Cell Signaling

Ashok Kumar HG

Introduction

- ***"Cell signaling is the process by which cells communicate with other cells within their body or with the external environment."***

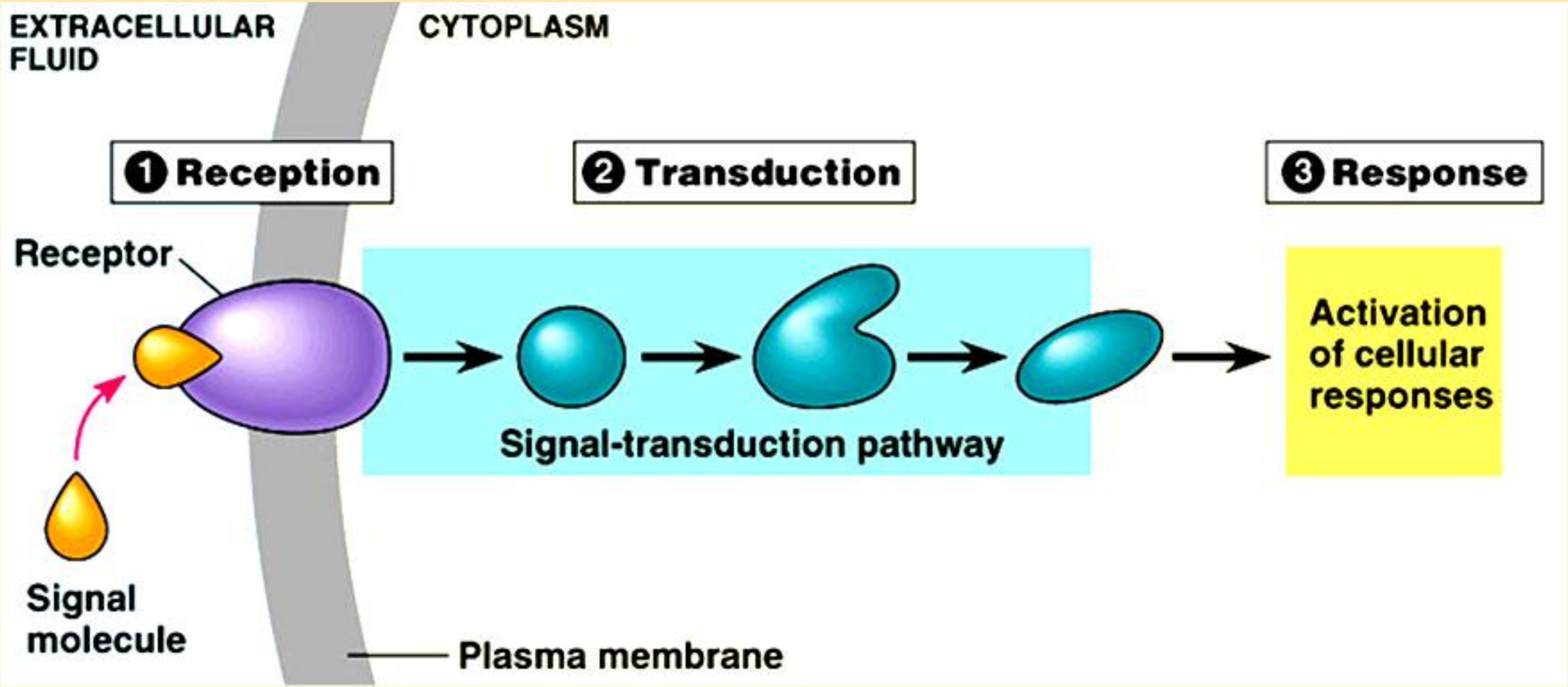
- Cell signaling can be intercellular as well as intracellular. Intracellular signals are produced by the same cells that receive the signal. Intercellular signals travel throughout the body. This permits specific glands to produce signals that act on different tissues.

- **Stages of Cell Signaling**

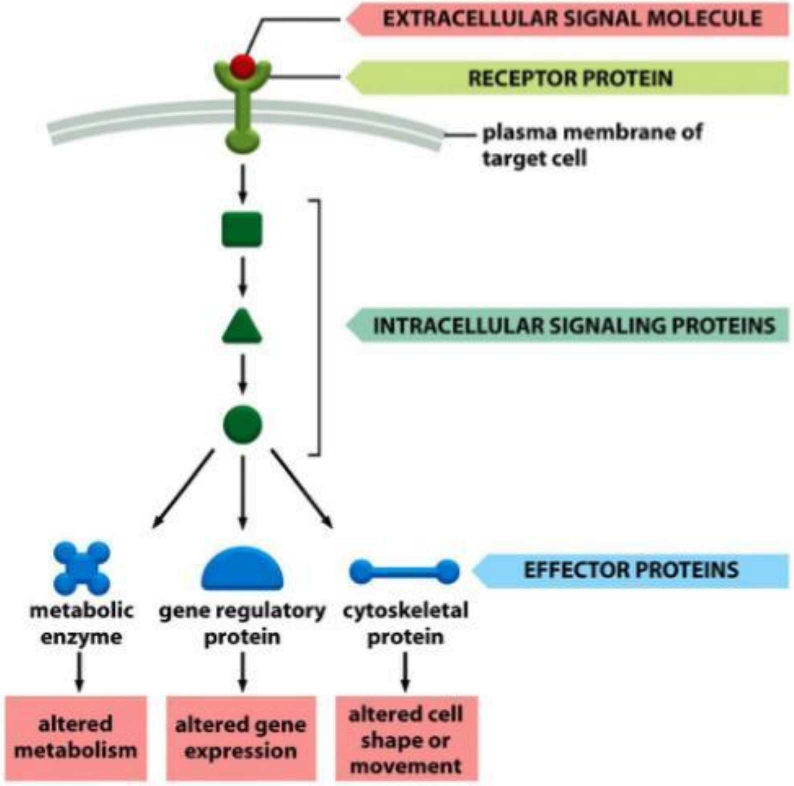
  Cell signaling takes place in the following three stages:

1. Binding of the signal molecule to the receptor.
2. Signal transduction, where the chemical signals activate the enzymes.
3. Finally, the response is observed

Introduction



Generalized Signaling Pathway



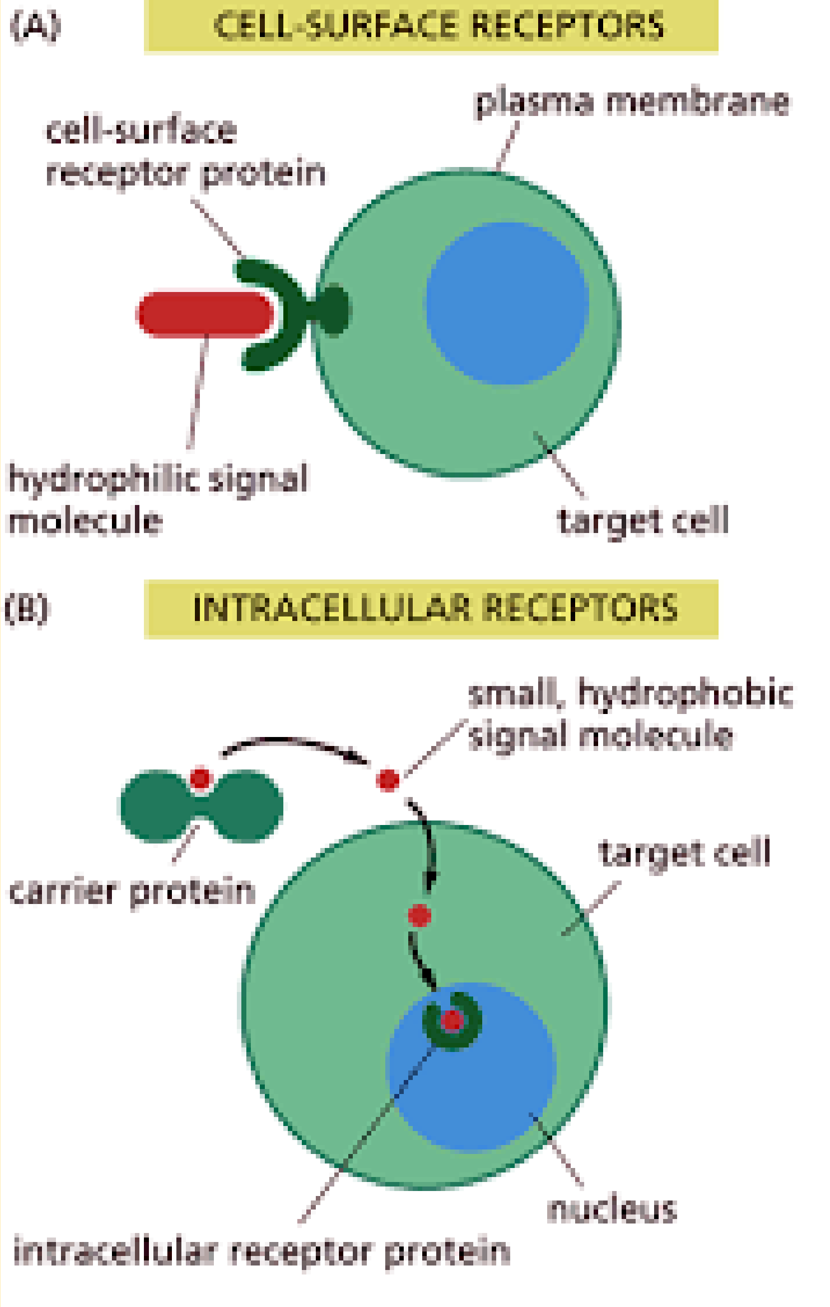
- Release signal molecule from signaling cell
- Bind and activate receptor in target cell
- Activate intracellular signaling pathway
- Alter effector protein(s) to change cell behavior

Cell Signaling Ligands

- Typically, cell signaling is either mechanical or biochemical and can occur locally. Additionally, **categories of cell signaling are determined by the distance a ligand must travel.** Likewise, hydrophobic ligands have fatty properties and include steroid hormones and vitamin D_3. These molecules are able to diffuse across the target cell's plasma membrane to bind intracellular receptors inside.
- On the other hand, hydrophilic ligands are often amino-acid derived. Instead, these molecules will bind to receptors on the *surface* of the cell. Comparatively, these polar molecules allow the signal to travel through the aqueous environment of our bodies without assistance.

Types of Cell Signaling Molecules

- *Intracrine* ligands are produced by the target cell. Then, they bind to a receptor within the cell.
- *Autocrine* ligands are distinct in that they function internally and on other target cells (ex. Immune cells).
- *Juxtacrine* ligands target adjacent cells (often called "contact-dependent" signaling).
- *Paracrine* ligands target cells only in the vicinity of the original emitting cell (ex. Neurotransmitters).
- Lastly, *Endocrine* cells produce hormones that have the important task of targeting distant cells and often travel through our circulatory system.


(A)
CELL-SURFACE RECEPTORS
cell-surface receptor protein
plasma membrane
hydrophilic signal molecule
target cell
(B)
INTRACELLULAR RECEPTORS
small, hydrophobic signal molecule
carrier protein
target cell
nucleus
intracellular receptor protein

Types of Cell Signaling Pathways

Intracellular Receptors

- A common type of signaling receptor is the *intracellular receptor*, which is located within the cytoplasm of the cell and generally **includes two types**. In addition to cytoplasmic receptors, nuclear receptors are a special class of protein with diverse DNA binding domains that when bound to steroid or thyroid hormones form a complex that enters the nucleus and modulates the transcription of a gene. IP_3 receptors are another class, which are located in the endoplasmic reticulum and carry out important functions like the release of Ca^{2+} that is so crucial for the contraction of our muscles and plasticity of our neural cells.

Ligand-gated Ion Channels

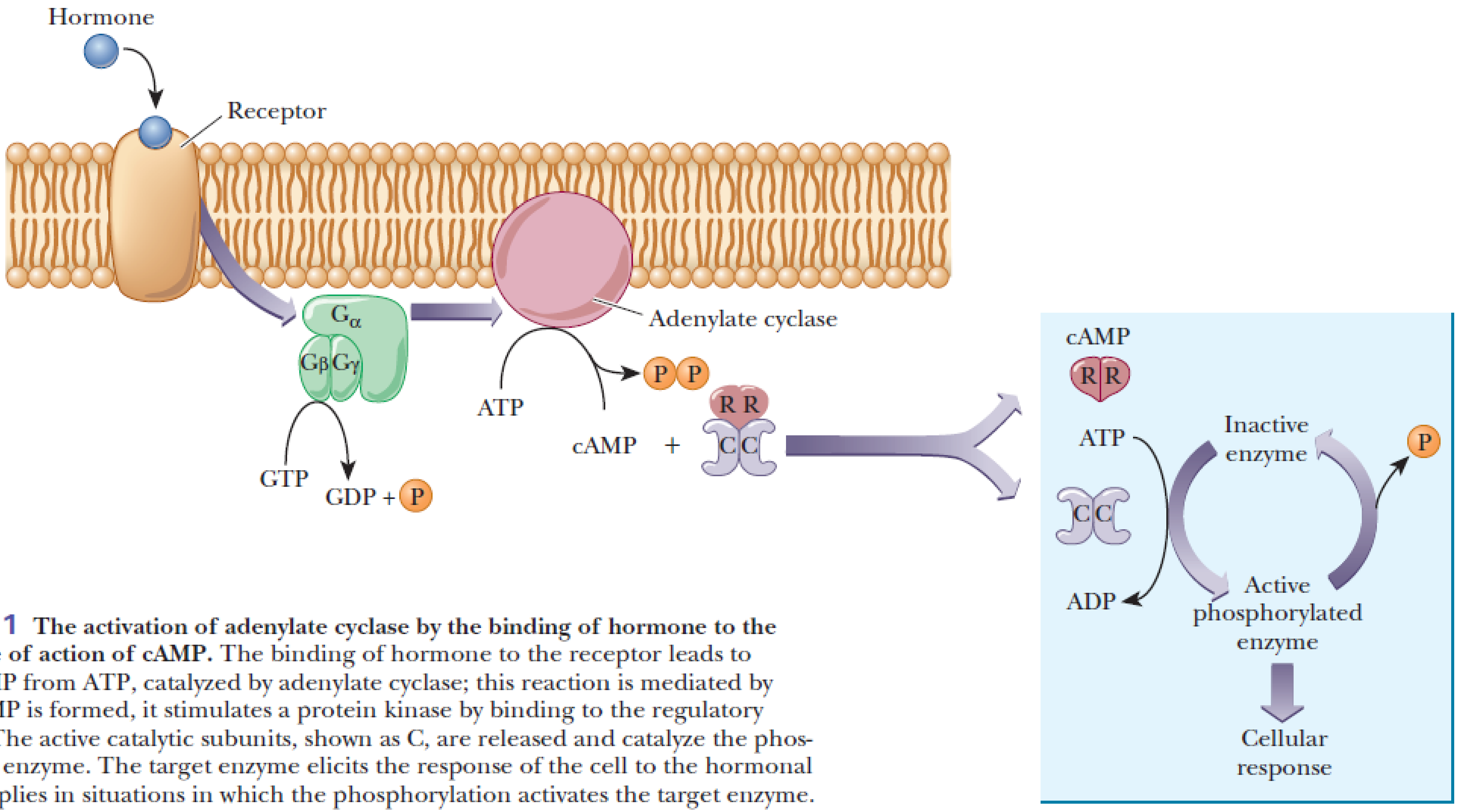
- Spanning our plasma membranes are another type of receptor called *Ligand-gated ion channels* that **allow hydrophilic ions to cross the thick fatty membranes of our cells** and organelles. When bound to a neurotransmitter like acetylcholine, ions (commonly K^+, Na^+, Ca^{2+}, or Cl^-) are allowed to flow through the membrane to allow the life-sustaining function of neural firing to take place, among many other functions!

G-protein Coupled Receptors

- Comparatively, *G-protein coupled receptors* (GPCRs) remain **the largest and most diverse group of membrane receptors in eukaryotes.** In fact, they are special in that they receive input from a diverse group of signals ranging from light energy to peptides and sugars. In effect, their mechanism of action also starts with a ligand binding to its receptor. However, the demarcation is that ligand binding results in the activation of a G protein that is then able to transmit an entire cascade of enzyme and second messenger activations that carry out an incredible array of functions like sight, sensation, inflammation, and growth.

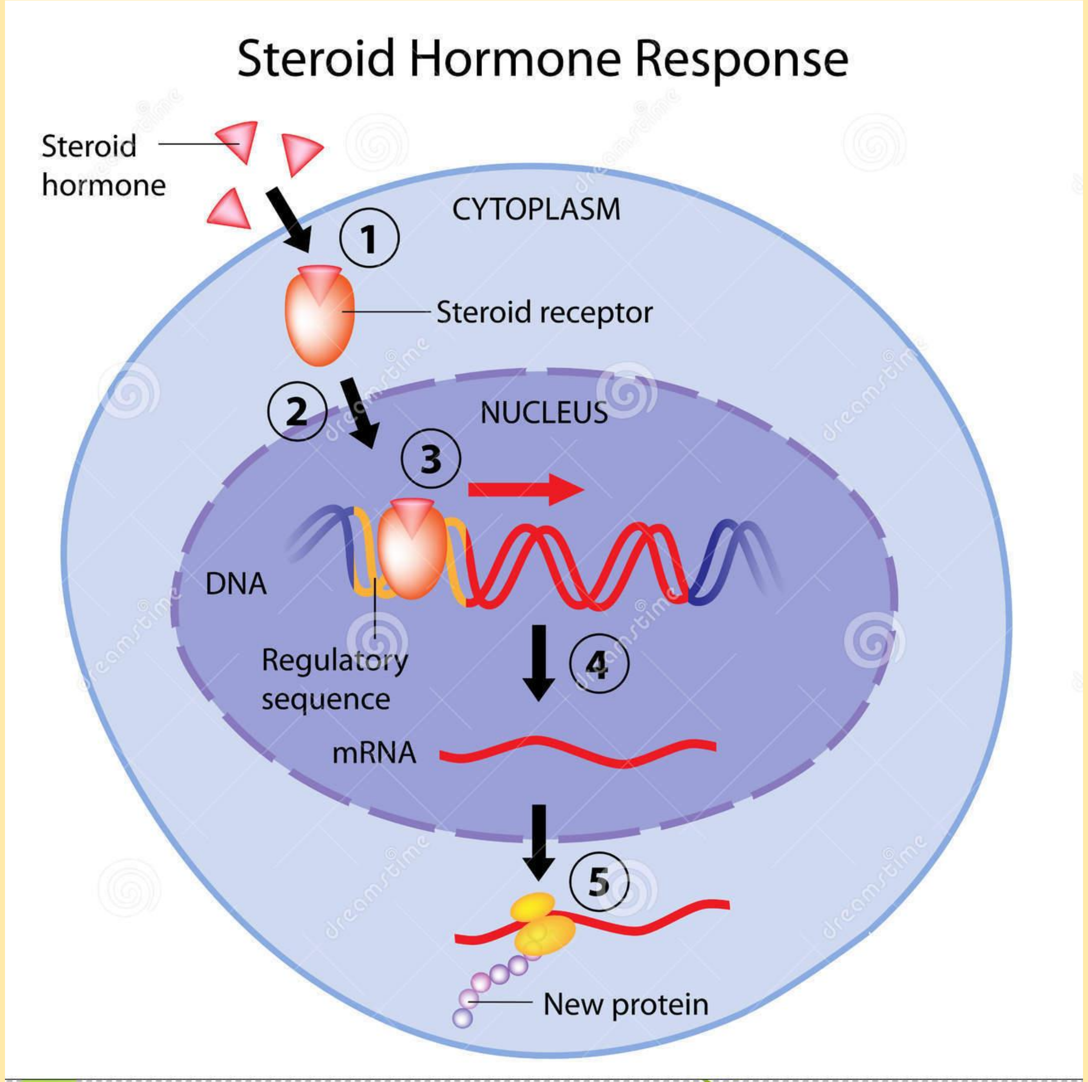
Receptor Tyrosine Kinases

- Likewise, receptor tyrosine kinases (RTKs) are another class of receptors revealed to show diversity in their actions and mechanisms of activation. For example, the general method of activation follows a ligand binding to the receptor tyrosine kinase, which allows their kinase domains to dimerize. Then, this dimerization invites the phosphorylation of their tyrosine kinase domains that, in turn, allow intracellular proteins to bind the phosphorylated sites and become "active." **An important function of receptor tyrosine kinases is their roles in mediating growth pathways.** Of course, the downside of having complex signaling networks lies in the unforeseen ways in which any alteration can produce disease or unregulated growth – cancer. Still, much is yet to be understood about cell signaling pathways, but one appreciable fact is that the importance they carry is nothing short of monumental.

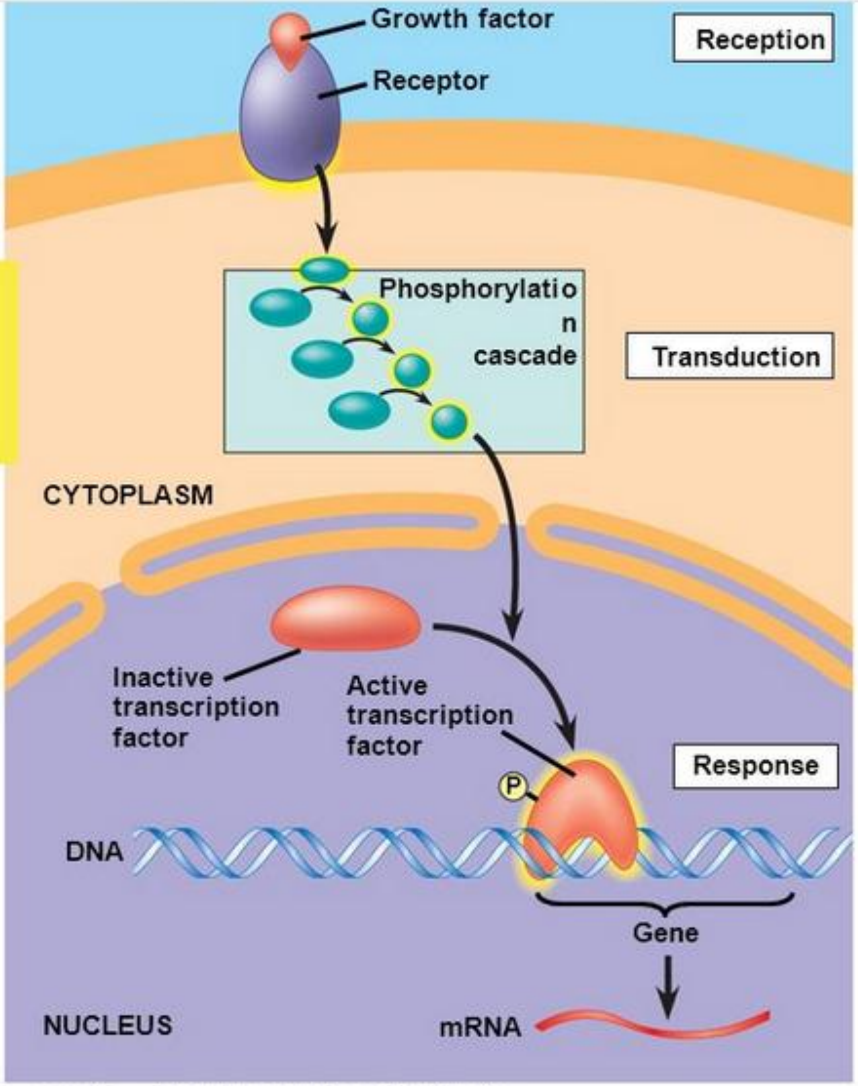


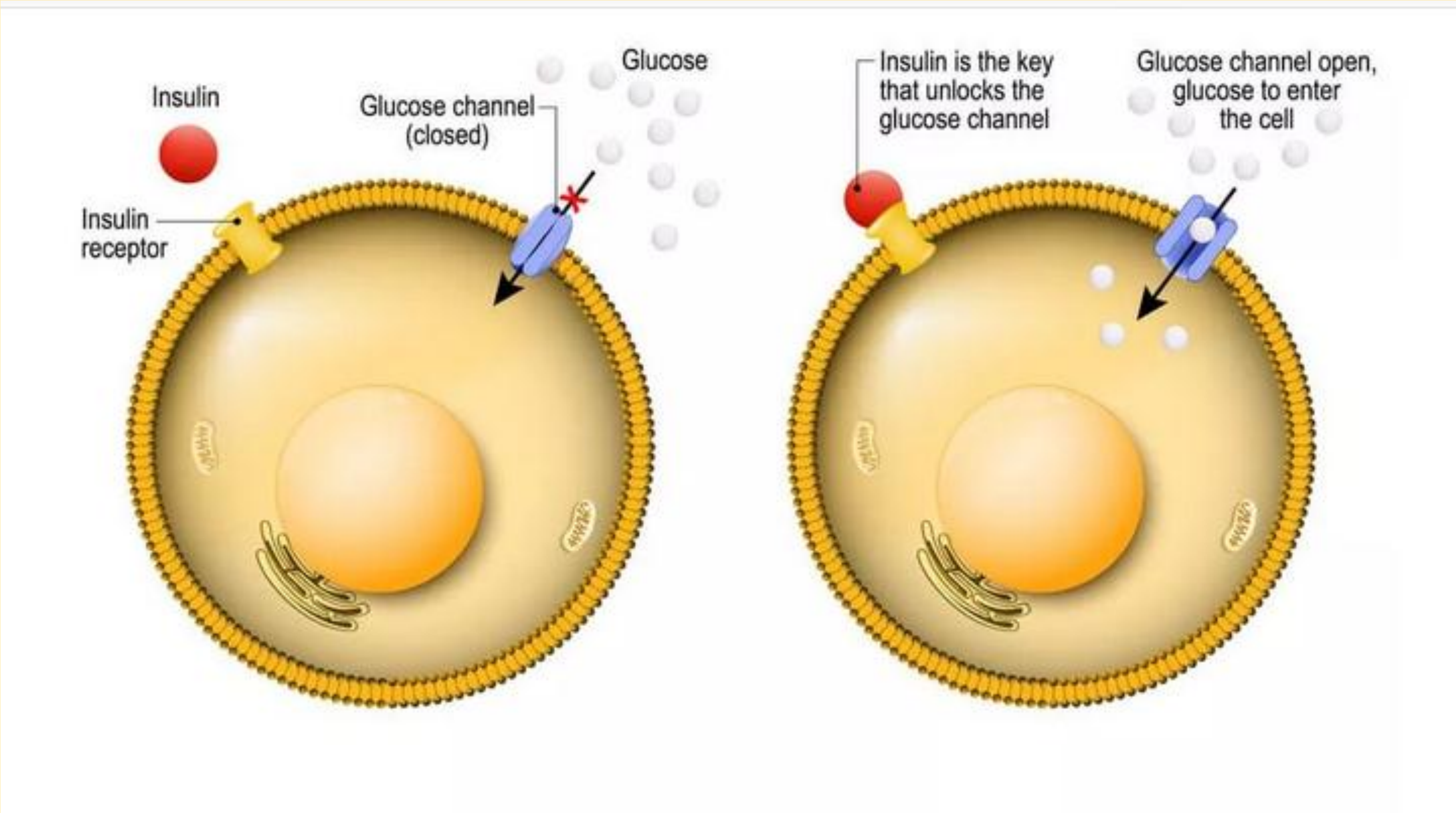
■ **FIGURE 24.11** **The activation of adenylate cyclase by the binding of hormone to the receptor and the mode of action of cAMP.** The binding of hormone to the receptor leads to the production of cAMP from ATP, catalyzed by adenylate cyclase; this reaction is mediated by a G protein. Once cAMP is formed, it stimulates a protein kinase by binding to the regulatory subunits, shown as R. The active catalytic subunits, shown as C, are released and catalyze the phosphorylation of a target enzyme. The target enzyme elicits the response of the cell to the hormonal signal. This scheme applies in situations in which the phosphorylation activates the target enzyme.

Action of Steroid hormone



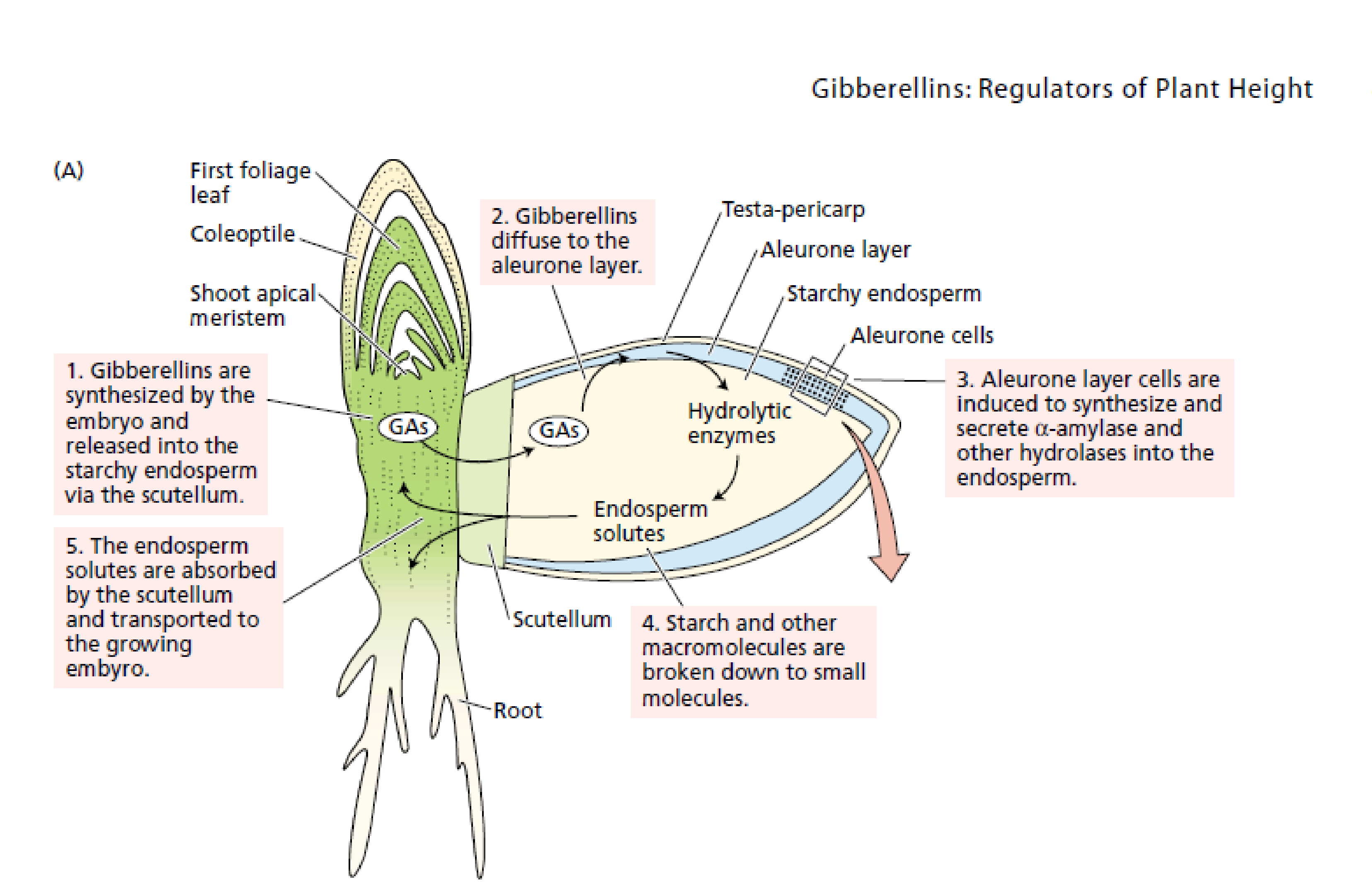
Modulating Gene Activity





A great (and well-used) example of a cell signaling pathway is seen in the balancing actions of insulin. Insulin, a small protein produced by the pancreas, is released when glucose levels in the blood get far too high. First, the high glucose levels in the pancreas stimulate the release of insulin into the bloodstream. Insulin finds its way to the cells of the body, where it attaches to the insulin receptors. This sets off a signal transduction pathway within each cell that causes the glucose channels to open, as seen in this graphic, As glucose flows into the cell, the glucose levels in the bloodstream are slowly decreased. The cells will use the glucose to create ATP energy or the cells store it as fats and starches for later use. Once the glucose level in the bloodstream has dropped to a sufficient level, the pancreas stops producing insulin, and the cells shut down their glucose channels.

Mechanism of action of Gibberellins



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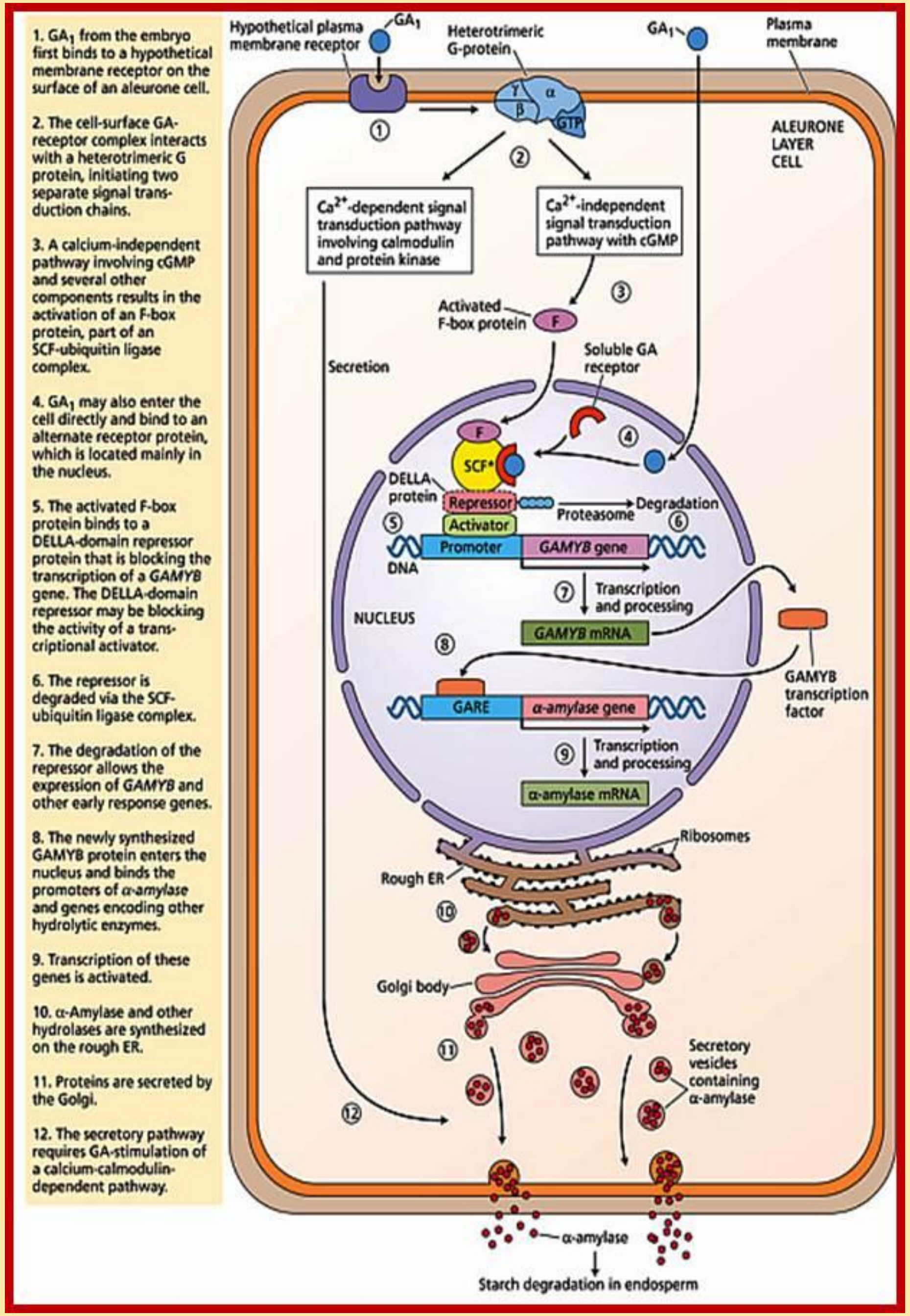

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