Signalling Molecules and Cellular Receptors

MBB

Biochemistry (H) III

CELLULAR COMMUNICATION ENSURES REGULATION OF BIOLOGICAL PROCESSES WITHIN VARIOUS ENVIRONMENTS FROM SINGLE-CELLED TO MULTICELLULAR ORGANISMS.

Key Points

- The ability of cells to communicate through chemical signals originated in single cells and was essential for the evolution of multicellular organisms.
- In multicellular organisms, cells send and receive chemical messages constantly to coordinate the actions of distant organs, tissues, and cells.

- Cells can receive a message, transfer the information across the plasma membrane, and then produce changes within the cell in response to the message.
- Single-celled organisms, like yeast and bacteria, communicate with each other to aid in mating and coordination.
- Cellular communication has developed as a means to communicate with the environment, produce biological changes, and, if necessary, ensure survival.

Key term

- **biofilm**: a thin film of mucus created by and containing a colony of bacteria and other microorganisms

Introduction

- Imagine what life would be like if you and the people around you could not communicate.
- You would not be able to express your wishes to others, nor could you ask questions to find out more about your environment.
- Social organization is dependent on communication between the individuals that comprise that society; without communication, society would fall apart.

- As with people, it is vital for individual cells to be able to interact with their environment.
- This is true whether a cell is growing by itself in a pond or is one of many cells that form a larger organism.

- In order to properly respond to external stimuli, cells have developed complex mechanisms of communication that can receive a message, transfer the information across the plasma membrane, and then produce changes within the cell in response to the message.

- In multicellular organisms, cells send and receive chemical messages constantly to coordinate the actions of distant organs, tissues, and cells.

- The ability to send messages quickly and efficiently enables cells to coordinate and fine-tune their functions.

- While the necessity for cellular communication in larger organisms seems obvious, even single-celled organisms communicate with each other.

- Yeast cells signal each other to aid mating. Some forms of bacteria coordinate their actions in order to form large complexes called biofilms or to organize the production of toxins to remove competing organisms.

- The ability of cells to communicate through chemical signals originated in single cells and was essential for the evolution of multicellular organisms.

- The efficient and error-free function of communication systems is vital for all forms of life.

The major types of signalling mechanisms that occur in multicellular organisms are paracrine, endocrine, autocrine, and direct signalling.

FORMS OF SIGNALLING

Forms of signalling

- There are four categories of chemical signalling found in multicellular organisms: paracrine signalling, endocrine signalling, autocrine signalling, and direct signalling across gap junctions.

- The main difference between the different categories of signaling is the distance that the signal travels through the organism to reach the target cell. It is also important to note that not all cells are affected by the same signals.

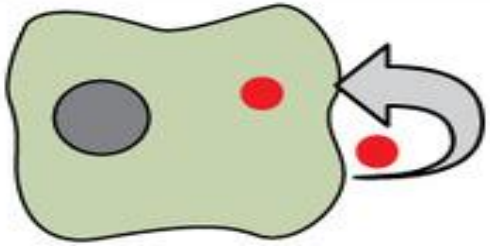
- **autocrine signaling**: produced by signaling cells that can also bind to the ligand that is released: the signaling cell and the target cell can be the same or a similar cell (prefix auto- means self)

- **paracrine signaling**: a form of cell signaling in which the target cell is near (para = near) the signal-releasing cell

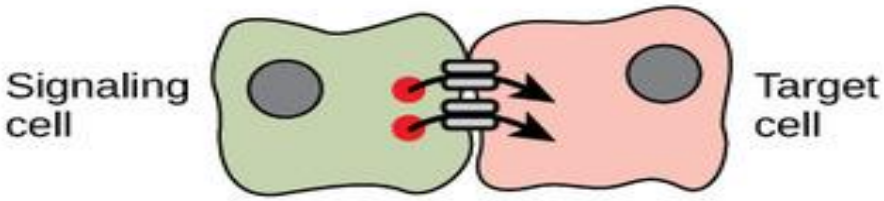
- **endocrine signaling**: signals from distant cells that originate from endocrine cells, usually producing a slow response, but having a long-lasting effect

Forms of Chemical Signaling

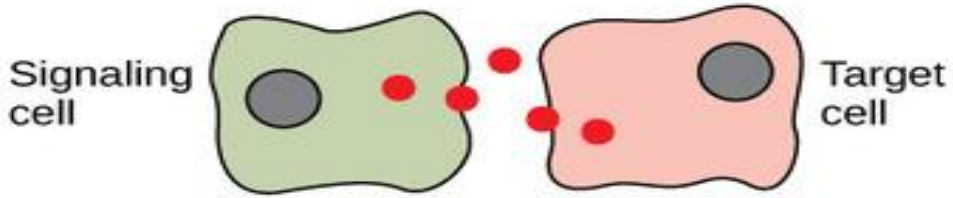
Autocrine	A cell targets itself.



Signaling across gap junctions	A cell targets a cell connected by gap junctions.



Paracrine	A cell targets a nearby cell.



Endocrine	A cell targets a distant cell through the bloodstream.

Forms of Chemical Signaling: In chemical signaling, a cell may target itself (autocrine signaling), a cell connected by gap junctions, a nearby cell (paracrine signaling), or a distant cell (endocrine signaling). Paracrine signaling acts on nearby cells, endocrine signaling uses the circulatory system to transport ligands, and autocrine signaling acts on the signaling cell. Signaling via gap junctions involves signaling molecules moving directly between adjacent cells.

Paracrine Signaling

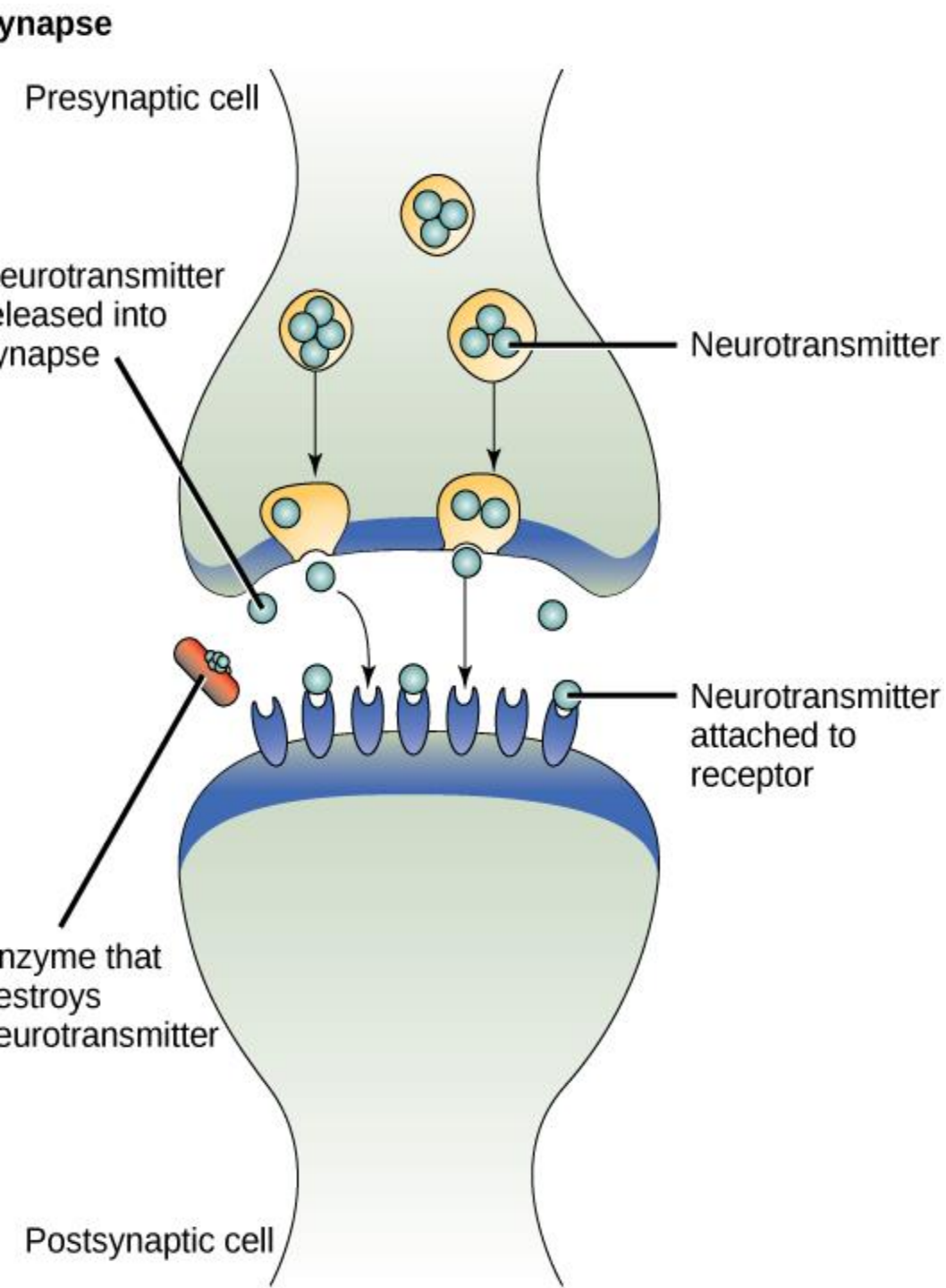
- Signals that act locally between cells that are close together are called paracrine signals.
- Paracrine signals move by diffusion through the extracellular matrix.
- These types of signals usually elicit quick responses that last only a short amount of time.

- In order to keep the response localized, paracrine ligand molecules are normally quickly degraded by enzymes or removed by neighboring cells.
- Removing the signals will reestablish the concentration gradient for the signal, allowing them to quickly diffuse through the intracellular space if released again.

- One example of paracrine signalling is the transfer of signals across synapses between nerve cells.
- A nerve cell consists of a cell body, several short, branched extensions called dendrites that receive stimuli, and a long extension called an axon, which transmits signals to other nerve cells or muscle cells.

- The junction between nerve cells where signal transmission occurs is called a synapse.
- A synaptic signal is a chemical signal that travels between nerve cells.
- Signals within the nerve cells are propagated by fast-moving electrical impulses.
- When these impulses reach the end of the axon, the signal continues on to a dendrite of the next cell by the release of chemical ligands called neurotransmitters by the presynaptic cell (the cell emitting the signal).

- The neurotransmitters are transported across the very small distances between nerve cells, which are called chemical synapses.
- The small distance between nerve cells allows the signal to travel quickly; this enables an immediate response.



Synapsis: The distance between the presynaptic cell and the postsynaptic cell—called the synaptic gap—is very small and allows for rapid diffusion of the neurotransmitter. Enzymes in the synapatic cleft degrade some types of neurotransmitters to terminate the signal.

Endocrine Signaling

- Signals from distant cells are called endocrine signals; they originate from endocrine cells. In the body, many endocrine cells are located in endocrine glands, such as the thyroid gland, the hypothalamus, and the pituitary gland.
- These types of signals usually produce a slower response, but have a longer-lasting effect.

- The ligands released in endocrine signalling are called hormones, signalling molecules that are produced in one part of the body, but affect other body regions some distance away.

- Hormones travel the large distances between endocrine cells and their target cells via the bloodstream, which is a relatively slow way to move throughout the body.
- Because of their form of transport, hormones get diluted and are present in low concentrations when they act on their target cells.
- This is different from paracrine signalling in which local concentrations of ligands can be very high.

Autocrine Signalling

- Autocrine signals are produced by signalling cells that can also bind to the ligand that is released.
- This means the signalling cell and the target cell can be the same or a similar cell (the prefix auto- means self, a reminder that the signalling cell sends a signal to itself).
- This type of signalling often occurs during the early development of an organism to ensure that cells develop into the correct tissues and take on the proper function.

- Autocrine signaling also regulates pain sensation and inflammatory responses.
- Further, if a cell is infected with a virus, the cell can signal itself to undergo programmed cell death, killing the virus in the process.
- In some cases, neighboring cells of the same type are also influenced by the released ligand.

- In embryological development, this process of stimulating a group of neighboring cells may help to direct the differentiation of identical cells into the same cell type, thus ensuring the proper developmental outcome.

Direct Signaling Across Gap Junctions

- Gap junctions in animals and plasmodesmata in plants are connections between the plasma membranes of neighboring cells.
- These water-filled channels allow small signaling molecules, called intracellular mediators, to diffuse between the two cells.
- Small molecules, such as calcium ions (Ca^{2+}), are able to move between cells, but large molecules, like proteins and DNA, cannot fit through the channels.

- The transfer of signalling molecules communicates the current state of the cell that is directly next to the target cell; this allows a group of cells to coordinate their response to a signal that only one of them may have received.
- In plants, plasmodesmata are ubiquitous, making the entire plant into a giant communication network.