8.1: Cell Signaling

How do cells receive signals from their environment and how do they communicate among themselves? It is intuitively obvious that even bacterial cells must be able to sense features of their environment, such as the presence of nutrients or toxins, if they are to survive. In addition to being able to receive information from the environment, multicellular organisms must find ways by which their cells can communicate among themselves. Since different cells take on specialized functions in a multicellular organism, they must be able to coordinate activities perfectly like the musicians in an orchestra performing a complicated piece of music. Cells grow, divide, or differentiate in response to specific signals. They may change shape or migrate to another location. At the physiological level, cells in a multicellular organism, must respond to everything from a meal just eaten to injury, threat or the availability of a mate. They must know when to repair damage to DNA, when to undergo apoptosis (programmed cell death) and even when to regenerate a lost limb. A variety of mechanisms have arisen to ensure that cell-cell communication is not only possible, but astonishingly swift, accurate and reliable.

How are signals sent between cells?
Like pretty much everything that happens in cells, signaling is dependent on molecular recognition. The basic principle of cell-cell signaling is simple. A particular kind of molecule, sent by a signaling cell, is recognized and bound by a receptor protein in (or on the surface of) the target cell. The signal molecules are chemically varied- they may be proteins, short peptides, lipids, nucleotides or catecholamines, to name a few. The chemical properties of the signal determine whether its receptors are on the cell surface or intracellular. If the signal is small and hydrophobic it can cross the cell membrane and bind a receptor inside the cell. If, on the other hand, the signal is charged, or very large, it would not be able to diffuse through the plasma membrane. Such signals need receptors on the cell surface, typically transmembrane proteins that have an extracellular portion that binds the signal and an intracellular part that passes on the message within the cell.
Receptors are specific for each type of signal, so each cell has many different kinds of receptors that can recognize and bind the many signals it receives. Because different cells have different sets of receptors, they respond to different signals or combinations of signals. The binding of a signal molecule to a receptor sets off a chain of events in the target cell. These events could cause change in various ways, including, but not limited to, alterations in metabolic pathways or gene expression in the target cell.

![Figure 8.1.1: Cellular Signaling](image)

How the binding of a signal to a receptor brings about change in cells is the topic of this section. Although the specific molecular components of the various signal transduction pathways differ, they all have some features in common:

- The binding of a signal to its receptor is usually, though not always, followed by the generation of a new signal(s) within the cell. The process by which the original signal is converted to a different form and passed on within the cell to bring about change is called signal transduction.
- Most signaling pathways have multiple signal transduction steps by which the signal is relayed through a series of molecular messengers that can amplify and distribute the message to various parts of the cell.
- The last of these messengers usually interacts with a target protein(s) and changes its activity, often by phosphorylation.

When a signal sets a particular pathway in motion, it is acting like an ON switch. This means that once the desired result has been obtained, the cell must have a mechanism that acts as an OFF switch.

Understanding this underlying similarity is helpful, because learning the details of the different pathways becomes merely a matter of identifying which molecular component performs a particular function in each individual case. We will consider several different signal transduction pathways, each mediated by a different kind of receptor. The first two examples we will examine are those with the fewest steps between the binding of the signal by a receptor and a cellular response.

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