

Bahirji Smarak Mahavidyalaya, Basmathnagar

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Swami Ramanand Teerth Marathwada University, Nanded

Faculty of Science and Technology – Four Year UG Programme (w.e.f. June 2026)

STUDY NOTES

B.Sc. First Year, Semester-I

ZOOLOGY

SZOOCT1101 : Biodiversity of Non-chordates

Periods: 30 | Credits: 02 | Marks: 50

Department of Zoology

Prepared as exam-oriented study material following the prescribed syllabus

BY

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Course Objectives and Outcomes

Course objectives

- To broadly understand biodiversity, habitat, adaptation, anatomical organization and taxonomic status of non-chordate phyla in relation to other animal taxa.
- To understand the basics of biological classification and its conceptual framework.
- To appreciate the structural and functional correlation between different non-chordate groups.

Course outcomes

- The student will be able to identify a given non-chordate up to class level.
- Ability to understand the contribution of non-chordates in the biodiversity index of any given habitat.
- Ability to understand and appreciate the ecological and economic importance of non-chordates.
- Ability to identify and describe external morphology and internal anatomical features of representative non-chordate species.

Course contents and distribution of periods

Unit	Contents	Hrs
1	1.1 Protozoa: general characters, classification, locomotory organelles and locomotion; 1.2 <i>Plasmodium vivax</i> ; 1.3 Porifera: general characters, classification; 1.4 Canal system in <i>Sycon</i> , economic importance of Porifera	7
2	2.1 Coelenterata, polymorphism in Hydrozoa; Platyhelminthes; 2.2 <i>Taenia solium</i> ; 2.3 Nematelminthes; 2.4 <i>Ascaris lumbricoides</i>	8
3	3.1 Annelida, metamerism, vermiculture and vermicomposting; 3.2 Arthropoda; 3.3 Metamorphosis in insects; 3.4 Cockroach (external morphology, digestive, respiratory, nervous systems), economic importance of insects	7
4	4.1 Mollusca, economic importance; 4.2 Echinodermata; 4.3 Star fish, larval forms in echinoderms; 4.4 Hemichordata: general characters and affinities	8
	Total	30

Text books (prescribed)

- Sedgwick, A.A. *Students Text Book of Zoology*, Vol. I, II and III. Central Book Depot, Allahabad.
- Parker, T.J. and Haswell, W.A. *Text Book of Zoology*, Macmillan Co., London.

How to use these notes

- Read the unit-wise syllabus box first, then the notes topic by topic.
- Tables summarise classification; learn the examples as they are frequently asked.
- Draw neat labelled diagrams in the examination (life cycle of *Plasmodium*, canal system of *Sycon*, *Taenia* scolex and proglottid, digestive system of cockroach, starfish aboral and oral views, larval forms). Diagrams carry good marks.
- Practise the “likely examination questions” at the end of each unit.

Contents

Unit	Topics covered
Unit 1	Introduction to Non-chordates; Protozoa (characters, classification, locomotion); Plasmodium vivax; Porifera; Canal system in Sycon; Economic importance of Porifera
Unit 2	Coelenterata; Polymorphism in Hydrozoa; Platyhelminthes; Taenia solium; Nematelminthes; Ascaris lumbricoides
Unit 3	Annelida; Metamerism; Vermiculture and vermicomposting; Arthropoda; Metamorphosis in insects; Cockroach (morphology, digestive, respiratory, nervous systems); Economic importance of insects
Unit 4	Mollusca and its economic importance; Echinodermata; Star fish; Larval forms in echinoderms; Hemichordata and its affinities
Extra	Likely examination questions (end of each unit); Quick revision table; Reference books

UNIT 1: PROTOZOA AND PORIFERA

Syllabus (7 hrs): 1.1 Protozoa – general characters, classification up to class level, locomotory organelles and locomotion; 1.2 Plasmodium vivax – structure, life cycle, pathogenicity, control; 1.3 Porifera – general characters and classification; 1.4 Canal system in Sycon, economic importance of Porifera.

Introduction to Non-chordates

The animal kingdom is divided into two broad groups: **Chordata** (animals possessing a notochord, a dorsal hollow nerve cord and pharyngeal gill slits at some stage of life) and **Non-chordata** (animals lacking these features). Non-chordates, formerly called invertebrates, make up about 95% of all known animal species. They range from microscopic single-celled protozoans to large squids and giant clams, and live in marine, freshwater, terrestrial and parasitic habitats.

Basic concepts

- **Biodiversity** – the variety of living organisms at the genetic, species and ecosystem levels in a given habitat.
- **Taxonomy** – the science of naming, describing and classifying organisms. The hierarchy is Kingdom → Phylum → Class → Order → Family → Genus → Species.
- **Grades of organisation** – cellular (Porifera), tissue (Coelenterata), organ (Platyhelminthes) and organ-system (Nemathelminthes onwards).
- **Symmetry** – asymmetrical (many sponges), radial (Coelenterata, Echinodermata adults) and bilateral (Platyhelminthes onwards).
- **Germ layers** – diploblastic (two layers: ectoderm and endoderm) and triploblastic (three layers: ectoderm, mesoderm, endoderm).
- **Coelom** – acoelomate (no body cavity), pseudocoelomate (cavity not fully lined by mesoderm) and eucoelomate (true coelom lined by mesoderm).
- **Segmentation** – body divided into repeated units (metameres), as in Annelida and Arthropoda.

1.1 Phylum Protozoa

General characters

- Microscopic, acellular (unicellular) animals; the body is a single cell performing all life functions, so the grade of organisation is protoplasmic.
- Found in water, moist soil, and as parasites or commensals in other animals.
- Body is covered by a plasma membrane (pellicle in some). Cytoplasm is differentiated into outer clear **ectoplasm** and inner granular **endoplasm**.
- Locomotion by pseudopodia, flagella or cilia; some are sessile or non-motile.
- Nutrition may be holozoic, saprozoic, holophytic (autotrophic) or parasitic.
- Respiration and excretion by diffusion through the body surface. Freshwater forms have a **contractile vacuole** for osmoregulation.
- Reproduction: asexual by binary fission, multiple fission or budding; sexual by syngamy or conjugation.
- Many form protective **cysts** to survive unfavourable conditions.
- One or more nuclei present; nuclei may be of one type or two types (macronucleus and micronucleus in ciliates).

Classification up to class level

Following the traditional classification (Honigberg et al., 1964), based mainly on locomotory organelles, Protozoa is divided into four classes:

Class	Locomotory organelle	Key characters	Examples
1. Sarcodina (Rhizopoda)	Pseudopodia (lobopodia, filopodia, rhizopodia, axopodia)	Body naked or with shell; amoeboid, no fixed shape; asexual by binary fission; mostly free-living, some parasitic.	Amoeba proteus, Entamoeba histolytica, Foraminifera, Radiolaria
2. Mastigophora (Flagellata)	One or more flagella	Body with definite shape; pellicle present; includes phytoflagellates (with chlorophyll) and zooflagellates; binary fission is longitudinal.	Euglena, Volvox, Trypanosoma, Giardia, Leishmania
3. Ciliophora (Ciliata)	Cilia throughout life	Two types of nuclei (macro and micronucleus); distinct cytostome; contractile vacuoles; transverse binary fission; sexual reproduction by conjugation.	Paramecium, Vorticella, Balantidium, Stentor
4. Sporozoa	Absent in adult (except gametes of some)	All are endoparasites; spore-forming; complex life cycle with alternation of sexual and asexual phases; no contractile vacuole.	Plasmodium, Monocystis, Eimeria, Toxoplasma

Note: Modern classification places protozoans in the Kingdom Protista (Whittaker's five-kingdom system), but the syllabus follows the traditional zoological approach of treating them as the phylum Protozoa within Kingdom Animalia.

Locomotory organelles and locomotion in Protozoa

Protozoa move by three types of locomotory organelles – pseudopodia, flagella and cilia – and by body contractions in some forms.

A. Pseudopodial (amoeboid) locomotion

Pseudopodia are temporary, finger-like or thread-like projections of cytoplasm. Four types are recognised: **lobopodia** (broad, blunt – Amoeba), **filopodia** (thin, pointed – Euglypha), **rhizopodia** or reticulopodia (branching and anastomosing – Foraminifera) and **axopodia** (stiff, supported by an axial rod of microtubules – Actinosphaerium).

Mechanism (sol-gel theory): The cytoplasm of Amoeba exists in two states – a fluid **plasmasol** (endoplasm) and a semi-solid **plasmagel** (ectoplasm). When a pseudopodium is to be formed, the plasmagel at the tip liquefies and the plasmasol streams forward. At the tip, the plasmasol flows outwards and changes into plasmagel (called the fountain zone), forming a tube. At the rear, the plasmagel converts back into plasmasol and flows forward. The animal thus glides forward. The contraction of actin–myosin filaments in the cytoplasm provides the force, and ATP supplies energy.

B. Flagellar locomotion

A flagellum is a long, whip-like cytoplasmic extension with an internal structure of **9+2 microtubules** (nine peripheral doublets and two central singlets) enclosed in a membrane. It arises from a basal body (blepharoplast). Flagellar movement is of three kinds: (i) **oar-like** (stroke in one plane and recovery stroke – Euglena), (ii) **undulating wave** (waves pass from base to tip, pushing the animal – Trypanosoma, which has an undulating membrane) and (iii) **conical or spiral** (flagellum rotates like a screw). The beat propels the organism forward by pulling or pushing it through water.

C. Ciliary locomotion

Cilia are short, numerous, hair-like processes with the same 9+2 structure, arising from basal granules (kinetosomes). In Paramecium the cilia beat in a coordinated way called **metachronal rhythm** – a wave-like sequence in which each cilium beats slightly after the one in front. Each cilium has an effective stroke (rigid, backward) and a recovery stroke (flexible, forward), so the animal swims forward while rotating along its long axis. The coordination is controlled by a **neuromotor system** (motorium and neurofibrils).

D. Other types

- **Metaboly / euglenoid movement** – wave-like contractions of the body in *Euglena*.
- **Gliding** – slow movement without visible organelles in gregarines and some sporozoans, possibly by secretion of mucilage or surface waves.

Feature	Pseudopodia	Flagella	Cilia
Number	Variable, temporary	One to few	Numerous
Length	Variable	Long	Short
Structure	Cytoplasmic projection, no axoneme (except axopodia)	9+2 axoneme	9+2 axoneme
Movement	Flowing, sol-gel change	Undulatory / whip-like	Oar-like, metachronal
Example	Amoeba	<i>Euglena</i>	Paramecium

1.2 Plasmodium vivax – the Malarial Parasite

Systematic position: Phylum Protozoa; Class Sporozoa; Order Haemosporida; Genus *Plasmodium*; Species *vivax*. It causes **benign tertian malaria** (fever recurring every 48 hours). Other human species are *P. falciparum* (malignant tertian), *P. malariae* (quartan, 72 hours) and *P. ovale*. It is a digenetic parasite, requiring two hosts: **man (intermediate host)** and the female **Anopheles mosquito (definitive host)**. Man is the host where asexual reproduction occurs (schizogony); the mosquito is where sexual reproduction occurs (sporogony).

Structure

- **Trophozoite (in RBC):** The youngest stage is the small **ring-shaped signet stage** with a central vacuole, a peripheral cytoplasm and a nucleus pushed to one side. It grows into an amoeboid trophozoite.
- **Schuffner's dots** – red granules seen in infected RBCs, which also become enlarged and pale.
- **Merozoites** – small, oval, uninucleate bodies about 1.5 µm long formed by schizogony; each has an apical complex for invasion.
- **Sporozoites** – sickle-shaped, slender, uninucleate bodies (about 12–15 µm) found in the salivary glands of mosquito; the infective stage for man.
- **Gametocytes** – round macrogametocyte (female, with eccentric nucleus and dense cytoplasm) and microgametocyte (male, with central nucleus and pale cytoplasm).
- **Ookinete, oocyst** – stages in the mosquito stomach; the oocyst contains thousands of sporozoites.
- The parasite feeds on haemoglobin by pinocytosis through the cytostome; the undigested pigment is deposited as **haemozoin** (malarial pigment).

Life cycle

The life cycle is completed in two hosts and involves three phases: schizogony, gametogony and sporogony.

I. Cycle in Man (Schizogony)

- **Infection:** An infected female *Anopheles* bites a person and injects sporozoites with saliva into the blood.
- **Pre-erythrocytic (hepatic) cycle:** Within about 30 minutes sporozoites enter liver cells (hepatocytes). They grow into cryptozoites and undergo schizogony to form cryptomerozoites. Merozoites are released after about 8 days. Some enter new liver cells to form **metacryptozoites** (exo-erythrocytic cycle). In *P. vivax* some sporozoites remain dormant as **hypnozoites**, causing relapse months later.
- **Erythrocytic cycle:** Merozoites invade red blood cells, becoming ring-shaped trophozoites → amoeboid trophozoites → schizonts. The schizont divides into 12–24 merozoites. The RBC bursts (every 48 hours), releasing merozoites, toxins and haemozoin. The merozoites invade fresh RBCs and the cycle repeats.
- **Gametocyte formation:** After several cycles some merozoites develop into male and female gametocytes inside RBCs. These cannot develop further in man and need the mosquito.

II. Cycle in Mosquito (Sporogony)

- A female *Anopheles* ingests gametocytes along with blood. In the stomach, the gametocytes are released from the RBC.
- **Gametogenesis:** The microgametocyte forms 6–8 flagellated, thread-like microgametes by exflagellation; the macrogametocyte matures into one macrogamete.
- **Fertilisation:** A microgamete fuses with a macrogamete to form a zygote, which becomes a motile **ookinete** (vermiform).
- The ookinete penetrates the stomach wall and forms a rounded **oocyst** on its outer surface. The oocyst nucleus divides repeatedly (sporogony) to produce thousands of sporozoites.
- The oocyst bursts after 10–12 days, and sporozoites migrate to the salivary glands, ready to infect another person.

Remember: Definitive host = female *Anopheles* (sexual cycle). Intermediate host = man (asexual cycle). Infective stage to man = sporozoite. Infective stage to mosquito = gametocyte. Only the female mosquito bites because she needs a blood meal for egg maturation.

Pathogenicity

- **Incubation period:** about 10–14 days between the bite and onset of symptoms.
- **Malarial paroxysm:** A cycle of three stages every 48 hours – (i) *cold stage* with shivering and chills, (ii) *hot stage* with high fever up to 40–41 °C and headache, (iii) *sweating stage* with profuse sweating and fall of temperature. It is caused by simultaneous rupture of schizonts, releasing haemozoin and toxins.
- **Anaemia** due to destruction of RBCs; **splenomegaly** (enlarged spleen) and hepatomegaly.
- **Relapse** due to hypnozoites in liver in *P. vivax* and *P. ovale* infections.
- *P. vivax* infection is rarely fatal; however, *P. falciparum* causes cerebral malaria and blackwater fever.

Diagnosis and control measures

- **Diagnosis:** Microscopic examination of Giemsa-stained thick and thin blood smears; rapid diagnostic tests (RDTs); PCR.
- **Treatment:** Chloroquine for blood stages; **primaquine** for hypnozoites (radical cure); artemisinin-based combination therapy (ACT) for resistant strains; quinine for severe cases.
- **Vector control:** Spraying insecticides (DDT, malathion, pyrethroids) in homes; use of insecticide-treated bed nets; larvicidal oils (Paris green, kerosene) on breeding water.
- **Biological control:** Larvivorous fishes such as *Gambusia* and *Poecilia* (guppy) in ponds, ducks, and bacteria like *Bacillus thuringiensis israelensis*.
- **Environmental measures:** Draining stagnant water, filling pits and ditches, cleaning water tanks and covering containers.
- **Personal protection:** Mosquito repellent, full-sleeve clothes, screens on windows, avoiding outdoor exposure at dusk and dawn.
- **Prophylaxis** with chloroquine for travellers; health education and national programmes (National Vector Borne Disease Control Programme in India).

1.3 Phylum Porifera

The name Porifera (L. *porus* = pore, *ferre* = to bear) means “pore-bearers”. Commonly called **sponges**, they were first recognised as animals by Grant (1825), who named the phylum. Sponges are the simplest multicellular animals and are placed in the sub-kingdom Parazoa since they lack true tissues and organs.

General characters

- Multicellular, mostly marine (about 150 freshwater species such as *Spongilla*), sessile, asymmetrical or radially symmetrical.
- Cellular grade of organisation; no true tissues or organs, though cells are specialised for functions.
- Body surface has numerous minute pores (**ostia**) and one or more large openings (**osculum**).

- Body wall has an outer **pinacoderm** (pinacocytes), inner **choanoderm** (choanocytes or collar cells) and a middle gelatinous **mesohyl** containing amoebocytes and skeleton.
- The body is perforated by a **canal system** through which water circulates, bringing food and oxygen and removing wastes.
- Skeleton of calcareous or siliceous **spicules** and/or protein **spongin fibres**.
- Nutrition holozoic; intracellular digestion by choanocytes and amoebocytes (filter feeders).
- No nervous system or sensory cells; no definite excretory or circulatory organs.
- Reproduction: asexual by budding, fragmentation and **gemmules** (internal buds in freshwater sponges); sexual with larval stages (amphiblastula or parenchymula). Sponges are mostly hermaphrodite.
- Excellent power of regeneration.

Classification up to class level

Class	Skeleton	Canal system	Characters	Examples
1. Calcarea (Calcispongiae)	Calcareous spicules (calcium carbonate)	Ascon, sycon, leucon	Small, marine, shallow water; spicules monaxon, triaxon or tetraxon; larva amphiblastula.	Sycon (Scypha), Leucosolenia, Clathrina, Grantia
2. Hexactinellida (Hyalospongiae)	Siliceous six-rayed (triatron) spicules	Sycon type	Glass sponges; deep-sea; cup- or vase-shaped; syncytial tissue; no pinacoderm.	Euplectella (Venus' flower basket), Hyalonema
3. Demospongiae	Siliceous spicules (not six-rayed) and/or spongin fibres	Leucon type	Largest class (about 90% of species); marine and freshwater; large, irregular, often brightly coloured.	Spongilla, Euspongia, Chalina, Cliona

Note: A fourth class, Sclerospongiae (coralline sponges), is recognised in some books; it is not part of the three-class scheme normally followed at this level.

Types of canal systems in sponges

Type	Description	Example
Ascon	Simplest; vase-shaped; ostia open directly into a large spongocoel lined by choanocytes; single osculum	Leucosolenia
Sycon	Body wall folded to form radial canals (lined with choanocytes) and incurrent canals; spongocoel lined by flat cells	Sycon
Leucon	Most complex; many flagellated chambers; extensive branching canals; reduced spongocoel; many oscula	Spongilla, Euspongia

1.4 Canal System in Sycon

Sycon (Scypha) is a marine sponge of the class Calcarea, found attached to rocks in shallow coastal waters. It has a cylindrical, vase-like body about 2–3 cm long, attached by the base, with an apical osculum surrounded by a fringe of long monaxon spicules. The canal system is of the **sycon (syconoid) type**, which is intermediate in complexity.

Path of water flow

Water from outside → Dermal ostia → Incurrent canals → Prosopyles → Radial canals (flagellated chambers) → Apopyles → Spongocoel (paragastric cavity) → Osculum → Outside.

- **Dermal ostia** – numerous minute pores on the body surface, each formed by a porocyte, through which water enters.

- **Incurrent (inhalant) canals** – blind-ended spaces lying between the radial canals, communicating with the exterior through the dermal ostia.
- **Prosopyles** – tiny pores that connect the incurrent canals with radial canals.
- **Radial canals** – finger-like, lined by flagellated choanocytes; the sites of food capture and digestion. The beating of flagella creates the water current.
- **Apopyles** – openings of the radial canals into the spongocoel.
- **Spongocoel** – central cavity lined with flat pinacocytes (not choanocytes).
- **Osculum** – the large aperture at the top through which water is expelled.

Functions of the canal system

- **Feeding** – water brings microscopic food (bacteria, plankton) which choanocytes engulf.
- **Respiration** – oxygen diffuses from water into cells; CO₂ diffuses out.
- **Excretion** – ammonia and wastes are removed by the outgoing current.
- **Reproduction** – sperm are carried out by the water and eggs are fertilised in the body; larvae are dispersed.
- **Support** – water pressure helps maintain body shape.

Economic Importance of Porifera

- **Bath sponges:** The skeleton of spongin from *Euspongia* (bath sponge) and *Hippospongia* (horse sponge) is used for bathing, cleaning, painting and polishing.
- **Medicine:** Sponges produce bioactive compounds with anti-cancer, anti-viral, anti-inflammatory and antibiotic activity (e.g., spongothymidine and spongouridine, used to develop Ara-A and Ara-C drugs).
- **Surgery:** Sponge pieces were once used to absorb blood and apply medicine.
- **Ornamental value:** The glass sponge *Euplectella* (Venus' flower basket) is a prized ornament and a traditional wedding gift in Japan.
- **Ecology:** They are good filters of water and provide shelter to crabs, shrimps and worms. They form a food source to some fishes and nudibranchs.
- **Harmful effects:** *Cliona* (boring sponge) damages oyster shells and pearl culture; some sponges foul ship hulls and clog water pipes; *Spongilla* can clog filter beds.
- **Research:** Used as models in cell aggregation, regeneration, and evolution of multicellularity studies.

Likely examination questions – Unit 1

- Describe the general characters and classification of Protozoa with examples. (5 marks)
- Describe locomotory organelles in Protozoa. (5 marks)
- Describe the life cycle of *Plasmodium vivax* in man and mosquito. (8 marks)
- Write a note on the pathogenicity and control of malaria. (4 marks)
- Describe the canal system of Sycon. (5 marks)
- Write short notes: Pseudopodia; Gemmules; Economic importance of sponges; Schizogony. (3 marks each)

UNIT 2: COELENTERATA, PLATYHELMINTHES AND NEMATHELMINTHES

Syllabus (8 hrs): 2.1 Coelenterata – general characters, classification, polymorphism in Hydrozoa; Platyhelminthes – general characters, classification; 2.2 Taenia solium – structure, life cycle, pathogenicity, control; 2.3 Nematelminthes – general characters, classification; 2.4 Ascaris lumbricoides – structure, life cycle, pathogenicity, control.

2.1 Phylum Coelenterata (Cnidaria)

The phylum was named Coelenterata by Leuckart (1847) because of the single body cavity, the coelenteron. The name Cnidaria (by Hatschek) refers to the stinging cells, **cnidoblasts**. It includes hydra, jellyfishes, sea anemones and corals.

General characters

- Aquatic, mostly marine; sessile or free-swimming; solitary or colonial.
- **Radial symmetry** (or biradial); the body is sac-like with one opening, the mouth, surrounded by tentacles.
- **Diploblastic** animals with tissue grade of organisation: outer ectoderm (epidermis), inner endoderm (gastrodermis) and an intermediate non-cellular jelly-like **mesoglea**.
- Body cavity is the **coelenteron (gastrovascular cavity)** with a single opening for both ingestion and egestion (incomplete digestive system).
- **Cnidoblasts (cnidocytes)** containing stinging organelles called nematocysts are present on tentacles; used for defence, food capture and anchorage.
- Digestion is both extracellular (in the coelenteron) and intracellular.
- Nervous system is a simple **nerve net**; no brain. Sense organs like statocysts and ocelli in medusae.
- No circulatory, respiratory or excretory organs.
- **Polymorphism**: two body forms – a sessile cylindrical **polyp** and a free-swimming umbrella-shaped **medusa**.
- Reproduction asexual by budding (polyp) and sexual by gametes (medusa); life cycle often shows **alternation of generations (metagenesis)**. Larva is planula.

Classification up to class level

Class	Characters	Examples
1. Hydrozoa	Polyp form dominant (or both forms); solitary or colonial; mesoglea acellular; gonads ectodermal; coelenteron without septa; marine and freshwater.	Hydra, Obelia, Physalia (Portuguese man-of-war), Velella, Millepora
2. Scyphozoa	True jellyfishes; medusa dominant, polyp reduced; mesoglea cellular; gonads endodermal; margin with tentacles and tentaculocysts; all marine.	Aurelia (moon jelly), Rhizostoma, Cassiopeia, Pelagia
3. Anthozoa (Actinozoa)	Only polyps, no medusa; pharynx (stomodaeum) and mesenteries (septa) present; solitary or colonial; skeleton in corals; all marine.	Metridium and Adamsia (sea anemones), Gorgonia (sea fan), Corallium (red coral), Pennatula (sea pen), Fungia

Memory tip: Hydrozoa = “hydra-like”, polyp dominant; Scyphozoa = “cup animals” (jellyfish), medusa dominant; Anthozoa = “flower animals”, only polyps.

Cnidoblasts and nematocysts

A cnidoblast is a modified interstitial cell bearing a stinging capsule (**nematocyst**) containing a coiled hollow thread and a poisonous fluid (hypnotoxin), and a trigger-like bristle called the **cnidocil**. When touched, the thread is discharged, injects poison and paralyzes prey. Hydra has four types of nematocysts: penetrants (stenoteles), volvents (desmonemes), glutinants (isorhizas) and streptolines.

Polymorphism in Hydrozoa

Polymorphism is the occurrence of two or more structurally and functionally different types of individuals (zooids) in the life cycle or in a colony of one species. In Coelenterata it is basically of two types, the polyp and the medusa; colonial hydrozoans show further specialised zooids.

1. Polyp and medusa

Feature	Polyp	Medusa
Shape	Cylindrical, tubular	Umbrella or bell-shaped
Mode of life	Sessile, attached by base	Free-swimming
Mesoglea	Thin	Thick, jelly-like
Mouth	Terminal, on the hypostome	Lower side (manubrium)
Reproduction	Asexual (budding)	Sexual (gametes)
Example	Hydra, Obelia colony	Obelia medusa, Aurelia

2. Polymorphism in Obelia (a colonial hydroid)

Obelia is a marine colonial hydroid that shows dimorphism in the polyp generation and a free medusa. The colony is a branched, plant-like structure covered with a chitinous **perisarc**; the living tissue within is the **coenosarc**. It has the following zooids:

- **Hydranth (gastrozoid/nutritive polyp)**: feeding zooid with a mouth and tentacles; ingests and digests food. Enclosed by a cup, the hydrotheca.
- **Gonangium (blastostyle/reproductive polyp)**: has no mouth or tentacles; produces medusa buds. Enclosed by gonotheca.
- **Medusa**: free-swimming, small, saucer-shaped with 8 statocysts; produces gametes which on fertilisation develop into a ciliated planula larva that settles and forms a new colony.

Thus Obelia shows **metagenesis** – alternation of the asexual polypoid generation (producing medusae by budding) with the sexual medusoid generation (producing zygote by gametes).

3. Polymorphism in Physalia (Portuguese man-of-war)

Physalia is a floating siphonophore colony with several kinds of polymorphic zooids: **pneumatophore** (gas-filled float), **gastrozooids** (feeding polyps), **dactylozooids** (long tentacle-like defensive zooids with powerful nematocysts), **gonozooids** (reproductive), and **nectophores** (swimming bells) in other siphonophores. The extreme specialisation of zooids that cannot live alone demonstrates the division of labour in a colony.

Significance of polymorphism

- Division of labour between members improves efficiency of the colony.
- Allows different modes of living – sedentary feeding polyp and dispersive medusa.
- Helps in dispersal of the species and survival in different habitats.

Phylum Platyhelminthes

The name (Gr. *platys* = flat; *helmin* = worm) refers to the flatworms. They were first recognised as a separate group by Gegenbaur (1859). They include free-living turbellarians (planaria), and parasitic flukes and tapeworms.

General characters

- Dorsoventrally flattened, leaf-like or ribbon-like, unsegmented (except in tapeworm strobilation) bodies; **bilaterally symmetrical**.
- **Triploblastic and acoelomate** – the space between the body wall and gut is filled with mesenchyme (parenchyma).

- **Organ grade** of organisation, with no true organ system for respiration and circulation.
- Digestive system incomplete (a mouth and a branched blind gut); completely absent in tapeworms.
- Excretion by **flame cells (protonephridia)**; these also osmoregulate.
- Nervous system consists of a pair of anterior cerebral ganglia and longitudinal nerve cords connected by transverse commissures (ladder-like).
- No respiratory or circulatory system; parasitic forms are largely anaerobic.
- Mostly hermaphrodite (monoecious) with complex reproductive organs; internal fertilisation.
- Life cycle of parasites is complicated, with one or more larval stages and intermediate hosts. Suckers, hooks and a thick tegument (cuticle) are adaptations for parasitism.

Classification up to class level

Class	Characters	Examples
1. Turbellaria	Mostly free-living, aquatic; body covered by ciliated epidermis; mouth ventral; rod-like rhabdites present; regeneration is high.	Planaria (Dugesia), Bipalium, Leptoplana
2. Trematoda	Parasitic flukes; leaf-like body with suckers; thick cuticle without cilia; digestive tract present; complicated life cycle with snails as intermediate hosts.	Fasciola hepatica (liver fluke), Schistosoma (blood fluke), Opisthorchis
3. Cestoda	Endoparasitic tapeworms; ribbon-like, segmented (proglottids); no digestive system; scolex with suckers and hooks; absorb nutrients via tegument.	Taenia solium, Taenia saginata, Echinococcus, Hymenolepis

2.2 Taenia solium (Pork Tapeworm)

Systematic position: Phylum Platyhelminthes; Class Cestoda; Order Cyclophyllidea; Genus *Taenia*; Species *solium*. It is an endoparasite in the small intestine of man (definitive host). The pig is the intermediate host. It is commonly called the pork tapeworm.

Structure

- **Habit and habitat:** Found attached to the intestinal wall of man. A single tapeworm may be 2–4 metres long.
- **Body parts:** The body consists of a scolex (head), neck and a strobila (chain of proglottids).
- **Scolex:** Small, pea-sized, globular; has four cup-like **suckers** and a rostellum bearing a double crown of 22–32 **hooks** (armed scolex), used for attachment.
- **Neck:** A short, narrow, unsegmented region, the zone of growth where new proglottids form continuously (strobilation).
- **Strobila:** Made of 800–1000 proglottids arranged in three zones – *immature* (near the neck; reproductive organs developing), *mature* (hermaphrodite with fully developed male and female organs) and *gravid* (terminal, filled with uterus containing eggs, whose other organs have degenerated).
- **Body wall:** Outer **tegument** with microtriches (for absorption), basement membrane, circular and longitudinal muscles.
- **Digestive system:** Absent; nutrients are absorbed directly by the tegument from the host's digested food.
- **Excretory system:** Protonephridia with flame cells that open into longitudinal excretory canals.
- **Nervous system:** A pair of ganglia in the scolex and longitudinal nerve cords.
- **Reproductive system:** Monoecious. Each mature proglottid has about 150–200 testes, vas deferens, cirrus; female organs: a three-lobed ovary, oviduct, vagina, vitelline gland, ootype with Mehlis' gland and a uterus.

Life cycle

- **Hosts:** Primary (definitive) host – man; secondary (intermediate) host – pig. Man may sometimes act as an intermediate host.
- **Gravid proglottids** detach in groups of 4–5 and pass with faeces. Each proglottid contains about 30,000–50,000 eggs. The eggs are infective immediately; each egg contains a six-hooked embryo, the **onchosphere (hexacanth embryo)**.
- The pig acquires infection by eating food or vegetation contaminated with human faeces. In the pig's stomach and intestine the egg shell is digested and the onchosphere is released.
- The onchosphere bores through the intestinal wall using its hooks and enters blood vessels, reaching the striated muscles (tongue, neck, heart, etc.).
- In muscle, it loses the hooks and develops into a bladder-like larva, **cysticercus (bladderworm)**, with an invaginated scolex, after 60–70 days. Pork with cysticerci is called “**measly pork**”.
- Man gets infected by eating raw or undercooked measly pork. In the intestine, the cysticercus evaginates its scolex, attaches itself to the mucosa by hooks and suckers and grows into an adult worm in about 2–3 months.

Cycle in short: Man (adult) → eggs in faeces → pig (onchosphere → cysticercus in muscle) → man eats measly pork → adult tapeworm.

Pathogenicity

- Infection with the adult is called **taeniasis**. Symptoms include abdominal pain, indigestion, nausea, loss of appetite, diarrhoea or constipation, weakness and weight loss (the worm absorbs nutrients).
- Infection with the larva (when man ingests eggs through contaminated food or by autoinfection) causes **cysticercosis**. Cysticerci lodge in muscles, eyes, brain and heart.
- **Neurocysticercosis** (cysts in the brain) causes epilepsy, headache and seizures; it is a leading cause of acquired epilepsy in endemic regions. Ocular cysticercosis can cause blindness.
- Toxins released by the parasite may produce allergies and anaemia.

Control and treatment

- **Cooking** pork thoroughly (above 60 °C) or freezing kills cysticerci. Meat inspection at slaughterhouses to remove infected pork.
- **Sanitation:** Proper disposal of human faeces and avoiding open defecation; pigs should be kept away from human waste and fed hygienically.
- **Personal hygiene:** Washing hands, vegetables and fruits; drinking clean water.
- **Drugs:** Praziquantel, niclosamide or albendazole for adult worms; albendazole and corticosteroids for neurocysticercosis. The scolex must be expelled to avoid regrowth.
- Health education and treating carriers.

2.3 Phylum Nemathelminthes (Aschelminthes)

The word *nema* means thread and *helminth* means worm – roundworms. They are mostly free-living in water and soil or parasitic in plants and animals. Class Nematoda is the main group; it includes more than 25,000 described species.

General characters

- Elongated, cylindrical, unsegmented, tapering at both ends (spindle-shaped); **bilaterally symmetrical**.
- **Triploblastic and pseudocoelomate** – a body cavity (pseudocoel) lies between the body wall and the gut, not lined by mesoderm.
- Body covered by a tough, non-living, flexible **cuticle**, secreted by the epidermis, which resists host digestive enzymes.
- Body wall muscles are **longitudinal only** (no circular muscles), producing a whip-like thrashing movement.

- Complete alimentary canal with mouth, muscular pharynx, intestine and anus – the first group to possess a **complete digestive system**.
- No circulatory and respiratory systems; the pseudocoelomic fluid acts as a hydrostatic skeleton and transports materials.
- Excretory system with H-shaped canal system (renette cells) or protonephridia in some.
- Nervous system: a circumenteric nerve ring with longitudinal nerve cords.
- Sexes separate (**dioecious**) with sexual dimorphism; females are larger; fertilisation internal.
- Many are important parasites of man, animals and plants.

Classification up to class level

Under the older system, Phylum Aschelminthes is divided into classes; the syllabus requires an understanding of the following major classes:

Class	Characters	Examples
1. Nematoda (Secernentea and Adenophorea)	True roundworms; free-living or parasitic; cuticle thick; excretory system present in some; separate sexes.	Ascaris, Enterobius (pinworm), Ancylostoma (hookworm), Wuchereria (filarial worm), Trichinella
2. Nematomorpha	Long, thin hairworms (horsehair worms); larvae parasitic in arthropods; adults free-living; digestive tract degenerate.	Gordius
3. Rotifera	Microscopic, with a wheel organ (corona) of cilia; freshwater; mastax (pharynx) with jaws.	Rotaria, Brachionus
4. Gastrotricha	Minute, ventral cilia, scale-covered body; marine and freshwater.	Chaetonotus

2.4 Ascaris lumbricoides (Roundworm)

Systematic position: Phylum Nematelminthes; Class Nematoda; Order Ascaroidea; Genus *Ascaris*; Species *lumbricoides*. It is a common endoparasite of the small intestine of man, particularly children, and is found worldwide. It is a **monogenetic** parasite since it completes the life cycle in one host (man).

Structure

- **Shape and size:** Elongated cylindrical worms, pointed at both ends. Female: 20–40 cm; male: 15–30 cm. Colour is pinkish-white or creamy.
- **Sexual dimorphism:** The male is smaller and has a **curved posterior end** with two **copulatory spicules** projecting from the cloaca. The female is longer and straight, with a ventral genital pore at about the anterior one-third.
- **Mouth:** Terminal, with three lips (one dorsal and two ventrolateral) bearing sensory papillae and tiny denticles.
- **Body wall:** Thick cuticle (non-cellular, with collagen), syncytial epidermis (hypodermis) forming four longitudinal cords (dorsal, ventral and two lateral – the lateral ones contain excretory canals) and a layer of longitudinal muscle cells.
- **Pseudocoel:** Fluid-filled cavity containing the gut and reproductive organs.
- **Digestive system:** Mouth → buccal cavity → muscular pharynx → intestine (a straight tube of one-cell-thick wall) → rectum → anus. Food consists of semi-digested food of the host.
- **Excretory system:** H-shaped, a pair of lateral canals joined by a transverse canal opening through an excretory pore on the ventral side behind the pharynx.
- **Nervous system:** A circumpharyngeal nerve ring with six papillae and longitudinal nerve cords.

- **Reproductive system:** *Male:* single, coiled, thread-like testis → vas deferens → seminal vesicle → ejaculatory duct → cloaca. *Female:* paired ovaries → oviducts → uteri → unite to form a short vagina → female genital pore.

Life cycle

- **Fertilisation** occurs internally in the intestine; a female can lay up to 200,000 eggs per day. The fertilised eggs have a thick, protective, mamillated shell and are passed with human faeces.
- **Development in soil:** In moist, warm soil, the zygote develops into a first stage juvenile (rhabditiform) and moults to the second stage within the egg in about 2–3 weeks. This **embryonated egg** is the infective stage.
- **Infection:** Man gets infected by swallowing embryonated eggs through contaminated vegetables, fruits, water or soiled hands.
- **Migration:** In the duodenum, the eggs hatch to release second-stage juveniles. They bore through the intestinal wall, enter blood or lymph vessels, reach the liver and then the heart and finally the **lungs** (about 4–7 days). Here they moult twice and grow (3rd and 4th stage).
- They break out of the capillaries into the alveoli, move up the bronchi and trachea (**Loeffler's syndrome** phase) to the pharynx and are swallowed again.
- In the small intestine, the final moult produces the adult; they become sexually mature in 2–3 months. The adult lives for 1–2 years.

Remember: Infective stage = embryonated egg with second stage juvenile. Host = man only (no intermediate host). Mode of infection = oral (faeco-oral route).

Pathogenicity

The disease caused is **ascariasis**.

- **Lung phase:** Migrating larvae cause pneumonitis, cough, fever, wheezing and eosinophilia (**Loeffler's syndrome**).
- **Intestinal phase:** Abdominal pain, vomiting, diarrhoea, loss of appetite and malabsorption leading to malnutrition and poor growth in children.
- Heavy infestations can cause **intestinal obstruction**, perforation or peritonitis. Worms may migrate to the bile duct, appendix or pancreatic duct, causing jaundice and pancreatitis.
- Metabolic wastes and secretions act as allergens, causing urticaria and asthma.

Control and treatment

- **Treatment:** Albendazole, mebendazole, pyrantel pamoate or piperazine citrate; periodic mass deworming in schools.
- **Sanitation:** Sanitary latrines, avoiding the use of human night-soil as manure, safe disposal of faeces.
- **Personal hygiene:** Washing hands before eating and after defecation, trimming nails, washing raw vegetables and fruits, boiling or filtering drinking water, covering food from flies.
- **Health education** in endemic communities and treating infected persons to cut the source of infection.

Differences between *Taenia solium* and *Ascaris lumbricoides*

Character	<i>Taenia solium</i>	<i>Ascaris lumbricoides</i>
Phylum / class	Platyhelminthes / Cestoda	Nemathelminthes / Nematoda
Body	Flat, segmented, ribbon-like	Round, cylindrical, unsegmented
Coelom	Acoelomate	Pseudocoelomate
Digestive system	Absent	Complete
Sexes	Hermaphrodite	Dioecious
Hosts	Man and pig	Only man
Infective stage	Cysticercus (to man); egg (for cysticercosis)	Embryonated egg

Character	Taenia solium	Ascaris lumbricoides
Disease	Taeniasis, cysticercosis	Ascariasis

Likely examination questions – Unit 2

- Give general characters and classification of Coelenterata with examples. (5 marks)
- What is polymorphism? Explain with reference to Hydrozoa. (5 marks)
- Describe the structure and life cycle of Taenia solium. (8 marks)
- Write a note on the pathogenicity and control of Ascaris. (4 marks)
- Write short notes: Nematocysts; Cysticercus; Metagenesis; Loeffler's syndrome. (3 marks each)

UNIT 3: ANNELIDA AND ARTHROPODA

Syllabus (7 hrs): 3.1 Annelida – general characters, classification, metamerism, vermiculture and vermicomposting; 3.2 Arthropoda – general characters and classification; 3.3 Metamorphosis in insects; 3.4 Cockroach – external morphology, digestive, respiratory and nervous systems; economic importance of insects.

3.1 Phylum Annelida

The name comes from Latin *annulus* = little ring, and Gr. *eidos* = form, referring to the ring-like segments of the body. The phylum includes earthworms, leeches and marine polychaetes. It was established by Lamarck (1809).

General characters

- Bilaterally symmetrical, elongated, **metamerically segmented** worms; found in marine, freshwater and terrestrial habitats; some are parasitic.
- **Triploblastic and eucoelomate** – true coelom lined by mesoderm (schizocoelous). It is the first phylum with a true coelom.
- Organ-system grade of organisation. Body wall has cuticle, epidermis, circular and longitudinal muscles and peritoneum.
- Locomotion by **setae** (chaetae) or parapodia with muscles; leeches use suckers.
- Digestive system is complete, with specialised regions (pharynx, oesophagus, crop, gizzard, intestine).
- **Closed type circulatory system** with blood vessels; blood is red due to dissolved haemoglobin (in plasma).
- Respiration through the moist skin (cutaneous) or gills (in polychaetes).
- Excretion by coiled tubular **nephridia**, one pair per segment (metanephridia).
- Nervous system consists of a dorsal cerebral ganglion (brain), circumpharyngeal connectives and a double ventral nerve cord with ganglia in each segment.
- Sexes: separate (Polychaeta) or hermaphrodite (earthworm, leech). Development is direct or with a **trochophore** larva in marine forms.

Classification up to class level

Class	Characters	Examples
1. Polychaeta	Mostly marine; well-developed head with eyes and tentacles; parapodia with many setae; sexes separate; no clitellum; trochophore larva.	Nereis (sandworm), Arenicola (lugworm), Chaetopterus, Aphrodite
2. Oligochaeta	Terrestrial or freshwater; few setae; no parapodia; no distinct head; hermaphrodite; clitellum present; direct development.	Pheretima posthuma, Lumbricus, Eisenia fetida, Tubifex
3. Hirudinea	Leeches; ectoparasites or predators; flattened body with fixed 33 segments; anterior and posterior suckers; no setae; coelom reduced; clitellum temporary.	Hirudinaria (Indian cattle leech), Hirudo medicinalis, Pontobdella
4. Archiannelida	Small, marine, primitive annelids without setae or parapodia; sometimes included with polychaetes.	Polygordius, Protodrilus

Metamerism in Annelida

Metamerism (metameric segmentation) is the division of the body along its long axis into a linear series of similar units, the **metameres or somites**, each containing a repetition of body parts like muscles, nephridia, nerves, blood vessels and gonads. Annelids are the first animals to show true metamerism, in which both the external and internal parts are segmented, separated by partitions called **septa**.

Features

- In an earthworm (*Pheretima*) the body has about 100–120 segments. External rings correspond to internal septa, the coelom is divided into compartments.
- Each segment (except the first and last) contains a set of setae, a pair of nephridia, ganglion, nerves, blood vessels and part of the alimentary canal.
- Some organs, such as reproductive organs, are restricted to some segments (segments 9–10 for the spermathecae; 14 for the female pore; 18 for male pores in *Pheretima*) – showing **heteronomous metamerism**.
- New segments are added from a growth zone just in front of the pygidium (anal segment).

Types

- **Homonomous metamerism:** all segments are similar (e.g., most of the body in earthworm and *Nereis*).
- **Heteronomous metamerism:** segments are differentiated into regions with specialised functions (e.g., head, thorax, abdomen in arthropods; anterior segments with reproductive organs in earthworm).

Significance

- Increases the efficiency of movement and allows independent movement of body parts.
- Segment's loss or damage does not stop vital functions (redundancy of organs).
- Allows regional specialisation (tagmatisation), which is the origin of body regions in arthropods.
- Facilitates burrowing by hydrostatic skeleton in coelomic compartments.
- Provides the basis for the evolution of higher animals; evidence for the annelid–arthropod relationship.

Vermiculture and Vermicomposting

Vermiculture is the scientific method of breeding and raising earthworms in controlled conditions. **Vermicomposting** is the process of converting organic waste into nutrient-rich manure (**vermicompost**) using earthworms. The final product, containing worm castings, is called **vermicast**.

Earthworm species used

- *Eisenia fetida* (red wriggler / tiger worm) – the most widely used composting worm.
- *Eudrilus eugeniae* (African night crawler).
- *Perionyx excavatus* (Indian blue worm) – common in tropical climates.
- *Lampito mauritii* – a native Indian earthworm.

Method of vermicomposting

- **Site selection:** A shaded, well-drained, cool area protected from rain, direct sunlight and predators (ants, birds, frogs).
- **Bed preparation:** A tank, pit or tray with a base layer of 3–4 cm of coarse material (broken bricks, gravel), followed by sand and a bedding layer of dry leaves, coir pith, straw or paper.
- **Feed:** Partially decomposed cow dung, kitchen waste, crop residue, vegetable waste and farm refuse. Avoid oily food, meat, citrus, and plastics.
- **Worm introduction:** About 1000–2000 worms per square metre are introduced onto the bed.
- **Maintenance:** Moisture maintained at 60–70% by sprinkling water; temperature 20–30 °C; pH around 6.5–7.5.
- **Harvest:** After 45–60 days the compost looks dark brown, soft and odourless. Watering is stopped and the compost is collected as a heap; worms migrate downwards and are separated.

Advantages of vermicompost

- Rich in nitrogen, phosphorus, potassium, micronutrients, humus, enzymes and growth hormones.
- Improves soil aeration, structure, water retention and microbial activity.
- Eco-friendly alternative to chemical fertilisers; improves yield and quality of crops.
- Efficient disposal of municipal, agricultural and household wastes.

- Provides employment and income (sale of worms and compost); worms can be used as protein feed for fish and poultry.

3.2 Phylum Arthropoda

The name is derived from Gr. *arthron* = joint and *podos* = foot, meaning animals with jointed legs. It is the largest phylum of the animal kingdom, having more than 80% of known species. It was established by Von Siebold (1848). Arthropods include crustaceans, insects, spiders, scorpions, centipedes and millipedes.

General characters

- Bilaterally symmetrical, **metamerically segmented**, with the body divided into regions (head, thorax and abdomen, or cephalothorax and abdomen).
- Triploblastic, with the true coelom reduced and replaced by a blood-filled **haemocoel** (mixocoel).
- Appendages are **paired and jointed**, modified for walking, feeding, swimming, sensation or reproduction.
- Body covered by a hard **chitinous exoskeleton** (cuticle) secreted by the epidermis; it is shed periodically by **moulting (ecdysis)** to allow growth.
- Striated muscles that are attached to the exoskeleton.
- Digestive tract is complete with foregut, midgut and hindgut; mouthparts are adapted for various diets.
- **Open circulatory system** with a dorsal tubular heart; blood (haemolymph) flows through sinuses.
- Respiration by gills (aquatic), book gills/book lungs, or **tracheae** (terrestrial insects).
- Excretion by green glands (crustaceans), **Malpighian tubules** (insects, arachnids) or coxal glands.
- Nervous system: dorsal brain, circumpharyngeal ring and a double ventral nerve cord with ganglia. Sensory organs include compound eyes, ocelli, antennae, statocysts.
- Sexes are usually separate with sexual dimorphism; internal fertilisation; development often indirect with larval stages (metamorphosis).

Classification up to class level

Class	Characters	Examples
1. Crustacea	Mostly aquatic; two pairs of antennae; head and thorax fused as cephalothorax; biramous appendages; respiration by gills; green glands for excretion.	Prawn (Palaemon), Crab (Cancer), Daphnia, Cyclops, Lobster, Barnacle
2. Insecta (Hexapoda)	Body in head, thorax and abdomen; one pair of antennae; three pairs of legs ; usually two pairs of wings; respiration by tracheae; Malpighian tubules; metamorphosis.	Cockroach (Periplaneta), Butterfly, Honey bee, Housefly, Locust, Mosquito
3. Arachnida	Cephalothorax and abdomen; no antennae; four pairs of walking legs; chelicerae and pedipalps; respiration by book lungs or tracheae.	Spider, Scorpion, Tick, Mite, King crab (Limulus – class Merostomata)
4. Chilopoda	Centipedes; flattened body; one pair of legs per segment ; poison claws (forcipules) on first trunk segment; carnivorous.	Scolopendra, Lithobius
5. Diplopoda	Millipedes; cylindrical body; two pairs of legs per apparent segment (diplosegments); herbivorous.	Julus, Spirostreptus
6. Onychophora (Prototracheata)	Connecting link between Annelida and Arthropoda; soft cuticle; unjointed legs; tracheae.	Peripatus

Note: In the older classification Limulus belongs to Merostomata. Peripatus (Onychophora) is a connecting link between Annelida (nephridia, ciliated gonoducts, soft cuticle) and Arthropoda (tracheae, haemocoel, claws).

Insects – the most successful animals

Insects number over a million described species (about 70% of all animals). Reasons for their success are: the protective chitinous exoskeleton, small size, ability to fly, efficient tracheal respiration, high reproductive rate, metamorphosis (reduces competition between young and adults), specialised mouthparts, and the ability to adapt to nearly all habitats.

3.3 Metamorphosis in Insects

Metamorphosis (Gr. *meta* = change, *morphe* = form) is the post-embryonic development in which an insect passes through a series of changes in form, structure and habit from the egg to the adult stage. It is controlled by hormones: **ecdysone** (moulting hormone from the prothoracic gland) and **juvenile hormone** (from the corpora allata). A high level of juvenile hormone keeps the larva in the larval stage; when it drops, pupation occurs.

Types of metamorphosis

1. Ametabolous (no metamorphosis)

The young resembles the adult except in size and sexual maturity. Moulting continues in adulthood. Example: silverfish (*Lepisma*), springtails.

2. Hemimetabolous (incomplete metamorphosis)

Life stages: **egg → nymph → adult** (paurometabolous). The nymph resembles the adult but lacks wings and mature reproductive organs; wing pads appear and grow with each moult. Example: cockroach, grasshopper, bugs, termites. In dragonflies and mayflies the young is aquatic (a **naiad**) and differs from the adult – termed hemimetabolous in the strict sense.

3. Holometabolous (complete metamorphosis)

Life stages: **egg → larva → pupa → adult (imago)**. The larva is very different from the adult. The pupa is a non-feeding, usually immobile stage, in which the larval organs are broken down (histolysis) and adult organs are built (histogenesis) from imaginal discs. Example: butterfly, moth, housefly, mosquito, honey bee, beetle.

Feature	Incomplete metamorphosis	Complete metamorphosis
Stages	Egg, nymph, adult (3)	Egg, larva, pupa, adult (4)
Young stage	Nymph – similar to adult	Larva – very different from adult
Pupa	Absent	Present
Wings	Wing pads outside	Wings develop inside the pupa
Feeding habits	Young and adult feed on the same food	Larva and adult feed on different food
Example	Cockroach, locust	Butterfly, housefly, mosquito

Example: Life cycle of a butterfly / silkworm moth

The female lays eggs on the host plant. The egg hatches into a caterpillar (larva) with biting mouthparts that eats voraciously and moults 4–5 times (instars). The full-grown larva spins a protective silk **cocoon** (silkworm) or forms a chrysalis (butterfly) – the pupal stage – inside which the organs are rebuilt. The adult emerges (eclosion) with wings, a coiled proboscis and compound eyes.

Significance of metamorphosis

- Avoids competition for food between young and adults.
- Larva is adapted for feeding and growth, adult for reproduction and dispersal.
- The pupa helps the insect survive adverse seasons (diapause).

3.4 Cockroach (*Periplaneta americana*)

Systematic position: Phylum Arthropoda; Class Insecta; Order Dictyoptera (Orthoptera); Genus *Periplaneta*; Species *americana*. The American cockroach is a nocturnal, omnivorous, cosmopolitan household pest found in kitchens, drains and warm places. It is a common representative insect studied in zoology.

External morphology

- **Size and colour:** About 34–53 mm long, reddish-brown, dorsoventrally flattened and shiny with a leathery appearance.
- **Body division:** The body is divided into head, thorax and abdomen; covered by hard chitinous exoskeleton with sclerites – tergum (dorsal), sternum (ventral) and pleuron (lateral) – joined by flexible arthrodial membranes.
- **Head:** Pear-shaped, hypognathous (mouthparts directed downward), has a pair of **compound eyes** (kidney-shaped), two **fenestrae** (simple eye-spots), a pair of long filamentous **antennae** (sensory), and mouthparts of the biting and chewing type.
- **Mouthparts:** *Labrum* (upper lip), a pair of *mandibles* (toothed, for cutting food), a pair of *maxillae* (with palp, galea and lacinia), *labium* (lower lip with labial palps), and a tongue-like *hypopharynx* (with salivary duct opening).
- **Thorax:** Three segments – prothorax, mesothorax and metathorax; each bears a pair of walking legs (six legs, each with coxa, trochanter, femur, tibia and tarsus with five joints, ending in claws and a pad called arolium). The meso- and metathorax bear wings.
- **Wings:** Two pairs. The forewings (**tegmina**) are thick, leathery and protective; the hindwings are membranous and used for flight. Females have shorter wings than males in some species.
- **Abdomen:** Ten segments. Male: a pair of anal styles on the 9th sternum and a pair of anal cerci on the 10th; female: only cerci, and the 7th sternum is boat-shaped, forming the brood pouch (genital pouch). Spiracles (10 pairs) are present on the lateral side of the thorax (2 pairs) and abdomen (8 pairs).

Digestive system

The alimentary canal runs from mouth to anus and is divided into foregut (stomodaeum), midgut (mesenteron) and hindgut (proctodaeum). The first and last regions are lined by chitin; the midgut is endodermal.

- **Foregut:** Mouth → pharynx → oesophagus → **crop** (a large thin-walled storage organ) → **gizzard** (proventriculus), which has six chitinous teeth for grinding and a set of bristles (pulvilli) for filtering food.
- **Midgut:** Short tube bearing 6–8 finger-like **hepatic caecae** (gastric caecae) at its anterior end, which secrete digestive enzymes and absorb nutrients. The stomodaeal valve prevents backflow of food.
- **Hindgut:** Ileum, colon and rectum. At the junction of midgut and hindgut, there are 60–150 thin, long, yellowish **Malpighian tubules** that excrete uric acid. The rectum has six rectal papillae that absorb water.
- **Salivary glands:** A pair of salivary glands with a salivary receptacle near the crop; the secretion contains amylase which begins the digestion of starch.

Physiology: Food is crushed by mandibles, mixed with saliva and swallowed. Starch digestion begins in the crop, grinding in the gizzard, and digestion/absorption of proteins, fats and carbohydrates occurs in the midgut by enzymes from hepatic caecae. The undigested wastes are egested through the anus. Cockroaches also depend on symbiotic bacteria and protozoa in the gut for cellulose digestion.

Respiratory system

Respiration is by an extensive network of air tubes, the **tracheal system**, which delivers oxygen directly to tissues, so blood does not carry oxygen.

- **Spiracles:** 10 pairs of openings (2 thoracic and 8 abdominal) provided with valves and filter hairs for controlling air entry and exit, and preventing water loss.

- **Tracheae:** Spiracles open into longitudinal and transverse tracheal tubes lined with a chitinous spiral thickening (taenidia), which prevent collapse.
- **Tracheoles:** Branching of tracheae into very fine fluid-filled tubules that reach each cell and are the site of gas exchange.
- **Mechanism:** Air enters and leaves the spiracles by the contraction and relaxation of abdominal muscles (ventilation). The thoracic spiracles open during inspiration, and abdominal spiracles open during expiration. Diffusion at the tracheoles transfers oxygen to cells.

Nervous system

The nervous system consists of the central, peripheral and sympathetic (visceral) nervous systems.

- **Central nervous system:** A **supra-oesophageal ganglion (brain)** lying in the head above the oesophagus; it is connected by a pair of **circum-oesophageal connectives** to the **sub-oesophageal ganglion**. From here a double **ventral nerve cord** extends backward with 9 ganglia – three in the thorax and six in the abdomen. The ganglia are connected by paired longitudinal connectives.
- **Brain:** Has three regions – protocerebrum (optic lobes, eyes), deutocerebrum (antennae) and tritocerebrum (labrum, gut).
- **Peripheral nervous system:** Nerves arising from the ganglia innervate the muscles, legs, wings, antennae and other organs.
- **Sympathetic nervous system:** Includes the frontal ganglion, hypocerebral ganglion and visceral ganglia, which control the foregut, heart and endocrine glands.
- **Sense organs:** Compound eyes (mosaic vision), antennae (smell and touch), maxillary and labial palps (taste), anal cerci (sensitive to air currents and vibrations), and tympanal organs.

Economic Importance of Insects

A. Beneficial insects

- **Honey and wax:** The honey bee (*Apis*) produces honey and beeswax (apiculture).
- **Silk:** The silkworm (*Bombyx mori*) yields mulberry silk; tasar, eri and muga silks come from wild silkworms.
- **Lac:** *Laccifer lacca* produces lac used for varnish, shellac and bangles.
- **Pollination:** Bees, butterflies, moths and beetles pollinate crops and wild plants, increasing yield.
- **Biological control:** Predators and parasitoids such as ladybird beetles, praying mantis, *Trichogramma* wasps and dragonflies control crop pests and mosquitoes.
- **Scavengers:** Dung beetles, ants and blowfly larvae recycle organic waste and dead matter.
- **Medicine and food:** Cantharidin from blister beetles; maggot therapy to clean wounds; edible insects as protein source; *Drosophila* as a model organism in genetics.
- **Dyes:** Cochineal insects provide a red dye (carmine).

B. Harmful insects

- **Agricultural pests:** Locusts, grasshoppers, aphids, stem borers, bollworms and termites damage crops; weevils and beetles destroy stored grains.
- **Vectors of disease:** *Anopheles* (malaria), *Aedes* (dengue, chikungunya), *Culex* (filariasis), housefly (cholera, typhoid), tsetse fly (sleeping sickness), sand fly (kala-azar), rat flea (plague), body louse (typhus).
- **Household pests:** Cockroaches (contaminate food), termites (damage wood), clothes moth and silverfish (damage fabrics and books), bed bugs.
- **Parasites:** Lice, fleas and bot flies on humans and domestic animals.

Likely examination questions – Unit 3

- Describe the general characters and classification of Arthropoda. (6 marks)
- What is metamerism? Explain its significance in Annelida. (5 marks)

- Describe vermiculture and vermicomposting. (5 marks)
- Describe the types of metamorphosis in insects. (5 marks)
- Describe the digestive and respiratory systems of cockroach. (8 marks)
- Describe the nervous system of cockroach. (5 marks)
- Write a note on economic importance of insects. (5 marks)

UNIT 4: MOLLUSCA, ECHINODERMATA AND HEMICHORDATA

Syllabus (8 hrs): 4.1 Mollusca – general characters, classification, economic importance; 4.2 Echinodermata – general characters, classification; 4.3 Star fish – external morphology, larval forms in Echinoderms; 4.4 Hemichordata – general characters and affinities.

4.1 Phylum Mollusca

The name is derived from Latin *mollis* = soft, since the body is soft and unsegmented. It is the second-largest phylum after Arthropoda with about 85,000–100,000 living species. The study of molluscs is called **Malacology**; the study of shells is **Conchology**. The phylum was named by Cuvier.

General characters

- Found in marine, freshwater and terrestrial habitats; free-living, sedentary or parasitic.
- Soft-bodied, **unsegmented** with bilateral symmetry (asymmetrical in gastropods due to torsion).
- Triploblastic and **eucoelomate**, but the coelom is reduced to the pericardial cavity and the cavity around the gonads and kidneys.
- The body consists of a head, a muscular **foot** (for locomotion), a **visceral mass** (containing organs) and a fleshy **mantle** (pallium) which secretes the shell.
- Usually has a calcareous **shell** made of one, two or eight pieces; reduced or absent in slugs, octopus.
- Mantle cavity houses the gills (**ctenidia**) for respiration, anus, nephridiopores and genital apertures.
- Digestive tract is complete; the mouth has a rasping organ, the **radula** (a ribbon with chitinous teeth), except in bivalves. A digestive gland (“liver”) is present.
- **Open circulatory system** (except cephalopods, which have a closed system); heart with auricles and ventricle; respiratory pigment haemocyanin (blue blood).
- Excretion through a pair of **metanephridia (kidneys, organ of Bojanus)**.
- Nervous system with paired ganglia (cerebral, pedal, pleural and visceral) joined by connectives; sense organs include statocysts, osphradia, eyes and tentacles.
- Sexes are separate (or hermaphrodite as in garden snail); development through the **trochophore** and **veliger** larvae; glochidium larva in freshwater mussels.

Classification up to class level

Class	Characters	Examples
1. Monoplacophora	Single, shield-like shell; bilateral symmetry; serially repeated gills and muscles; deep-sea “living fossils”.	Neopilina
2. Amphineura (Polyplacophora)	Marine; elongated body with a shell of eight overlapping plates; flattened foot; no head tentacles or eyes. Called chitons.	Chiton
3. Gastropoda	Largest class; spirally coiled shell (univalve); distinct head with tentacles and eyes; torsion during development; creeping foot; radula present.	Pila (apple snail), Helix, Limax (slug), Aplysia (sea hare), Patella (limpet)
4. Scaphopoda	Tusk shell; tubular, open at both ends; no head, eyes or gills; foot is conical.	Dentalium
5. Pelecypoda (Bivalvia/Lamellibranchia)	Body laterally compressed; bivalve shell ; hatchet-shaped foot; no head and radula; gills are plate-like (lamellibranch); filter feeders.	Unio (freshwater mussel), Mytilus, Ostrea (oyster), Pinctada (pearl oyster), Teredo (shipworm)
6. Cephalopoda	Highly developed marine molluscs; head with tentacles or arms bearing suckers; foot modified to funnel (siphon); shell internal or absent; closed circulatory system; large eyes and brain; ink gland.	Sepia (cuttlefish), Loligo (squid), Octopus, Nautilus

Note: **Torsion** is the 180° twisting of the visceral mass relative to the head and foot during development of gastropod larvae. It brings the mantle cavity, anus and gills to the front. **Coiling** is a separate spiral winding of the shell.

Economic Importance of Mollusca

A. Beneficial aspects

- **Food:** Oysters, mussels, clams, squids, octopus, cuttlefish, snails and scallops are eaten worldwide and are a source of protein.
- **Pearls:** Pearls are produced by the pearl oyster (*Pinctada vulgaris*, *Pinctada margaritifera*) and some freshwater mussels (*Lamellidens*, *Unio*). Pearl culture is practised in India (Gulf of Mannar, Kutch).
- **Mother-of-pearl:** The nacreous inner layer of shells of *Pinctada*, *Turbo* and *Haliotis* is used to make buttons, jewellery, inlay work and ornaments.
- **Shell uses:** Shells of oysters and snails are used to prepare lime, cement, poultry grit and decorative items; cowries (*Cypraea*) once served as currency.
- **Ink and dye:** Sepia ink from cuttlefish is used as a pigment; Tyrian purple dye from *Murex*.
- **Medicine and research:** Giant axons of squid (*Loligo*) are used in neurophysiological research; extracts from molluscs have anti-cancer and antibiotic properties; *Conus* venom is used to develop painkillers (ziconotide).
- **Ecological role:** Bivalves are natural water filters; molluscs serve as food for fish, birds and other animals; fossil shells help in determining the age of rocks.

B. Harmful aspects

- **Intermediate hosts** of parasites: freshwater snails (*Lymnaea* for liver fluke *Fasciola*; *Planorbis* and *Bulinus* for *Schistosoma*).
- **Crop pests:** Land snails and slugs (*Achatina fulica* – giant African snail, *Limax*) damage crops, gardens and nurseries.
- **Wood borers:** The shipworm (*Teredo navalis*) bores into wooden ships, jetties and piers.
- Oyster beds are damaged by predatory gastropods such as *Murex* and *Urosalpinx*.
- Poisonous cone snails (*Conus*) can be fatal to humans; shellfish poisoning can result from eating contaminated bivalves.

4.2 Phylum Echinodermata

The name comes from Gr. *echinos* = spiny, *derma* = skin, i.e., “spiny-skinned” animals. They are exclusively marine and are found from the intertidal zone to the deep sea. Their larva is bilaterally symmetrical, but the adult is radially symmetrical (usually pentamerous). This phylum includes starfish, brittle stars, sea urchins, sea cucumbers and sea lilies. The group is placed with Chordates in the Deuterostomia based on embryonic development.

General characters

- Exclusively marine; free-moving or sessile; solitary.
- **Adults are pentamerous (five-part) radially symmetrical;** larvae are bilateral.
- Triploblastic, **enterocoelous coelom;** organ-system grade of organisation.
- The body wall has a thin epidermis, a dermis with calcareous **ossicles** forming an endoskeleton, often with spines, and **pedicellariae**.
- Unique **water vascular system** (ambulacral system) with tube feet (podia) for locomotion, feeding and respiration.
- Digestive system is usually complete (anus absent in brittle stars); mouth is oral (ventral), anus aboral (dorsal).

- Circulatory (haemal) system is poorly developed with no heart; respiration by dermal branchiae (papulae), tube feet, and respiratory trees (holothurians).
- No excretory organs; wastes are removed by amoebocytes (coelomocytes).
- Nervous system is primitive, with a circumoral nerve ring and radial nerves; no brain.
- Sexes separate (**dioecious**); fertilisation external; development indirect with free-swimming larva. Show high power of **regeneration** and **autotomy**.

Classification up to class level

Class	Characters	Examples
1. Asteroidea	Star-shaped body with 5 arms, which merge with the central disc; tube feet with suckers in ambulacral grooves; pedicellariae present.	Asterias (starfish), Pentaceros, Astropecten
2. Ophiuroidea	Brittle stars; long, thin, flexible arms sharply marked off from the disc; no anus; no pedicellariae; tube feet without suckers.	Ophiura, Ophiothrix, Amphiura
3. Echinoidea	Sea urchins; globular or flat (sand dollar); skeleton forms a rigid test; spines movable; Aristotle's lantern for feeding.	Echinus, Cidaris, Echinocardium, Clypeaster
4. Holothuroidea	Sea cucumbers; elongated, cucumber-like; leathery body with microscopic ossicles; tentacles around the mouth; respiratory tree.	Holothuria, Cucumaria, Thyone
5. Crinoidea	Sea lilies and feather stars; attached by a stalk or free; branching arms with pinnules; oral surface upward; primitive and oldest echinoderms.	Antedon (feather star), Metacrinus

4.3 Star Fish (Asterias) – External Morphology

Systematic position: Phylum Echinodermata; Class Asteroidea; Genus *Asterias*. Starfishes are marine, bottom-dwelling, carnivorous animals that feed on oysters, clams and snails. They are found on rocky shores and sandy sea beds.

External morphology

- **Shape and size:** A flattened, star-shaped body with a central disc and five tapering arms (rays), 5–15 cm across; colour is orange, red or brown, which provides camouflage.
- **Oral surface (ventral):** The surface that is in contact with the substratum. Includes: **mouth** in the centre of the central disc, surrounded by a soft peristome; five **ambulacral grooves** run from the mouth along the undersurface of each arm. Each groove contains two or four rows of **tube feet** (podia) with terminal suckers, protected by movable spines. At the tip of each arm is a small tentacle with a red eyespot (optic cushion).
- **Aboral surface (dorsal):** Upper side, rough due to short spines of the endoskeleton. It bears: the **anus** (a small central pore); the **madreporite** (a calcareous, sieve-like plate located between two arms, which opens into the water vascular system); numerous **papulae (dermal branchiae)** – thin-walled projections of the coelom for respiration and excretion; **pedicellariae** – tiny pincer-like structures that keep the body clean and protect papulae.
- **Spines:** Short calcareous spines are scattered over the body. Along the ambulacral groove the spines are specifically named adambulacral spines.
- **Body wall:** Epidermis (ciliated), dermis (connective tissue with ossicles), muscle layers and coelomic epithelium.

Locomotion and water vascular system (in brief)

Sea water enters through the madreporite → stone canal → ring canal around the mouth → five radial canals (one in each arm) → lateral canals → tube feet (ampullae and podia). Contractions of the ampulla force water into the podium, extending it; the sucker adheres to the surface; the muscles of the podium then shorten it,

pulling the animal forward. The tube feet move in coordinated waves. The system is used for locomotion, food capture (opening bivalve shells), respiration and sensory perception.

Feeding

The starfish clamps its arms onto a bivalve shell and pulls the valves apart by the tube feet. It everts its cardiac stomach through the mouth and into the prey, digesting it externally. The partly digested food is drawn back into the body, where digestion is completed in the pyloric stomach and pyloric caeca.

Larval Forms in Echinoderms

Echinoderms develop indirectly, passing through a free-swimming bilaterally symmetrical larval stage that undergoes metamorphosis to become the radial adult. The larvae show the relationship of echinoderms to chordates. Each class has its characteristic larva.

Larva	Class	Features
Bipinnaria	Asteroidea (starfish)	The first larva; bilaterally symmetrical, with ciliated bands forming looped arms; no brachia; free-swimming and feeding.
Brachiolaria	Asteroidea	The later stage of bipinnaria; develops three short arms (brachiolar arms) with adhesive tips and a sucker at the anterior end for fixation, then settles and metamorphoses.
Ophiopluteus	Ophiuroidea	Has long slender arms supported by calcareous rods; pluteus-like larva with 4 pairs of arms.
Echinopluteus	Echinoidea	Easel-like larva with six or more long arms supported by skeletal rods, covered with ciliated bands.
Auricularia	Holothuroidea	Bilaterally symmetrical larva; ciliated bands form a continuous loop; the pupa-like form is called doliolaria.
Doliolaria	Holothuroidea, Crinoidea	Barrel-shaped larva with 3–5 transverse ciliated bands; non-feeding; develops from auricularia and settles.

Significance of larvae

- The bilateral symmetry of the larva shows that echinoderms evolved from bilaterally symmetrical ancestors.
- The larva of Echinodermata (e.g., Auricularia) resembles the **tornaria larva** of Hemichordata – supporting a close evolutionary relationship between echinoderms and chordates.
- The larval stage helps in dispersal of the species.

4.4 Phylum Hemichordata

Hemichordata (Gr. *hemi* = half; *chorda* = cord) were once classified as a subphylum of Chordata by Bateson (1885), but are now placed as a separate phylum. They are marine, worm-like animals living in burrows or tubes in sand and mud. The best-known member is *Balanoglossus* (“acorn worm” or tongue worm). The other class is Pterobranchia (e.g., *Rhabdopleura*, *Cephalodiscus*).

General characters

- Marine, soft-bodied, worm-like, bilaterally symmetrical, solitary (Enteropneusta) or colonial (Pterobranchia).
- Triploblastic, **enterocoelous**, coelomate animals.
- The body is divided into three regions: an anterior conical **proboscis**, a short collar, and a long **trunk**, each with its own coelomic cavity.
- Body wall is ciliated and glandular. Burrowing is done by the proboscis.
- **Notochord-like structure (stomochord)**: a short, hollow, forward projection of the buccal cavity into the proboscis, once thought to be a notochord.

- **Pharyngeal gill slits** present in the trunk, opening to the exterior through gill pores; used for respiration.
- **Dorsal and ventral nerve cords**; the dorsal cord in the collar region is hollow (collar cord).
- Open circulatory system with a heart vesicle and a central sinus; blood is colourless.
- Excretion through the proboscis gland (glomerulus).
- Sexes separate; development is direct or through a **tornaria larva**, which resembles the bipinnaria of echinoderms.

Affinities of Hemichordata

Hemichordates show mixed characters of Chordata, Echinodermata and Non-chordates, so they are considered a link between these groups.

A. Chordate affinities

- **Pharyngeal gill slits** are present, as in chordates.
- **Stomochord** was formerly considered homologous to the notochord (though now regarded as different).
- A **dorsal hollow nerve cord** (in the collar region) is present.
- Dorsal heart, a ventral blood flow pattern (anterior flow in the dorsal vessel is opposite to that in annelids).
- Possibly a post-anal tail in some forms; endostyle-like structure.

B. Non-chordate affinities

- Notochord is absent in reality; the stomochord is an outgrowth of the gut.
- A solid ventral nerve cord, as in non-chordates.
- An open circulatory system, ciliated epidermis and the absence of a post-anal tail.

C. Affinities with Echinodermata

- Both are deuterostomes with enterocoelous coelom formed from the archenteron.
- Radial cleavage and the blastopore becomes the anus.
- The **tornaria larva** of *Balanoglossus* closely resembles the **bipinnaria/auricularia larva** of echinoderms (dipleurula type) – with the same ciliated bands and a similar structure. Also similar in the biochemical level – creatine phosphate in both groups.

D. Affinities with Annelida

- Burrowing, worm-like body with ciliated epidermis; larva (tornaria) resembles the trochophore in the apical tuft and ciliary bands.
- A ventral nerve cord and a dorsal blood vessel.

Conclusion: Hemichordata is a distinct phylum showing a mosaic of characters. Based on gill slits, dorsal nerve cord and larval resemblance to echinoderms, it is considered an evolutionary link between non-chordates (Echinodermata) and chordates. Tornaria larva evidence shows that chordates and echinoderms probably shared a common deuterostome ancestor.

Likely examination questions – Unit 4

- Give general characters and classification of Mollusca up to class level. (6 marks)
- Write an account of economic importance of Mollusca. (5 marks)
- Describe the external morphology of starfish. (5 marks)
- Describe larval forms in Echinodermata. (5 marks)
- Discuss the affinities of Hemichordata. (5 marks)
- Write short notes: Radula; Torsion; Water vascular system; Tornaria larva; Pearl formation. (3 marks each)

Quick Revision: Important Points

Topic	Key points to remember
Protozoa classes	Sarcodina (pseudopodia), Mastigophora (flagella), Ciliophora (cilia), Sporozoa (no locomotory organelle)
Plasmodium vivax	Man – intermediate host; female Anopheles – definitive host; infective stage – sporozoite; paroxysm every 48 hours; hypnozoites cause relapse
Porifera	Classes: Calcarea, Hexactinellida, Demospongiae; canal types: ascon, sycon, leucon; collar cells = choanocytes
Coelenterata	Diploblastic; cnidoblasts; polyp and medusa; classes: Hydrozoa, Scyphozoa, Anthozoa
Platyhelminthes	Acoelomate, flame cells; classes: Turbellaria, Trematoda, Cestoda; Taenia – cysticercus in pig muscle
Nemathelminthes	Pseudocoelomate; complete gut; dioecious; Ascaris infective stage – embryonated egg
Annelida	Metamerism, closed circulation, nephridia; classes: Polychaeta, Oligochaeta, Hirudinea
Arthropoda	Jointed legs, chitinous exoskeleton, haemocoel; classes: Crustacea, Insecta, Arachnida, Chilopoda, Diplopoda
Metamorphosis	Ametabolous, hemimetabolous (nymph), holometabolous (larva, pupa); hormones – ecdysone and juvenile hormone
Cockroach	10 pairs of spiracles; gizzard with 6 teeth; 6–8 hepatic caecae; Malpighian tubules; 9 ventral ganglia
Mollusca	Mantle, foot, radula, shell; classes: Monoplacophora, Amphineura, Gastropoda, Scaphopoda, Pelecypoda, Cephalopoda
Echinodermata	Pentamerous radial symmetry, water vascular system, enterocoelic coelom; classes: Asteroidea, Ophiuroidea, Echinoidea, Holothuroidea, Crinoidea
Hemichordata	Proboscis–collar–trunk; gill slits; stomochord; tornaria larva; link between non-chordates and chordates

Reference books

- Sedgwick, A.A. *Students Text Book of Zoology*, Vol. I, II and III. Central Book Depot, Allahabad.
- Parker, T.J. and Haswell, W.A. *Text Book of Zoology*, Macmillan Co., London.
- Supplementary reading: Kotpal, R.L. *Modern Text Book of Zoology – Invertebrates*, Rastogi Publications; Jordan, E.L. and Verma, P.S. *Invertebrate Zoology*, S. Chand.

Note to students: These notes are a study aid prepared from the prescribed syllabus. Always refer to the prescribed textbooks and your teachers' lectures, and draw diagrams from them for the examination.