- Different areas resonate with different frequencies

18. Tympanic reflex

Protective reflex involving contraction of stapedius and tensor tympani muscles during loud sounds.

19. Impedance matching

Mechanism that increases sound transmission from air to cochlear fluid.

Mechanisms

- Lever action of ossicles.
- Area difference between tympanic membrane and oval window.

20. Attenuation reflex in middle ear

Reflex contraction of middle ear muscles reducing transmission of loud sounds.

21. Masking in audition

Interference of one sound with perception of another sound.

22. Draw and label : Organ of corti

REFER DIAGRAM SECTION

23. Cochlear microphonics

Electrical potentials generated by hair cells in response to sound vibrations.

24. Hearing is impaired during severe cold or sore throat. Why?

Due to blockage of Eustachian tube causing unequal pressure across tympanic membrane.

GUSTATION

SHORT ANSWERS

1. Draw a neat labelled diagram of a taste bud and describe the taste pathway

REFER DIAGRAM SECTION

Taste pathway

Facial nerve.

Glossopharyngeal nerve.

Vagus nerve.

Nucleus tractus solitarius.

Thalamus.

Gustatory cortex.

2. Draw and label : Taste pathway

REFER DIAGRAM SECTION

3. Describe the mechanism of transduction of sweet and salt sensation. Add a note on ageusia

Sweet sensation

Sweet substances bind G protein coupled receptors.

Second messenger activation.

Depolarization of taste cells.

Neurotransmitter release.

Salt sensation

Sodium enters through ion channels.

Depolarization occurs.

Neurotransmitter released.

Ageusia

Loss of taste sensation.

Causes

Nerve lesions.

Zinc deficiency.

Infections.

OLFACTION

SHORT ANSWERS

1. Draw and label olfactory mucous membrane

REFER DIAGRAM SECTION

2. Sniffing helps in the act of smelling

Sniffing increases air flow over olfactory mucosa, bringing more odoriferous substances in contact with receptors and improving smell perception.