Chapter 3: Plant Kingdom

Exercises — Exercises

Q1 What is the basis of classification of algae?

SOLUTION

Algae are classified primarily on the basis of the following criteria:

1. Type of pigments present: Chlorophyceae (green algae) contain chlorophyll a and b; Phaeophyceae (brown algae) contain chlorophyll a, c, carotenoids and fucoxanthin (a xanthophyll); Rhodophyceae (red algae) contain chlorophyll a, d and phycoerythrin.
2. Nature of stored food: Green algae store starch; brown algae store laminarin or mannitol; red algae store floridean starch (similar to amylopectin and glycogen).
3. Cell wall composition: Green algae have a cellulose cell wall; brown algae have cellulose covered with algin; red algae have cellulose, pectin and polysulphate esters.
4. Flagellar number, position and type of insertion: Green algae have 2-8 equal flagella with apical insertion; brown algae have 2 unequal flagella with lateral insertion; red algae are non-motile (flagella absent).
5. Habitat: Though most algae are aquatic, the three classes differ in the proportion of freshwater vs marine forms.

Answer: Algae are classified into Chlorophyceae, Phaeophyceae and Rhodophyceae based on the type of photosynthetic pigments, nature of stored food, cell wall composition, and flagellar number and position.

Q2 When and where does reduction division take place in the life cycle of a liverwort, a moss, a fern, a gymnosperm and an angiosperm?

SOLUTION

Reduction division (meiosis) produces haploid spores or gametes from diploid cells. The timing and location differ across plant groups:

Liverwort (e.g., Marchantia):
Meiosis occurs in the capsule of the sporophyte. Certain cells (spore mother cells) in the capsule undergo meiosis to produce haploid spores.

Moss (e.g., Funaria):

Meiosis occurs in the capsule of the sporophyte (which is differentiated into foot, seta and capsule). Spore mother cells within the capsule undergo meiosis to form haploid spores.

Fern (pteridophyte, e.g., Dryopteris):
Meiosis occurs in the sporangia borne on the sporophylls (leaves) of the sporophyte. Spore mother cells in the sporangia divide meiotically to produce haploid spores.

Gymnosperm (e.g., Pinus):
Meiosis occurs at two locations — (i) in microsporangia on the male cones, where microspore mother cells divide meiotically to form microspores (pollen grains); and (ii) in megasporangia (ovules) on the female cones, where the megaspore mother cell divides meiotically to produce four megaspores.

Angiosperm (flowering plants):
Meiosis occurs in two locations — (i) in the anthers, where pollen mother cells undergo meiosis to form microspores (pollen grains); and (ii) in the ovule, where the megaspore mother cell undergoes meiosis to form megaspores (one of which develops into the embryo sac).

Answer: In liverworts and mosses, meiosis occurs in the capsule of the sporophyte. In ferns, it occurs in sporangia on sporophylls. In gymnosperms and angiosperms, meiosis occurs in both microsporangia (forming pollen) and megasporangia (forming megaspores in ovules).

Q3 Name three groups of plants that bear archegonia. Briefly describe the life cycle of any one of them.

SOLUTION

Three groups of plants that bear archegonia (flask-shaped female sex organs):
1. Bryophytes (liverworts and mosses)
2. Pteridophytes (ferns and horsetails)
3. Gymnosperms

Life cycle of a moss (e.g., Funaria):

The dominant generation is the gametophyte (haploid, n). It has two stages:
(a) Protonema stage: A haploid spore germinates to form a creeping, green, branched, filamentous protonema.
(b) Leafy stage: A lateral bud on the protonema grows into an upright, leafy shoot

bearing spirally arranged leaves and attached to soil by multicellular branched rhizoids. This leafy shoot bears the sex organs.

Sexual reproduction:
The male sex organs (antheridia) and female sex organs (archegonia) are produced at the apex of the leafy shoots — on the same or different plants.
Antheridia produce biflagellate antherozoids (male gametes).
Archegonia are flask-shaped and each contains a single egg.
Water is essential for antherozoids to swim to the archegonium. An antherozoid fuses with the egg to form a diploid (2n) zygote.

Sporophyte generation:
The zygote does not undergo immediate meiosis. It divides mitotically and develops into a sporophyte differentiated into foot, seta and capsule.
The sporophyte is not free-living; it remains attached to and dependent on the gametophyte for nutrition.
Cells (spore mother cells) in the capsule undergo meiosis to produce haploid spores.
Spores are dispersed and germinate to produce new protonema, completing the life cycle.

This constitutes an alternation of generations: haploid gametophyte alternates with diploid sporophyte, with the gametophyte being dominant.

Answer: Bryophytes, pteridophytes and gymnosperms bear archegonia. In mosses, the dominant haploid gametophyte produces antheridia and archegonia; fertilisation forms a diploid sporophyte (foot, seta, capsule) that undergoes meiosis in the capsule to form spores, which germinate into new gametophytes.

Q4 Mention the ploidy of the following: protonemal cell of a moss; primary endosperm nucleus in dicot, leaf cell of a moss; prothallus cell of a fern; gemma cell in Marchantia; meristem cell of monocot, ovum of a liverwort, and zygote of a fern.

SOLUTION

1. Protonemal cell of a moss: Haploid (n) — the protonema is part of the gametophyte generation.
2. Primary endosperm nucleus in dicot: Triploid (3n) — formed by fusion of one male gamete (n) with two polar nuclei (n + n), giving 3n.
3. Leaf cell of a moss: Haploid (n) — the leafy shoot is part of the gametophyte;

all its cells are haploid.

4. Prothallus cell of a fern: Haploid (n) — the prothallus is the gametophyte of pteridophytes.

5. Gemma cell in Marchantia: Haploid (n) — gemmae are produced by the gametophyte and are thus haploid.

6. Meristem cell of monocot: Diploid (2n) — the plant body of angiosperms (sporophyte) is diploid.

7. Ovum of a liverwort: Haploid (n) — the egg (ovum) is produced by the gametophyte and is a haploid gamete.

8. Zygote of a fern: Diploid (2n) — formed by fusion of a haploid male gamete (n) and a haploid egg (n).

Answer: Protonemal cell (n); primary endosperm nucleus (3n); leaf cell of moss (n); prothallus cell (n); gemma cell in Marchantia (n); meristem cell of monocot (2n); ovum of liverwort (n); zygote of fern (2n).

Q5 Write a note on economic importance of algae and gymnosperms.

SOLUTION

Economic importance of Algae:

1. Food: Several marine algae are used as food — Porphyra, Laminaria and Sargassum are among ~70 species of marine algae consumed by humans, especially in East Asian countries. Chlorella, a unicellular protein-rich alga, is used as a food supplement even by space travellers.

2. Commercial products: Marine brown and red algae produce hydrocolloids — algin (from brown algae) and carrageen (from red algae) — used in industries as stabilisers and emulsifiers.

3. Agar: Obtained from Gelidium and Gracilaria; used to grow microorganisms in laboratories and in preparation of ice-creams, jellies and cosmetics.

4. Oxygen production and CO_2 fixation: At least half of the total CO_2 fixation on Earth is carried out by algae. They increase dissolved oxygen in aquatic environments.

5. Primary producers: Algae form the base of aquatic food chains, serving as the primary producers of energy-rich compounds for all aquatic animals.

Economic importance of Gymnosperms:

1. Timber: Conifers like Pinus, Cedrus and Abies are major sources of soft wood used in construction, furniture and paper pulp industries.

2. Resins and turpentine: Pinus and related conifers yield resins used in paints, varnishes and adhesives; turpentine is a distillate used as solvent.
3. Medicines: Several gymnosperms have medicinal value, e.g., Taxol (from Taxus) is an anti-cancer drug.
4. Ornamental use: Cycas, Araucaria and various conifers are popular ornamental plants in gardens and parks.
5. Food: Seeds of Cycas and Pinus are edible. Cycas seeds yield sago starch.
6. Nitrogen fixation: Coralloid roots of Cycas harbour nitrogen-fixing cyanobacteria, enriching soil fertility.

Answer: Algae are economically important as food (Porphyra, Chlorella), commercial agar (Gelidium, Gracilaria), algin and carrageen, and as oxygen producers/primary producers. Gymnosperms provide timber (Pinus, Cedrus), resins, turpentine, anti-cancer taxol (Taxus), and ornamental plants (Cycas).

Q6 Both gymnosperms and angiosperms bear seeds, then why are they classified separately?

SOLUTION

Although both gymnosperms and angiosperms produce seeds, they differ in several fundamental characteristics that justify placing them in separate groups:

1. Enclosure of ovules/seeds:
Gymnosperms (gymnos = naked, sperma = seed): Ovules are not enclosed by any ovary wall; they are borne naked on the surface of megasporophylls. The seeds that develop are thus naked (uncovered).
Angiosperms: Ovules are enclosed within an ovary. After fertilisation, the ovary develops into a fruit, and seeds are enclosed within the fruit.

2. Flowers:
Gymnosperms do not produce true flowers. Microsporophylls and megasporophylls are arranged in cones (strobili).
Angiosperms produce flowers — specialised reproductive structures in which pollen grains and ovules develop.

3. Double fertilisation and endosperm:
Gymnosperms undergo simple fertilisation. There is no double fertilisation and the endosperm (nutritive tissue) is haploid, formed before fertilisation.
Angiosperms undergo double fertilisation: one male gamete fuses with egg

(forming diploid zygote) and another fuses with two polar nuclei (forming triploid primary endosperm nucleus), giving rise to triploid endosperm.

4. Vascular tissue and leaves:
Gymnosperms generally have needle-like or scale-like leaves adapted for extreme conditions; they lack companion cells in the phloem.
Angiosperms have a wide diversity of leaf forms and possess companion cells in the phloem.

5. Diversity and evolutionary advancement:
Gymnosperms are less diverse (~1000 species) and evolutionarily older.
Angiosperms are the most diverse group (~250,000 species) and most evolutionarily advanced.

Answer: Despite both bearing seeds, gymnosperms have naked ovules/seeds (borne on megasporophylls, no ovary), no flowers, no double fertilisation, and haploid endosperm; whereas angiosperms have enclosed ovules (in ovary forming fruit), true flowers, double fertilisation, and triploid endosperm — justifying their separate classification.

Q7 What is heterospory? Briefly comment on its significance. Give two examples.

SOLUTION

Definition of Heterospory:
Heterospory is the condition in which a plant produces two morphologically distinct types of spores — microspores (small, male) and megaspores (large, female) — in two different types of sporangia (microsporangia and megasporangia), which give rise to male and female gametophytes, respectively.
In homosporous plants, all spores are of the same type and size.

Significance of Heterospory:
1. Precursor to seed habit: The female gametophyte in heterosporous plants is retained within the megaspore/megasporangium on the parent sporophyte. The development of the young embryo within the retained female gametophyte is a direct forerunner of the seed condition seen in gymnosperms and angiosperms. Thus, heterospory is considered an important step in evolution toward the seed habit.
2. Nutritional advantage: The megaspore provides a larger food reserve for the developing female gametophyte and the early embryo, increasing the chances of

survival.

3. Sexual differentiation: It results in complete separation of male and female gametophytes, promoting cross-fertilisation and reducing self-fertilisation, which enhances genetic variation.

Examples of heterosporous plants:

1. Selaginella (a pteridophyte / lycopsid) — produces microspores and megaspores in microsporangia and megasporangia respectively.
2. Salvinia (a heterosporous water fern / pteridophyte) — similarly produces distinct micro and megaspores.

Answer: Heterospory is the production of two types of spores — microspores (male, small) and megaspores (female, large) — in distinct sporangia. It is significant as a forerunner of the seed habit (female gametophyte retained in megaspore on parent), promotes cross-fertilisation, and provides nutritional advantage. Examples: Selaginella and Salvinia.

Q8 Explain briefly the following terms with suitable examples:- (i) protonema (ii) antheridium (iii) archegonium (iv) diplontic (v) sporophyll (vi) isogamy

SOLUTION

(i) Protonema:

The protonema is the first stage of the gametophyte in mosses, arising directly from the germination of a haploid spore. It is a creeping, green, branched, frequently filamentous structure. From the secondary protonema, lateral buds develop into the upright leafy gametophyte stage.

Example: Funaria (a moss).

(ii) Antheridium:

The antheridium is the male sex organ in bryophytes and pteridophytes (and in gymnosperms at a reduced level). It is a multicellular structure that produces biflagellate male gametes called antherozoids. Water is required for the antherozoids to swim to the archegonium.

Example: Marchantia (liverwort), Dryopteris (fern).

(iii) Archegonium:

The archegonium is the flask-shaped multicellular female sex organ present in bryophytes, pteridophytes and gymnosperms. It has a swollen base (venter) containing the egg cell and a narrow neck through which antherozoids travel to

fertilise the egg.
Example: Funaria (moss), Cycas (gymnosperm).

(iv) Diplontic:
Diplontic refers to a life cycle in which the diploid (2n) sporophyte is the dominant, free-living photosynthetic generation. The gametophyte is highly reduced and dependent on the sporophyte. Meiosis occurs in the reproductive organs to produce gametes directly (not spores).
Example: All seed plants (gymnosperms and angiosperms); also Fucus among algae.

(v) Sporophyll:
A sporophyll is a leaf-like appendage (modified leaf) that bears sporangia. In pteridophytes, sporophylls bear sporangia and may aggregate to form compact cone-like structures called strobili (e.g., Selaginella, Equisetum). In gymnosperms, microsporophylls bear microsporangia and megasporophylls bear ovules (megasporangia).
Example: Selaginella (pteridophyte), Pinus (gymnosperm).

(vi) Isogamy:
Isogamy is a type of sexual reproduction in which the two fusing gametes are morphologically and physiologically similar (equal in size). The gametes may be flagellated (as in Ulothrix) or non-flagellated (as in Spirogyra).
Example: Ulothrix and Spirogyra (both green algae).

Answer: (i) Protonema — first filamentous stage of moss gametophyte (e.g., Funaria); (ii) Antheridium — multicellular male sex organ producing biflagellate antherozoids (e.g., Marchantia); (iii) Archegonium — flask-shaped female sex organ containing egg (e.g., Funaria); (iv) Diplontic — sporophyte (2n) is dominant generation (e.g., angiosperms); (v) Sporophyll — leaf bearing sporangia (e.g., Selaginella); (vi) Isogamy — fusion of similar-sized gametes (e.g., Ulothrix).

Q9 Differentiate between the following:- (i) red algae and brown algae (ii) liverworts and moss (iii) homosporous and heterosporous pteridophyte

SOLUTION

(i) Red Algae vs Brown Algae:
Red Algae (Rhodophyceae):
- Pigments: chlorophyll a, d and phycoerythrin (gives red colour)

- Stored food: floridean starch (similar to amylopectin and glycogen)
- Cell wall: cellulose, pectin and polysulphate esters
- Flagella: absent (non-motile gametes and spores)
- Habitat: marine (majority); some in freshwater; found at great depths in oceans
- Examples: Porphyra, Polysiphonia, Gracilaria, Gelidium

Brown Algae (Phaeophyceae):
- Pigments: chlorophyll a, c, carotenoids and fucoxanthin (gives olive-green to brown colour)
- Stored food: laminarin or mannitol
- Cell wall: cellulose covered with algin (gelatinous coating)
- Flagella: 2, unequal, laterally inserted (pear-shaped biflagellate zoospores)
- Habitat: primarily marine; some freshwater (rare)
- Examples: Laminaria, Fucus, Sargassum, Ectocarpus

(ii) Liverworts vs Mosses:
Liverworts:
- Plant body: thalloid, dorsiventral, closely appressed to substrate (e.g., Marchantia) or leafy with two rows of tiny leaf-like appendages
- Asexual reproduction: by fragmentation or by gemmae in gemma cups
- Sporophyte: differentiated into foot, seta and capsule; relatively simple
- Rhizoids: unicellular
- Dominant stage: gametophyte (thallus)
- Examples: Marchantia, Riccia

Mosses:
- Plant body: more complex; upright leafy shoot with spirally arranged leaves
- Gametophyte has two stages: (1) protonema (creeping, filamentous, from spore germination) and (2) leafy shoot stage
- Asexual reproduction: by fragmentation and budding in secondary protonema
- Sporophyte: more elaborate than liverwort; foot, seta and capsule; well-developed spore dispersal mechanism
- Rhizoids: multicellular and branched
- Examples: Funaria, Polytrichum, Sphagnum

(iii) Homosporous vs Heterosporous Pteridophytes:
Homosporous Pteridophytes:
- Produce only one type of spore — all spores are alike in size and morphology
- All spores germinate into bisexual gametophytes (prothallus) bearing both

antheridia and archegonia
- More common among pteridophytes
- Examples: Dryopteris, Pteris, Adiantum (ferns); Equisetum

Heterosporous Pteridophytes:
- Produce two morphologically distinct types of spores: microspores (small, male) and megaspores (large, female)
- Microspores germinate into male gametophytes; megaspores into female gametophytes
- Female gametophyte is retained within megaspore on the parent sporophyte — a forerunner of the seed habit
- Examples: Selaginella, Salvinia

Answer: (i) Red algae have phycoerythrin pigment, floridean starch, no flagella; brown algae have fucoxanthin, laminarin/mannitol, 2 unequal flagella. (ii) Liverworts are thalloid/dorsiventral with unicellular rhizoids and simple sporophyte; mosses have a two-stage gametophyte (protonema + leafy shoot), multicellular rhizoids, and more elaborate sporophyte. (iii) Homosporous pteridophytes produce one type of spore giving bisexual prothallus; heterosporous produce micro- and megaspores giving separate male and female gametophytes.

Q10 Match the following (column I with column II) Column I: (a) Chlamydomonas (b) Cycas (c) Selaginella (d) Sphagnum, Column II: (i) Moss (ii) Pteridophyte (iii) Algae (iv) Gymnosperm

SOLUTION

Matching Column I with Column II:

(a) Chlamydomonas — (iii) Algae
Chlamydomonas is a unicellular, biflagellate green alga belonging to Chlorophyceae.

(b) Cycas — (iv) Gymnosperm
Cycas is a gymnosperm bearing pinnate leaves and coralloid roots; male and female cones are on different plants.

(c) Selaginella — (ii) Pteridophyte
Selaginella is a heterosporous pteridophyte belonging to Lycopsida; it produces micro- and megaspores.

(d) Sphagnum — (i) Moss

Sphagnum is a moss (bryophyte) well known for forming peat; it can hold large amounts of water.

Answer: (a) Chlamydomonas — (iii) Algae; (b) Cycas — (iv) Gymnosperm; (c) Selaginella — (ii) Pteridophyte; (d) Sphagnum — (i) Moss.

Q11 Describe the important characteristics of gymnosperms.

SOLUTION

Gymnosperms (gymnos = naked, sperma = seeds) are a group of seed-bearing plants in which the ovules are not enclosed within an ovary wall and the seeds are naked (not covered by fruit). Important characteristics:

1. Habit: Medium to tall trees or shrubs. Cycas is palm-like; conifers like Pinus are tall trees; Sequoia is the tallest tree species.
2. Roots: Generally tap roots. Some genera show special adaptations — mycorrhizal association in Pinus; coralloid roots (with nitrogen-fixing cyanobacteria) in Cycas.
3. Stems: Unbranched (Cycas) or branched (Pinus, Cedrus).
4. Leaves: May be simple or compound. Adapted to withstand temperature, humidity and wind extremes. Conifers have needle-like leaves to reduce surface area, with thick cuticle and sunken stomata to reduce water loss. In Cycas, pinnate compound leaves persist for a few years.
5. Heterospory: Gymnosperms are heterosporous — they produce microspores (in microsporangia on microsporophylls of male cones/strobili) and megaspores (in megasporangia within ovules on megasporophylls of female cones).
6. Reduced gametophytes: Both male and female gametophytes are highly reduced and remain within sporangia on the sporophyte. The male gametophyte is the pollen grain. The female gametophyte is the multicellular structure within the megasporangium bearing two or more archegonia.
7. Pollination: Pollen grains are released from microsporangia and carried by wind to ovules borne on megasporophylls. A pollen tube grows toward the archegonia in the ovule.
8. Fertilisation and seeds: Following fertilisation, the zygote develops into an embryo and the ovules develop into seeds. Seeds are naked — not enclosed in any fruit.
9. Cones (strobili): Sporophylls (microsporophylls and megasporophylls) are arranged spirally along an axis to form male and female cones, respectively. In

Pinus, both cones are on the same tree; in Cycas, they are on different plants (dioecious).

10. Independent gametophytes absent: Unlike bryophytes and pteridophytes, the gametophytes have no independent free-living existence; they remain within the sporangia on the sporophyte.

Answer: Gymnosperms are naked-seeded vascular plants characterised by: tap roots (mycorrhizal in Pinus, coralloid in Cycas); needle-like or compound leaves with thick cuticle; heterospory (micro- and megaspores in male and female cones); reduced gametophytes retained within sporangia; wind pollination via pollen tubes; naked seeds (ovules not enclosed in ovary); no true fruit; examples — Cycas, Pinus, Ginkgo.