Cyanobacteria: Salient Feature

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A. Occurrence of Cyanobacteria:

- Cyanobacteria or blue green algae are the one of most successful, most self-contained, autotrophic organisms on earth.
- They present in all types of environments—

Fresh water

Sea water

Salt marshes

Moist rocks

Tree trunks

Moist soils

Hot springs.

- The red sea is named after the colouration provided by red coloured planktonic cyanobacteria known as *Trichodesmium erythraeum*.
- They can live on every type of substrate.
- Many of them have the ability of nitrogen fixation.

B. Morphology of Cyanobacteria:

Chrococcus

- a) Cyanobacteria may be

  i) Unicellular: *Chrococcus*, *Anacystis*, *Gleocapsa*, *Synecoccus*

  ii) Colonial: After division, cells join together with their common gelatinous matrix: *Nostoc*.

  iii) Non-filamentous: Cell division proceeds alternatively in two line (right angles to each other) e.g. *Gomphaera* or in three planes e. g. *Eucapsis*.

  iv) Filamentous: Result of repeated cell division without in a single plane and in single direction forming a chain or thread (trichome).

  (1) Trichome straight: *Arthospira*

  (2) Spirally coiled: *Spirulina*.

  b) Each trichome consists of enclosed sheath of mucilage and one or more cellular strands called ***Filament***.

  Oscillatoria: Single trichome.

  Microcoleus: Several trichome.

  c) Single trichome filaments may further be of two types,

  Homocystous (undifferentiated): *Oscillatoria* and

  Heterocystous (differentiated, having heterocysts): *Nostoc*.

  d) Colonies develop in some cases, e.g., *Nostoc*.

  e) Flagella are absent but gliding movements are known in a number of cyanobacteria.

  Oscillatoria: named on the basis of pendulum like oscillating movements of its anterior region.

C. Cell Structure of Cyanobacteria:

1. Cell structure is typically prokaryotic.
2. One envelope organization with peptidoglycan wall
3. Naked DNA
4. 70S ribosomes
5. Absence of membrane bound structures (endoplasmic reticulum, mitochondria, Golgi bodies, plastids, lysosomes, sap vacuoles).
6. The cell wall is ***four*** layered with peptidoglycan present in the second layer.

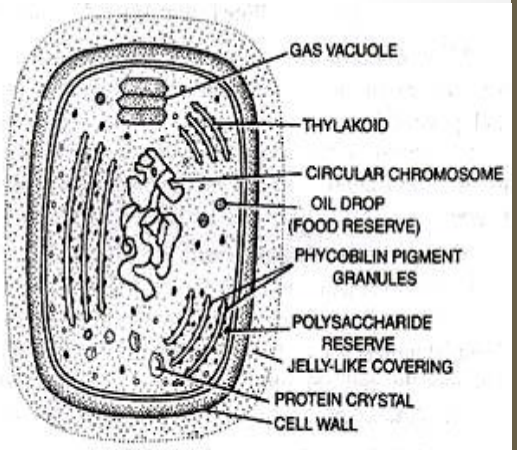
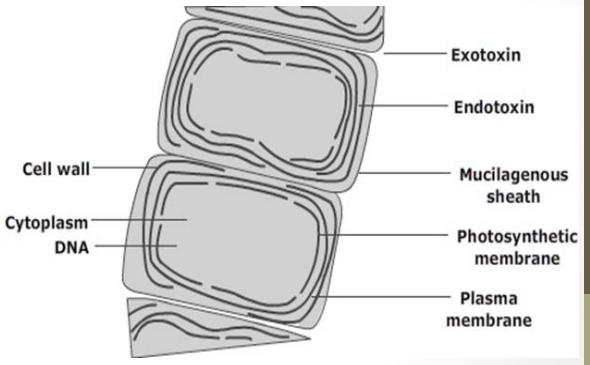


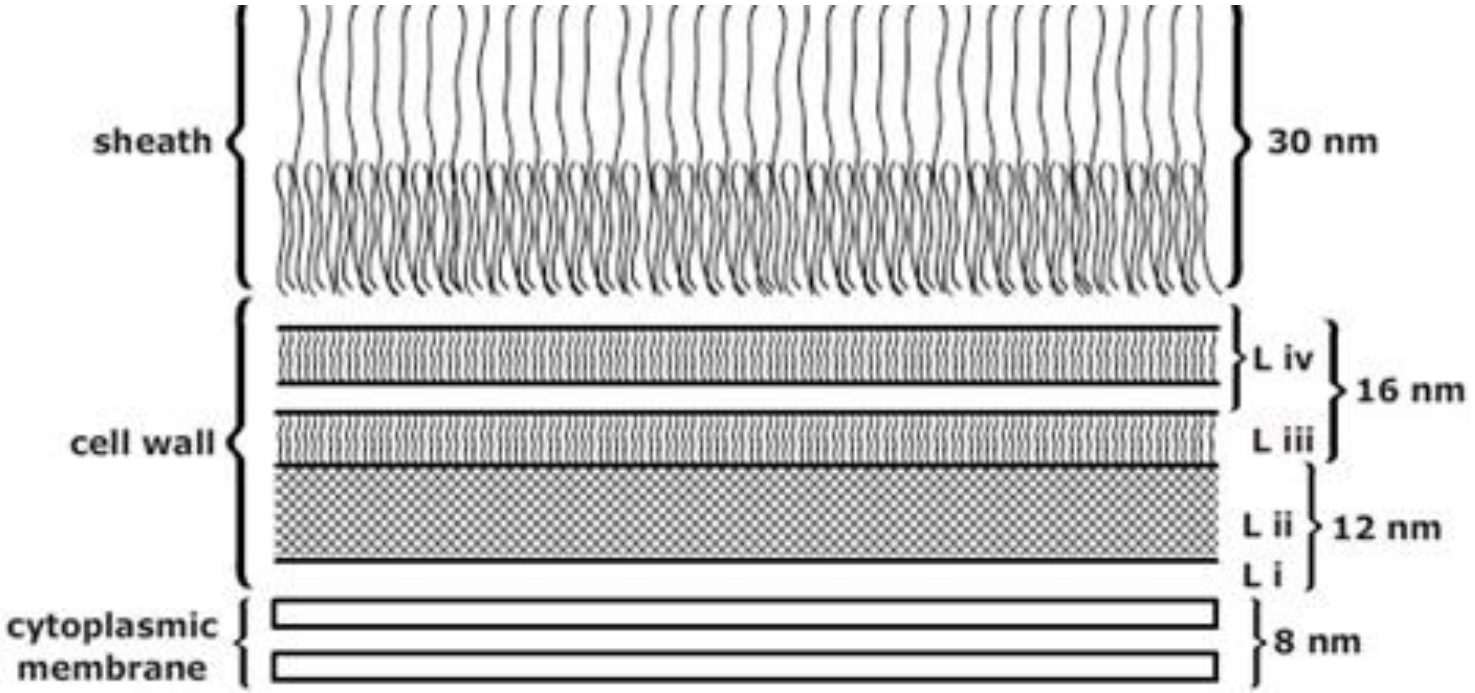
Fig. 2.18. Ultrastructure of a cyanophycean cell.

- Light microscope: cyanophycean cells have two envelopes:
  - Mucilaginous sheath and
  - cell wall.
- Mucilaginous sheath may be absent in some forms.
- Cell wall is made up of two layers:
  - Inner hemi-cellulosic and
  - Outer pectic.
- Inside it lies the plasma membrane.
- The sheath is thick and slimy.



- Cells may have
  - Individual sheath, e.g. spherical in *Chlorococous*,
  - Cylindrical in *Nostoc*, interrupted in *Oscillatoria*.
- The sheath is characteristic of blue-green algae and this is how they are called Myxophyceae, which means slime algae.
- Generally, The ***sheath*** is quite thick, colourless and has a watery consistency.
- It is made up of pectic compounds.
- Sheath may be variously pigmented, lamellated or stratified.
- Sheath may be red (i.e. acidic), blue (i.e. basic) and yellow/brown, (with high salt content).
- It protects the cell against desiccation and against UV irradiation.
- Pectin secretion by the protoplast of cyanophyceae is a primitive character.
- Under electron microscope, the sheath appears fibrillar and two-layered.
- Fibers are less dense in the outer part than the inner.
- Between the sheath and cell wall, there is a zone of low electric density.
- Cell wall appears Four-layered, L1, L2, L3 and L4. Outer and middle are separated from each other by a clear space.
- Cytoplasmic membrane is proteinaceous and two-layered, electron-opaque.

Myxophycean cell wall under electron microscope

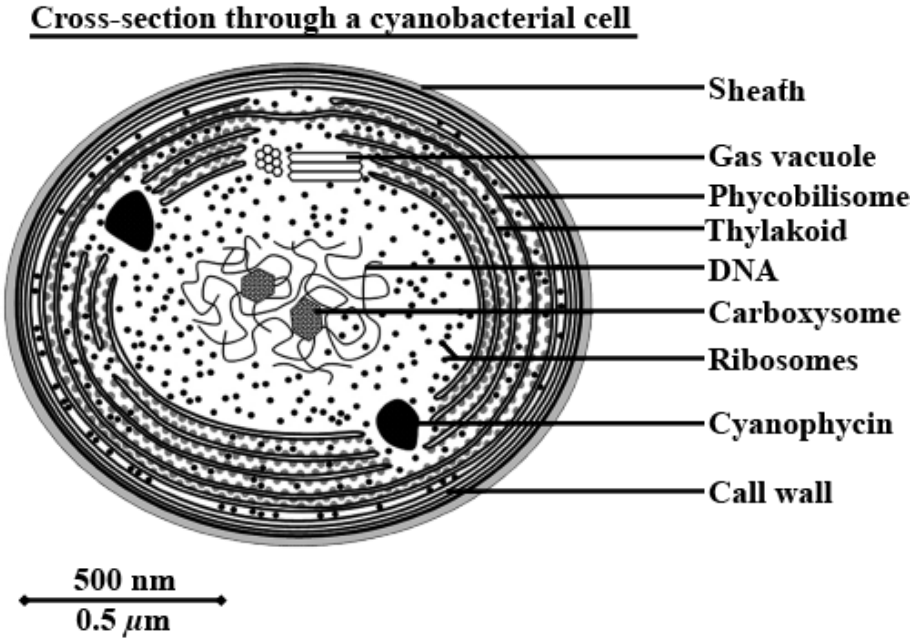


Chloroplast

- In cyanophyceae,
  - Vegetative cell is for photosynthesis,
  - Spores make the resting stage and
  - Heterocysts, i.e. the specialized cells are meant for nitrogen fixation.
- The outer part of the protoplast contains a number of photosynthetic thylakoids: called ***chromoplasm***.
- The thylakoids
  - Lie freely in the cytoplasm.
  - Single or paired
- Photosynthesis I & II
- Their membranes contain chlorophyll a, carotenes and xanthophyll's. Chlorophyll b is absent.
- Attached to the thylakoid membranes are small granules known as ***phycobilisomes***.

- The phycobilisomes possess accessory photosynthetic pigments known as phycobilins.
- The phycobilins are of three types—
  - phycocyanin (blue),
  - allophycocyanin (blue) and
  - phycoerythrin (red).
- Differential formation of phycobilins produces specific colouration which is adapted to absorbing maximum amount of solar radiation.
- Therefore, cyanobacteria are not always blue green.
- They may appear purplish, violet, brownish, etc.
- Instead of typical vacuoles or sap vacuoles, gas vacuoles or pseudo-vacuoles are found.
- Each gas vacuole consists of a number of submicroscopic units called gas vesicles.
- Gas vacuoles provide buoyancy regulating mechanism and pneumatic strength.

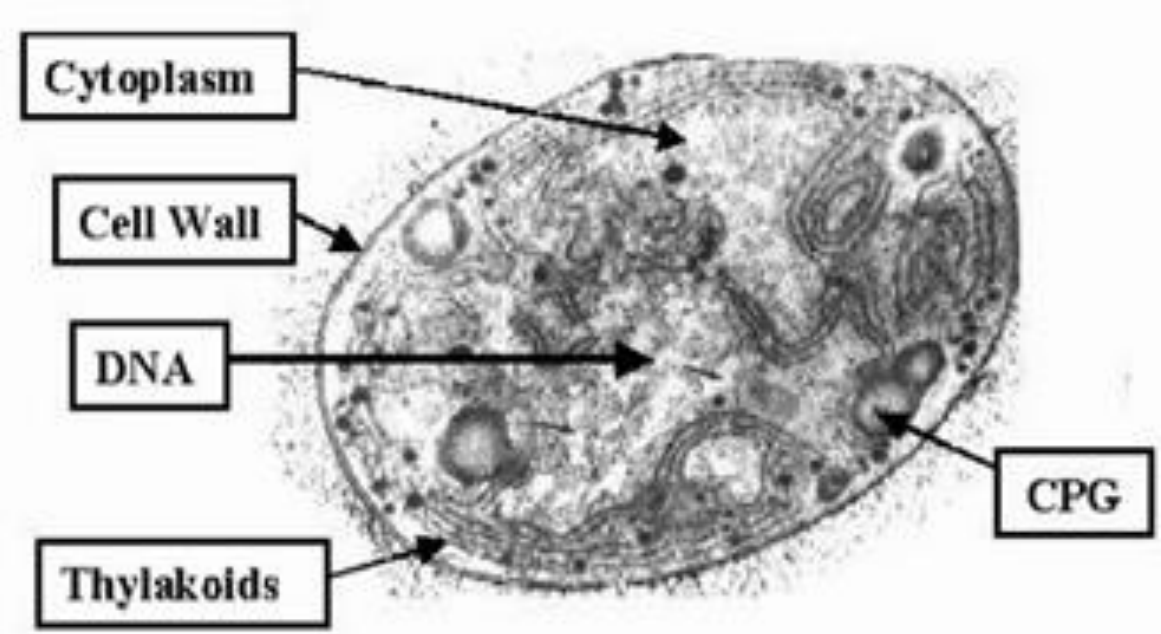
- A naked, circular, double stranded DNA lies coiled generally in the central part of the cytoplasm known as centroplasm.
- It is often called ***nucleoid***: It is actually Semicircular group of coiled membranes often attaches the plasma membrane.
- 70S ribosomes occur here and there.
- Four types of inclusions occur in the cells.
  - They are α-granules (cyanophycean starch),
  - β-granules (lipid droplets),
  - Volutin granules and
  - Polyhedral bodies (ribulose biphosphate carboxylase).



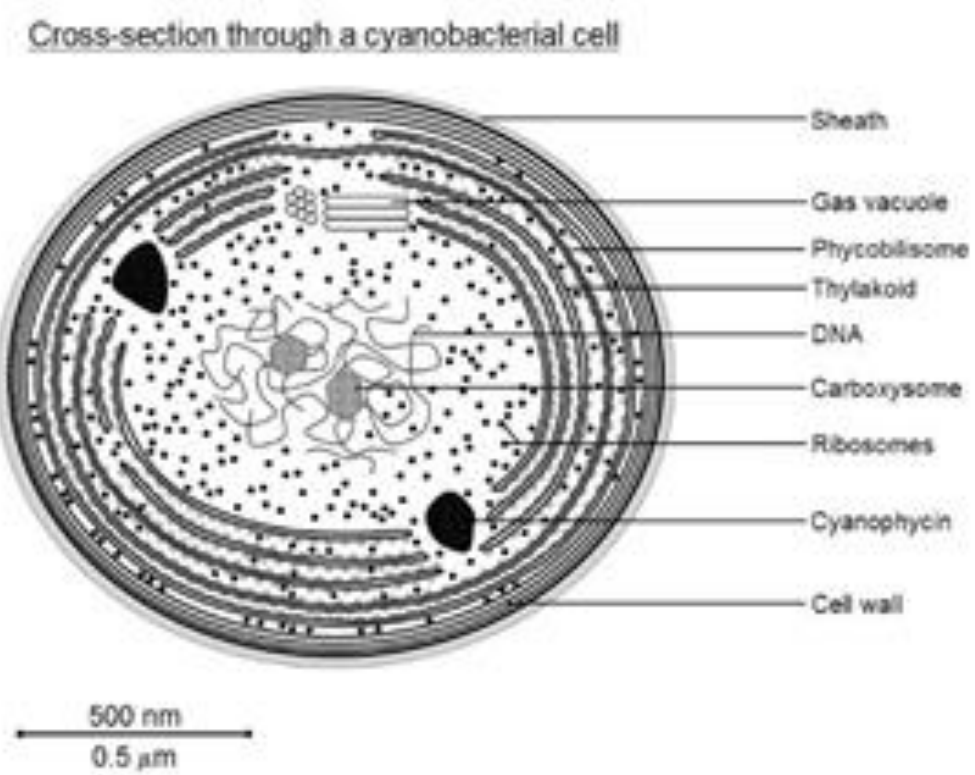
Carbon storage or food storage

- In the form of ***Cyanophycean*** starch: A less opaque lipid layer separates them.
- **Protoplast** has elementary internal structure.
- Lack of organized nucleus, plastids, mitochondria, Golgi apparatus and sap vacuoles.
- It has:
  - Peripheral chromoplasm: Photosynthetic structure.
  - Central light area centroplasm: Central body.
- It is made up of complex lamellar system, thylakoids.
- Generally present towards periphery, sometimes as in *Anabaena* throughout the protoplasm.
- Thylakoids are narrow tube like structures and apart from being photosynthetic, they are also seat of cellular respiration.
- Therefore, they are named as photosynthetic respiratory membranes.
- Particles of phycobilisome and phycobiliproteins are attached to these membranes .

Electron micrograph of an cyanophycean cell



Diagrammatic section through a prokaryotic cell



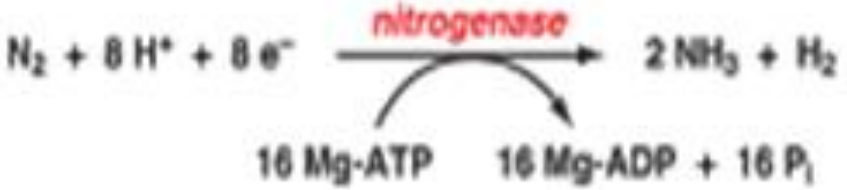
d) Heterocyst of Cyanobacteria:

- It is a large-sized pale coloured thick-walled cell which occurs in terminal, intercalary or lateral position in filamentous cyanobacteria, e.g., *Nostoc*.
- The thick wall is impermeable to oxygen but permeable to nitrogen.
- Mucilage sheath is absent.
- Photosystem II is absent.
- Thylakoids lack phycobilisomes.
- Therefore, non-cyclic photosynthesis is absent but cyclic photophosphorylation occurs.
- Heterocyst is dependent for its nourishment on adjacent vegetative cells.
- It has enzyme ***nitrogenase***.
- Heterocyst is specialized to perform nitrogen fixation.

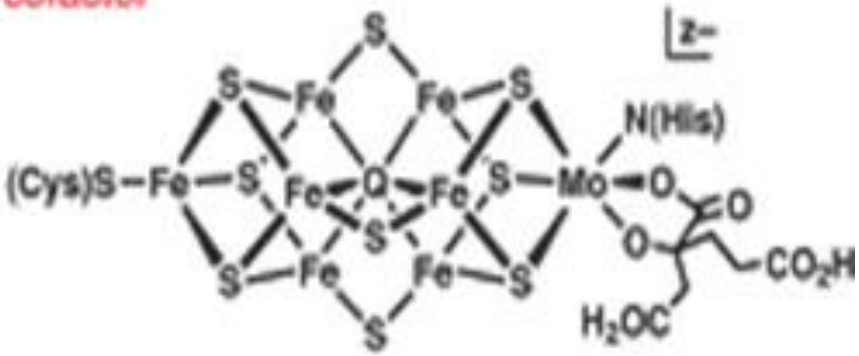
Heterocyst
Specialized cells for fixing nitrogen

- They are thick walled cells occurring in sideways position of cyanobacteria.
- They are permeable to nitrogen and impermeable to oxygen.
- They are seats of photophosphorylation but no photosynthesis.
- For survival, it depends on the adjacent cells.
- Often polar nodules are present at their ends.
- They contain ***carboxylase*** enzymes, necessary for nitrogen fixation.
- The enzyme is sensitive to oxygen.
- The enzymes have
  - iron/sulphur (cofactor), and
  - With a heterometal (Fe Mo Co), which is easily destroyed by oxygen.

Biological Nitrogen Fixation

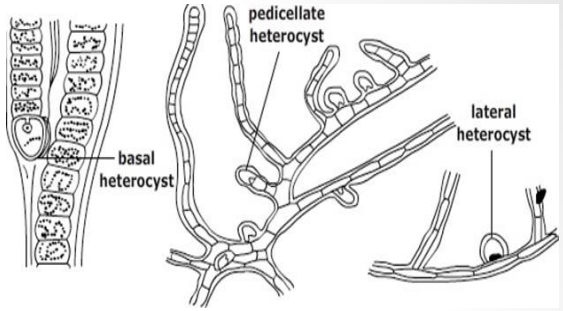


FeMo-cofactor

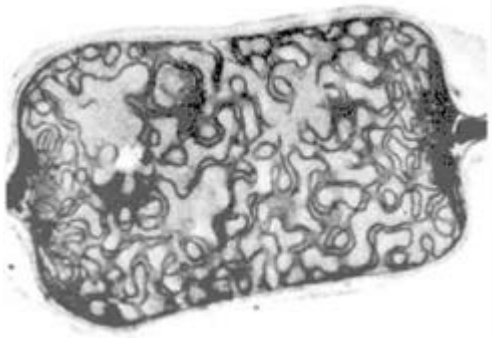


- The thick wall of heterocyst prevents diffusion of oxygen.
- They have pale-yellow homogenous content.
- Heterocysts are not found in all filamentous Myxophyceae but occur in all members of Order Nostocales and Stigonematales (except Oscillatoriaceae).
- They are
  - terminal
  - intercalary,
  - basal,
  - lateral (on the side of branch) and
  - pedicellate (at the end of lateral branches).

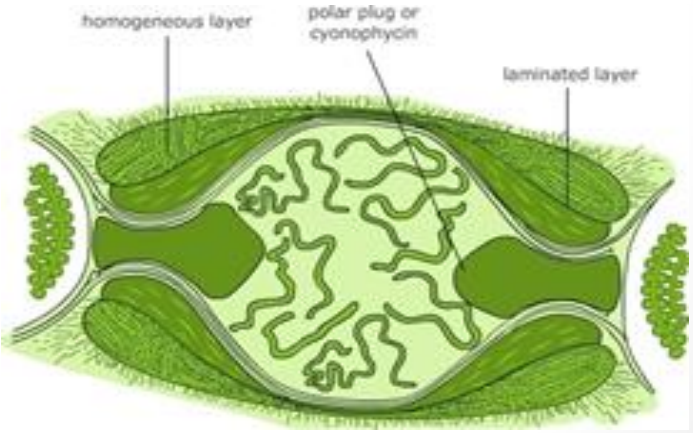
Basal heterocyst in *Tolypothrix distorta*;
Pedicellate heterocysts in *Mastigocladus testarum*;
Lateral heterocyst in *Nostochopsis lobatus*



Electron micrograph of a heterocyst



Diagrammatic representation of structure and contents of mature heterocyst



- The wall of the heterocyst is two-layered.
- Outer layer is persistent, chemically pectin or cellulose.
- Inner layer is cellulosic.
- Polar Nodule may be
  - One (when heterocyst is terminal),
  - two (intercalary) or
  - three pores
  - *Brachytrichia balani*: perforate the heterocyst.
- These are the site of protoplasmic connections.
- A prominent polar granule or plug is present at each pore.
- Heterocyst matrix contains photosynthetic lamellae, some ribosomes and other granules.

In low N_2 environments, cyanobacteria produces larger, thicker-walled heterocysts

- During transformation of a vegetative cell into heterocyst, volume of cell increases, cell wall becomes thick and adds layers to it, all pigments disappear except carotenoids, thylakoids reorganize and most granular bodies vanish.
- Components are replaced by two lipids, namely glycolipid and acil-lipid.
- Their functions are diverse, reproductive bodies which lost function, storage, mechanical, salt accumulation.
- They help in fragmentation as they are the points of breakage, related to frequency of cell division, stimulate production of akinetes, secondary reproductive organs, correlation with formation of gas vacuoles, responsible for sporulation of vegetative cells, can reproduce like other ordinary cells of trichome, can germinate to form new filaments, sites of nitrogen fixation.

e) Reproduction of Cyanobacteria:

- Cyanobacteria mostly multiply by asexual methods.
- Binary fission,
- Fragmentation with or without formation of small segments called hormogones (hormogonia),
  - Hormospores,
  - Akinetes,
  - Endospores,
  - Nanocytes,
  - Exospores, etc.
- Typical sexual reproduction involving formation and fusion of gametes is absent but like bacteria, gene recombination can occur by three types of parasexual methods— conjugation, transformation and transduction.

f) Gaidukov phenomenon

- It is also known as ***complementary chromatic adaptation***.
- It is the phenomenon in which algae absorbs maximum light to perform photosynthesis.
- In this process, the pigment composition changes to increase its efficiency for the maximum adoption of light.
- Many members of Cyanophyceae changes their color with respect to the wavelength of sunlight.
- It may appear:
  - Blue-green in yellow light
  - Green in red light
  - Reddish in green light.
- Gaidukon (1903) first invented this phenomenon and according to his name, it is lso known as Gaidukov phenomenon.

Comparison between the prokaryotes (bacteria) and eukaryotes

Feature	Prokaryotes	Eukaryotes
Nucleus/Nucleolus	Absent (bacterial chromosome found as looping circular Nucleoid)	Present
Size (diameter)	1-10mm	10-100mm
Membrane Bound Organelles	None (bacteria do posses ribosomes)	Present
Cell Division	Binary Fission (simpler form of cell division)	Mitosis