Quorum Sensing

quorum sensing

- The ability of bacteria to sense and respond to environmental stimuli such as pH, temperature, the presence of nutrients, etc has been long recognized as essential for their continued survival

- Bacteria communicate with one another using chemical signal molecules

- Bacteria leak a chemical into their surroundings (autoinducer) which is small organic molecules or peptides/lipds.

- Gram-negative bacteria employ **N-acyl homoserine lactones** (AHLs), alkyl quinolones (AQs) and fatty acidmethyl esters.

- Gram-positive bacteria use peptides like the **autoinducing peptides** (AIPs).

quorum sensing

- Quorum sensing is a process of bacterial cell-to-cell communication involving the production and detection of extracellular signaling molecules (autoinducers).

- Quorum sensing is a phenomenon that allows both Gram-negative and Gram-positive bacteria to sense one another and to regulate a wide variety of physiological activities.

- Such activities include symbiosis, virulence, motility, antibiotic production, and biofilm formation.

quorum sensing history

- Quorum sensing was originally discovered in the luminescent bacterium ***Vibrio fischeri***

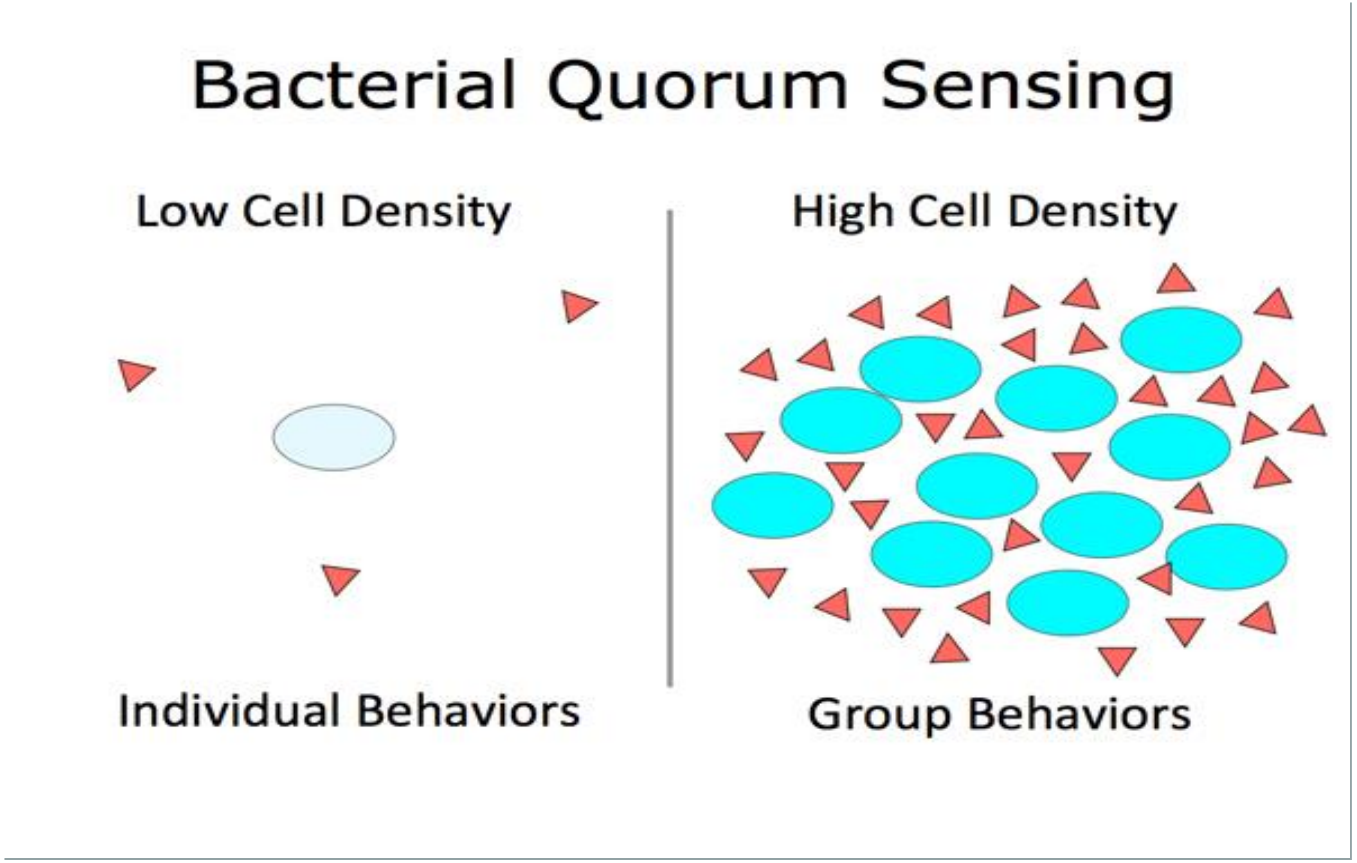
- Nealson *et al.* (1970) – luminescence in the marine Gram-negative bacterium *Vibrio fischeri* controlled by self-produced chemical signal

- Eberhard *et al*. (1981) identified the *V. fischeri* autoinducer signal to be *N*-3-oxo-hexanoyl-L-homoserine lactone

- Engebrecht *et al.* (1983) cloned the genes for the signal generating enzyme, the signal receptor and the *lux* genes

quorum sensing

- Fuqua *et al*. (1994) introduced the term **quorum sensing** to describe cell-cell signaling in bacteria



A brief overview of the process

- Quorum sensing can be divided into at least 4 steps:

  (1) production of small biochemical signal molecules by the bacterial cell

  (2) release of the signal molecules, either actively or passively, into the surrounding environment

  (3) recognition of the signal molecules by specific receptors once they exceed a threshold concentration, leading to

  (4) changes in gene regulation

- When these autoinducers reach a **critical threshold** level, they activate bacterial quorum sensing genes that enable the bacteria to behave as a multicellular population rather than as individual single-celled organisms. In this way, individual bacteria within a group are able to benefit from the activity of the entire group.

Mechanism of quorum sensing:

- It is the feedback control system. Bacteria continuously produce a small amount of signal called auto inducer.
- Most of the Gram-positive bacteria produce auto inducer which are acylhomoserine lactones (AHLs). *Staphylococcus aureus* and other bacteria produce peptide auto inducers. *E. coli* and *S. typhimurium* produce a quorum sensing molecule of 1 kDalton. These extracellular inducers are diffused out.
- Besides, bacteria also recognise the presence of auto inducer.
- The bacterial membrane protein acts both as receptor of auto inducer and activator of gene transcription.
- *Vibrio fischeri* produces luminescence and is the best studied quorum sensing system.

- Luminescence is associated with lux operon system which consists of two main regulatory genes luxl and luxR and other genes (luxCDABEG) which synthesize chemicals to produce light.
- LuxI encodes a protein which catalyses the synthesis of a wide range of AHLα.
- LuxR encodes a protein which acts both as a receptor for AHL and as a transducer of the signal that activates the other genes of lux operon.
- The luxCDABEG genes are expressed after binding AHL to the luxR protein.
- The luxA and luxB genes synthesise the α- and β- subunits of bacterial luciferase.
- The other genes encode polypeptides which facilitate the synthesis of the substrate and produces light.
- Autoinducer of *V. fischeri* is N-(3-oxo-hexanoyl)-L- homoserine lactone.

quorum sensing

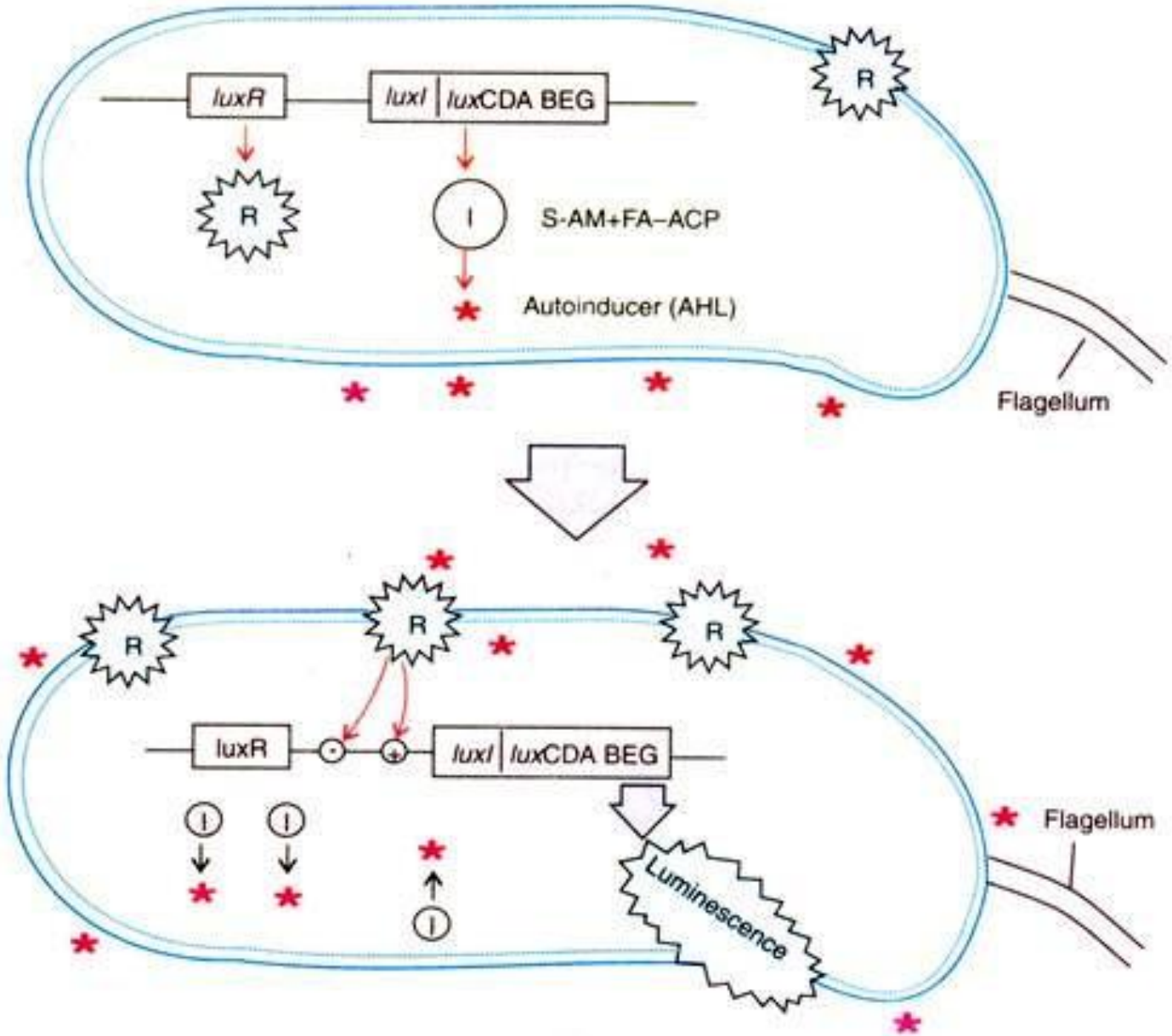


Fig. 27.6 : Operation of *luxI/luxR* system and luminescence in *Vibrio fischeri*.

CHEMOTAXIS

Introduction

- **Chemotaxis -** Composed of two words "**chemo** + **taxis".**
- **Chemo** means a "**chemical substance**" is a form of matter that has constant chemical composition and characteristic properties.
- **Taxis** means "**arrangement**" is the movement of an organism in response to a stimulus such as light or the presence of food.
- **Chemotaxis** is the movement of an organism/bacteria in response to a chemical stimulus i.e., move away or towards substances that are present in the environment through a non-random process.
- This movement is often directed either
  - **Positive chemotaxis -** movement **towards attractants (nutrients)** or
  - **Negative chemotaxis -** movement **away from the repellents (toxin).**

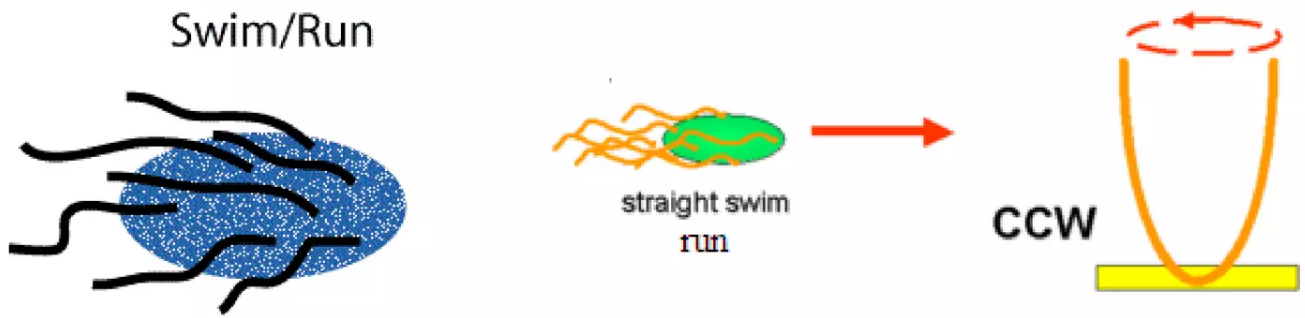
- **Chemoattractants -** Chemicals that attract bacteria.
  - e.g., for ***E.coli*** amino acids (serine and aspartic acid), sugars (maltose, ribose, galactose, glucose), dipeptides, pyrimidines and electron acceptors (oxygen, nitrate, fumarate).

- **Chemorepellents -** Chemicals that drive bacteria away.
  - e.g., for ***E.coli*** amino acid (leucine), metal ion (Ni), pH, potentially noxious chemicals (alcohols and fatty acids).

- ***E. coli*** uses **temporal gradients** to guide its motion.
- Uses a **biased-random-walk strategy** to sample space and convert spatial gradients to temporal ones.
- In **liquid environments**, *E. coli* **swims** in a pattern than resembles a random walk.

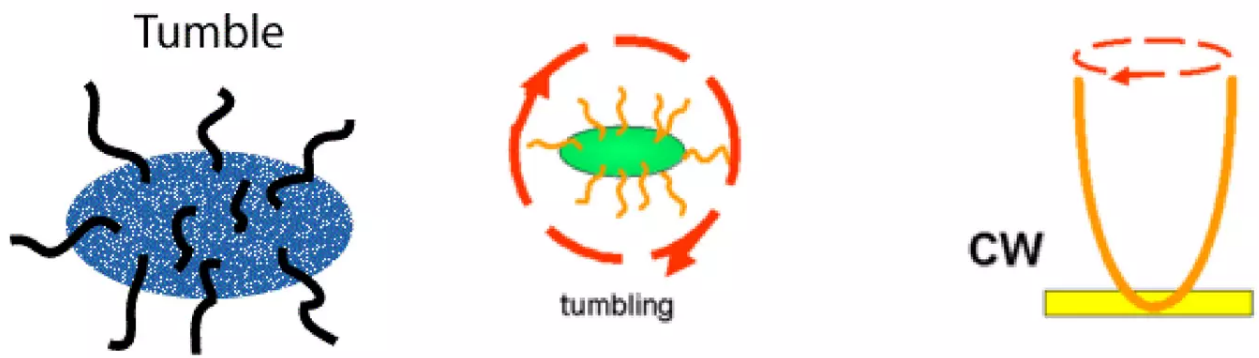
Chemotaxis Behavior

- ***E. coli* moves up a gradient of attractant -**
  - Detects a net positive change in attractant concentration,
  - Reduces the probability of a tumble and tends to continue going up the gradient.
- **Swim/Runs** - the cell keeps a rather constant direction which produce **Counter clockwise** rotation.
- The runs last about **1 sec** on average.



Counter clockwise swimming behavior in *E. coli*

- ***E. coli* detects a concentration of repellent increases with time -**
  - The cell increases tumbling frequency,
  - Tends to change direction and avoid swimming toward repellents.
- **Tumbles** - the bacterium stops and randomly changes direction which produce **Clockwise** rotation.
- The tumbles about **0.1 sec** on average.



Clockwise flagellar rotation in *E.coli*

Bacteral Chemotaxis

The bacterial flagella are arranged into bundles which diverge into separate bundles when they drive clock wise (CW) and converge to a single bundle when they are rotating counter clockwise (CCW). The Bacteria thus has two states of motion

(A) swimming in a straight line (v=14-30 µm/sec, in average for 0.8s) and

(B) tumble, in average for 0.2s.

If for the bacteria the concentratrion of an attractant increases over time, tumbling is suppressed. As result, the bacteria performs a biased diffusion process towards increasing concentration of the attractant.