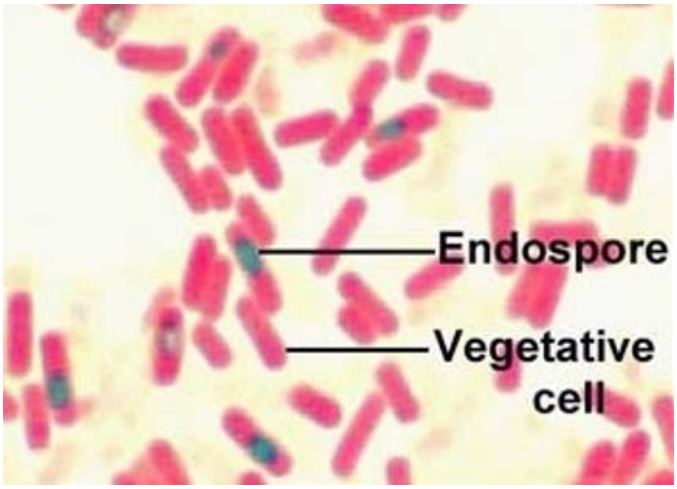
5- Endospores

When essential nutrients are depleted, certain gram-positive bacteria, such as those of the genera **Clostridium** and **Bacillus**, form specialized "resting" cells called **endospores.**

Endospores are dormant, non-reproductive, and enzymatically inert forms of bacterial vegetative cells.

The primary function of most endospores is to ensure the survival of a bacterium through periods of environmental stress. They are therefore resistant to radiation, desiccation, lysozyme, temperature, starvation, and chemical disinfectants.

*For example, 7500-year-old endospores of *Thermoactinomyces vulgaris* from the freezing muds of Elk Lake in Minnesota have germinated when rewarmed and placed in a nutrient medium. **(المثال للاطلاع)**



Bacterial endospore structure:- From the inner to the outer:

a) The core (contains the bacterial DNA).

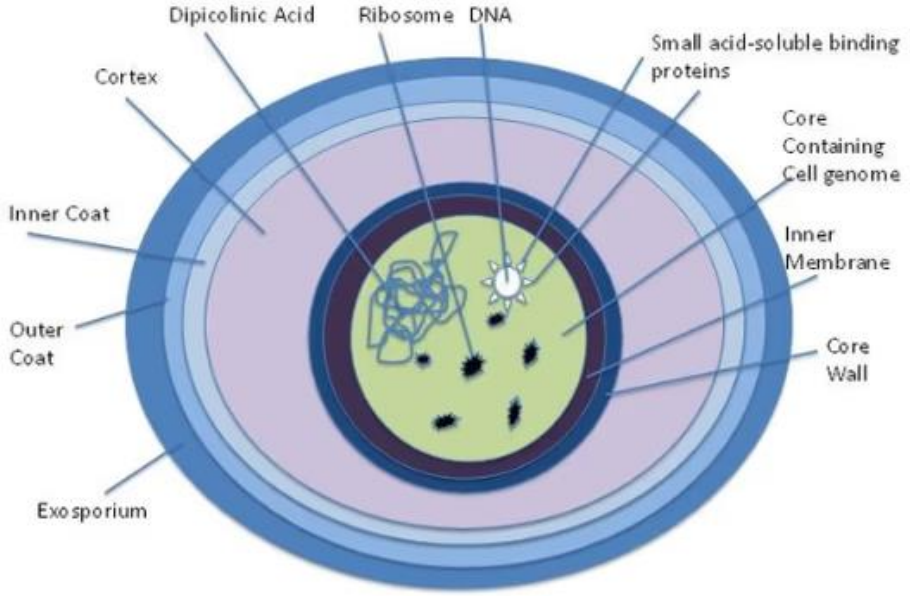
b) Inner membrane

c) Cortex

d) Outer membrane

e) Coat

f) ***Exosporium**, a facultative external structure present only in some bacterial spores



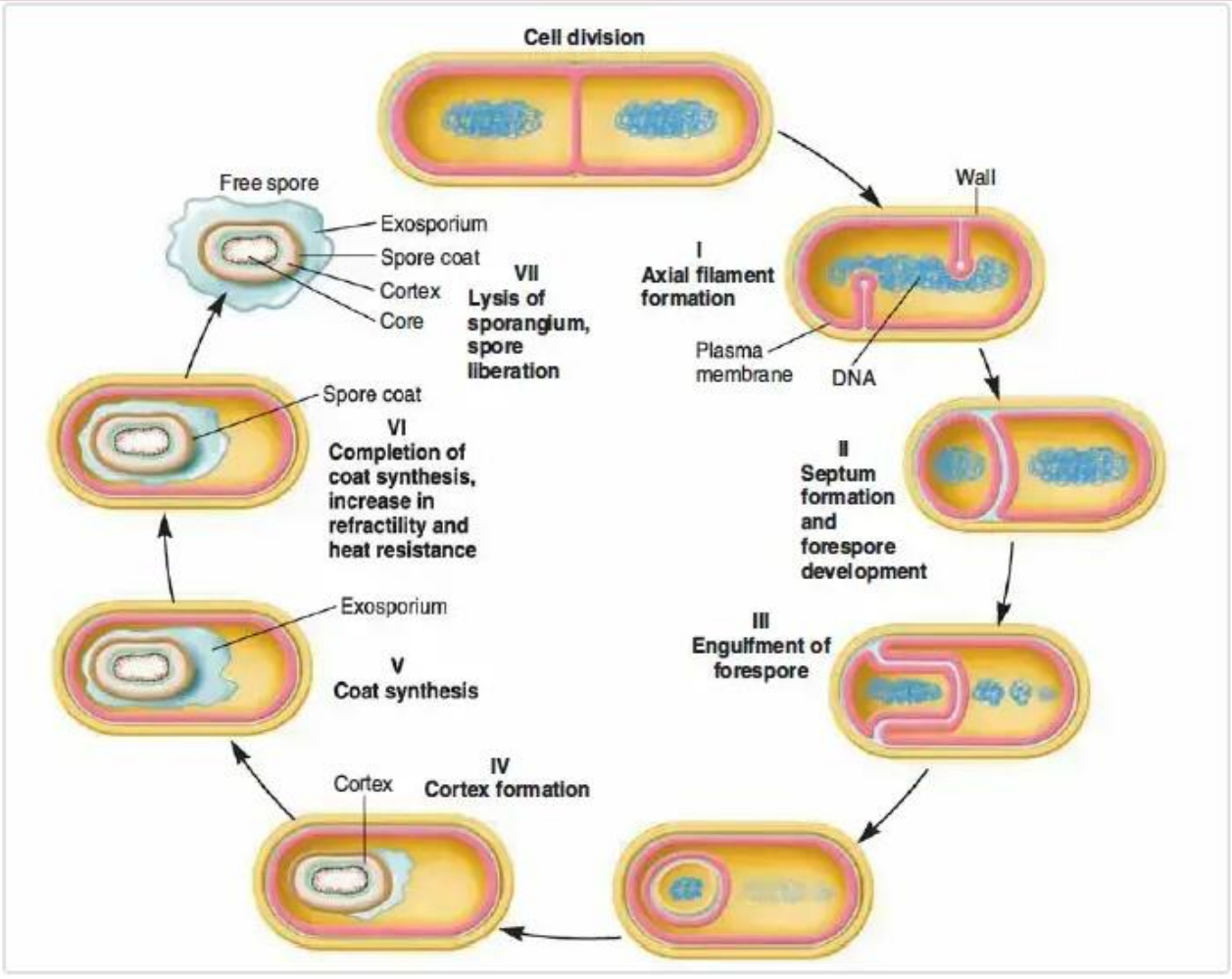


Fig: Endospore Formation Steps

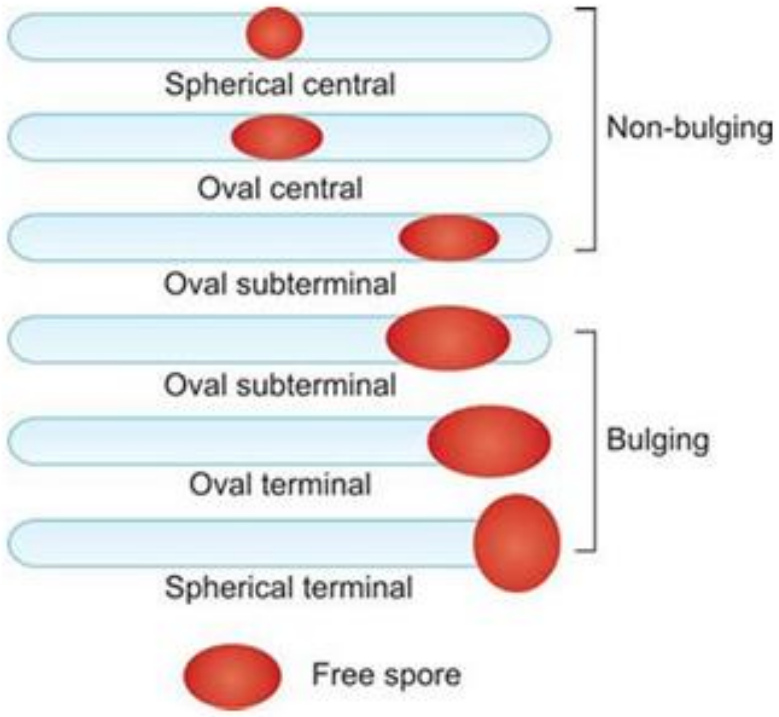
Unlike vegetative cells, endospores contain **dipicolinic acid** and a large number of **calcium ions (Ca 2+).** Dipicolinic acid forms a complex with calcium ions within the endospore core. This complex binds free water molecules, causing dehydration of the spore. As a result, the heat resistance of macromolecules within the core increases. The calcium-dipicolinic acid complex also functions to protect DNA from heat denaturation, thereby increasing the stability of DNA.

The location of the endospores in bacterial cell:-

1- Central / e.g.: *Bacillus cereus*

2- Terminal /e.g.: *Clostridium tetani*

3- Subterminal / e.g.: *Clostridium botulinum*



External Structures (cell wall appendages)

1- **Glycocalyx**

2- **Pili (Fimbriae)**

3- **Flagella**

1- Glycocalyx (Slime Layer and Capsule)

Beyond the cell wall, some bacteria have an additional layer called the glycocalyx. The structural features and chemical composition of glycocalyx differ depending on the species of bacteria, in general this additional layer may be composed of **polysaccharides, polypeptides, or both** and can come in one of **two forms:**

a- Slime Layer

A glycocalyx is considered a slime layer when **the glycoprotein molecules are loosely associated with the cell wall.** Bacteria that are covered with this loose shield are protected from dehydration and loss of nutrients.

b- Capsule

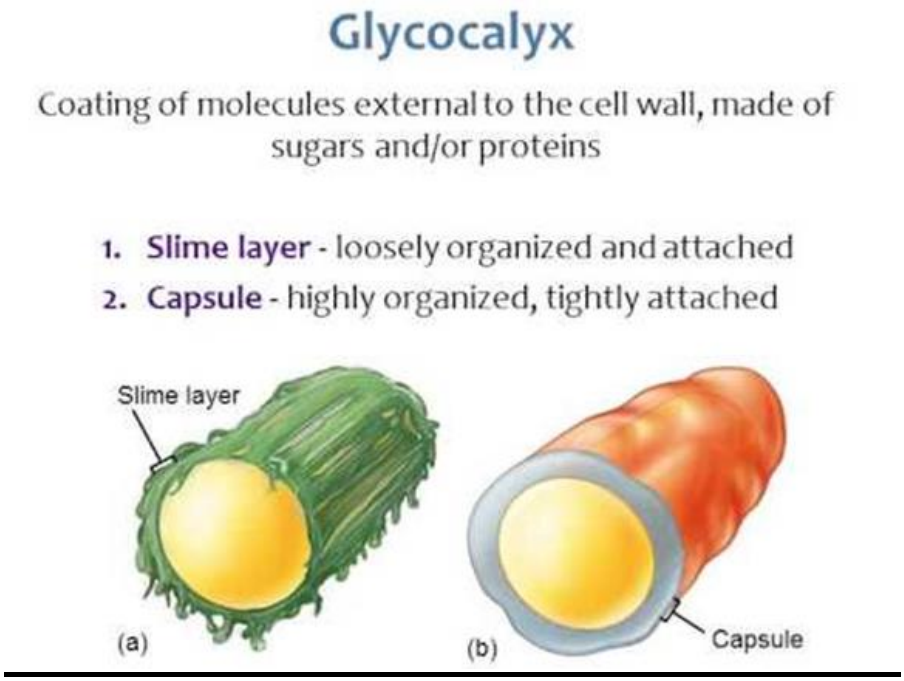
A glycocalyx is considered a capsule when **the polysaccharides are more firmly attached to the cell wall.** Capsules have a gummy, sticky consistency and provide protection as well as adhesion to solid surfaces and to nutrients in the environment.

*Bacteria that possess capsules are considered to be encapsulated, and generally have greater pathogenicity (ability to cause disease) because capsules **protect bacteria from phagocytosis** (white blood cells of the immune system). The adhesive power of capsules is also **a major factor in the initiation of some bacterial diseases.**

• Functions of glycocalyx

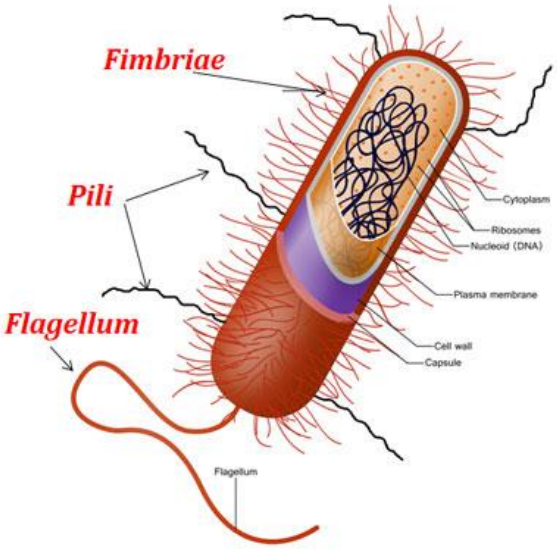
- attachment
- protection of pathogens from the host immune system
- protection from phagocytosis

(الشكل غير مطلوب)



2- Pili and Fimbriae

Pili and Fimbriae are filamentous structures composed of protein , that extend from the surface of a cell and can have many functions.



Cell-Surface Appendages of a Bacterial Cell

Difference between Fimbriae and Pili

Fimbriae (S., Fimbria)	Pili (S., Pilus)
Tiny, bristle-like fibers arising from bacterial cells	Hair-like microfibers on the surface of bacteria
Occur in both Gram-positive and Gram-negative bacteria	Occur in Gram-negative bacteria.
Around 200-400 fimbriae occur per bacterial cell	Only 1-10 pili occur per bacterial cell.
Made up of fimbrillin protein	Made up of pilin protein.
Governed by bacterial genes in the nucleoid region (chromosome)	Governed by plasmid genes.
Shorter	Longer
Thin	Thicker
Less rigid	More rigid
Attach the bacterium to the substrate	Aid in bacterial conjugation

3- Flagella

Flagella (singular: flagellum): thin hair-like appendages that protrude from the cell body of certain bacteria, often much longer than the cell itself, and used for **locomotion** in many bacteria (move the bacteria towards nutrients and other attractants). .

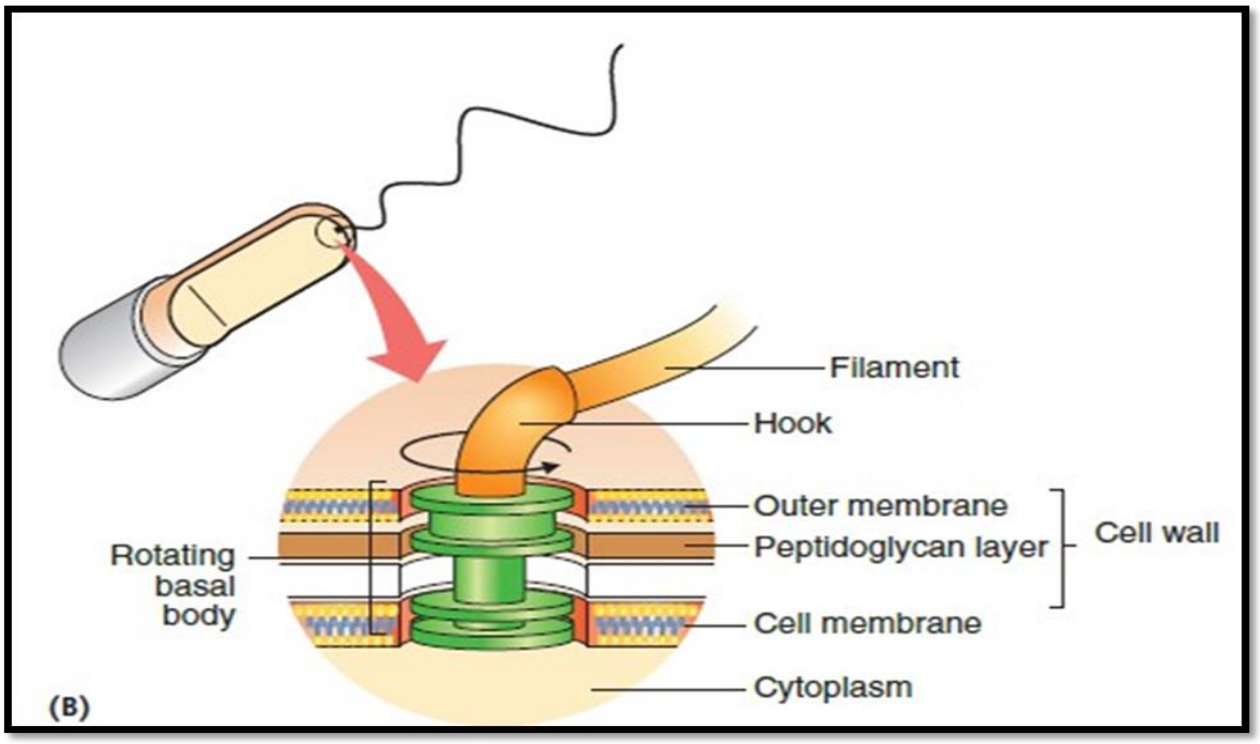
They consist of the three main components:

1- **Filament (helical propeller)**

2- **Hook (universal joint)**

3- **Basal body (rotary motor)**

(الشكل الاتي غير مطلوب)



Structure of bacterial flagellum

***The filament** is the largest part, is about 20 nm in diameter, extends out to the cell's environment, and is usually composed of many subunits of a single protein called **flagellin**.

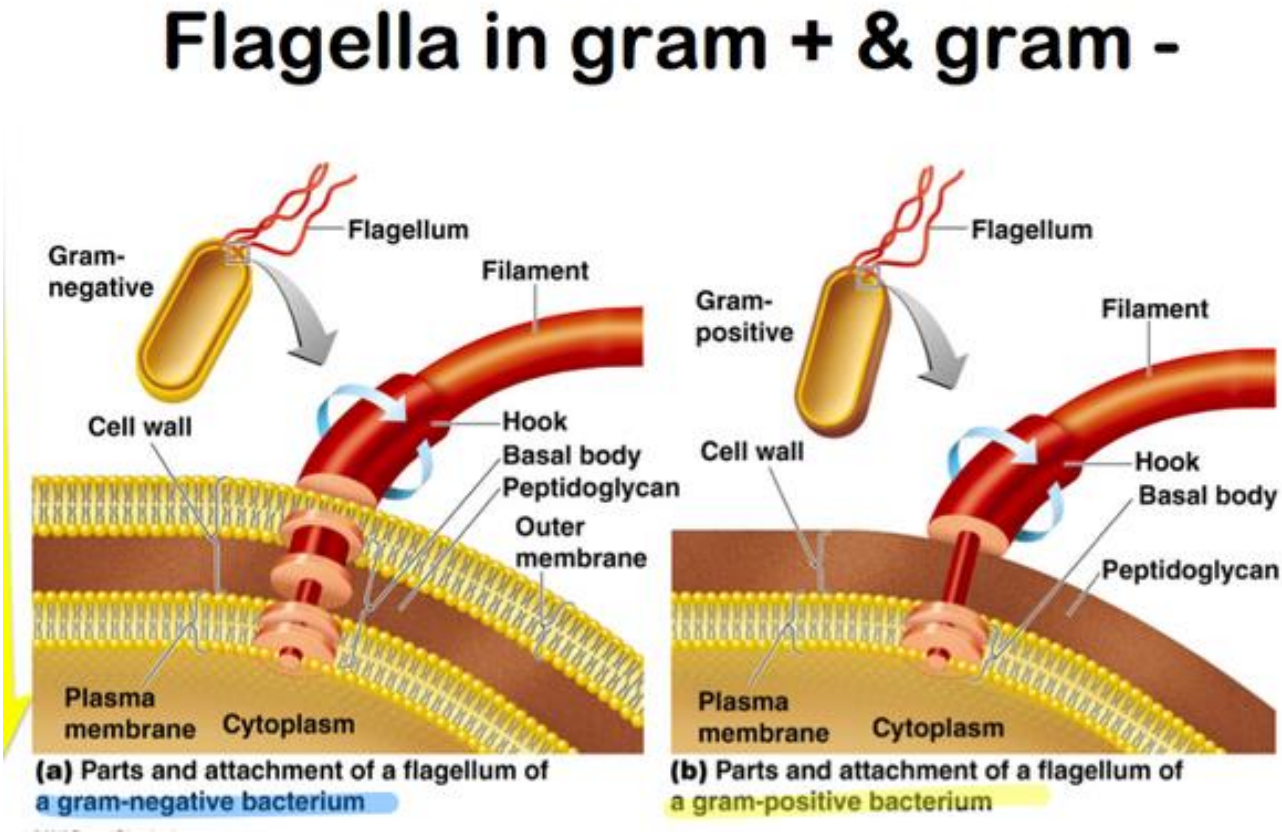
***The hook:** is a short tubular structure, It is different in structure than that of the filament, It connects the filament to the basal body.

***The basal body** consists of a central rod or shaft surrounded by a set of rings.

The flagellar structure of **Gram-positive bacteria** has **two rings** in the basal body.

The flagellar structure of **Gram-negative bacteria** has **four rings** in the basal body.

(الشكل الاتي غير مطلوب)



Gram Positive 2 rings in basal body -Gram Negative 4 rings in basal body.

Flagella arrangement schemes

Different species of bacteria have different **numbers and arrangements** of flagella:

1- **Atrichous bacteria:** Flagella absent

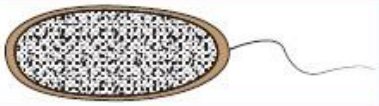
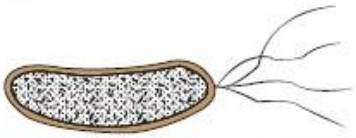
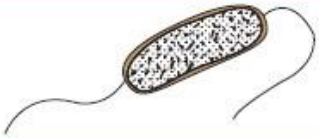
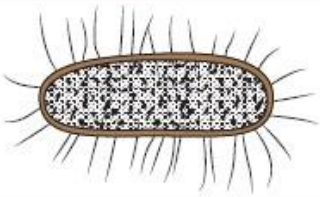
2-**Monotrichous bacteria:** Single polar flagellum

3-**Amphitrichous bacteria:** Single flagellum at both ends.

4-**Lophotrichous bacteria:** tuft of flagella at one or both ends.

5-**Peritrichous bacteria:** Many flagella all over the body.

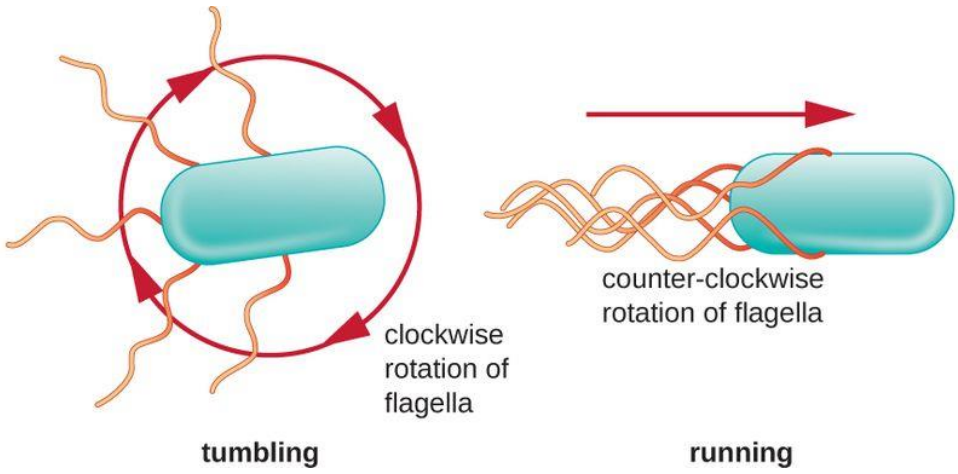
Table 7.1: Arrangement of bacterial flagella

Structure	Flagella type	Example
	Monotrichous(single flagella on one side)	*Vibrio cholera*
	Lophotrichous(tuft of flagella on one end)	*Pseudomonas fluorescens*
	Amphitrichous(single or tuft on both ends)	*Aquaspirillum serpens*
	Peritrichous(flagella throughout the cells)	*Salmonella typhi*

Rotation of the flagellum is an energy-dependent process driven by the basal body, and the direction of rotation determines the nature of the resulting cellular movement.

When flagella bundle together they rotate **counterclockwise,** and the bacteria **run** or move in a straight line.

Clockwise rotation causes the tuft (group) of flagella to spread, resulting in the randomly **tumbling** of the cell (الشكل الاتي غير مطلوب)



Types of movement

Bacterial movement occurs in response to stimuli (**taxis**). In the presence of favorable stimuli, the receptors found on the surface of the cells, send signals to the flagella, which then adjust their speed and direction of rotation.

Taxis: **directed movement in response to chemical or physical gradients**

- **Chemotaxis: a** response to chemicals.
- **Phototaxis:** a response to light
- **Aerotaxis:** a response to oxygen
- **Osmotaxis:** a response to ionic strength
- **Hydrotaxis:** a response to water
- **Magnetotaxis:** a response to magnetic field