

Kingdom Protista: notes and practice questions

These notes and practice questions cover the Kingdom Protista chapter of FSc Part 1 (Class 11) Biology, as taught under the Pakistani intermediate board curricula (Punjab Textbook Board / Federal Board syllabi, based on the National Curriculum for Biology XI–XII). The notes explain the five-kingdom classification system and Protista's place within it, the classification of protists into algae, protozoa and fungus-like groups, and their economic and medical importance, including the malaria life cycle, algae as a food and oxygen source, and red tides. Twenty practice questions with a full answer scheme follow the notes.

Key ideas

- The five-kingdom system (proposed by R. H. Whittaker in 1969) sorts living things into Monera, Protista, Fungi, Plantae and Animalia, mainly on cell type, body organisation and mode of nutrition.
- Kingdom Protista (also known in some classifications as Protocista, a name associated with L. Margulis's later revision of the five-kingdom system) is a heterogeneous, "left-over" group of eukaryotes that are not true fungi, plants or animals — its members are often unrelated to one another except by exclusion from the other kingdoms.
- Most protists are unicellular, but the kingdom also includes colonial and simple multicellular forms, such as large seaweeds.
- Protists are divided, for study, into three informal groups: algae (photosynthetic), protozoa (heterotrophic, animal-like) and fungus-like protists (absorptive, saprophytic).
- The three algal phyla in this chapter — Chlorophyta, Phaeophyta and Rhodophyta — are told apart mainly by their photosynthetic pigments, stored food and cell wall composition.
- The four protozoan groups — Rhizopoda, Ciliophora, Sporozoa and Mastigophora — are told apart mainly by the presence, type, or absence of a locomotory organelle.
- *Plasmodium* (Sporozoa) causes malaria and has a two-host life cycle: an asexual phase in humans and a sexual phase in the female *Anopheles* mosquito.
- Slime moulds and water moulds resemble fungi in being saprophytic and absorptive, but differ from true fungi in cell wall chemistry and life history, which is why they are placed in Protista and not in Kingdom Fungi.
- Algae are major producers of atmospheric oxygen and are used directly as food and indirectly as a source of agar and alginates.
- Rapid growth of certain algae (mainly dinoflagellates) produces "red tides", which can poison shellfish and kill fish through toxins and oxygen depletion.

The five-kingdom system and the place of Protista

Early classifications split all living things into only two kingdoms, Plantae and Animalia. This



worked poorly for microscopic organisms that photosynthesise yet also move and feed like animals, or that are neither clearly plant-like nor animal-like. To solve this, Whittaker grouped organisms using three criteria taken together: whether the cell is prokaryotic or eukaryotic, whether the body is unicellular, colonial or truly multicellular with tissues, and whether nutrition is photosynthetic (autotrophic), absorptive (saprophytic) or ingestive (holozoic).

Applying these criteria gives five kingdoms: Monera (prokaryotic, e.g. bacteria), Protista (eukaryotic, mostly unicellular or simple multicellular), Fungi (eukaryotic, absorptive, chitin cell walls), Plantae (eukaryotic, multicellular, photosynthetic, cellulose cell walls, non-motile) and Animalia (eukaryotic, multicellular, ingestive, no cell wall, generally motile).

Kingdom Protista is defined negatively: it contains every eukaryotic organism that does not fit the strict definitions of Fungi, Plantae or Animalia. Because its members were assigned by *exclusion* rather than by shared ancestry, the kingdom is polyphyletic (its members do not all descend from one common protist ancestor) and is often nicknamed a "dustbin" or "catch-all" kingdom. Some protists photosynthesise like plants, some ingest food like animals, and some absorb nutrients like fungi — a single kingdom therefore has to be defined loosely, purely by what its members are *not*.

Note on naming: Whittaker's original 1969 scheme named this kingdom "Protista." The alternative name "Protocista" — which explicitly folds in multicellular forms such as large seaweeds and slime moulds — comes from Lynn Margulis's later revision of the five-kingdom system. Pakistani FSc board syllabuses (Punjab Textbook Board / Federal Board) use "Kingdom Protista," which is the term used throughout this resource.

Classification of Protista

Algae — the photosynthetic protists

Algae are photosynthetic protists that lack the true roots, stems, leaves and vascular tissue of land plants, even though some (such as brown algae) grow large and superficially plant-like. The FSc syllabus places algae in three phyla, separated chiefly by their photosynthetic pigments, the form in which they store food, and their cell wall material.

Feature	Chlorophyta (green algae)	Phaeophyta (brown algae)	Rhodophyta (red algae)
Main pigments	Chlorophyll a and b (masks other pigments, giving a grass-green colour)	Chlorophyll a and c, plus the brown carotenoid fucoxanthin, which masks the green chlorophyll	Chlorophyll a, plus red phycobilin pigments (phycoerythrin) and phycocyanin, which mask the chlorophyll
Stored food	Starch, in the chloroplast around a protein body called a pyrenoid	Laminarin (a polysaccharide) and the sugar alcohol mannitol	Floridean starch, a glycogen-like polysaccharide stored outside the chloroplast
Cell wall	Cellulose	Cellulose plus algin (alginic acid), which makes the wall slimy and flexible	Cellulose, sometimes strengthened with deposits of calcium carbonate

Habitat	Mostly fresh water and damp soil; a few marine and a few in symbiosis (e.g. in lichens)	Almost entirely marine, mainly in cool coastal waters	Mostly marine, often in deeper or warmer water than brown algae
Example	<i>Spirogyra</i> — an unbranched filamentous freshwater alga with spiral, ribbon-shaped chloroplasts	<i>Fucus</i> (bladder wrack) — a flattened, branching, leathery seaweed with gas-filled bladders that keep it afloat	<i>Gracilaria</i> (or <i>Polysiphonia</i> , used as the standard example in some textbook editions) — a branched, thread-like red seaweed used commercially as a source of agar

A filamentous green alga such as *Spirogyra* is built as an unbranched chain of identical cylindrical cells joined end to end; each cell has a thin cellulose wall, a large central vacuole, a peripheral cytoplasm containing one or more long spiral, ribbon-like chloroplasts with pyrenoids, and a single nucleus suspended in strands of cytoplasm that cross the vacuole. This body plan (a simple filament with no differentiated tissues) is typical of many green algae and is why algae are not classed with true plants.

Protozoa — the animal-like protists

Protozoa are heterotrophic, mostly unicellular protists that ingest or absorb food rather than photosynthesising. The syllabus groups them mainly by the presence, type, or absence of a locomotory organelle.

Group	Locomotory organelle	Nutrition	Example
Rhizopoda (Sarcodina)	Pseudopodia (temporary cytoplasmic extensions)	Holozoic, by phagocytosis	<i>Amoeba proteus</i>
Ciliophora	Cilia, covering the whole cell	Holozoic, particles swept into a cytostome (cell mouth)	<i>Paramecium caudatum</i>
Mastigophora (Flagellata)	One or more flagella	Photosynthetic and/or heterotrophic (mixotrophic in some genera)	<i>Euglena viridis</i>
Sporozoa	None in the adult/feeding stage	All parasitic, absorb nutrients from the host	<i>Plasmodium vivax</i>

Amoeba: has no fixed shape, no cell wall and no permanent locomotory structure; it moves and feeds by extending finger-like pseudopodia, which flow around a food particle and enclose it in a food vacuole for digestion (a process called phagocytosis). A contractile vacuole periodically fills with excess water and empties to the outside, removing water that enters by osmosis (osmoregulation), because *Amoeba* lives in fresh water, which is more dilute than its cytoplasm. It reproduces asexually by binary fission. A related genus, *Entamoeba histolytica*, is a parasite of the human gut that causes amoebic dysentery.

Paramecium: is a slipper-shaped ciliate with a firm but flexible pellicle, so it keeps a constant shape. Coordinated beating of its cilia drives it through water and sweeps food particles down an oral groove into a cytostome, where food vacuoles form and digest the food; the cell also has an anal pore for egesting waste. It has two kinds of nuclei: a large macronucleus, which controls everyday metabolic and growth functions, and one or more small micronuclei, which carry the

genetic material exchanged during sexual reproduction. *Paramecium* reproduces asexually by transverse binary fission and sexually by conjugation, in which two cells exchange micronuclear material before separating.

Euglena: is a flagellate with chloroplasts containing chlorophyll a and b, like a plant, but it can also feed heterotrophically (absorbing dissolved organic matter) when kept in the dark, so it is described as mixotrophic. It has no cell wall; instead a flexible, protein-based pellicle just inside the cell membrane allows limited changes of shape. A red eyespot (stigma) shades a light-sensitive swelling near the base of the longer of its two flagella and allows phototaxis (movement towards light for photosynthesis). Food made by photosynthesis is stored as paramylon, a starch-like polysaccharide unique to euglenoids, and a contractile vacuole removes excess water.

Some syllabus editions also list the parasitic flagellate *Trypanosoma*, which causes sleeping sickness (trypanosomiasis) and is transmitted by the tsetse fly, as a second Mastigophora example — check your own textbook edition for whether this is required.

Fungus-like protists

Slime moulds and water moulds feed by absorption, like fungi, but their cell biology and life cycles differ enough from true Fungi that both are classified in Protista.

Slime moulds (Myxomycota): in their feeding stage, plasmodial slime moulds such as *Physarum polycephalum* exist as a single, multinucleate mass of naked cytoplasm called a plasmodium, which creeps slowly over damp, decaying wood or leaf litter and engulfs bacteria and organic particles by phagocytosis — an animal-like, amoeboid feeding habit. When conditions become dry or food runs out, the plasmodium stops moving and develops into stalked fruiting bodies that release spores, a fungus-like reproductive strategy. Slime moulds therefore show a mixture of animal-like (motile, phagocytic) and fungus-like (spore-producing, saprophytic) features.

This account covers plasmodial slime moulds (Myxomycota). Some syllabus editions also distinguish cellular slime moulds (Acrasiomycota), e.g. *Dictyostelium*, whose amoeboid cells live and feed separately before aggregating into a fruiting body when food runs out — check your own textbook edition for whether this is required.

Water moulds (Oomycota): such as *Phytophthora infestans* and *Saprolegnia*, grow as fine, branching, thread-like hyphae, like fungi, and absorb nutrients from their surroundings or from a host. Unlike true fungi, however, their cell walls are made of cellulose rather than chitin, their hyphae are typically coenocytic (multinucleate, with few or no cross-walls), and they usually reproduce asexually by means of motile, flagellated zoospores, and sexually by oogamy (a large non-motile egg fertilised by a smaller gamete). *Phytophthora infestans* causes late blight of potato, a disease that destroys leaves and tubers in humid conditions and historically caused severe crop losses; *Saprolegnia* is a common water mould that infects the skin, gills and eggs of fish, especially where the skin is already damaged.

Economic and medical importance

Malaria: transmission, life cycle and prevention

Plasmodium is a sporozoan that causes malaria in humans. It is transmitted only by the bite of an infected female *Anopheles* mosquito (male mosquitoes feed on plant juices, not blood, so they cannot transmit the parasite). Several species infect humans, including *Plasmodium vivax*, *P.*

falciparum, *P. malariae* and *P. ovale*; *P. falciparum* causes the most severe disease. The life cycle is digenetic, alternating between two hosts, with asexual reproduction in humans and sexual reproduction in the mosquito.

In the human host (asexual phase):

1. While feeding, an infected female *Anopheles* injects saliva containing thread-like sporozoites into the person's skin, from where they enter the bloodstream and travel to the liver.
2. On reaching the liver, sporozoites invade liver cells and multiply asexually by repeated division (schizogony) to form many merozoites — this liver stage produces no symptoms.
3. Merozoites burst out of the liver cells into the blood and invade red blood cells (RBCs).
4. Inside an RBC, a merozoite grows into a trophozoite and then a schizont, which again divides by schizogony into new merozoites; the RBC then ruptures, releasing the merozoites together with cell debris and parasite toxins into the plasma.
5. This sudden release triggers the bouts of fever and chills typical of malaria; because RBCs tend to rupture in synchronised batches, the fever recurs at regular intervals — about every 48 hours for *P. vivax* and *P. ovale* (tertian fever) and about every 72 hours for *P. malariae* (quartan fever).
6. Released merozoites invade fresh RBCs and repeat this erythrocytic cycle, so the infection and the symptoms recur unless treated.
7. After several such cycles, some merozoites inside RBCs develop instead into sexual forms called gametocytes (male microgametocytes and female macrogametocytes), which do not themselves cause further RBC rupture but are infective to a mosquito that bites the patient.

In the mosquito (sexual phase):

1. A female *Anopheles* takes up gametocytes when it feeds on an infected person's blood.
2. In the mosquito's gut, the microgametocyte divides to release several thread-like microgametes (a process called exflagellation), and a macrogametocyte matures into a macrogamete; a microgamete fertilises a macrogamete to form a zygote.
3. The zygote elongates into a motile ookinete, which burrows through the gut wall and settles beneath its outer lining to form an oocyst.
4. Inside the oocyst, the nucleus divides repeatedly (sporogony) to produce many sporozoites.
5. The mature oocyst ruptures, and the sporozoites migrate through the body cavity to the mosquito's salivary glands, ready to be injected into the next human host the mosquito bites, completing the cycle.

Prevention and control rely on breaking this cycle at either host: protecting people from mosquito bites (insecticide-treated bed nets, window screens, repellents), reducing the mosquito population (indoor residual spraying with insecticide, removing or treating stagnant water where *Anopheles* larvae breed, introducing larvivorous fish), and reducing the human reservoir of infection through prompt diagnosis and antimalarial drug treatment of patients.

Algae as a food and oxygen source

Marine phytoplankton (chiefly unicellular algae) photosynthesise on a vast scale and, together with cyanobacteria, are responsible for a very large share of the oxygen entering the atmosphere and

oceans each year, in addition to forming the base of most aquatic food webs. Seaweeds are eaten directly in many cuisines (for example, red algae such as *Porphyra* are dried and used as nori) and algae are also harvested for industrial products: agar, extracted from the cell walls of red algae such as *Gracilaria* (or *Polysiphonia*), is used as a gelling agent in food and as the solid medium on which microbiologists grow bacterial cultures; alginates, extracted from brown algae such as *Fucus* and kelps, are used as thickeners and stabilisers in foods, cosmetics and pharmaceuticals.

Red tides

Under warm, nutrient-rich conditions, certain planktonic algae (most often dinoflagellates) can multiply extremely rapidly, producing dense blooms that discolour coastal water reddish-brown — a "red tide". Many of the organisms responsible release toxins that accumulate in filter-feeding shellfish, making them poisonous to the people who eat them, and can also kill fish directly. In addition, when the bloom dies off, its decomposition by bacteria consumes large amounts of dissolved oxygen, which can suffocate fish and other marine animals over a wide area. Red tides therefore damage fisheries, aquaculture and coastal tourism.

Section A: multiple choice

Choose the one best answer, A–D. [1] each.

- 1. The five-kingdom system of classification is credited to:
A. Linnaeus B. Whittaker C. Darwin D. Haeckel [1]
- 2. Which pigment combination is characteristic of Phaeophyta?
A. Chlorophyll a and b only B. Chlorophyll a and c, plus fucoxanthin C. Chlorophyll a and d, plus phycoerythrin D. Chlorophyll a only [1]
- 3. The food reserve typically stored by red algae (Rhodophyta) is:
A. Starch B. Laminarin C. Floridean starch D. Paramylon [1]
- 4. The locomotory organelle used by *Paramecium* is:
A. Pseudopodia B. A single flagellum C. Cilia D. None; it is non-motile [1]
- 5. Which protist has chloroplasts, can also feed heterotrophically in the dark, and is bounded by a flexible pellicle rather than a rigid cell wall?
A. *Amoeba* B. *Euglena* C. *Plasmodium* D. *Spirogyra* [1]
- 6. Malaria is transmitted to humans by:
A. A female *Culex* mosquito B. A female *Anopheles* mosquito C. A male *Anopheles* mosquito D. A housefly [1]
- 7. The sexual phase of the *Plasmodium* life cycle (gamete formation and sporogony) takes place in:
A. The human liver B. Human red blood cells C. The body of the mosquito D. The human intestine [1]
- 8. Which fungus-like protist, a water mould, causes late blight of potato?
A. *Physarum* B. *Phytophthora* C. *Plasmodium* D. *Fucus* [1]

Section B: short answer

- **9.** Define Kingdom Protista and explain why it is often described as a "heterogeneous" or "dustbin" kingdom. [3]
- **10.** State three differences between Chlorophyta and Phaeophyta, based on pigments, stored food and habitat. [3]
- **11.** State three structural or functional differences between *Amoeba* and *Paramecium*. [3]
- **12.** Describe the pellicle and mode of nutrition of *Euglena*, and explain what the term "mixotrophic" means. [3]
- **13.** Name the four groups into which Protozoa are classified according to their means of locomotion, and state the locomotory organelle used by each. [3]
- **14.** What are slime moulds? State two features that make them fungus-like and one feature of their feeding stage that is animal-like. [3]
- **15.** Explain briefly why algal "red tides" are considered harmful to marine life and to human economic activity. [3]
- **16.** Give three economic uses of algae to humans, other than their role in red tides. [3]

Section C: structured questions

- **17.** This question is about the classification of algae.
 - (a) Name the three phyla into which algae are classified in Kingdom Protista, and give one named example of each. [3]
 - (b) State the food reserve of Rhodophyta, and explain one economic use that depends on a substance extracted from red algal cell walls. [2]
 - (c) Describe, in words, the general body structure of a filamentous green alga such as *Spirogyra*. [2]
- **18.** This question is about protozoan structure and function.
 - (a) Describe how *Amoeba* obtains its food, naming the process involved. [2]
 - (b) Explain the role of the contractile vacuole in *Amoeba* and in *Paramecium*. [2]
 - (c) State one function of the macronucleus and one function of the micronucleus in *Paramecium*. [2]
 - (d) Name one parasitic protozoan, other than *Plasmodium*, and the disease it causes in humans. [1]
- **19.** This question is about malaria.
 - (a) Name the organism that causes malaria and state the protozoan group to which it belongs. [1]
 - (b) Describe, in outline, the part of the life cycle of this organism that occurs in the human body, from the mosquito bite to the appearance of fever. [3]
 - (c) Describe, in outline, the part of the life cycle that occurs in the mosquito. [2]
 - (d) State one practical method of preventing the spread of malaria. [1]
- **20.** This question is about fungus-like protists and the economic importance of algae.

- (a) State two differences between the cell walls of water moulds (Oomycota) and those of true fungi. [2]
- (b) Name one water mould and describe the damage it causes to a named host. [2]
- (c) Explain why algae are considered important producers of atmospheric oxygen. [2]
- (d) Suggest one reason why a large algal bloom can lead to the death of fish in a lake or coastal water. [1]

Answers

1. B — Whittaker (1969) proposed the five-kingdom system.
2. B — Phaeophyta have chlorophyll a and c together with the brown pigment fucoxanthin, which masks the chlorophyll and gives the algae their brown colour.
3. C — Rhodophyta store food as floridean starch.
4. C — *Paramecium* is covered in cilia, which it uses for both locomotion and feeding.
5. B — *Euglena* photosynthesises using chloroplasts but can also absorb organic nutrients heterotrophically in the dark (mixotrophic), and is bounded by a flexible pellicle rather than a cell wall.
6. B — only the female *Anopheles* mosquito transmits malaria; males do not feed on blood.
7. C — gamete formation, fertilisation and sporogony all occur within the body of the mosquito.
8. B — *Phytophthora infestans* is a water mould that causes late blight of potato.
9. Kingdom Protista is the eukaryotic kingdom that contains all organisms not classified as Fungi, Plantae or Animalia [1]. It is "heterogeneous"/a "dustbin" kingdom because its members were grouped by exclusion rather than by common ancestry [1], so it contains very different organisms (photosynthetic algae, ingestive protozoa, absorptive fungus-like forms) that are not all closely related to one another [1].
10. Any three of: Chlorophyta have chlorophyll a and b, Phaeophyta have chlorophyll a and c plus fucoxanthin [1]; Chlorophyta store starch, Phaeophyta store laminarin [1]; Chlorophyta are mostly freshwater, Phaeophyta are almost entirely marine [1].
11. Any three of: *Amoeba* moves by pseudopodia, *Paramecium* moves by cilia [1]; *Amoeba* has no fixed shape, *Paramecium* has a fixed (slipper) shape due to its pellicle [1]; *Amoeba* has one type of nucleus, *Paramecium* has two types (macronucleus and micronucleus) [1]; *Amoeba* engulfs food anywhere on its surface, *Paramecium* takes in food through a fixed oral groove/cytostome [1].

12. The pellicle is a flexible, protein-based layer just inside the cell membrane that allows *Euglena* some change of shape but keeps it more definite than *Amoeba* [1]. Nutrition: it photosynthesises using chlorophyll a and b in its chloroplasts in the light [1], but can absorb dissolved organic matter heterotrophically when kept in the dark [1]. Mixotrophic means an organism can obtain nutrition by more than one method (here, both photosynthesis and heterotrophic absorption) (credit within the above marks if not otherwise given).

13. Rhizopoda — pseudopodia; Ciliophora — cilia; Mastigophora — flagella; Sporozoa — no locomotory organelle in the adult stage (1 mark for each correctly paired group, up to a maximum of [3]).

14. Slime moulds are fungus-like protists that feed saprophytically on decaying organic matter [1]. Fungus-like features (1 mark for both together): they produce spores from stalked fruiting bodies, and they are saprophytic/absorptive like fungi [1]. Animal-like feature: their feeding stage is a motile, multinucleate plasmodium that engulfs food by phagocytosis [1].

15. Red tides are harmful because the algae involved (often dinoflagellates) release toxins that accumulate in shellfish and poison people who eat them, and can kill fish directly [1]; when the huge algal population dies, bacterial decomposition uses up dissolved oxygen in the water [1], which suffocates fish and other aquatic animals and damages fisheries/tourism [1].

16. Any three of: eaten directly as food (e.g. seaweed/nori) [1]; source of agar, used in food and as a microbiological culture medium [1]; source of alginates, used as thickeners/stabilisers in food and other products [1]; major producers of atmospheric oxygen and the base of aquatic food chains [1].

17. (a) Chlorophyta, e.g. *Spirogyra*; Phaeophyta, e.g. *Fucus*; Rhodophyta, e.g. *Gracilaria* (or *Polysiphonia*) [3, 1 per correctly paired phylum and example].
(b) Floridean starch [1]; agar, extracted from red algal cell walls, is used as a gelling agent in food and as a solid growth medium for culturing bacteria [1].
(c) An unbranched filament (chain) of similar cylindrical cells joined end to end [1]; each cell has a thin cellulose wall, a large vacuole, one or more spiral ribbon-shaped chloroplasts with pyrenoids, and a nucleus [1].

18. (a) *Amoeba* extends pseudopodia around a food particle, enclosing it within a food vacuole [1]; this process is phagocytosis, and digestion occurs within the food vacuole [1].
(b) The contractile vacuole collects excess water that has entered the cell by osmosis (since the organism lives in a hypotonic freshwater environment) and periodically expels it to the outside, so it maintains osmotic balance/prevents bursting [2].
(c) Macronucleus — controls everyday metabolic/vegetative functions and growth [1]; micronucleus — involved in genetic exchange during sexual reproduction (conjugation) [1].
(d) *Entamoeba histolytica*, which causes amoebic dysentery [1].

19. (a) *Plasmodium*; Sporozoa (both the name and the group are needed for the mark) [1].
(b) Sporozoites are injected into the skin by the mosquito bite, then enter the blood and travel to

the liver, where they multiply asexually (schizogony) to form merozoites [1]; merozoites invade red blood cells, grow, and undergo schizogony to form more merozoites [1]; the red blood cells rupture, releasing merozoites and toxins, which causes the fever, and the released merozoites go on to infect fresh red blood cells [1].

(c) The mosquito ingests gametocytes with a blood meal; male and female gametes form and fuse to give a zygote [1]; the zygote becomes a motile ookinete that forms an oocyst in the gut wall, within which sporogony produces sporozoites that migrate to the salivary glands [1].

(d) Any one of: using insecticide-treated bed nets/window screens; indoor residual spraying with insecticide; removing/treating stagnant water where *Anopheles* breeds; prompt diagnosis and drug treatment of patients [1].

20. (a) Water mould (Oomycota) cell walls are made of cellulose, whereas true fungal cell walls are made of chitin [1]; water mould hyphae are typically coenocytic (few/no cross-walls) and asexual reproduction is by motile, flagellated zoospores, unlike most true fungi [1].

(b) *Phytophthora infestans* causes late blight of potato, destroying leaves and tubers in humid conditions [2] (or *Saprolegnia*, which infects the skin/gills of fish, especially where already damaged).

(c) Algae (including phytoplankton) photosynthesise on a very large scale in oceans and fresh water, and this photosynthesis releases oxygen as a by-product, contributing a very large share of the oxygen entering the atmosphere [2].

(d) Any one of: toxins released by the bloom poison fish directly; decomposition of the dead algal bloom by bacteria depletes dissolved oxygen, suffocating fish [1].