4.2: Quorum Sensing

Another type of community behavior at the unicellular level involves a behavior known as quorum sensing. This is a process by which organisms can sense the density of other organisms in their immediate environment. Each individual secretes a molecule, which they can also respond to; the organism’s response to this molecule dependent on the secreted molecule’s concentration and it is non-linear. So what does a non-linear response look like? As the concentration of signaling molecules increases, there is a discrete concentration, known as the threshold concentration; below the threshold concentration the cells (or organisms) do not change their behavior in response to the secreted compound. When cells or organisms are present at a low density, the concentration of the signaling molecule never exceeds the threshold concentration. As the density of organisms per unit volume increases, however, the concentration of the molecule exceeds the threshold concentration and interesting things start to happen; there are changes in behavior, often associated with changes in gene expression (we will consider what that means exactly later on).\(^{117}\)

A classic example of a number of cooperative and quorum sensing behaviors is provided by the light emitting marine bacteria *Vibrio fischeri*. These are marine bacteria that form a symbiotic relationship with the squid *Euprymna scolopes\(^{118}\)*. In these squid, *V. fischeri* bacteria colonize a special organ known as a light organ. The squid uses light emitted from this organ to confuse and hide from its own predators as it hunts its prey. While there are many steps in the colonization process, and its regulation is complex, we will just consider just a few to indicate how cooperative behaviors between the bacteria are critical. For the colonization of the squid’s light organs the *V. fischerei* bacteria must bind to a specific region of the juvenile squid. As they divide, they sense the presence of their neighbors and begin to secrete molecules that form of gooey matrix - this leads to the formation of a specialized aggregate of cells (known as a biofilm) that is essential for the bacteria to colonize the squid’s light organs. Within the biofilm, the bacteria acquire the ability to follow chemical signals produced by the squid’s light organ cells. The bacteria swim (through a process known as chemotaxis) toward these signals, thereby entering and colonizing the light organs.

The bacteria in the light organs emit light through a reaction involving the luciferin molecule. This reaction system
involves various coupled chemical reactions (we will consider in some detail the thermodynamics of such reactions in the next section of the course) and is catalyzed (that is, sped up) by the protein luciferase. The luciferase protein is encoded by one of the bacteria’s genes (its original role has been proposed to be in the “detoxification of the deleterious oxygen derivatives”\(^{119}\). Given that bacteria are small, you can imagine that very little light would be emitted from a single bacterium. If there were only a small number of bacteria within the light organ, it would be ineffectual to carry out the light emitting reaction. The light emitting reaction occurs only when the number of bacteria within a light organ becomes sufficiently high. But how do the bacteria know that they are in the presence of sufficient numbers of neighbors? Here is where quorum sensing comes into play. A molecule secreted by the bacteria regulates the components of the light reaction. At high concentrations of bacteria, the concentration of the secreted molecule rises above a threshold, and the bacteria respond by turning on their light emitting system.

Mechanistically similar systems are involved in a range of processes including the generation of toxins, virulence factors, and antibiotics directed against other types of organisms. These are produced only when the density of the bacterium rises above a threshold concentration. This insures that when a biologically costly molecule is made, it is effective – that is, it is produced at a level high enough to carry out its intended role. These high levels can only be attained through cooperative behaviors involving many individuals.

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**Contributors and Attributions**

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