EDITORIAL

Signals and Communication

To communicate over long distances with privacy we use telephone or computer systems consisting of wires and electricity. In living organisms inter- and intracellular communication is conveyed through chemistry, and such a system requires special characteristics to assure accuracy and privacy. One type of signal involves a stimulus from an external source that activates a receptor, sends the message through the membrane, and initiates a cascade of enzymatic steps, leading ultimately to an output response. There are many outputs—turning on a gene, releasing a neurotransmitter, controlling a mechanical change, and so forth—and there are many receptors—for light, taste, hormones, neurotransmitters, or nutrients, to name a few—thus requiring a large network of enzymatic pathways to provide speed and privacy. We are beginning to understand how these pathways transmit a signal from the surface of the cell to the molecules that produce the appropriate response, and that understanding is the subject of this issue of *Science*.

It is becoming evident that very different signaling systems use similar strategies to ensure that signals reach the desired target. Many signals are not meant to be "heard" throughout the cell. Rather, the components of a particular pathway are often localized together within the cell so that signals can be passed to a particular recipient. Mochly-Rosen discusses the role of localization of protein kinases, a compartmentalization using in some cases membrane anchoring and specificity of protein-protein interactions to provide accurate and uninterrupted communication. Protein lipidation is described by Casey. By covalent attachment of a large hydrophobic molecule, a protein can be modified so that it is directed to translocate to the membrane or to interact with other proteins. Some signals, like increases in the intracellular concentration of an ion such as Ca^{2+} would seem relatively nonspecific. However, as discussed by Ghosh and Greenberg, changes in the Ca^{2+} concentration within the cell can also be compartmentalized and can carry private messages as well as public ones. In fact, the particular type of Ca^{2+} channel through which Ca^{2+} enters a cell appears to determine which genes are activated.

Taniguchi describes signaling by cytokine receptors. These receptors for molecules such as interferons and interleukins are not enzymes themselves, but activate a variety of other associated proteins. Depending on which particular proteins are associated with the receptors, different messages can be transmitted between cells to control growth, antibody production, and other processes. Clark and Brugge discuss the integrins, sticky molecules on the surface of cells that help hold cells in place. These molecules also receive and transmit signals from neighboring cells or form proteins in the extracellular matrix on which the cell is growing. Here again, privacy is ensured as messages pass between proteins that are localized together with the integrins at sites of adhesion. Artavanis-Tsakonas, Matsuno, and Fortini discuss a new pathway that is still being mapped that apparently contributes to the regulation of development and control of cell fate in a broad spectrum of organisms from fruit flies to humans.

Biological signals need to be communicated privately—like telephone messages—in some cases, but in others, the well-being of the cell requires crosstalk between the pathways. Such crosstalk may allow integration of the multiple signals that a cell receives at any one time. The multiplicity of the incoming signals and the myriad of biological processes that are regulated suggest that there are more signal pathways than those already uncovered. The clever devices already revealed—compartmentalization, translocation, covalent lipid anchors, and others—suggest that nature has some secrets still to be unveiled. Elucidating these new concepts and clarifying the roles of privacy and crosstalk will provide those in the field of signal transduction with a lively and intriguing future. The communication lines within and between cells may be as sensitive and essential as the communication lines within and between nations.

L. Bryan Ray