Microbial Flocking, Quorums and Anti-Quorums

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Quorum sensing

Quorum sensing is a process in which bacteria and fungi monitor their cell-population density by measuring the concentration of small secreted signal molecules, called *autoinducers*. Many quorum sensing-processes, including bioluminescence, virulence factor production, biofilm formation, sporulation and motility, are controlled by these well-defined chemical signals elaborated by the organism. (See 1,2). Quorum sensing is also seen crucial to pathogenesis.

While species-specific quorum sensing apparently allows recognition of self in a mixed population, some quorum mechanisms function to detect the presence of other species. Thus one signal is used for *intraspecies* communication and the second signal is used for *interspecies* communication.

Quorum sensing can operate on scales of micrometres to millimetres, on a truly global scale, as detected by satellite images of 'milky seas' due to bioluminescence of e.g., *Vibrio harveyi*. (3) Bioluminescence plays a role in stimulation of DNA repair. (4). Strains of non-bioluminescent *Vibrio harveyi* are more prone to UV-induced DNA damage.

Among bacteria, quorum-sensing systems can be divided into two paradigmatic classes: LuxI/LuxR–type quorum-sensing systems in Gram-negative bacteria and oligopeptide/two-component–type quorum-sensing circuits in Gram-positive bacteria. In Gram-negative bacteria, the LuxI-like proteins are the enzymes responsible for producing specific acyl-homoserine lactone (AHL) autoinducers. In contrast, Gram-positive bacteria make and transport oligopeptide autoinducers into their environment. (1,2)

Recently, it has become apparent that diverse fungal species, like bacteria, also use quorum regulation to affect population-level behaviours such as sporulation, pseudo-mycelial and biofilm formation as well as pathogenesis. While *C. albicans* biofilm structure and composition can change under different environmental conditions, several reports describe *C. albicans* biofilms that are comprised of a basal yeast layer, abundant hyphae, and a calcofluor-binding extracellular matrix. Autoinducer *farnesol* can effectively block *C. albicans* biofilm and hyphae development while in small numbers during the stationary phase of growth, the auto-inducer, *tyrosol*, stimulates formation of hyphae. (2)

The fungus *Uromyces phaseoli* produces methyl 3,4-dimethoxycinnamate, a "self-inhibitor" of spore germination that is effective at nanomolar concentrations. Uredospores do not germinate unless the self-inhibitor is removed by an aqueous wash (akin to rain) leading to the suggestion that this signal may decrease competition within the population by blocking germination until a spore has dispersed. (2)

Interference of quorum-sensing (anti-quorums)

Current research confirms that both prokaryotes and eukaryotes possess interference strategies to disrupt microbial cell-cell communication. In various habitats, where bacteria and fungi are competing with other species, including colonising leaves and roots of plants, (See 5,6) for limited nutrients and energy resources, the ability to inactivate or remove an autoinducer, e.g. for antibiotic or anti-fungals, or to make an autoinducer antagonist could give one microbial species an advantage over another that relies on quorum sensing for occupation of a particular niche. Similarly, during infections by pathogenic bacteria and or fungi that depend on quorumsensing for virulence, the ability of the host or friendly symbiont to interfere with the signaling process is a key to stave off infection. For every class of quorum-sensing signal thus far identified, a mechanism has been discovered that inhibits, destroys, or removes it.

Flocking

"Flocking" behaviour is not limited to birds or fish. It is also observed in bacteria and 'slime moulds'. In the bacterium *Bacillus circulans* once a critical concentration of bacteria is reached, quorum sensing causes groups of bacteria to 'flock' together to behave as a multicellular organism with a 'head' and 'tail'. The 'flock' then moves rapidly to sites of nutrients. Daughter flocks can arise in the process. When conditions are sub-optimum, the 'flock' rotates and proceeds to undergo sporulation. Evidence indicates that flocking, motility and sporulation are the effects of complex mechanisms of inter-cellular communication via auto-inducers and quorum sensing.

References

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