BACTERIAL FLAGELLA

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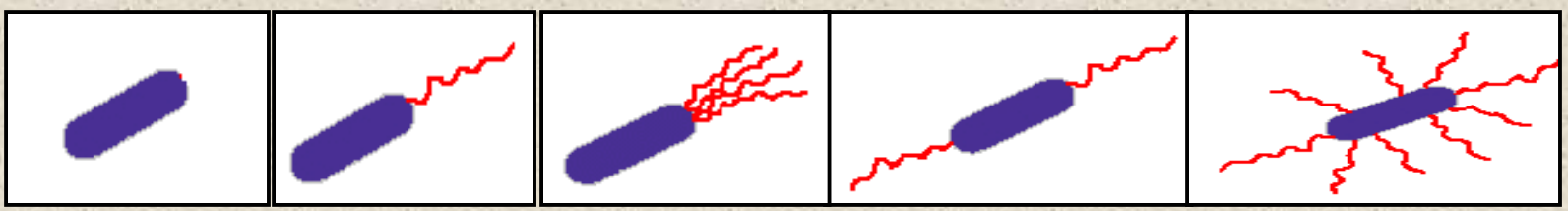
Flagellum – the organ of motility

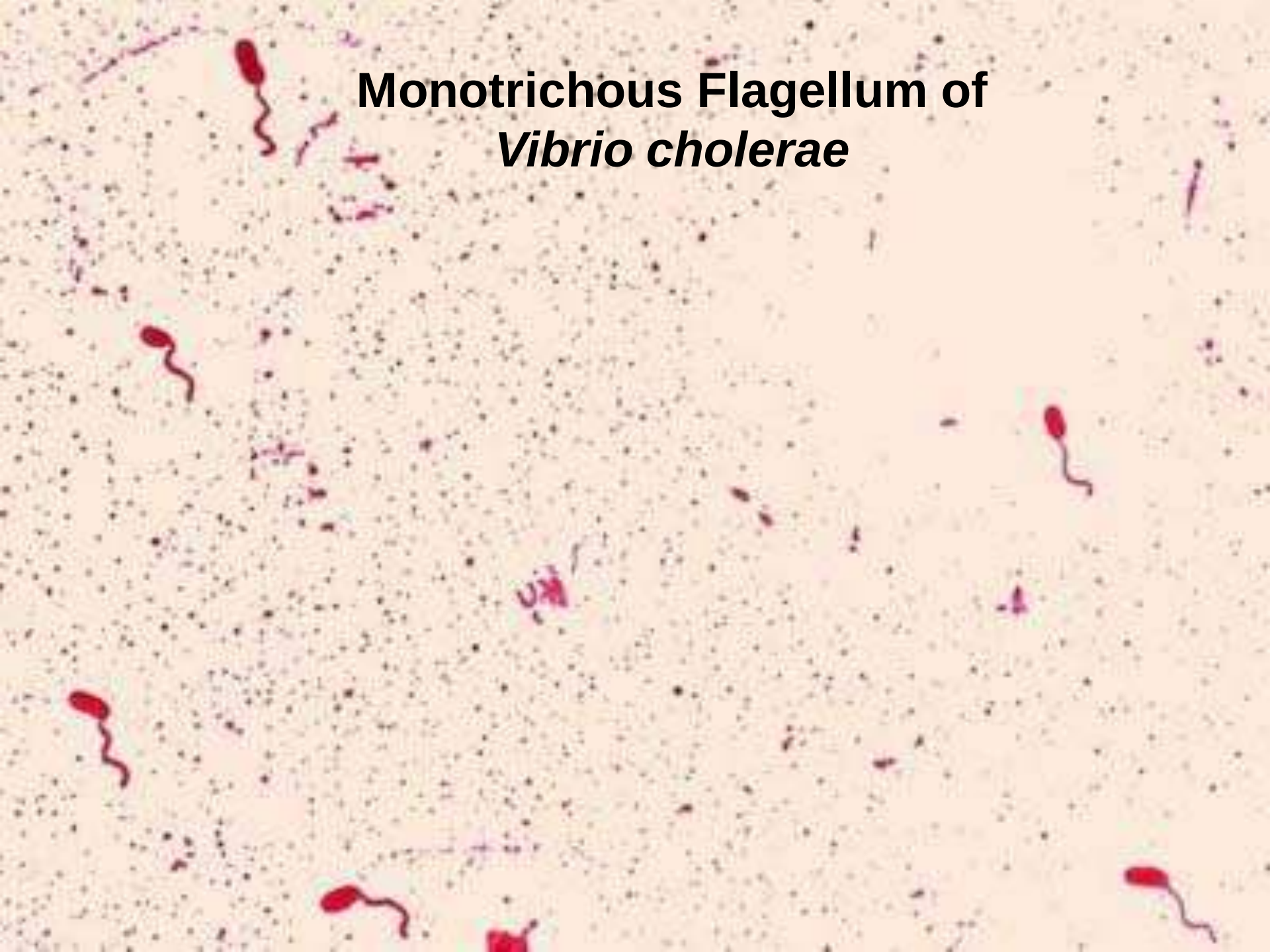
- Bacterial flagella are hair like, thin, helical appendages
- 12 - 30 nm in thickness and 15 - 20 μm long.
- several times longer than the bacterial cell.
- Most of the organisms that produce capsules are non-motile.
- None of the cocci of medical importance is motile.

Arrangements of bacterial flagella

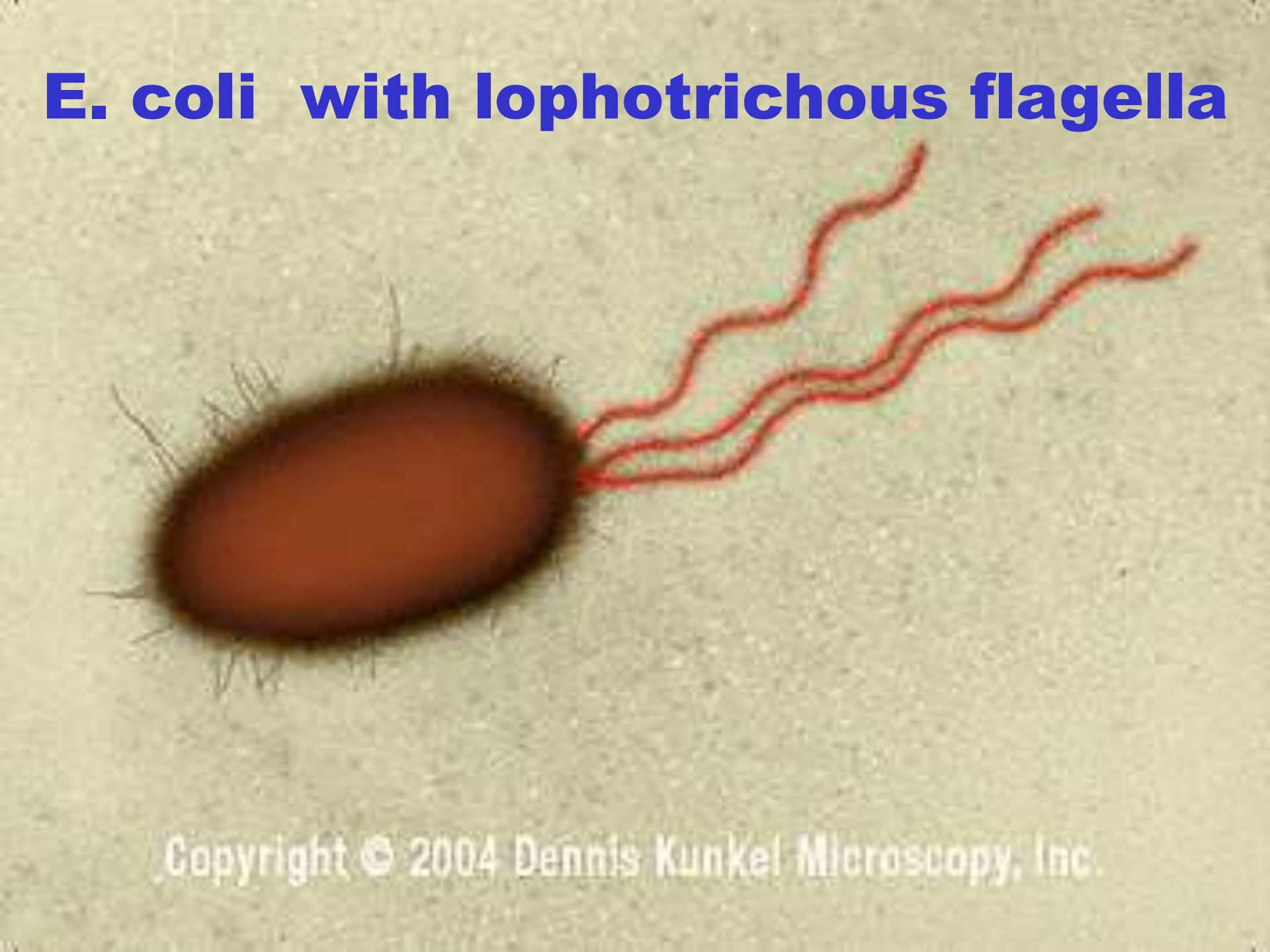


- **Atrichus - No flagella is present, e.g., Spirochetes**
- **Monotrichous - One polar flagella, e.g., *Pseudomonas aeruginosa***
- **Lophotrichous - A bunch of polar flagella at one or both ends , e.g., *Pseudomonas flourescens* (*lophos* - Greek for a crest).**
- **Amphitrichous - a single flagellum at both poles of the organism e.g., *Aquaspirillum serpens* (*amphi* - Greek for 'at each end').**
- **Peritrichous - Flagella all over the surface of cells, e.g., *Salmonella* Typhi (*peri* - around).**

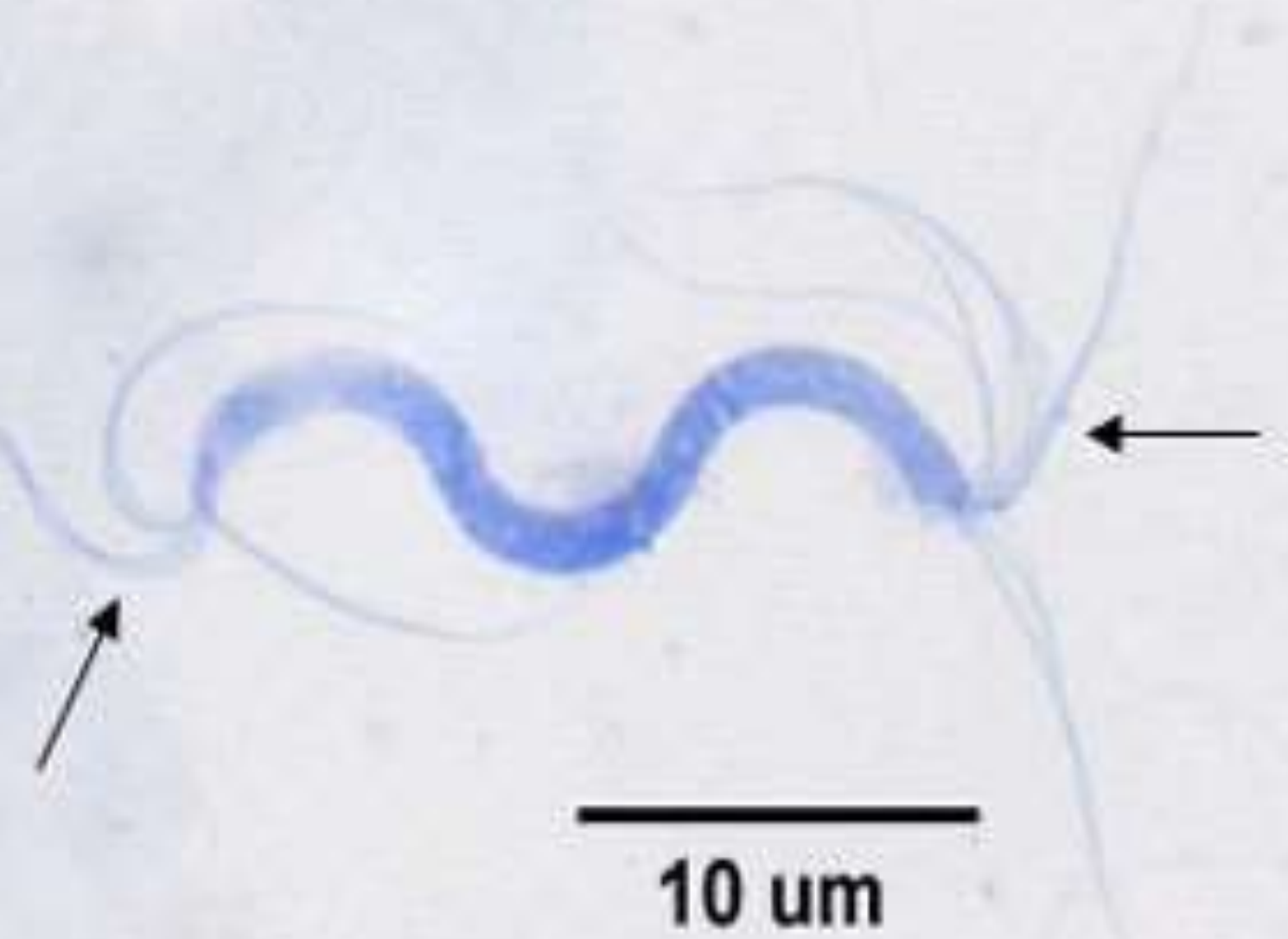
Monotrichous Flagellum of *Vibrio cholerae*



E. coli with lophotrichous flagella

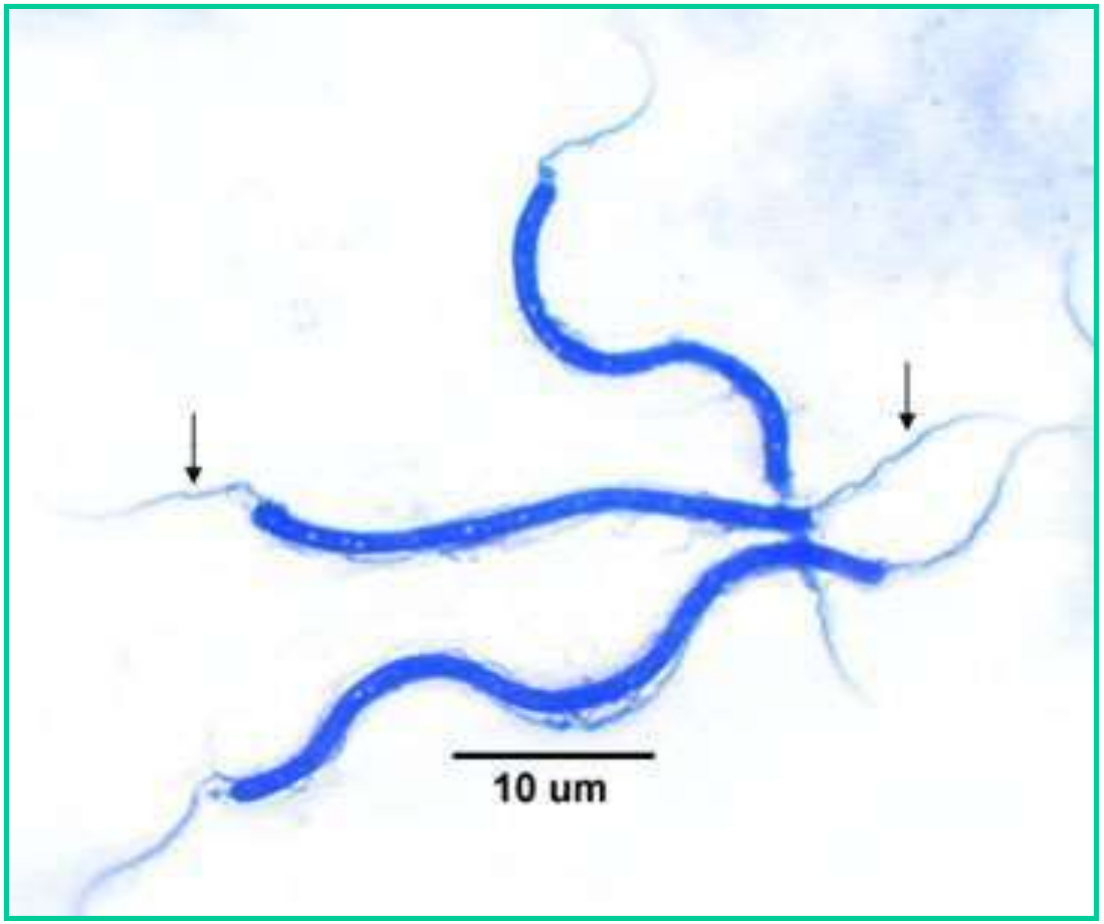


Spirillum with Lophotrichous Arrangement of Flagella



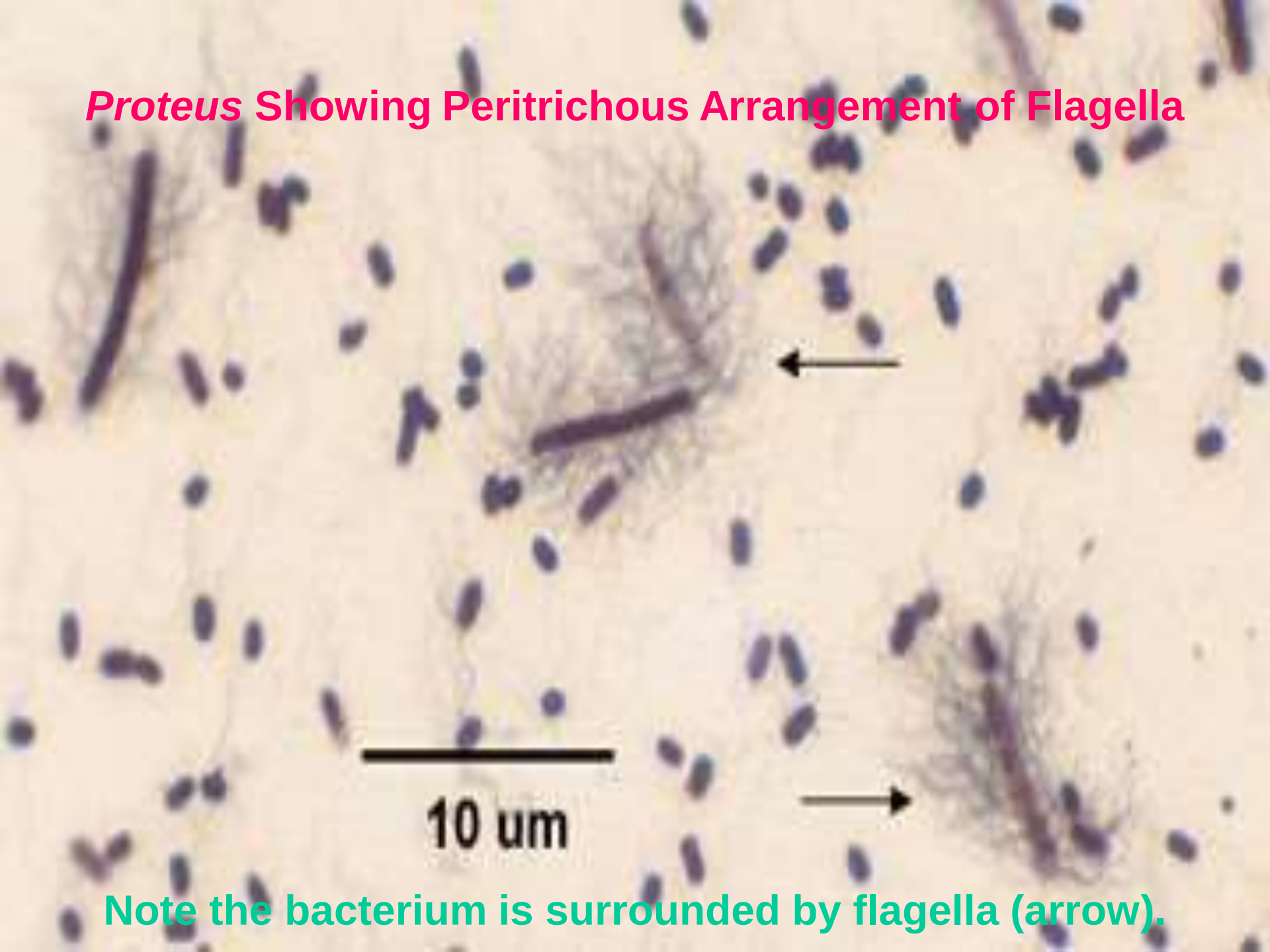
Note bundle of flagella at each pole (arrows).

Amphitrichous (*amphi* - Greek for 'at each end').- a single flagellum at both poles of the organism e.g., *Aquaspirillum serpens*



Note single flagellum at each pole (arrows).

Proteus Showing Peritrichous Arrangement of Flagella



Note the bacterium is surrounded by flagella (arrow).

Structure of flagella

- A flagellum is a hollow, rigid cylinder composed of three parts: a basal body, a hook, and a filament.
- Some Gram-negative bacteria have a sheath surrounding the flagellum.
- The filament is composed of the protein flagellin and is a hollow tube 20 nm thick. It ends with a capping protein.
- The basal body consists of protein rings that act as bearings.

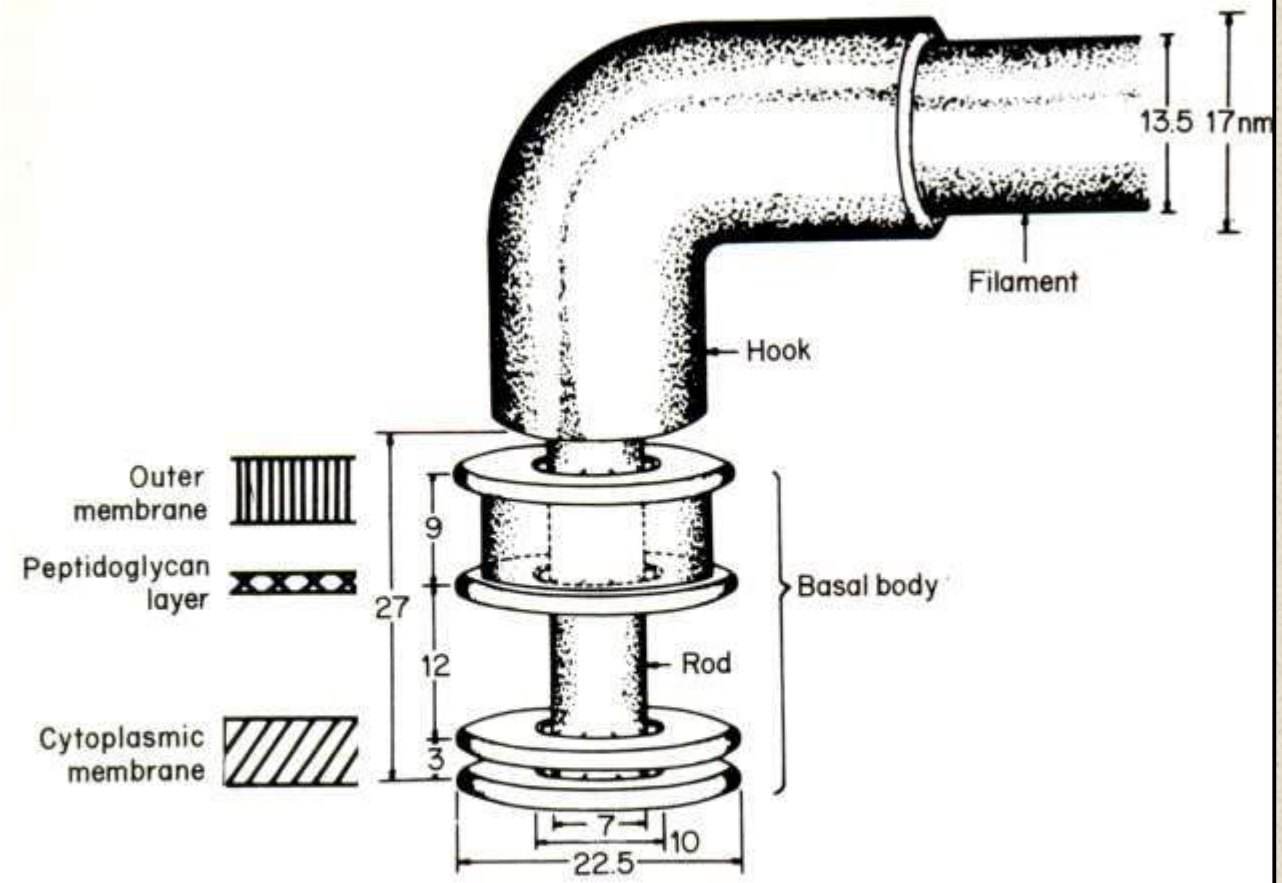


Diagram of the flagellar apparatus of *Escherichia coli*. The figures represent nanometres.

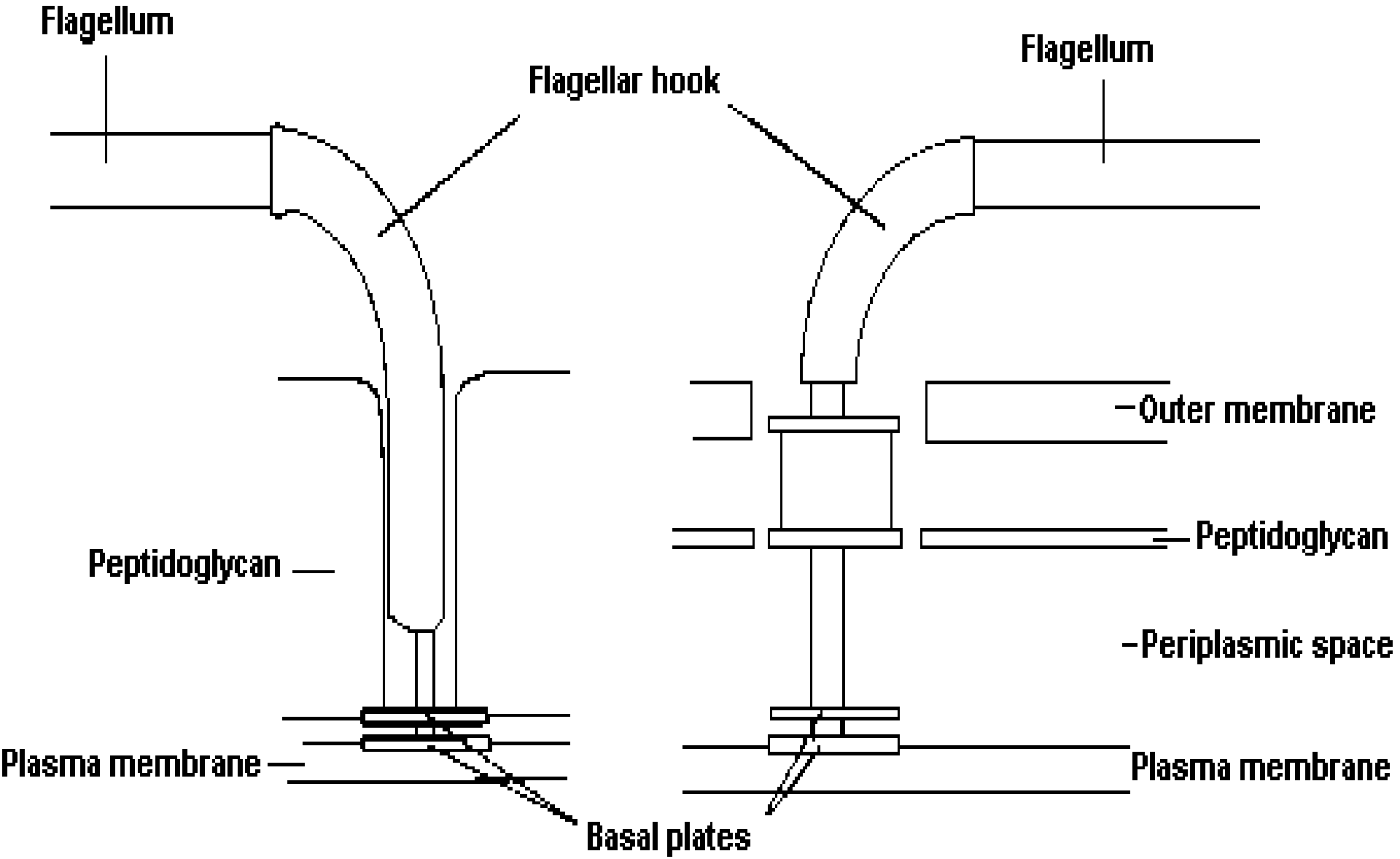
- **Gram-positive organisms have 2 basal body rings, one in the peptidoglycan layer and one in the plasma membrane.**
- **Gram-negative organisms have 4 rings:**

  L ring associates with the lipopolysaccharides

  P ring associates with peptidoglycan layer

  M ring is embedded in the plasma membrane

  S ring is directly attached to the plasma membrane
- **It is presumed that M ring function as a drive plate (motor) and S ring as a counter balance (stator), while the P and L rings act as bearings or bushings.**



Flagellum in a Gram-positive bacterium

Flagellum in a Gram-negative bacterium

Cell Envelope: Flagellum

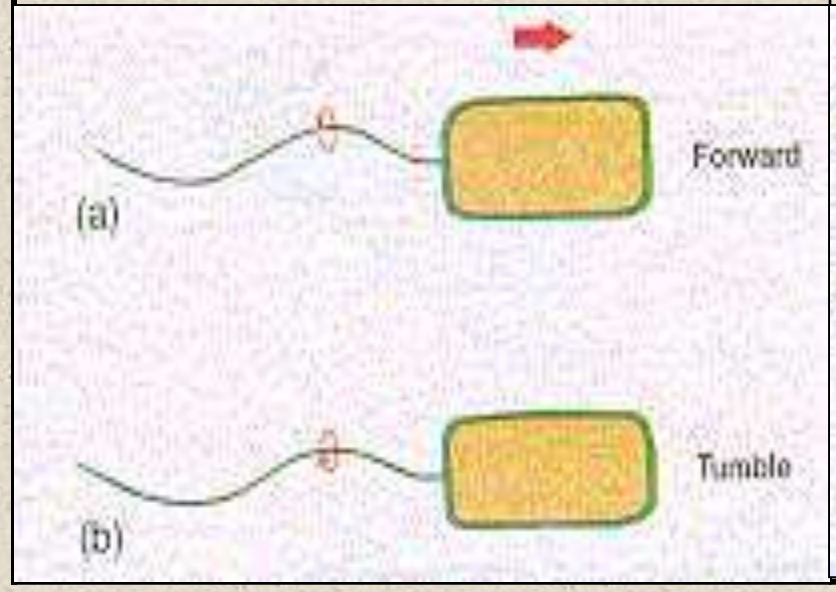
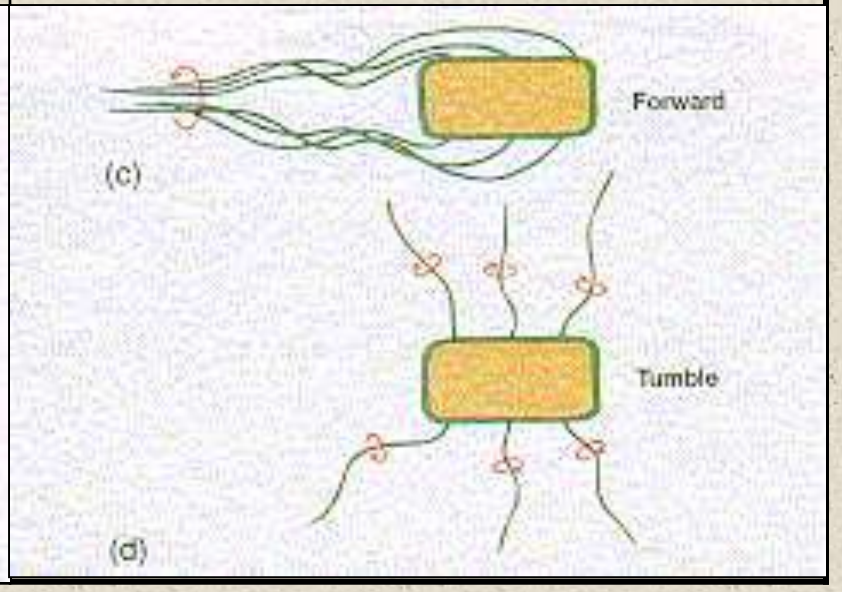
- The flagellar filament consists of polymerised molecules of a single protein called **flagellin**
- This protein forms the **H-antigen** of the bacterium (compare with the other **surface antigens**: somatic O-antigen (of LPS) or teichoic acid, and K-antigen (capsular antigen))

- **Flagellin has a mass of about 30,000 to 60,000 daltons.**
- **The amino acid composition of flagellin differs between species, but cysteine and tryptophan are always absent.**
- **Anti-flagellar antibodies are useful in serotyping and serodiagnosis of motile bacteria.**
- **The components of the flagellum are capable of self-assembly**
- **Both the basal body and the filament have a hollow core, through which the flagellin subunits are able to move into their respective positions.**
- **The filament grows at its tip rather than at the base.**

Movement of bacteria

- Bacteria propel themselves by rotating their helical flagella in a corkscrew like fashion.
- The direction of rotation of flagella determines the movement of the cell.
- Anticlockwise rotation of monotrichious polar flagella results in forward movement termed as "run".
- Clockwise rotation of the flagellum results in a random “tumbling” motion.
- Peritrichous bacteria move in a similar fashion where the bundling of the flagella during anticlockwise rotation results in “run ” and the clockwise flagellar rotation. causes bundle disruption resulting in “tumbling
- The speed of rotation of flagella is 200 to 1000 rpm.

FLAGELLAR MOTILITY

Movement in Monotrichous Bacteria	Movement in Peritrichous Bacteria
	

Movement of bacteria

- The rotation of flagellum is driven by the proton motive forces
- The rotor transports protons across the membrane, and is turned in the process

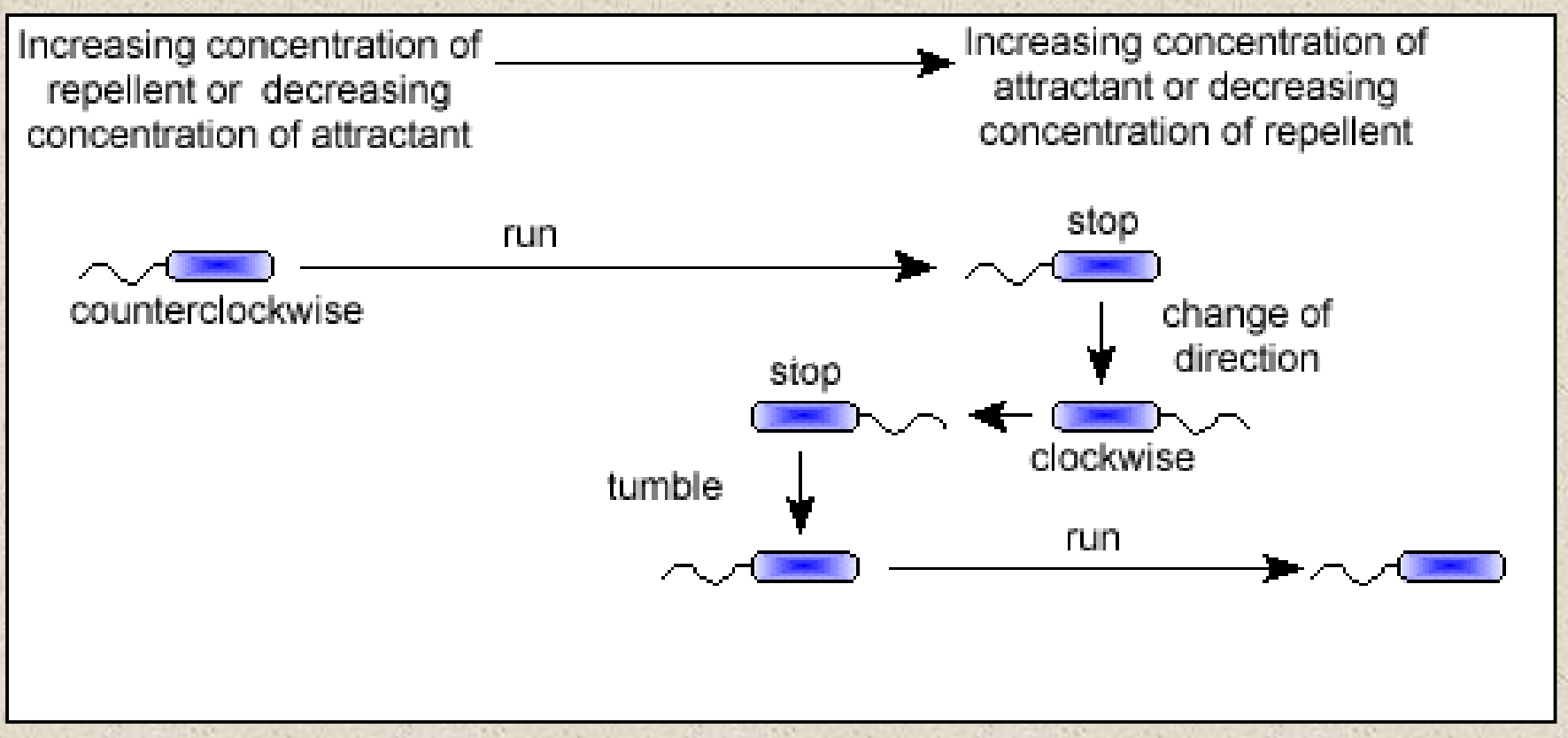
TAXIS

- Around half of all known bacteria are motile.
- Motility serves to keep bacteria in an optimum environment via taxis.
- A taxi is a motile response to an environmental stimulus.
- Bacteria can respond to chemicals (chemo taxis), light (photo taxis), osmotic pressure (osmo taxis), oxygen (aero taxis), and temperature (thermo taxis).
- Sensors for taxis are located in cell membrane

CHEMOTAXIS

- Chemotaxis is the movement toward or away from a chemical stimulus.
- Movement towards a useful chemical or away from a harmful chemical is called positive chemotaxis.
- Movement away from a useful chemical or towards a harmful chemical is called negative chemotaxis.
- Bacterial chemotaxis is controlled by a molecular sensors known as chemoreceptors, which are located in the cytoplasmic membrane or periplasm bacterium.
- Chemoreceptors convey information through a phosporylation cascade.

Chemotaxis


Increasing concentration of repellent or decreasing concentration of attractant
Increasing concentration of attractant or decreasing concentration of repellent
run
stop
counterclockwise
change of direction
stop
clockwise
tumble
run

Demonstration of motility

Direct observation of motility

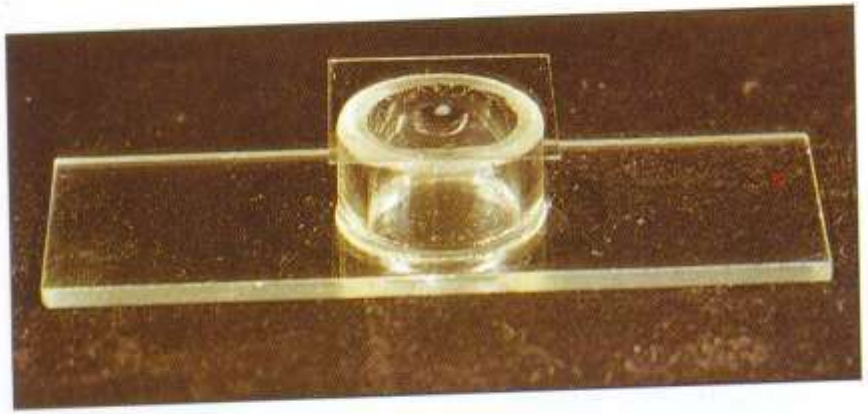
1. Hanging drop method
2. Phase-contrast microscopy
3. Dark-field microscopy

Motility Test medium

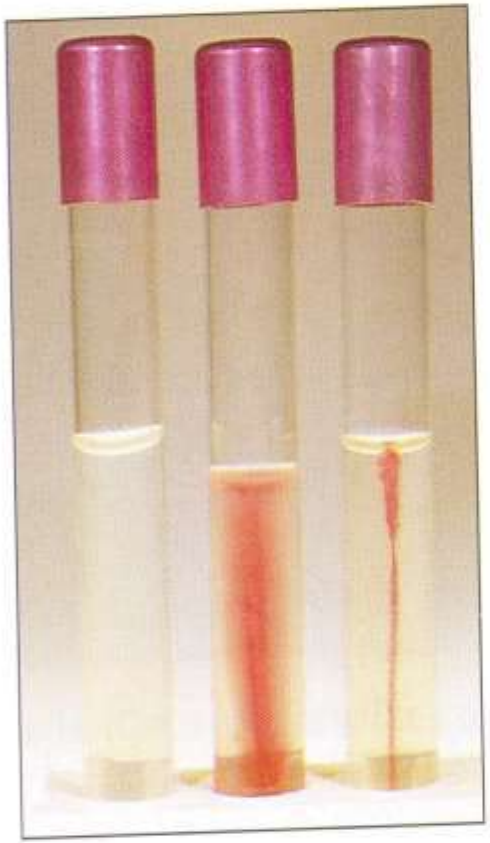
Semi-solid agar (0.3%)

Flagella staining

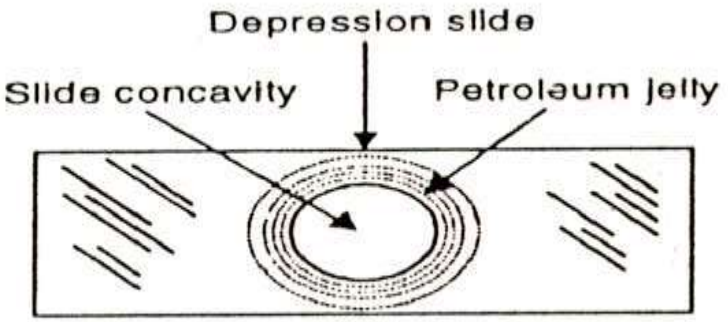
Leifson’s method



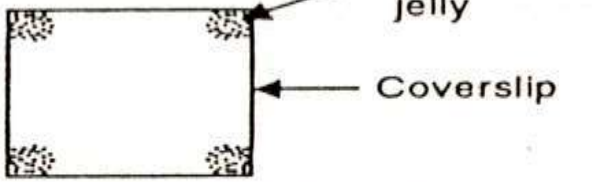
The hanging drop method for motility



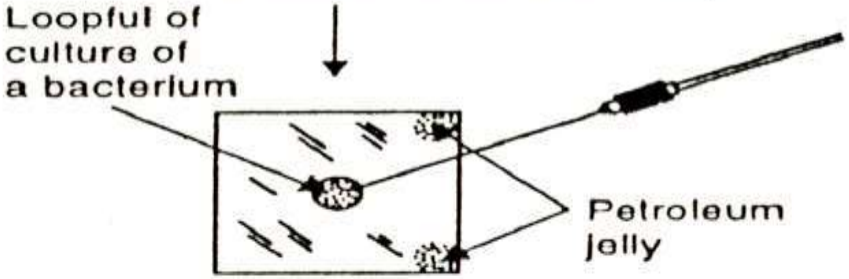
MIU medium.From left uninoculated, motile and non motile bacteria



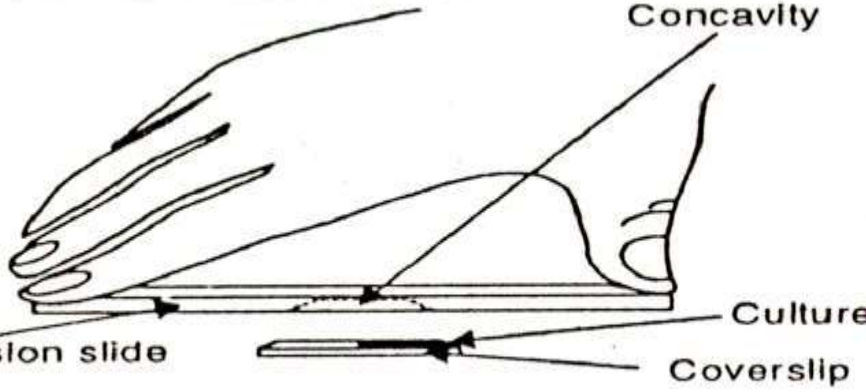
Spread a ring of petroleum jelly around the concavity of a depression slide



Apply petroleum jelly on four corners of the cover slip

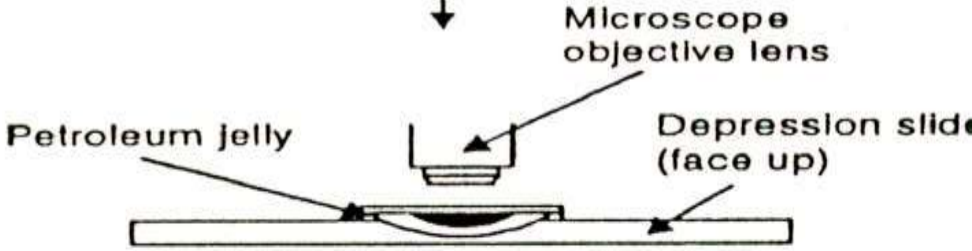


Place a loopful of a bacterial culture in the centre of the coverslip



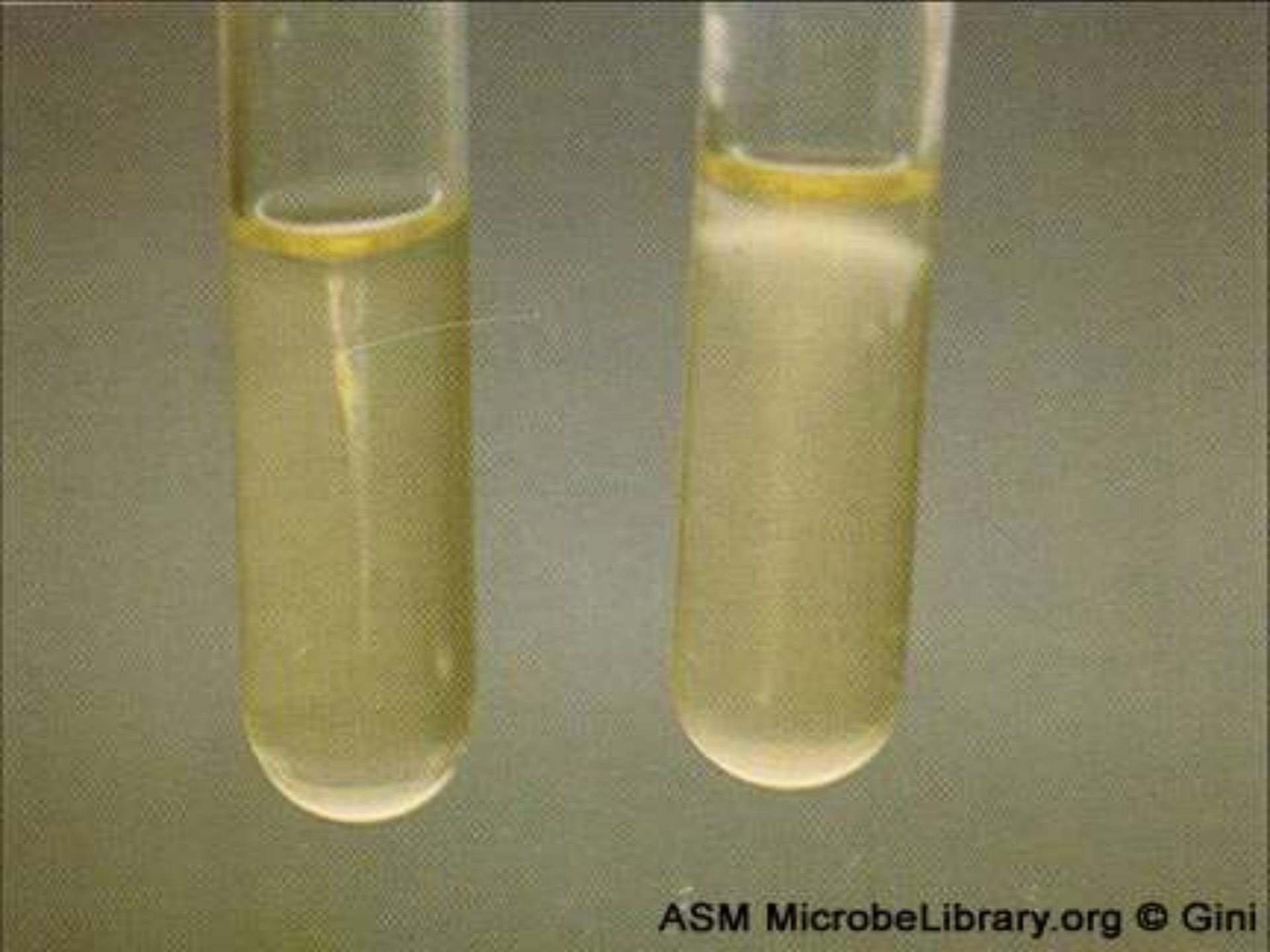
Place the depression slide on the coverslip with the concavity facing down

Turn the hanging-drop preparation over so that the culture drop adheres to the coversl



Place the slide on the microscope stage (coverslip up) and observe under low power and high power objectives

Hanging-drop procedure for microscopic observation of living bacteria.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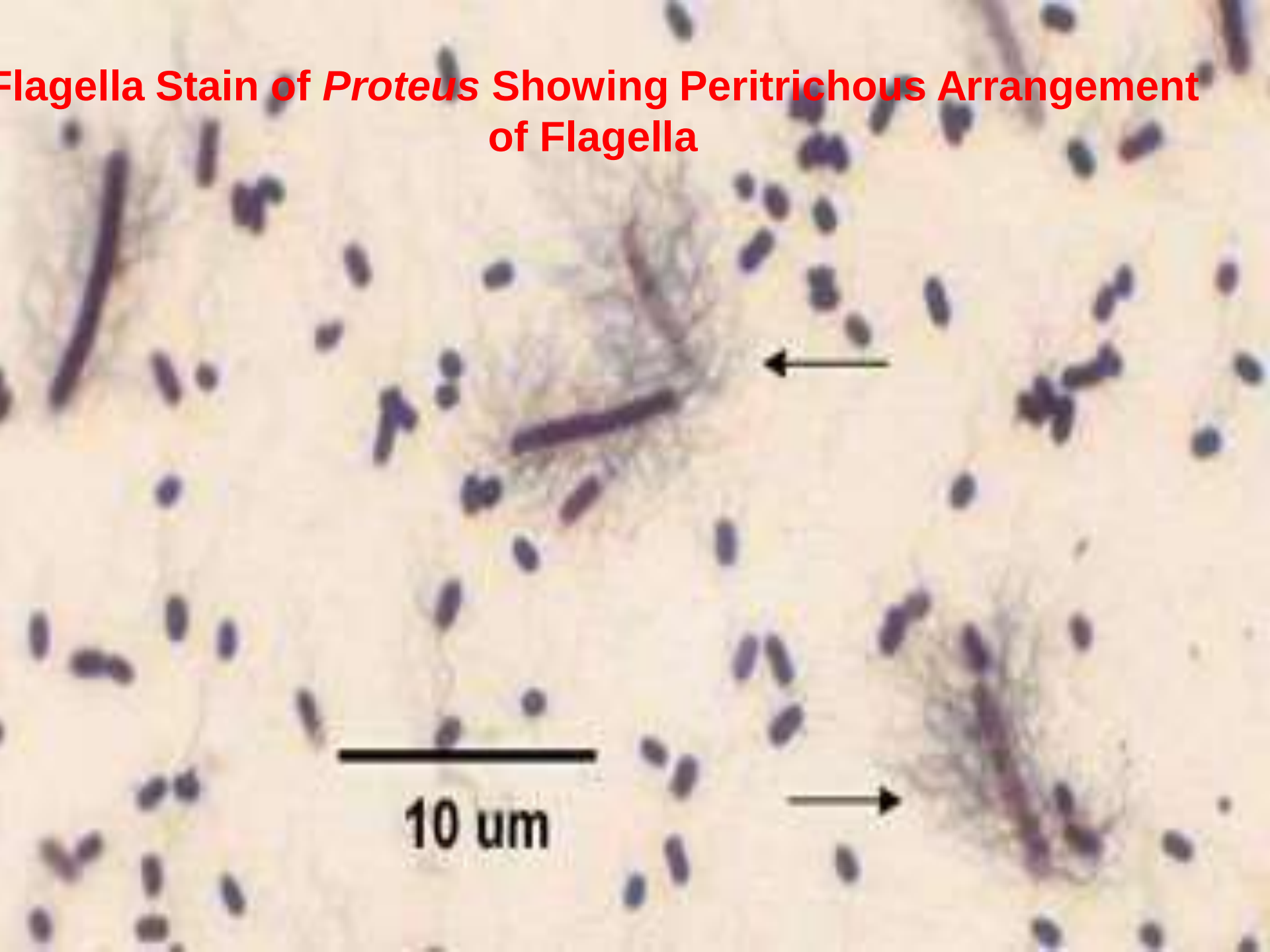
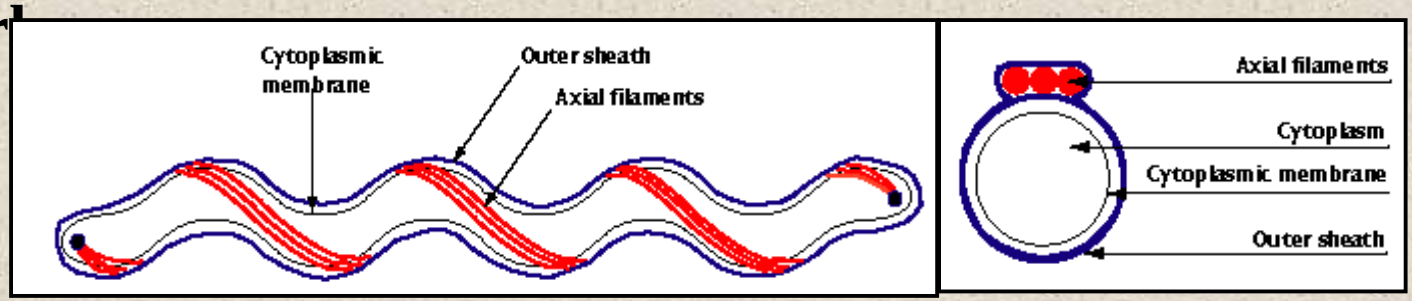
Flagella Stain of *Proteus* Showing Peritrichous Arrangement of Flagella



Endoflagella

- **Synonym: periplasmic or flagella, axial filament**
- **rotation of the cell in a spiral fashion and consequent locomotion**
- **located in the periplasmic space of spirochetes over their entire length and cause the entire bacterium to rotate and move as a cor**



Scanning Electron Micrograph of *Leptospira interrogans*