EXPLORE THE ISSUE BEING INVESTIGATED

Cyanobacteria Control Heterocyst Pattern Formation through Intercellular Signalling

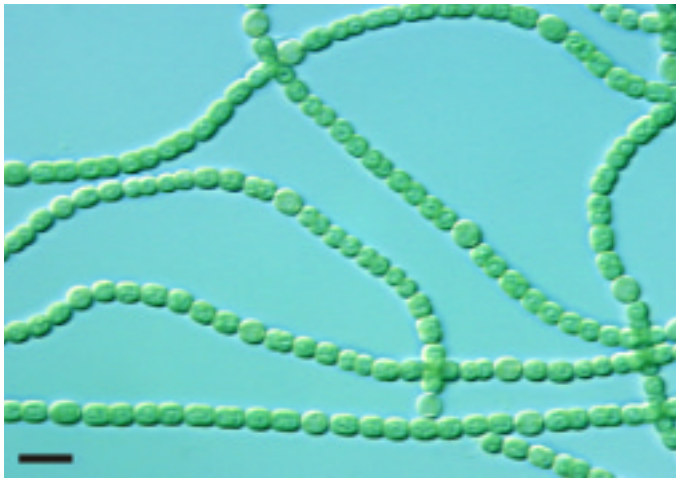
If every gene were expressed all the time, then all cells would be alike, and life on earth would be a uniform layer of green slime. What makes multicellular organisms with different kinds of cells and tissues possible is gene regulation—turning particular genes on at particular times. This gene control process, loosely called development, is the focus of much research in biology.

In order to get a clearer view of the basic mechanisms of development, researchers seek out simple model systems to study, with as few confounding factors as possible. One excellent model system for studying the basic mechanisms of development is found among filamentous cyanobacteria, prokaryotes that form long chains of photosynthetic cells. As long as an ample supply of metabolic nitrogen is available, every cell in one of these filaments is very much like every other, all busily involved in carrying out photosynthesis and all generating oxygen gas as a byproduct. However, if metabolic nitrogen supplies become depleted, certain cells of the chain undergo a developmental transformation. They cease photosynthesis and become tightly-encased cells called heterocysts. Heterocysts are specialized to produce metabolic nitrogen from atmospheric nitrogen gas, a process called nitrogen fixation. Unlike photosynthesis, nitrogen fixation is totally anaerobic—it is poisoned by oxygen.

You see the problem. To grow in a nitrogen-poor environment, a cyanobacterial cell must carry out photosynthesis (which generates oxygen) to gain energy for building molecules, and also must carry out nitrogen fixation (which is poisoned by oxygen) to gain the nitrogen needed for building proteins and other cell molecules.

The filamentous cyanobacteria solve this dilemma in a simple but elegant way by differentiating every tenth cell of the filament into a heterocyst. This one-dimensional developmental pattern spatially separates the two incompatible chemical processes into different cells. Heterocysts supply fixed nitrogen to neighboring photosynthetic cells, and in return are supplied with the products of photosynthesis.

This one-cell developmental process may serve as a model for basic developmental decisions. How is the decision to make a heterocyst reached? How is the spacing achieved? The laboratory of James Golden of Texas A & M University has been investigating heterocyst formation in the filamentous cyanobacterium *Anabaena*. They find that the process is far from simple—at least three programmed DNA rearrangements occur during heterocyst differentiation, and numerous genes are called into play. The lab has identified genes involved in the initial decision to form a heterocyst, and other genes involved in determining the pattern of heterocyst formation.



Heterocyst development in the filamentous cyanobacteria *Anabaena*. The filamentous *Anabaena* consists of photosynthetic vegetative cells (the smaller spherical cells) but the filaments develop a pattern of transforming vegetative cells into nitrogen-fixing heterocysts. About every tenth cell develops into a heterocyst (the larger spherical cells). Could a protein be controlling this developmental pattern? (Courtesy of James Golden.)

One of the later group of genes identified by Golden, a small 51-base pair gene dubbed *patS*, is crucial for the formation and mainentance of a normal 1-in-10 heterocyst spacing pattern. Over-expression of the *patS* gene completely blocks heterocyst formation. Many cell-to-cell signalling molecules in Gram-positive bacteria like cyanobacteria are peptides that diffuse from one cell to another, inhibiting some process in the cell receiving the peptide. It thus seemed reasonable to propose that the *patS* gene might encode a peptide signal released by the cells destined to become heterocysts, preventing neighboring photosynthetic cells from becoming heterocysts too. The pattern results from the fact that the peptide only diffuses a short distance, about five cells on either side of the nascent heterocyst.