CHAPTER

6

Kingdom Prokaryotae (Monera)

Animation 6.1: Enzyme
Source & Credit: Wikispaces

Kingdom Prokaryotae consists of organisms with prokaryotic cells. In Greek the word *Pro* **means** "before" and *karyon* means nucleus. Microbiologists place bacteria in two major categories: eubacteria (Greek for "true bacteria") and a much smaller division, the archaeobacteria (Greek for "ancient bacteria").

DISCOVERY OF BACTERIA

It had long been suspected that small creatures exist which are too small to be seen with naked eye. But their discovery was linked to the invention of microscope. A Dutch Scientist "AntonieVan Leeuwenhoek" (1673) was the first to report the microbes such as bacteria and protozoa. He used a simple microscope to describe bacteria and protozoa with accurate drawings and descriptions and called these small creatures as **"animalcules"**. He firstly observed small creatures in rain water, then confirmed these in saliva, vinegar, infusions and other substances.

The progress in understanding the nature and importance of these tiny organisms has been slow. The existance of microbes was further confirmed by Louis Pasteur's work. Pasteur went on making many discoveries in the field'of microbiology and medicine. His main achievements are the development of vaccines for disease **anthrax, fowl cholera** and **rabies.** He also made significant contributions in development of pasteurization process and development of fermentation industries. He proved that microorganisms could cause disease.

Rohert Koch formulated the **'germ theory of disease'**. He isolated typical rodshaped bacteria with squarish ends (baccilli) from (he blood of sheep that had died of anthrax. Then he discovered bacteria that caused **tuberculosis** and cholera. He formulated four **postulates,** which are the main pillars of the germ theory of disease. These are used to find out whether the organism found in disease lesions is the causal agent of the disease or not.

1. A specific organism can always be found in association with a given disease.
2. The organism can be isolated and grown in pure culture in the laboratory.
3. The pure culture will produce the disease when inoculated into susceptible animal.
4. It is possible to recover the organism in pure culture from experimentally infected animal.

Koch and his colleagues invented many techniques concerning inoculation, isolation, media preparation, maintenance of pure cultures and preparation of specimens for microscopic examinations.

OCCURRENCE OF BACTERIA

Bacteria are wide spread in their occurrence. They are found almost everywhere, in air, land, water, oil deposits, food, decaying organic matter, plants, man and animals. Their kind and number vary according to locality and environmental conditions. Some bacteria are always present and contribute towards the natural flora. Others are present in specific environments such as hot springs, alkaline/ acidic soil, highly saline environments, in highly polluted soils and waters.

Animation 6.2: Bacteria Animated
Source and Credit: pinterest

STRUCTURE OF BACTERIA

All bacterial cells invariably have a cell membrane, cytoplasm, ribosome, and chromatin bodies. The majority have a cell wall, which gives shape to the bacterial cell. Specific structures like capsule, slime, flagella, pili, fimbriae and granules are not found in all bacteria (refer to Fig. 4.17).

Size

Bacteria range in size from about 0.1 to 600 µm over a single dimension. Bacteria vary in size as much as in shape. The smallest (e.g., some members of the genus *Mycoplasma*) are about 100 to 200 µm in diameter, approximately the size of the largest viruses (poxviruses) *Escherichia coli,* a bacillus of about average size, is 1.1 to 1.5 µm wide by 2.0 to 6.0 µm long. Some spirochetes occasionally reach 500 µm in length whereas Staphylococci and Streptococci are 0.75 - 1.25µ in diameter.

Recently a huge bacterium has been discovered in the intestine of the brown surgeonfish, Acanthurus nigrofuscus. Epulopiscium fishelsoni grows as large as 600 µm by 80 µm, a little smaller than a printed hyphen. It is now clear that a few bacteria are much larger than the average eukaryotic cell.

Shape of Bacteria

On the basis of general shape, bacteria are classified into three categories. These shapes are known as cocci, bacilli and spiral .Although most of the bacterial species have fairly constant characteristic cell shape, yet some cells are pleomorphic and they can exist in a variety of shapes.

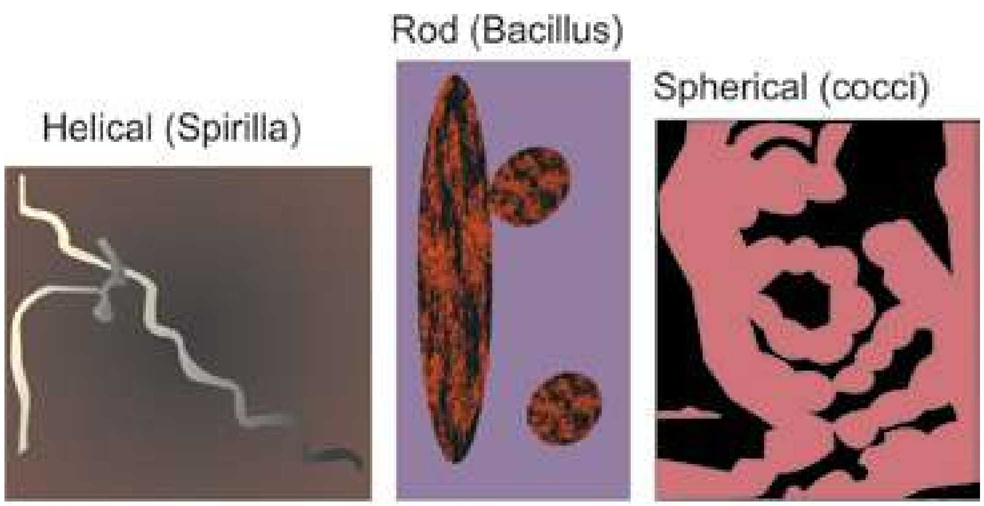


Fig 6.1 Shapes of Bacteria

Exceptions to the above shapes are trichome forming, sheathed, stalked, square, starshaped, spindle-shaped, lobed and filamentous bacteria.

The **cocci** are spherical or oval bacteria having one of several distinct arrangements based on their planes of division. If division is in one plane it will produce either a **diplococcus** or **streptococcus** arrangement. When cocci occur in pairs then arrangement is diplococcus, whereas when cocci form long chain of cells then arrangement is called as streptococci. When the division of cell is in two planes it will produce a **tetrad** arrangement. A tetrad is a square of 4 cocci. Thirdly, when the division is in three planes, it will produce a **sarcina** arrangement. Sarcina is a cube of 8 cocci. When division occurs in random planes, it will produce a **staphylococcus** arrangement in which cocci are arranged in irregular, often grape-like clusters. *Diplococcus pneumoniae* and *Staphylococcus aureus* are some examples of cocci.

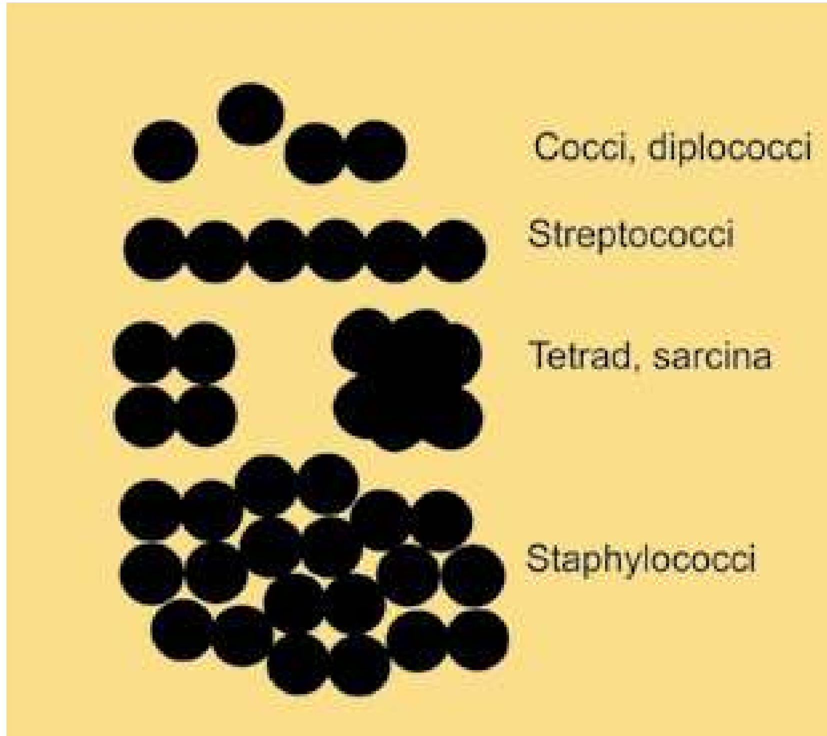


Fig. 6.2 Cocci

Animation 6.3: Bacteria shape
Source and Credit: gif2fly

Bacilli are rod-shaped bacteria. Bacilli all divide in one plane producing a **bacillus, streptobacillus,** or **diplobacillus**. Bacillus is a single cell of bacteria. Streptobacillus is a chain of bacilli. When rod shaped bacteria occur in pairs then arrangement of cells is known as diplobacilli. Examples of rod shaped bacteria are *Escherichia coli, Bacillus subtilis*, *Pseudomonas.*

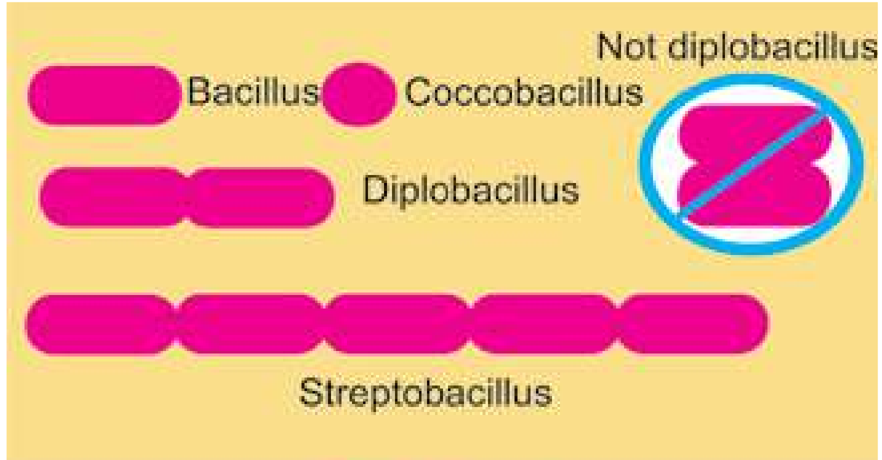


Fig. 6.3 Bacilli

Animation 6.4: Bacillus Bacteria
Source and Credit: gif2fly

The spiral shaped bacteria are spirally coiled. Spirals come in one of three forms, a **vibrio**, a **spirillum,** or a **spirochete**. Vibrio is curved or comma-shaped rod. Spirillum is a thick, rigid spiral. Spirochete is a thin, flexible spiral. Examples of spiral shaped bacteria are *Vibrio, Hyphomicrobium.*

Fig. 6.4 Spirilla

Animation 6.5: Spirillum
Source and Credit: gifsoup

Bacterial Cell Structure

Flagella and their frictions : These are extremely thin, hair like appendages. They come out through cell wall and originate from basal body, structure just beneath the cell membrane in the cytoplasm. They are made up oif protein **flagellin**. On the basis of presence of flagella, pattern of attachment of flagella and the number of flagella present bacteria are classified into different taxonomic groups. **Atrichous** means bacteria are without any flagella. When single polar flagellum is present then condition is known as **monotrichous.** If tuft of flagella is present only at one pole of bacteria then these are lophotrichous flagella. **Amphitrichous** is a condition when tuft of flagella at each of two poles is present. In **peritrichous** form, flagella surround the whole cell. Most of bacilli and spiral shaped bacteria have flagella. Cocci very rarely have flagella.

Primary function of flagella is to help in motility.With the help of flagella, flagellate bacteria can also detect and move in response to chemical signals which is a type of behaviour called as *Chemotaxis.*

Animation 6.6: Flagelo
Source and Credit: gifsoup

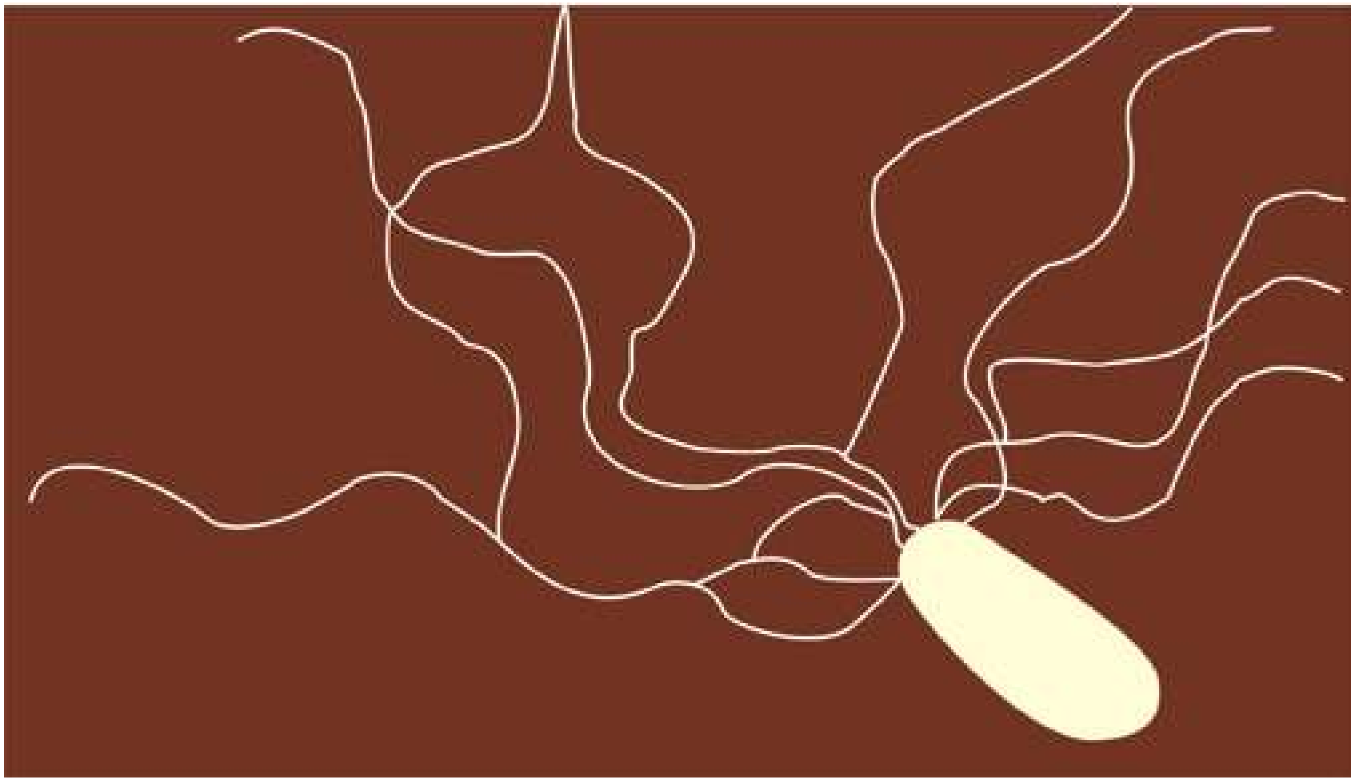


Fig. 6.5 Rod shaped bacterium with flagella (lophotricous)

Pili a. d their Fu. ctio. s

These are hollow, nonhelical, filamentous appendages. **Pili** are smaller than flagella and are not involved in motility. True pili are only present on gram-negative bacteria. They are made up of special protein called **pilin**. They are primarily involved in a mating process between cells called **conjugation** process. Some pili function as a **means** of attachment of bacteria to various surfaces.

The cell e. velope: The outer wrappi. g of bacteria

Bacterial surface and walls are very diverse. Collectively complexes of layer external to the cell protoplasm are called as cell envelope and include capsule, slime and cell wall.

Capsule : Bacteria produce capsule, which is made up of repeating polysaccharide units, and of protein, or of both, capsule is tightly bound to the cell. It has a thicker, gummy nature that gives sticky characters to colonies of encapsulated bacteria. It provides pathogenicity.

Slime : Some bacteria are covered with loose, soluble shield of macromolecules which is called as slime capsule and slime provides greater pathogenicity to bacteria and protects them against phagocytosis.

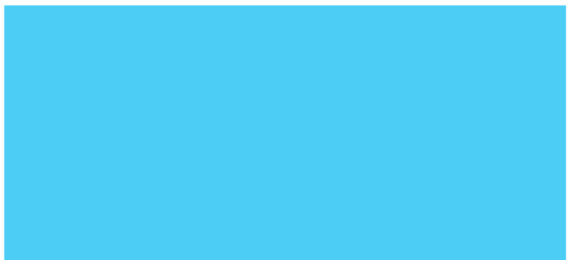
Cell Wall: Beneath the extracellular substances and external to cytoplasmic membrane cell wall is present. It is a rigid structure. It determines the shape of bacterium. Cell wall also protect the cells from osmotic lysis. Cell wall is only absent in mycoplasmas. Christain Gram developed the technique of gram stain. Bacteria could be divided into two groups based on their response to gram staining procedure. By this Staining technique **Gram-positive bacteria** are stained purple (retain the primary dye due to formation of CV-I complex) and **Gram-negative bacteria** are stained pink (retain secondary dye) in colour. There are many structural differences between two groups (Table 6.1) which are the primary basis for difference in staining behaviour.

Table 6.1: Comparison of Gram-positive and Gram-negative cell walls.

Characteristics	Gram-Positive	Gram-negative
Number of major layers	1	2
Chemical make up	Peptidoglycan (50% of dry weight in some bacterial cells) Teichoic acid Lipoteichoic acid	Lipopolysaccharides Lipoproteins Peptidoglycan 10% dry weight of some bacterial cells
Overall thickness	Lipids (1-4%) 20-80 nm	Lipids (11-12%) 8-11 nm
Outer membrane	No	Yes
Periplasmic space	Present in some	Present in all
Permeability	More permeable	Less permeable

The cell walls of most bacteria have a unique macromolecule called as **peptidoglycan**. Its amount varies in different types of bacteria. It is composed of framework of long glycan chains cross-linked with peptide fragments. The intact cell wall also contains chemical constituents such as sugar molecules, teichoic acid, lipoproteins and lipopolysaccharides, which are linked to peptidoglycan.

Several bacterial groups lack the cell wall structure characteristic of Gram positive or Gram negative bacteria, and some bacteria have no cell wall at all. Cell walls of archacnbactcria are different from eubacteria. They do not contain peptidoglycan. Their cell walls are composed of proteins, glycoproteins and polysaccharides).



Animation 6.7: Bacteria, gram positive bacilli
Source and Credit: gif2fly

Cell Membra.e

Just beneath the cell wall is the cell membrane or plasma membrane. It is very thin, flexible and completely surrounds the cytoplasm. Plasma membrane is very delicate in nature any damage to it results in death o f the organism. Bacterial membranes differ from eukaryotic membranes in lacking sterols such as cholesterol.

Cell membrane regulates the transport of proteins, nutrients, sugar and electrons or other metabolites. The plasma membranes of bacteria also contain enzymes for respiratory metabolism.

Cytoplasmic matrix

The cytoplasm of prokaryotic cell lacks membrane bound organelles and cytoskeleton (microtubules). The cytoplasmic matrix is the substance present between the plasma membrane and the nucleoid. It has gel like consistency. Small molecules can move through it rapidly. The plasma membrane and every thing present within it is known as protoplast. Thus the cytoplasmic matrix is a major part of protoplast. Other large discrete structures such as chromatin /nuclear body, ribosomes, mesosomes and granules and nucleoid are present in this matrix.

Nucleoid

A bacterial cell unlike the cells of eukaryotic organisms lacks discrete chromosomes and nuclear membrane. The nuclear material or DNA in bacterial cells occupies a position near to the center of cell. This material is a single, circular and double stranded DNA molecule. It aggregates as an irregular shaped dense area called the **nucleoid**. This **chromatin body** is actually an extremely long molecule of DNA that is tightly folded so as to fit inside the cell component. Since bacteria have a single chromosome, they are haploid.

Other names for nucleoid are nuclear body, chromatin body and nuclear region.

It is visible in the light microscope after staining with Feulgen stain.

Excherichi coli closed circle chromosome measures approximately 1,4000 μm

Plasmid

Many bacteria contain plasmids in addition to chromosomes. These are the circular, double stranded DNA molecules. They are self-replicating and are not essential for bacterial growth and metabolism. They often contain drug resistant, heavy metals, disease and insect resistant genes on them.

Plasmids are important vectors, in modem genetic engineering techniques.

Ribosomes

Ribosomes are composed of RNA and proteins. Some may also be loosely attached to plasma membranes. They are protein factories. There are thousands of ribosomes in each healthy growing cell. They are smaller than eukaryotic ribosomes.

Mesosomes

The cell membrane, invaginates into the cytoplasm forming structure called as **mesosome**. Mesosomes are'in the form of vesicles, tubules or lamellae. Mesosomes are involved in DNA replication and cell division where as some mesosomes are also involved in export of exocellular enzyme. Respiratory enzymes are also present on the mesosomes.

Gra.ules a.d storage bodies

Since bacteria exist in a very competitive environment where nutrients are usually in short supply. They tend to store extra nutrients when possible. These may be glycogen, sulphur, fat and phosphate. In addition, cells contain waste materials that are subsequently excreted. For example, common waste materials are alcohol, lactic acid and acetic acid.

Spores

Certain species of bacteria produce spores, either external to the vegetative cells (exospores) or within the vegetative cells (endospores). They are metabolically dormant bodies and are produced at a late-stage of cell growth. Spores are resistant to adverse physical environmental conditions such as light, high temperature, desiccation, pH and chemical agents, Under favorable conditions they germinate and form vegetative cells.

Cysts

Cysts are dormant, thick-walled, desiccation resistant forms and develop during differentiation of vegetative cells which can germinate under suitable condition. They are not heat resistant.

Nutritio. of Bacteria

Like other organisms bacteria need energy for their growth, maintenance and reproduction. Most bacteria are **heterotrophic** i.e.. they cannot synthesize their organic compounds from simple inorganic substances. They live either as saprophytes or as parasites. **Saprophytic bacteria** get their food from dead organic matter. Soil is full of organic compounds in the form of humus. Humus is the material resulting from the partial decay of plants and animals. Many soil inhabiting bacteria have vety extensive enzyme system that breaks down the complex substances of humus to simpler compounds. The bacteria can then absorb and utilize these simpler substances as a source of energy. **Parasitic bacteria** for their nutrition are fully dependent on their host.

Some kinds of bacteria are **auotrophic** i.e., they can synthesize organic compounds which are necessary for their survival from inorganic substances.These bacteria may be separated into two groups : **photosynthetic autotrophs** and **chemosynthetic autotrophs. Photosynthetic bacteria** possess chlorophyll which differs from the chlorophyll of green plants. Unlike most green plants, which have their chlorophyll in chloroplasts, bacterial chlorophyll is dispersed in the cytoplasm. During photosynthesis the autotrophic bacteria utilize hydrogen sulphide (H_2S) instead of water as a hydrogen source and liberate sulphur instead of oxygen. Nitrifying bacteria are chemosynthetic. **Chemosynthetic bacteria** oxidize inorganic compounds like ammonia, nitrate, nitrite, sulphur or ferrous iron and trap the energy thus released for their synthetic reactions. The overall reaction of photosynthesis in photosynthetic bacteria can be written as :

$$CO_2 + 2H_2S \xrightarrow[\text{Chlorophyll}]{\text{Light}} (CH_2O)_n + H_2O + 2S$$

Green sulphur bacteria, purple sulphur bacteria and purple non-sulphur bacteria are photosynthetic bacteria.

Respiratio. i. Bacteria

Respiration in bacteria may be aerobic (requiring free oxygen) or anaerobic not requiring free oxygen. Bacteria, which are able to grow in the presence of oxygen, are called aerobic bacteria. While those which can grow in the absence of oxygen are known as **anaerobic bacteria**. Some bacteria are neither aerobic nor anaerobic, but facultative. **Facultative bacteria** grow either in the presence or absence of oxygen. Some bacteria require a low concentration of oxygen for growth and are known as **microaerophilic.**

Pseudomonas is an aerobic bacterium.

Spirochete is an anaerobic bacterium.

E.coli is a facultative anaerobic bacterium.

Campylobacter is a microaerophilic bacterium.

Growth a.d Reproductio.

Bacterial growth refers commonly to increase in number of bacterial cells. Bacteria increase in number by an asexual means of reproduction, called binary fission. In binary fission parent cell enlarges, its chromosome duplicates, and plasma membrane pinches inward at the center of the cell. When nuclear material has been evenly distributed, the cell wall grows inward to separate cell into two. This sequence is repeated at intervals by each new daughter cell which in turn increases the population of cells. Once the division is complete, bacteria grow and develop their unique features. The interval of time until the completion of next division is known as generation time. Four distinct phases are recognized in bacterial growth curve.

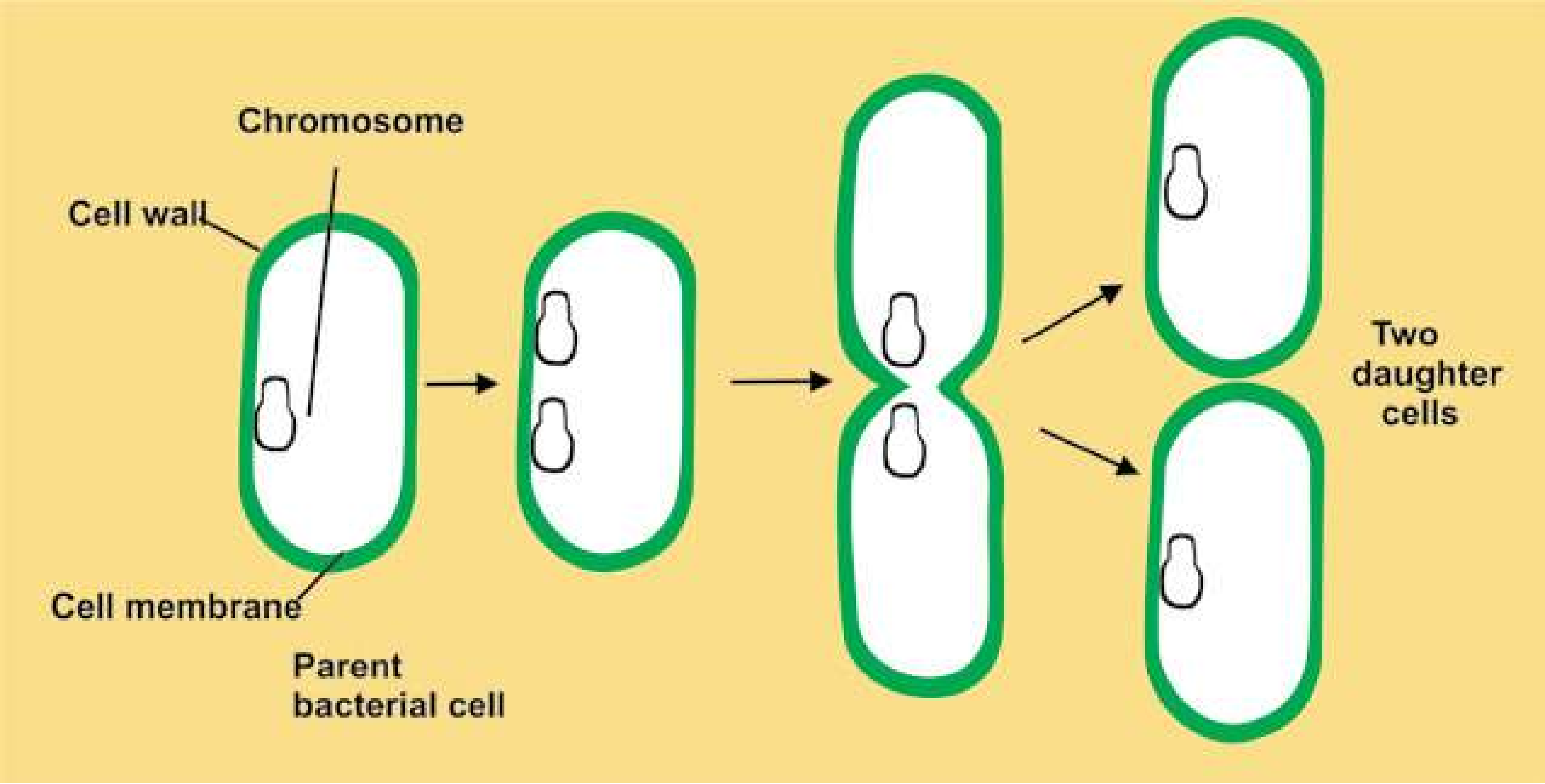


Fig. 6.6 Binary Fission in bacteria

1) Lag phase: It is phase of no growth. Bacteria prepare themselves for division.
2) Log phase: It is phase of rapid growth. Bacteria divide at exponential rate.
3) Stationary phase: Bacterial death rate is equal to bacterial rate of reproduction and multiplication.
4) Death/Decline phase: Bacteria start dying. Here the death rate is more than reproduction rate.

Bacteria lack traditional sexual reproduction and mitosis. However, some bacteria transfer genetic material from a donor bacterium to a recipient during a process called **conjugation**. Some conjugating bacteria use specialized **sex pili** to transfer genetic material. Conjugation produces new genetic combinations that may allow the resulting bacteria to survive under great variety of conditions.

IMPORTANCE OF BACTERIA

Ecological importa.ce
Bacteria are ecologically very important. They are highly adaptable as a group and are found nearly everywhere. They are able to decompose organic matter and play a significant role in the completion of cycles of nitrogen, phosphorus, sulfur and carbon.

Eco.omic Importa.ce
Bacteria are used in number of industries, including food, drugs (production of antibiotics and vaccines) and in biotechnology. Bacteria are also responsible for spoilage of food and vegetables. Many plant pathogens adversely affect the agricultural industry.

Medical Importa.ce
Bacteria are very common pathogens of humans. Approximately 200 species are known to cause diseases in humans. Many bacteria normally inhabit the bodies of man and other animals.

Co.trol of bacteria
Control of microorganisms is essential in home, industry as well as in medical fields . By controlling microorganisms one can prevent and treat diseases. Spoilage of foods and other industrial products can be inhibited by controlling microorganisms.

Microorganisms can be controlled by various methods.

Physical methods : In this, steam, dry heat, gas, filtration and radiation are used to control bacteria. The process in which we use physical agents to control bacteria/microorganism is known as **sterilization process**. Sterilization is destruction of all life forms.

High temperature is usually used in microbiological labs for control of microbes. Both dry heat and moist heat are effective. Moist heat causes coagulation of proteins and kills the microbes. Dry heat causes oxidation of chemical constituents of microbes and kills them.

Certain electromagnetic radiations below 300 nm are effective in killing of microorganisms. Gamma rays are in general used for sterilization process.

Heat sensitive compounds like antibiotics, seras,-hormones etc. can be sterilized by means of membrane filters.

Chemical methods: One can use **antiseptics**, **disinfectants** and **chemotherapeutic** agents for microbial control. Chemical substances used on living tissues that inhibit the growth of microorganism are called **antiseptics.**

The important chemical agents used for disinfection are oxidising and reducing agents. For example halogens and phenols, hydrogen peroxide, Potassium **permanganate**, alcohol and formaldehyde etc. inhibit the growth of vegetative cells and are used on nonliving materials.

Chemotherapeutic agents and **antibiotics** work with natural defense and stop the growth of bacteria and other microbes. These are Sulfonamides, tetracycline; penicillin, etc. They destroy or inhibit the growth of microorganisms in living tissues.

Microbicidal effect is one that kills the microbes immediately

Microbistatic inhibits the reproductive capacities of the cells and maintains the microbial population at constant size.

Modes ol action of different chemical and physical agents of control vary. Damage can result malfunctions in cell wall, cell membranes, cytoplasmic enzymes, or nucleic acid.

Immunization and Vaccination : Methods of prevention and treatment that have been introduced to control microbial diseases include **immunization** (e.g. **vaccination**), **antisepsis** (procedures to eliminate or reduce the possibility of infection), **chemotherapy** and public health measures (e.g. water purification, sewage disposal, and food preservation).

Pasteur made many discoveries concerning the cause and prevention of infectious diseases. In 1880's he isolated the bacterium responsible for **chicken cholera**. He grew it in a pure culture. To prove that he really had isolated the bacterium responsible for this disease Pasteur made use of the fundamental techniques devised by Koch. He arranged experiments for a public demonstration in which he repeated an experiment that had been successful in many previous trials in his laboratory.

He inoculated healthy chicken with his pure cultures and waited for them to develop chicken cholera and die. But to his dismay, the chickens failed to get sick and die. Reviewing each step of the experiment, Pasteur found that he had accidentally used the cultures several weeks old instead of fresh one grown especially for the demonstration. He soon discovered that somehow bacteria could lose their virulence, or ability to produce disease, after standing and growing old. But these attenuated, or less virulent, bacteria could still stimulate the host (in this case the chicken) to produce antibodies, substances that protect the host (in this case the chicken) against infection due to subsequent exposure to the virulent organism.

Pasteur next applied this principle of inoculation with attenuated cultures to the prevention of anthrax, and again it worked. He called the attenuated cultures of bacterial **vaccine** (a term derived from the Latin **Vacca**, "cow") and immunization with attenuated cultures of bacteria, **vaccination.**

Pasteur honoured Edward Jenner (1749-1823), who had successfully vaccinated a boy against small pox in 1796. Jenner had learned that milkmaids who contracted cowpox from the cows, they milked, never subsequently contracted the much more virulent small pox. Accordingly he tested this hypothesis by inoculating young James Phipps first with cowpox causing material and later with small pox causing material. The boy did not get small pox.

Then Pasteur also made a vaccine for **hydrophobia**, or rabies, a disease transmitted to people by bites from rabid dogs, cats, and other animals.

USE AND MISUSE OF ANTIBIOTICS

Antibiotics is a Greek word (**Anti-against-and Bios life)**. Antibiotics are the chemotherapeutic chemical substances which are used in treatment of infectious diseases. Antibiotics are synthesized and secreted by certain bacteria, actinomycetes and fungi. Today, some antibiotics are synthesized in the laboratory. However, their origins are living cells. To determine drug of choice, one must know its mode of action, possible adverse side effects in the human beings.

Use antibiotics as prescribed by the physicians. Take dose at regular intervals and complete the treatment as advised by the doctor.

Massive quantities of antibiotics are being prepared and used, which are followed by the widespread problems of drug resistance in microorganisms. This results in an increasing resistance against disease treatments. Misused antibiotics can interact with the human metabolism and in severe cases can cause death of human beings. Misuse of antibiotic such as penicillin can cause allergic reactions. Similarly streptomycin can affect auditory nerve thus causing deafness. Tetracycline and its related compounds cause permanent discoloration of teeth in young children.

CHARACTERISTICS OF CYANOBACTERIA

The cyanobacteria are the largest and most diverse group of photosynthetic bacteria which was previously known as **'blue green algae'**. Cyanobacteria are true prokaryotes. They vary greatly in shape and appearance. They range in diameter from about 1-10um and may be unicellular, exist as colonies of many shapes, or form **filaments** consisting of **trichomes** (chains of cells) surrounded by mucilaginous sheath. They have normal Gram-negative type cell wall. They lack flagella and often use gas vesicles to move in the water, and many filamentous species have gliding motility.

Their photosynthetic system closely resembles that of eukaryotes because they have chlorophyll a and photosystem II.They carry out oxygenic photosynthesis, i.e., they use water as an electron donor and generate oxygen during photosynthesis. Cyanobacteria use **phycobilins** as accessory pigments. Photosynthetic pigments and electron transport chain components are located in thylakoid membranes linked with particles called **phycobilisomes. Phycocyanin** pigment (blue) is their predominant phycobilin and $C0_2$ in them is assimilated through the Calvin cycle.

Reserve food material in cyanobacteria is **glycogen.** Cyanobacteria reproduce by binary fission, fragmentation. In cyanobacteria h**ormogonia, akinetes** and **heterocysts** are present.

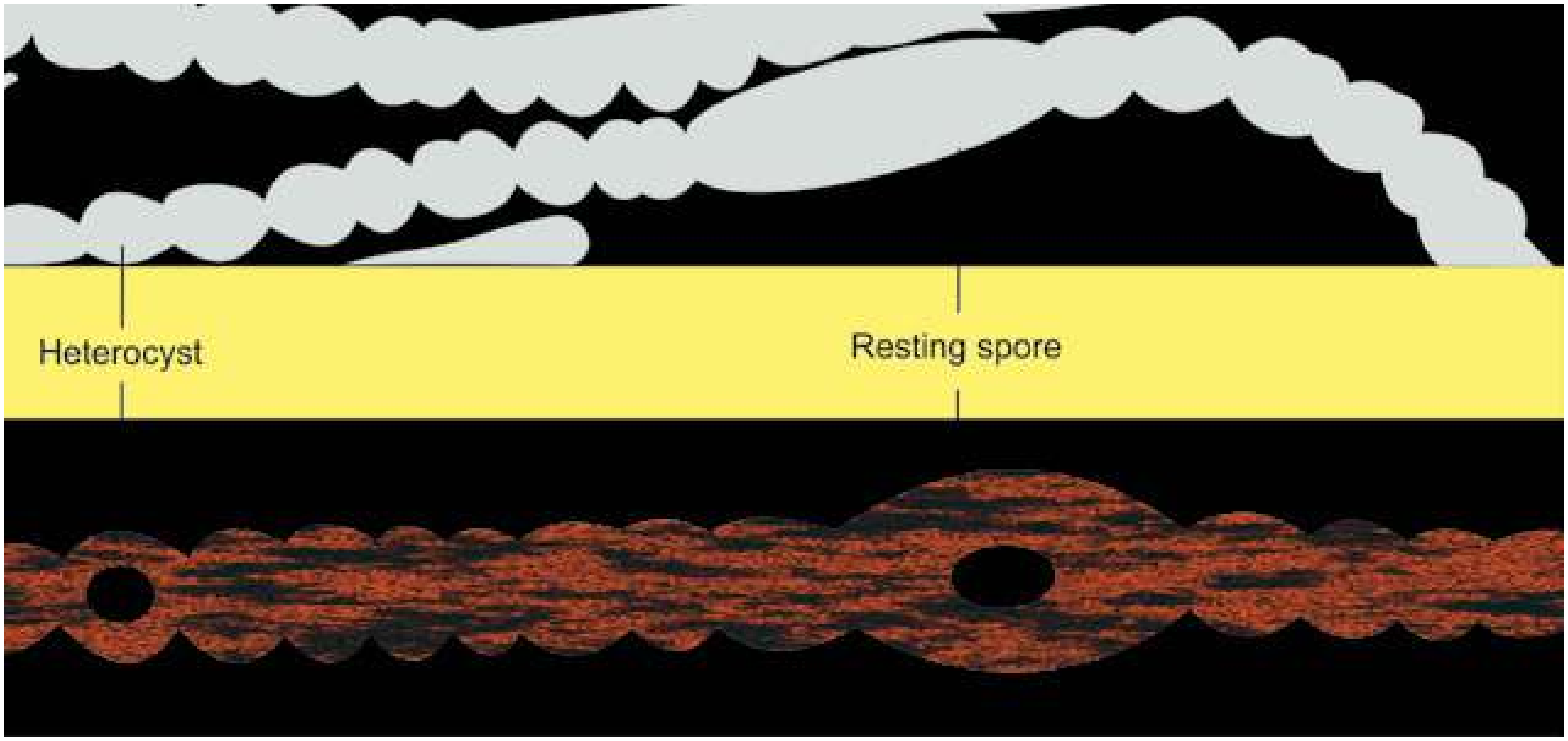


Fig. 6.8 Cyanobacterium *Anabaena*

ECONOMIC IMPORTANCE

They help in reclamation of alkaline soils . Cyanobacteria have **heterocysts**, which are helpful in the fixation of atmospheric nitrogen. They release O_2 in the environment due to their photosynthetic activity. *Oscillatoria* and few other cyanobacteria can be used as pollution indicator. They have symbiotic relationship with protozoa, fungi, and nitrogen fixing species form associations with angiosperms. They are photosynthetic partners in most of lichen association.

Super Blue green algae are basically expensive pond scum, in which cyanobacterium is a single celled organism that produces its own food through photosynthesis. It serves as a "complete whole food" which contain 60% protein with all essential amino acids in perfect balance.

Many species of cyanobacteria form **water blooms** where they often impart unpleasant smell and due to large amount of suspended organic matter water becomes unfit for consumption. Some species produce toxins that kill live stock and other animals that drink the water.

NOSTOC

Habitat a.d occurre.ce

Nostoc is common as terrestrial and subaerial cyanobacterium. It is widely distributed in alkaline soils and on moist rocks and cliffs. *Nostoc* forms a jelly like mass in which numerous filaments are embedded.

Structure

Trichomes are unbranched and appear beaded. Individual cells are mostly spherical but some times barrel shaped or cylindrical.

All cells in trichome are mostly similar in structure but at intervals are found slightly large , round, light yellowish thick walled cells called as **heterocysts.** Trichome mostly breaks near heterocyst and forms **hormogonia** and thus help in fragmentation.

Reproductio.

There is no sexual reproduction but it reproduces asexually by formation of hormogonia. Hormogonia are formed when filament break at different points into smaller pieces.This is due to death and decay of the ordinary cell or the heterocyst may serve as a breaking point. Reproduction can also be due to akinete formation. **Akinetes** are thick walled , enlarged vegetative cells which accumulate food and become resting cells. On arrival of favourable conditions they form normal vegetative cell.

EXERCISE

Q.1. Fill in the blanks.

(i) A bacterial arrangement in packets of eight cells is described as a-------------.
(ii) The shape and arrangement of is diplococci
(iii) Pili are tubular shafts in bacteria that serve as a means of-----------.
(iv) -------------- are unusual type of bacteria that live in extreme habitats.
(v) ------------- is a bacterium that is photosynthetic.
(vi) -------------- is a cyanobacterium.
(vii) ---------------- called as bloom forming organism.
(vii) Use of antibiotics is one of the means of controlling ------------- diseases.

Q.2. Short questions.

(i) (a) Name general characteristics that could be used to define the prokaryotes.
(b) Do any other microbial groups besides bacteria have prokaryotic cells?
(c) In what habitats are bacteria found? Give some general means by which bacteria derive nutrients.

(ii) (a) List functions that the cell membrane performs in bacteria.
(b) What are mesosomes and some of their possible functions?

(iii) What is unique about the structure of bacterial ribosomes?

(iv) Draw the three bacterial shapes.

(v) Name a bacterium that has no cell wall.

(vi) A gram stained discharge from an dbcess shows cocci in irregular grape like clusters. What is the most likely genus of this bacterium

(vii) Draw an outline and label (i) streptobacilli, (ii) diplococci, (iii) staphylococci.

(viii) You observe a culture of predominantly round (presumably spherical) bacteria that though apparently fully divided, nevertheless have failed to separate, thus resulting in long chains of cells. What, generally, might you call such an arrangement?

(ix) Match the following descriptions with the best answer.

(a) Division in one plane; cocci arranged in pairs	(a) Bacillus
(b) Division in one plane; cocci arranged in chains	(b) Streptobacillus
(c) Division in two planes; cocci arranged in a square of four	
	(c) Spirochete
(d) Division in one plane; rods completely separate after division.	(d) Spirillum
(e) Division in one plane; rods arranged in chains.	(e) Vibrio
(f) A comma shaped bacterium	(f) Streptococcus
(g) A thin, flexible spiral.	(g) Staphylococcus
(h) A thick, rigid spiral.	(h) Diplococcus
	(i) Tetrad
	(j) Sarcina

Q.3. Extensive Questions

(i) Describe in detail the structure of bacterial cell wall, emphasizing Gram positive and Gram negative properties.

(ii) Write an account of different methods used for controlling microbes.

(iii) Discuss the role of antibiotics and immunization in controlling bacterial diseases. What problem can arise due to misuse of antibiotics.

(iv) Describe general characteristics of Cyanobacteria with special reference to Nostoc.

(v) Write Notes on :

(a) Koch’s postulates (b) Shape of bacteria

(c) Flagella and pili (d) Growth in bacteria.