# Bacterial Cell Organization: Flagella, Endoflagella, Fimbriae, Pilli

By-

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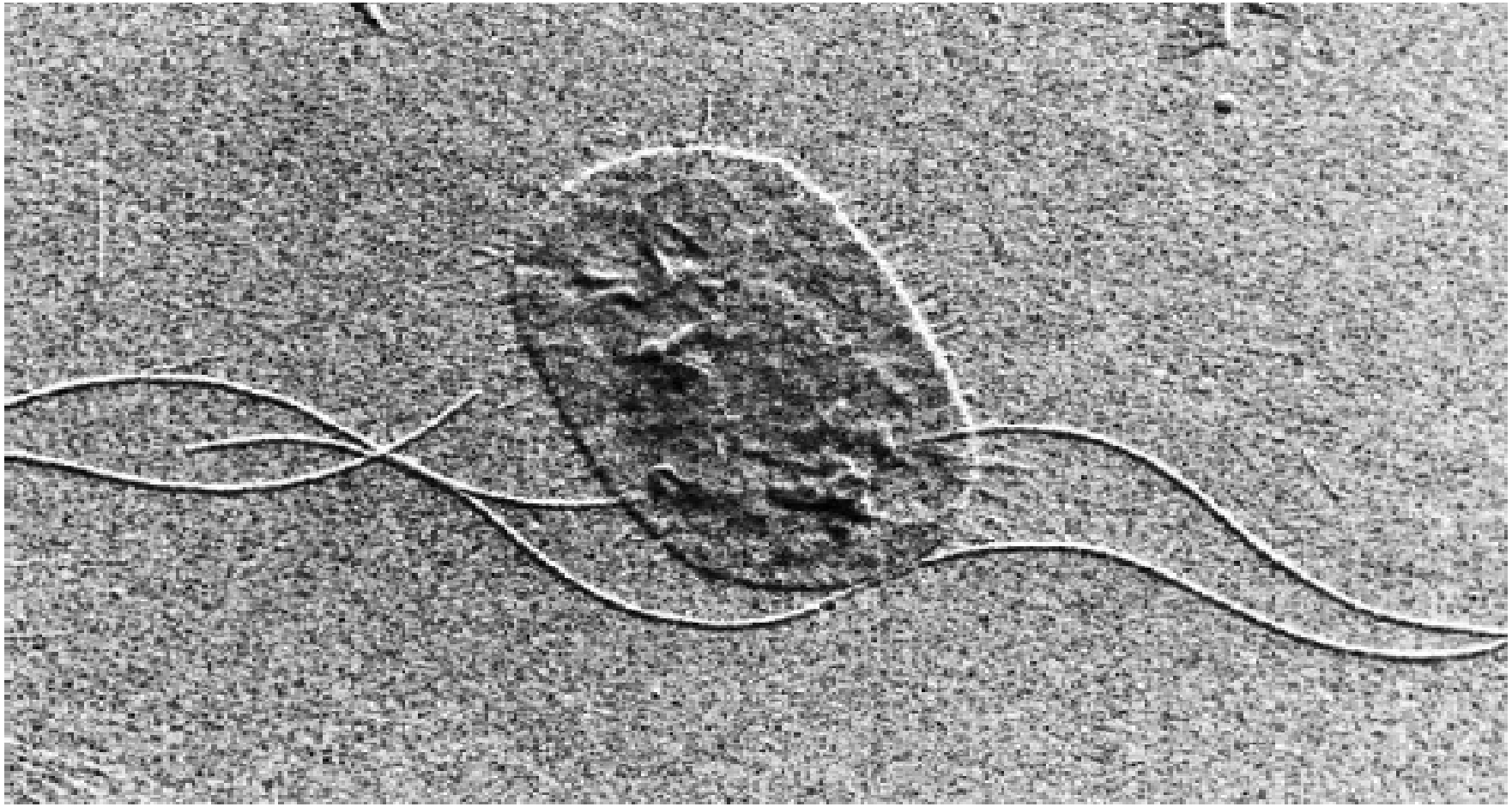
# Pili and Fimbriae

- Many gram-negative bacteria have short, fine, hairlike appendages that are thinner than flagella and not involved in motility.
- These are usually called fimbriae (s., fimbria).
- Although a cell may be covered with up to 1,000 fimbriae, they are only visible in an electron microscope due to their small size.
- They seem to be slender tubes composed of helically arranged protein subunits and are about 3 to 10 nm in diameter and up to several micrometers long.
- At least some types of fimbriae attach bacteria to solid surfaces such as rocks in streams and host tissues.

The long flagella and the numerous shorter fimbriae are very evident in this electron micrograph of *Proteus vulgaris*



# Sex pili

- Sex pili (s., pilus) are similar appendages, about 1 to 10 per cell, that differ from fimbriae in the following ways.
- Pili often are larger than fimbriae (around 9 to 10 nm in diameter).
- They are genetically determined by sex factors or conjugative plasmids and are required for bacterial mating.
- *Some bacterial* viruses attach specifically to receptors on sex pili at the start of their reproductive cycle.

**Some of the differences between fimbriae and pili are as follows:**

| Characteristics | Fimbriae | Pili |
|---|---|---|
| Definition | Fimbriae are tiny bristle-like fibers arising from the surface of bacterial cells. | Pili are hair like microfibers that are thick tubular structure made up of pilin. |
| Length | Shorter than pili | Longer than fimbriae. |
| Diameter | Thin | Thicker than fimbriae. |
| Number | No. of fimbriae are 200-400 per cell. | No of pili are less 1-10 per cell. |
| Made up of | Fimbrillin protein. | Pilin protein. |
| Rigidity | Less rigid. | More rigid than fimbriae. |

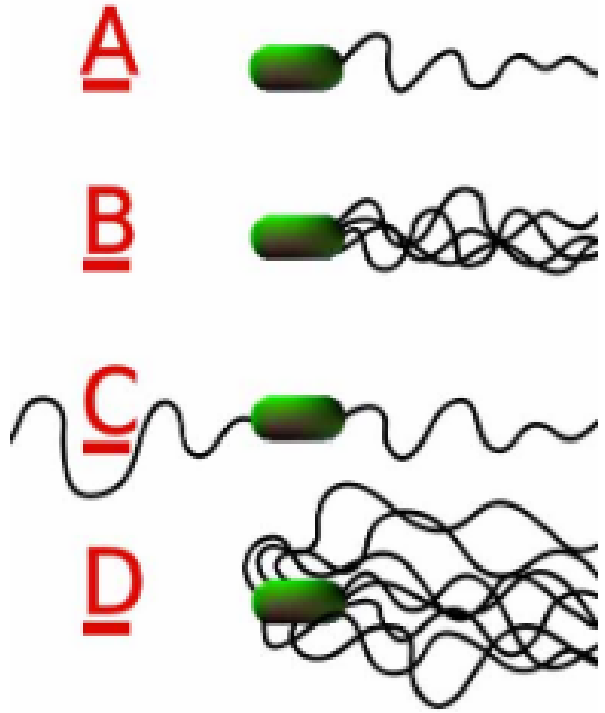
| | | |
|---|---|---|
| Formation | Is governed by bacterial genes in the nucleoid region. | Is governed by plasmid genes. |
| Function | Responsible for cell to surface attachment. Specialized for attachment i.e. enable the cell to adhere the surfaces of other bacteria. | Responsible for bacterial conjugation.<br><br>Two basic function of pili. They are gene transfer and attachment. |
| Motility | Do not function in active motility. | Type IV pili shows twitching type of motility. |
| Receptors | No receptors of other. | Serve as receptor for certain viruses. |
| Examples | *Salmonella typhimurium*, *Shigella dysenteriae*.<br>*Shigella dysenteriae* uses its fimbriae to attach to the intestine and then produces a toxin that causes diarrhea. | *Escherichia coli*, *Neisseria gonorrhoeae*.<br><br>*Neisseria gonorrhoeae*, the cause of gonorrhea, uses pili to attach to the urogenital and cervical epithelium when it causes disease. |

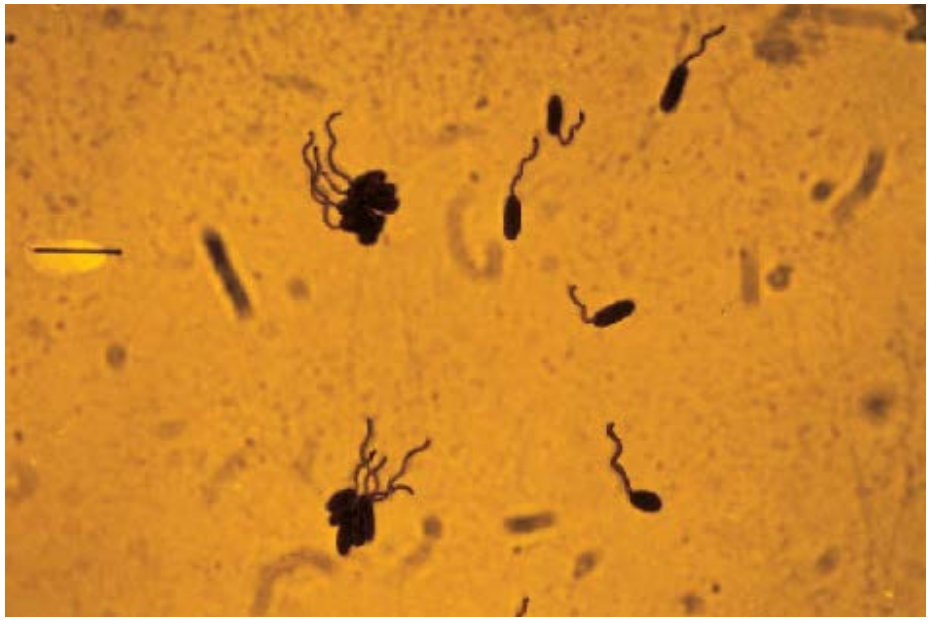
# Flagella and Motility

- Most motile bacteria move by use of flagella (s., flagellum), threadlike locomotor appendages extending outward from the plasma membrane and cell wall.
- They are slender, rigid structures, about 20 nm across and up to 15 or 20 m long.
- Flagella are so thin they cannot be observed directly with a bright-field microscope, but must be stained with special techniques designed to increase their thickness.
- The detailed structure of a flagellum can only be seen in the electron microscope.

# Flagellation

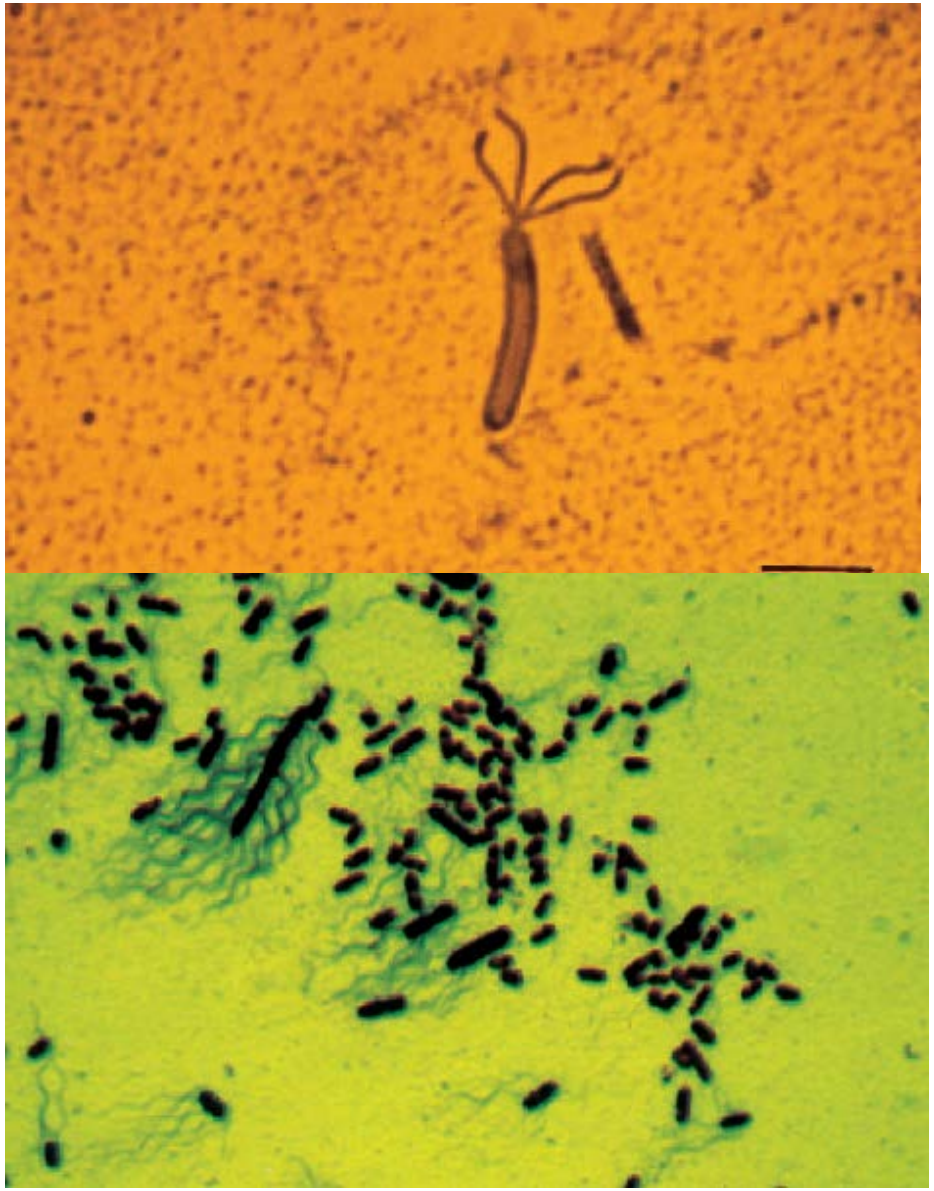
- Bacterial species often differ distinctively in their patterns of flagella distribution.
- **Monotrichous bacteria (*trichous means*** hair) have one flagellum; if it is located at an end, it is said to be a **polar flagellum (figure 3.31*a*).**
- ***Amphitrichous bacteria (amphi*** means “on both sides”) have a single flagellum at each pole.



# ...Flagellation

- In contrast, **lophotrichous bacteria (*lopho means tuft) have a*** cluster of flagella at one or both ends (figure 3.31*b).*
- *Flagella are* spread fairly evenly over the whole surface of **peritrichous (*peri*** means “around”) bacteria (figure 3.31*c).*
- Flagellation patterns are very useful in identifying bacteria.



# Flagellar Ultrastructure

- Transmission electron microscope studies have shown that the bacterial flagellum is composed of three parts.

  (1) The longest and most obvious portion is the filament, which extends from the cell surface to the tip.

  (2) A basal body is embedded in the cell; and

  (3) a short, curved segment, the hook, links the filament to its basal body and acts as a flexible coupling.
- The filament is a hollow, rigid cylinder constructed of a single protein called flagellin, which ranges in molecular weight from 30,000 to 60,000 Da.
- The filament ends with a capping protein.
- Some bacteria have sheaths surrounding their flagella.
- For example *Bdellovibrio has a membranous* structure surrounding the filament.
- *Vibrio cholerae has a* lipopolysaccharide sheath.

# ... Flagellar Ultrastructure

- The hook and basal body are quite different from the filament (**figure 3.32).**
- **Slightly wider than the filament, the hook is** made of different protein subunits.
- The basal body is the most complex part of a flagellum (figure 3.32 and **figure 3.33).**
- **In *E.*** *coli* and most gram-negative bacteria, the body has four rings connected to a central rod.
- The outer L and P rings associate with the lipopolysaccharide and peptidoglycan layers, respectively.
- The inner M ring contacts the plasma membrane.
- Gram positive bacteria have only two basal body rings, an inner ring connected to the plasma membrane and an outer one probably attached to the peptidoglycan.

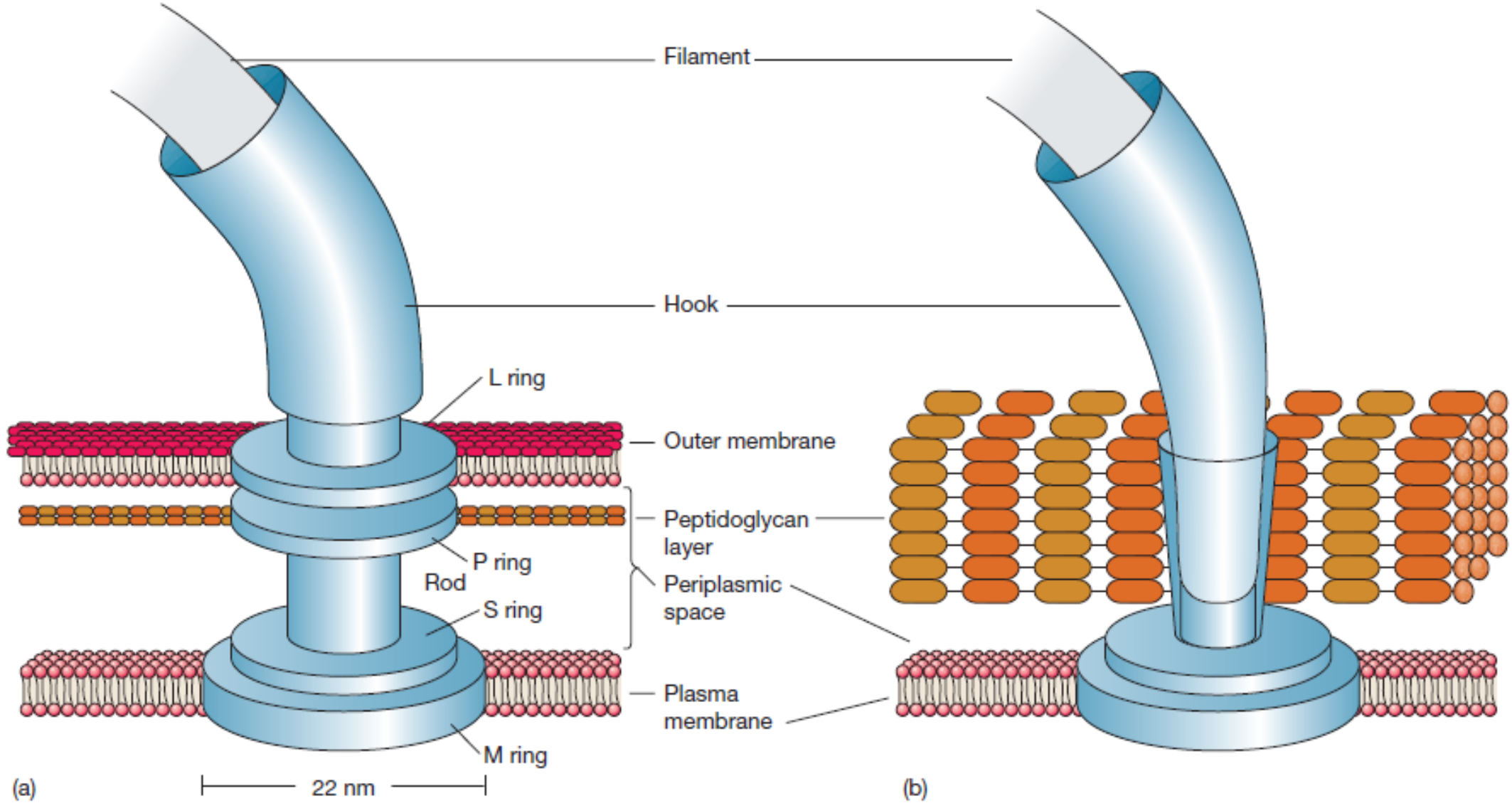



**Figure 3.33 The Ultrastructure of Bacterial Flagella.** Flagellar basal bodies and hooks in (**a**) gram-negative and (**b**) gram-positive bacteria.

# Flagellar Synthesis

- The synthesis of flagella is a complex process involving at least 20 to 30 genes.
- Besides the gene for flagellin, 10 or more genes code for hook and basal body proteins; other genes are concerned with the control of flagellar construction or function.
- It is not known how the cell regulates or determines the exact location of flagella.
- Bacteria can be deflagellated, and the regeneration of the flagellar filament can then be studied.
- It is believed that flagellin subunits are transported through the filament's hollow internal core.
- When they reach the tip, the subunits spontaneously aggregate under the direction of a special filament cap so that the filament grows at its tip rather than at the base (figure 3.34).
- Filament synthesis is an excellent example of self-assembly.
- Many structures form spontaneously through the association of their component parts without the aid of any special enzymes or other factors.
- The information required for filament construction is present in the structure of the flagellin subunit itself.

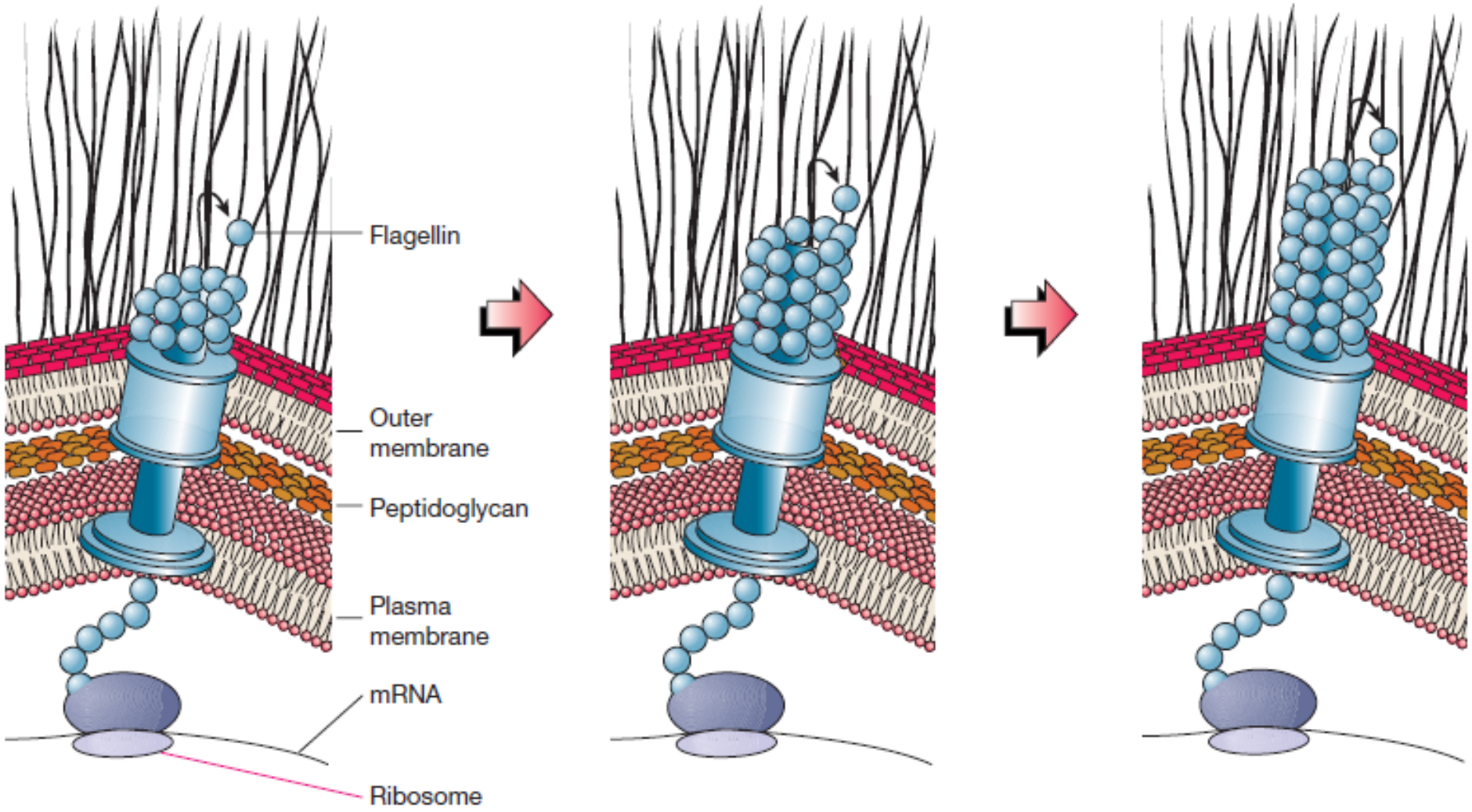
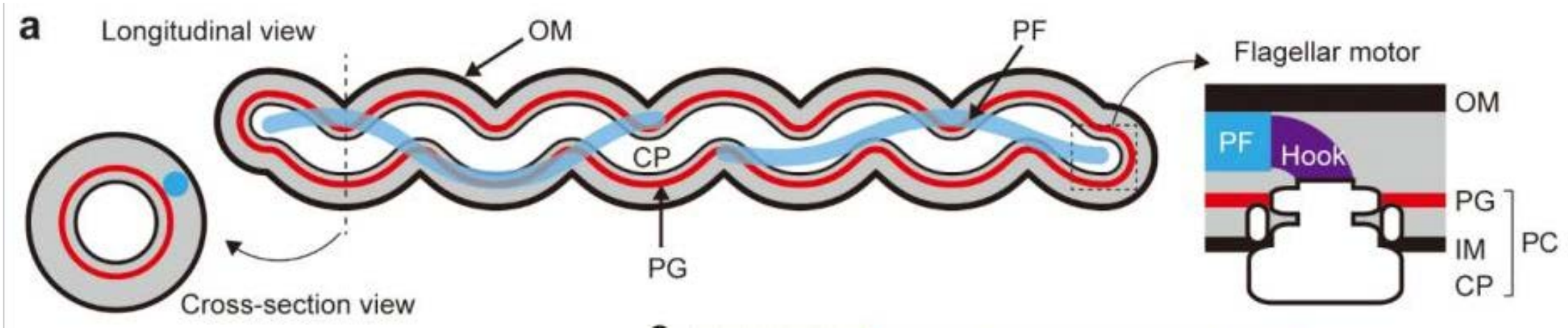



**Figure 3.34 Growth of Flagellar Filaments.** Flagellin subunits travel through the flagellar core and attach to the growing tip.

# Endoflagella

- Spirochetes can be distinguished from other flagellated bacteria by their long, thin, spiral (or wavy) cell bodies and endoflagella that reside within the periplasmic space, designated as periplasmic flagella (PFs).
- Because of location of their flagella, called **endoflagella** which are sometimes called *axial filaments*.
- Endoflagella are anchored at each end (pole) of the bacterium within the periplasmic space (between the inner and outer membranes) where they project backwards to extend the length of the cell.
- Each PF filament connects with a basal motor called the flagellar motor that is embedded in the cytoplasmic membrane and the peptidoglycan layer via a short, bent structure corresponding to the universal joint hook in the *E. coli* flagellar motor.
- The morphologies of the cell body and the PF as well as the number of PFs greatly differ among species.
- Rotation of the endoflagella causes the axial filament to rotate, and propels the spirochete in a twisting motion. *Treponema pallidum*, the bacterium that causes syphilis, moves around this way.


a
Longitudinal view
OM
PF
Flagellar motor
CP
PG
Cross-section view
OM
PF
Hook
PG
IM
CP
PC

# Electron micrograph of thin-sectioned *Treponema pallidum*.