

Bio Factsheet



Number 73

The Prokaryotic Cell

The contents of this Factsheet cover the relevant AS syllabus content of the major examining boards. By studying this Factsheet the candidate will gain a knowledge and understanding of the structure of a prokaryotic cell, the range of prokaryotic organisms and the importances of prokaryotic organisms.

Introduction

Bacteria (eg *Escherichia coli*) and Cyanobacteria (blue-green algae) (eg *Nostoc*) are single-celled and characteristically possess no nucleus. They are prokaryotic organisms.

Remember – a light microscope will only show the general shape of bacterial cells and does not have the magnification or resolving power to show the ultrastructure of cells, that is, the details of cell contents, an electron microscope is required.

Remember – the Cyanophyta or blue-green algae are now classed as Cyanobacteria because they are prokaryotic. Algae are all eukaryotic since they possess nucleated cells and cell organelles. In some older textbooks you may still find blue-green algae classed as Cyanophyta. This is now considered to be incorrect and you should refer to them as Cyanobacteria in AS and A2 examinations.

The prokaryotic cell is the simplest type of living cell. They are relatively small having a diameter in the range of 1 - 5 μm (micrometre), and a volume somewhere between one thousandth and one hundred thousandth of the volume of a typical plant or animal cell. Prokaryotic cells do not have membrane-bound organelles. Remember that a micrometer is 10^{-6} metre.

Form

Prokaryotes show a variety of cell shapes. The three most common are spheres (cocci), rods (bacilli) and spirals (spirilla). Examples of these are shown in Fig 1.

Ultra-structure

The prokaryotic cell has a **cell wall**, external to the plasma membrane. The wall confers rigidity and maintains the characteristic shape of the cell. It provides physical protection and prevents the cell from bursting in an hypo-osmotic environment in which the cell contents are more concentrated than the external solution. In bacterial cells the wall is 10 - 100 nm (nanometre) thick. (A nanometre is 10^{-9} of a metre). It is made from lipids, polysaccharides and proteins. Most bacterial cell walls contain a unique material called **peptidoglycan**. This compound consists of polymers of modified sugars cross-linked by short chain polypeptides. The specific polymers used vary from species to species. The end result is a net-like multilayered structure. The Blue-green algae have walls similar in structure to some bacteria. Cellulose is not used.

A gelatinous sheath or **capsule**, may be found external to the cell wall. This is found most commonly in blue-green algae. This structure, composed of polysaccharides, absorbs water. The capsule is therefore slimy and serves as a protective layer. (see Fig 2 and 3 overleaf)

Fig 1. Appearance of prokaryotic cells as seen under the high power of a light microscope

COCCI	RODS	SPIRILLA (curved rods)
Staphylococcus aureus 	Escherichia coli 	Vibrio cholerae
Neisseria gonorrhoea 	Bacillus anthracis 	Treponema pallidum
Streptococcus pneumoniae 	Corynebacterium diphtheriae 	Leptospira
Streptococcus pyogenes 		

Fig 2 and 3 show the general ultrastructure of a rod-shaped bacterium and a blue-green algal cell.

Fig 2. Ultrastructure of a rod-shaped bacterium

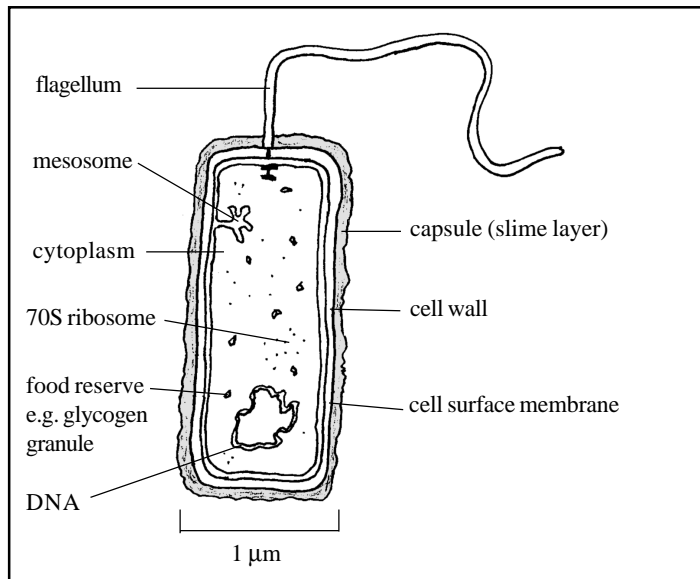
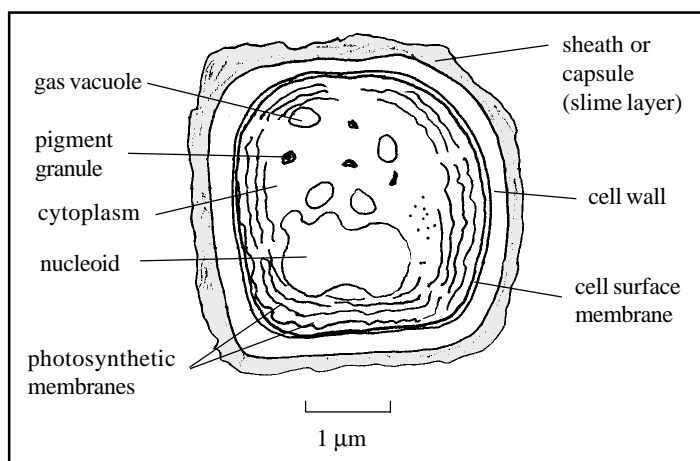


Fig 3. Ultrastructure of a blue green alga



The cell surface membrane, the **plasma membrane**, is composed of phospholipids and proteins. The proteins include enzymes that are involved in respiration, electron transport and nucleic acid synthesis. The membrane is partially permeable and exerts some control over which small molecules and ions can enter and leave the cell.

The cytoplasm of a prokaryote contains storage products (glycogen granules and lipid droplets), ribosomes and plasmids (circular pieces of DNA). The prokaryotic cell is not divided into areas of different function (compartmentalised) by internal membranes. The plasma membrane may however form **invaginations** (mesosomes), to provide internal membrane surfaces for special purposes; for example, the mesosomes are thought to be the site of respiration.

The feature that makes a prokaryotic cell very different from a eukaryotic cell is its genetic material. The bacterial DNA is in direct contact with the cytoplasm. There is no enclosing membrane and therefore **no recognisable nucleus**. Prokaryotes possess a single, continuous, **circular thread of DNA**. The DNA is located in a region of the cytoplasm called a **nucleoid**. Small structures called **plasmids** may also be present. These carry DNA with only a few genes responsible for special metabolic pathways and resistance to antibiotics. Plasmids can transfer between bacteria and it is this property that has made them important in genetic engineering.

The **ribosomes** found in prokaryotic cells are smaller than those of eukaryotes and are involved in protein synthesis. The rate at which bacteria divide requires a high level of protein synthesis and thus many ribosomes are needed. Thus ribosomes may constitute as much as 40% of the cell mass. Prokaryotic cells possess 70S ribosomes whereas eukaryotic cells possess 80S ribosomes. (S stands for Svedberg units and is a measure of how rapidly the ribosomes sediment in a centrifuge. 80S ribosomes sink quickest because they are heaviest)

Motile bacteria use **flagella** to move. These fibrous projections propel the cell through its environment by rotating clockwise or anticlockwise. The cell movement that results will be in a straight line or in a more uncontrolled, tumbling motion depending on the direction in which the flagellum is rotating. The flagella have a much simpler structure than the complex microtubule flagella of eukaryotic cells. The gas containing vacuoles of blue-green algae are probably for flotation so that the cells remain near the surface of the water and thus receive more light for photosynthesis.

Exam Hint - Candidates should be able to recognise and describe the features of prokaryotic cells as seen under the electron microscope

Table 1. Comparison of prokaryotic and eukaryotic cells

Feature	Prokaryote	Eukaryote
Diameter	0.5 - 5μm	up to 40μm
Organisation	Single-celled	Usually part of a tissue
Nucleus	Absent	Present
DNA	Single circular thread	Several linear chromosomes
Phospholipid plasma membrane	Present	Present
Ribosomes	Small 70S	Large 80S
Mitochondria	Absent	Present
Cell wall	Always present made from peptidoglycans (cellulose absent)	Present only in plant cells (cellulose present)

Importances of prokaryotes

1. Chemical cycles

Prokaryotes recycle elements linking the biological and physical components of the ecosystem. They play a significant role as decomposers in the carbon and nitrogen cycles, for example, the nitrifying bacteria *Nitrosomonas* and *Nitrobacter*. Some bacteria function as symbionts, for example, *Rhizobium leguminosarum* in the root nodules of Papilionaceous plants such as clover is important in the fixation of gaseous atmospheric nitrogen. Bacteria such as *Azotobacter* and blue green algae such as *Nostoc* are important free living nitrogen fixing bacteria in the soil.

2. Bacteria and disease

Poisonous chemicals called toxins, released by bacteria, are the most common cause of symptoms of bacterial disease. Toxins released by some types of bacteria may cause disease, even when the bacteria themselves are no longer present. Other types of bacteria produce toxins that are an integral part of the outer membranes of the bacterial cell itself. Both types of pathogen disrupt the natural physiology of the affected individual. Examples of pathogenic (disease causing) bacteria can be seen in Fig 1. For example, *Streptococcus pyogenes* can cause sore throats and tonsillitis, *Bacillus anthracis* causes anthrax, *Corynebacterium* causes diphtheria, *Vibrio cholerae* causes cholera, *Treponema* causes syphilis and *Leptospira* causes leptospirosis (rat borne fever).

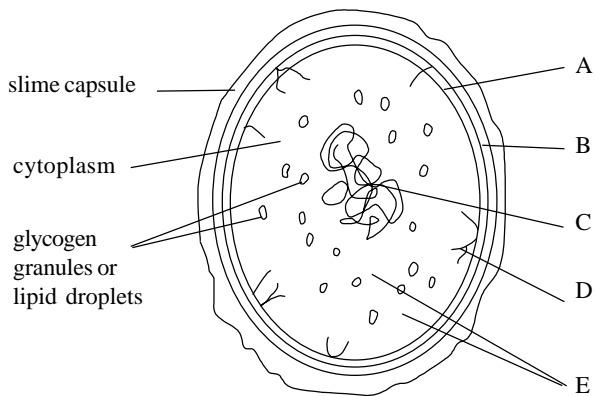
3. Biotechnology

Prokaryotes are useful agents employed in a variety of ways. Examples include:

- use of decomposers in sewage treatment;
- bacterial conversion of milk to yoghurt and cheese;
- manufacture of vitamins and antibiotics;
- use in recombinant DNA technology.

Practice Questions

1. Describe the organisation of genetic material in a prokaryotic cell. 6
2. What are:
 - (a) peptidoglycans, 4
 - (b) mesosomes, and 4
 - (c) plasmids? 4
3. The drawing below shows the ultrastructure of E. coli.



- (a) (i) Label structures A to E. 5
- (ii) State a function of part D. 1
- (iii) What term is given to this bacterial shape? 1
- (b) List three ways in which prokaryotic cells differ from eukaryotic cells. 3

Answers

Semicolons indicate marking points.

1. no true nucleus; DNA forms continuous circular structure; located in region of cytoplasm called nucleoid; plasmids; small circles of DNA; few genes; 6
2. (a) found in bacterial cell walls; polymers; modified sugars; crosslinked to short polypeptides; species specific; max 4
- (b) invaginations; plasma membrane; specific functions; e.g. site of respiration; 4
- (c) short strand of DNA; circular; carry few genes; associated with resistance; useful in recombinant DNA technology; 4
3. (a) (i) A = plasma membrane; B = cell wall; C = nuclear mass; D = mesosome; E = ribosomes; 5
- (ii) contain the enzymes for respiration/cell wall synthesis; 1
- (iii) coccus; 1
- (b) prokaryotic cells contain no membrane-bound organelles, eukaryotes do; prokaryote cells have no nuclear membrane, eukaryotes do/ prokaryotes have a nuclear mass; eukaryotes have a nucleus/prokaryotes have one long chromosome, eukaryotes have many chromosomes; prokaryotes have no nucleoli, eukaryotes do; prokaryotic cell walls contain murein, eukaryotic cell walls (if present) contain cellulose; prokaryotes contain 70S ribosomes, eukaryotes contain 80S ribosomes; max 3

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