Popular Article

QUORUM SENSING AND QUORUM QUENCHING: A BRIEF GENERAL REVIEW

Prashant Prajapati[1], Santanu Pal[1], Reddi Lokeswari[1], Dumala Naveen[1]

[1]Ph.D. Scholar, Veterinary Microbiology, ICAR-Indian Veterinary Research Institute, Izatnagar, 243122, India

**Corresponding author e-mail: spalmicro96@gmail.com*

ABSTRACT

Quorum sensing, a cell–cell communication is how bacteria control gene expression in response to population density. They release chemical signals called autoinducers that trigger changes in gene expression as their concentration increases. Using the technique known as quorum sensing, bacteria can keep an eye out for other bacteria in their surroundings and adjust their behaviour across the population in reaction to changes in the quantity or species of bacteria present in a community. QS oversees a wide range of physiological functions, encompassing symbiosis, virulence, competence, conjugation, antibiotic synthesis, motility, sporulation, and biofilm formation.

Keywords: Quorum sensing, cell-cell communication, bacteria, virulence, biofilm

I. INTRODUCTION

Chemical signal molecules are used by bacteria to interact with one another by the mechanism known as quorum sensing. Like higher creatures, these molecules provide essential information for coordinating the actions of vast clusters of cells. Chemical communication in bacteria entails the production, release, detection, and reaction to tiny hormone-like molecules known as autoinducers (AIs). Once the concentration of autoinducers reaches a certain threshold, gene expression is altered. Early in the 1980s, the genetic mechanism needed to produce autoinducer and bioluminescence was discovered. The autoinducer was then identified as a member of the N-acyl homoserine lactone (AHL) family of molecules.

The Latin term "quorum" refers to the minimum number of participants needed for a group to legitimately conduct an activity or transact commerce. In the 1970s, Nealson and co-workers discovered quorum sensing in two luminescent marine bacterial species, *Vibrio fischeri* and *Vibrio harveyi*. These bacteria can be found as free-living cells or as symbionts in an animal host's light-producing organ, i.e., luciferase structural operon luxCDABE, responsible for encoding enzymes crucial for light production. Light emission occurs solely at high cell-population densities, impelled by the accumulation of autoinducer signalling molecules secreted by the bacteria.

II. MECHANISM OF QUORUM SENSING

Despite the variations in how they are controlled and the exact processes involved, all known QS systems rely on three basic principles.

1. Community members create signalling molecules called AIs. These molecules are released at low levels when there are few cells around low cell density (LCD), making them hard to detect. But as cell density increases high cell density (HCD), the overall concentration of AIs rises, making detection possible.
2. AIs are picked up by receptors inside cells or on their surfaces.

3. When AIs are detected, genes that help with group behaviours are activated, along with an increase in AI production. This creates a feedback loop that helps coordinate actions within the population.

III. MECHANISM OF QS IN GRAM-POSITIVE AND GRAM-NEGATIVE BACTERIA

Auto-inducing peptides (AIPs) are used as signalling molecules by gram-positive bacteria for quorum sensing. AIPs are processed and secreted by the cell after they are produced. Those bind to a corresponding membrane-bound, two-component histidine kinase receptor when its extracellular concentration is high, which happens at HCD. Binding typically results in the activation of the receptor's kinase activity, where it auto-phosphorylates, and phosphate transfers to an appropriate cytoplasmic response regulator. The QS regulon's genes begin to transcribe when the phosphorylated response regulator does. AIPs are transferred back into the cell cytoplasm in certain instances of Gram-positive bacterial QS, where they interact with transcription factors to modify the activity of the transcription factor and, consequently, modify changes in gene expression.

Gram-negative bacteria use quorum sensing by employing AIs made up of small molecules. These are either other molecules whose synthesis requires S-adenosyl methionine (SAM) as a substrate or N-acyl homoserine lactones. AIs are generated within cells and freely permeate both the inner and outer membranes. At HCD, where the concentration of AIs is high enough, they bind transcription factors called cytoplasmic receptors. The QS regulon's gene expression is controlled by the AI-bound receptors. Two-component histidine kinase receptors can detect AIs in certain instances of Gram-negative bacterial QS.

IV. QS CONTROL OF VIRULENCE IN GRAM-POSITIVE AND GRAM-NEGATIVE BACTERIA

The AIs found in many Gram-positive bacteria are oligopeptide AIPs, which are recognized by two-component signal transduction systems that are confined to membranes. The AIPs have different sequences and structures and are encoded as precursors (pro-AIPs). Peptides cannot pass through the cell membrane; thus, specific transporters are needed for the secretion of AIPs. The pro-AIPs are also processed by the AIP transporters. The final processed AIPs can be linearized or cyclized, have a size range of 5 to 17 amino acids, and can undergo post-translational modification. Two-component sensor kinases that are membrane-bound are used to detect extracellular AIPs. When bound by the AIP, the sensor kinases auto-phosphorylate at conserved histidine. On a cognate cytoplasmic response-regulator protein, the phosphoryl group is transferred from the histidine to a conserved aspartate. The phosphorylated response regulator then regulates the expression of QS-target genes. The pro-AIP, transporter, histidine kinase receptor, and response regulator in these Gram-positive QS circuits are usually encoded in an operon. The phosphorylated response regulator triggers this operon's expression, which sets up an autoinducing feed-forward loop that synchronizes the QS response.

LuxI/LuxR type QS systems, which are homologous to the first QS system described from the bioluminescent marine symbiotic bacterium *Vibrio fischeri* are commonly used by gram-negative bacteria. In these systems, an acyl carrier protein (ACP) and SAM react to form a freely diffusible acyl-homoserine lactone, which is catalyzed by the AI synthase LuxI homolog. AHL AIs bind to appropriate cytoplasmic LuxR-like transcription factors at high concentrations. LuxR-type proteins are quickly broken down when they are not bound by AI, possibly to stop bacteria from "short-circuiting" their QS systems. The LuxR-type proteins are stabilized by AI binding, which enables them to fold, bind DNA, and start target gene transcription. Usually, LuxR-type proteins

bound to AHL also induce LuxI expression, creating a feed-forward auto-induction loop that releases AI into the surrounding area. There are homologs of LuxI/LuxR in over 100 species of Gram-negative bacteria. Different bacteria produce AHLs with varying side chain lengths and side chain decorations. It has been determined that acyl chains with modifications like carbonyl and hydroxyl moieties at the C3 position can range from C4 to C18. This chemical diversity facilitates highly specific interactions with partner LuxR proteins, which in turn promotes intraspecies-specific bacterial cell-cell communication.

Quorum sensing in viruses

Recently, a mechanism involving arbitrium in bacteriophages that infect multiple species of Bacillus has been described. The viruses exchange information with one another to determine their density about possible hosts. They make their decision about entering a lytic or lysogenic life cycle based on this information.

Quorum sensing in plants

Plant-pathogen interactions depend on QS, and their research has advanced the field of QS more broadly. *Agrobacterium tumefaciens*, a crop pathogen with a wider host range, and *Pantoea stewartii* subsp. *stewartii* in maize/corn provided the first X-ray crystallography results for some of the key proteins. Quorum-sensing molecules mediate these interactions, which are crucial in preserving the pathogenicity of bacteria toward other hosts, including humans. The effects of N-Acyl homoserine lactone (AHL), one of the quorum sensing-signalling molecules in gram-negative bacteria, on plants can be used to understand this mechanism.

Quorum sensing in social insects

Social insect colonies are a great illustration of a decentralized system since no one person directs leading or choosing the course of action for the entire colony. It has been demonstrated that quorum sensing is used by several social insect groups like group decision-making. *Temnothorax albipennis* ant colonies build their nests in tiny spaces between rocks. These ants must move quickly to find a new nest when the rocks shift and the nest is divided. Quorum sensing is another method used by honey bees (*Apis mellifera*) to choose new nest locations. Swarming is the process by which large colonies procreate.

Quorum quenching

The technique of preventing quorum sensing by interfering with signalling is known as quorum quenching. This can be accomplished in a few different ways, such as by degrading the signalling molecules themselves, introducing molecules that mimic the signalling molecules and block their receptors, inactivating the signalling enzymes, or changing the quorum sensing signals because of an enzyme activity.

Quorum-sensing enzymes are known to be inhibited by triclosan and cloventel. In two-component signalling, closantel causes the histidine kinase sensor to aggregate. These substances inhibit the enoyl-acyl carrier protein (ACP) reductase, which prevents the synthesis of N-acyl homoserine lactones (AHLs), a class of signalling molecules. Halogenated furanone, which mimics AHL molecules, and synthetic Al peptides (AIPs), which mimic naturally occurring AIPs, are two classes of well-known mimicking molecules. These organizations prevent receptors from attaching to their substrate or lower the number of receptors within the cell. Rapid-resolution liquid chromatography (RRLC) was recently used to investigate the AHL degradation kinetics of a well-researched quorum-quenching bacterial strain (KM1S).

V. CONCLUSION

It is now clear that cell-cell communication is the norm in the bacterial world and that understanding this process is fundamental to all of microbiology, including industrial and clinical microbiology. Quorum sensing was, until recently, considered to promote exclusively intra-species

communication and thus enable clonal populations of bacteria to count their cell numbers and alter gene expression in unison. While some autoinducers indeed appear to be extremely species-specific, new research shows that others are either genus-specific or promote inter-genera communication. Bacterial quorum-sensing signal detection and relay apparatuses are complex and often consist of multiple circuits organized in a variety of configurations. Bacteria routinely exist in fluctuating environments containing complex mixtures of chemicals, some of which are signals and some of which presumably do not convey meaningful information. Quorum sensing network organization evolved to solve the set of communication needs a particular species of bacteria encounters. Elements of these elegant solutions for deciphering complex chemical vocabularies appear to be conserved and used for analogous purposes in eukaryotes.

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