Luminescent Bacteria

Luminescence is the emission of light by an object. Living organisms including certain **bacteria** are capable of luminescence (**bioluminescence**). Bacteria are the most abundant luminescent organism in nature.

Bacterial luminescence has been studied most extensively in several marine bacteria (e.g., *Vibrio harveyi*, *Vibrio fischeri*, *Photobacterium phosphoreum*, *Photobacterium leiognathi*), and in *Xenorhabdus luminescens*, a bacterium that lives on land. The precise molecular mechanisms of luminescence differ between these bacteria. But, the general scheme of the process is similar.

In luminescent bacteria (and other luminescent organisms as well) this general scheme involves an enzyme that is dubbed luciferase. A suite of genes dubbed lux genes code for the enzyme and other components of the luminescent system. The different bacteria are dissimilar in the sequence of their lux genes and in the enzyme reactions that produce luminescence. However, the general pattern of the reaction is the same.

A similarity between the luminescent bacteria concerns the conditions that prompt the luminescence. A key factor is the number of bacteria that are present. This is also known as the cell density (i.e., the number of bacteria per given volume of solution or given weight of sample). A low cell density (e.g., less than 100 living bacteria per milliliter) does not induce luminescence, whereas luminescence is induced at a high cell density (e.g., 10^{10} to 10^{11} living bacteria per milliliter).

The effect of cell density is particularly evident in those luminescent bacteria that live in the ocean. When living free in the ocean water, *Vibrio fischeri* is not luminescent. However, when living in a confined space such as the inside of a fish or squid, *Vibrio fischeri* is luminescent. Bacterial luminescence may have evolved as a means of enhancing the survival of the bacteria species. For example, the luminescence of *Vibrio fischeri* in a squid enables the squid to camouflage itself from undersea predators in the moonlit ocean. In return for this protection, the squid provides the bacteria with a hospitable environment.

The influence of cell density on bacterial luminescence is due to the nature of the luminescent process. The bacteria produce a chemical called homoserine lactone. At low cell densities, the chemical exits a bacterium and drifts away in the fluid that surround the cell. But at high cell densities when the bacteria are tightly packed together, the homoserine lactone stays in the immediate vicinity of the bacteria. Then, the chemical is able to stimulate the activity of the lux genes that are responsible for the luminescence. This occurs when the homoserine lactone binds to a protein in the bacterial **cytoplasm** called LuxR. The LuxR-homoserine lactone complex then binds to a region of the bacterial **DNA** that is the master control for the activity of the lux genes.

Bacterial luminescence is due to the action of the enzyme called luciferase. Luciferase catalyses the removal of an electron from two compounds. Excess energy is liberated in this process. The energy is dissipated as a luminescent blue-green light. Luminescent bacteria contain a number of genes that are found linked to each other in the bacterial genome, and which are controlled by a common regulatory region of the DNA. This arrangement of genes is called an **operon** .

The lux genes are involved in the production of luciferase, in the production and activity of the LuxR protein that detects the homoserine lactone, and in the chemicals reactions that produce the compounds on which the luciferase acts.

Bacteria utilize homoserine lactone in other cell-to-cell communications that are cell-density dependent. One example is the formation of the adherent, exopolysaccharide-enmeshed populations, known as biofilms, by the bacterium *Pseudomonas aeruginosa*. Another example is the bacterium *Agrobacterium* that produces diseases in some plants. The phenomenon has been termed **quorum sensing**.

The lux **gene** system responsible for bacterial luminescence has become an important research tool and commercial product. The incorporation of the luminescent genes into other bacteria allows the development of bacterial populations to be traced visually. Because luminescence can occur over and over again and because a bacterium's cycle of luminescence is very short (i.e., a cell is essentially blinking on and off), luminescence allows a near instantaneous (i.e., "real time") monitoring of bacterial behavior. The use of lux genes is being extended to eukaryotic cells. This development has created the potential for the use of luminescence to study eukaryotic cell density related conditions such as cancer.