Dr.Roshni Rajamohan

Deshbandhu College

SIGNAL TRANSDUCTION

Eukaryotes both uni- and multi-cellular organisms respond to external signals which need co-ordination between cells- intra & inter cellular ,which is achieved through chemical signals in cell-cell communication. Signal transduction is the process by which a chemical or physical signal is transmitted through a cell as a series of molecular events (protein phosphorylation catalyzed by protein kinases) involving second messengers, which ultimately results in a cellular response

- **Specific**- structural complementarity between the signal and receptor molecules
- **Sensitive**-

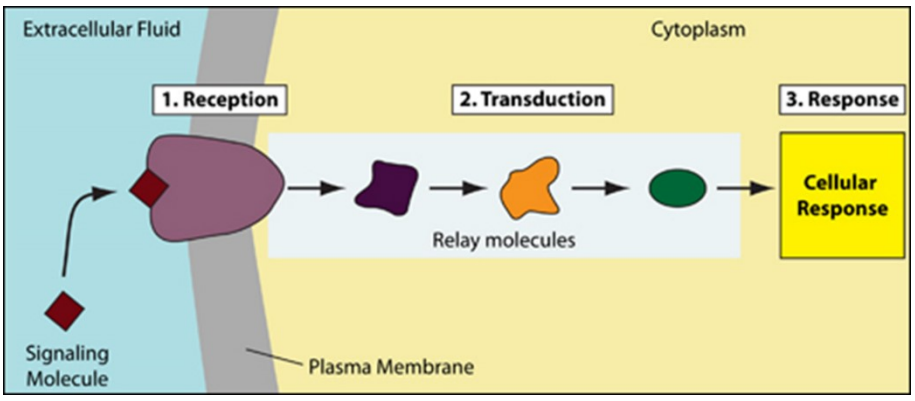
  a) high affinity between receptor and signal molecules

  b) reaction of the receptor-ligand interaction

  c) the amplification of the signal by downstream enzyme cascades.
- **Integration & Co-ordination** - despite receiving multiple signals, the system produces a unified response that maintains homeostasis in the cell and subsequently the whole organism.

Components of signal transduction

Both plants and animals, have similar transduction components.

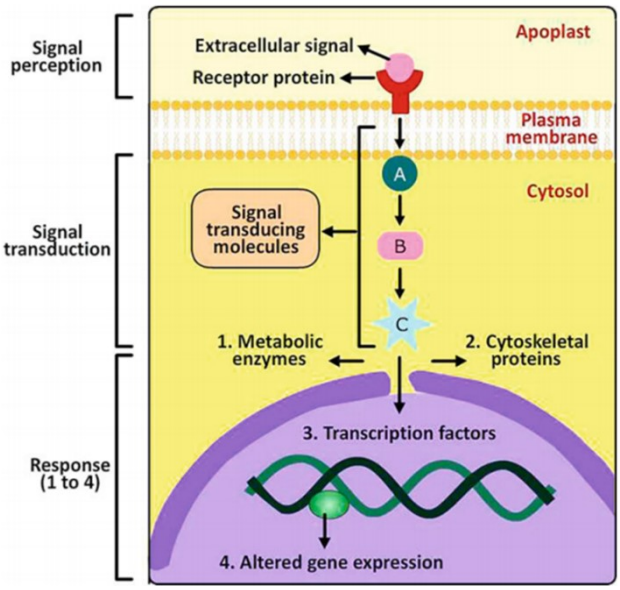


1. **Signal molecules/ Ligands/ Extracellular messengers/ primary messengers**
2. **Receptors**
3. **Second messengers/effector molecules**

Dr.Roshni Rajamohan

Deshbandhu College

4. **Downstream response elements**



Signal Transduction involves

- **Sensing** of signal **by the receptor**
- **Transfer** of the information from the signal from one biochemical form to another **(transduction)** so as to **amplify** the impact of signal leading to a **cellular response**.
- Signal transduction pathway consists of protein kinases and protein phosphatases whose catalytic actions change the conformations, and thus the activities, of the proteins they modify.

SIGNAL MOLECULES

- Any environmental or intracellular input, which initiates one or more responses in the cell/plant, is referred as a signal.
- Plant cells are sensitized to the signals (perception) by employing specialized sensor proteins, termed **receptors**
- **The signal is perceived by a receptor at the surface**
- The information is transferred from the site of perception to the site of response- **Signal transduction-** which includes a series of biochemical steps

RECEPTOR MOLECULES

- Receptors are specialized sensor proteins located on the plasma membrane, cytoplasm, endomembrane system, or in the nucleus.
- In quite a few cases, receptors can move from one cell compartment to another.

RESPONSE

- The response due to a signal can be biochemical, physiological, morphological, or developmental.
- The response to a signal is regulated by

❖ the nature of plant part experiencing the signal (root, leaf, meristematic tissue, etc.)

❖ the stage of tissue development (physiologically active cells or fully differentiated cells)

❖ the previous environmental sensing

❖ the circadian clocks.

Dr.Roshni Rajamohan

Deshbandhu College

Spatial Aspects of Signal Transduction

Cell autonomous (intracellular) responses

1. Stomatal opening and closing
2. Chloroplast movement

II. Non-cell autonomous (transcellular) responses

1. Radial patterning in roots mediated by SHR transcription regulator
2. Gravitropic bending of roots modulated by differential auxin flow
3. Floral induction through transmission of FT from leaves to shoot apex

Temporal Aspects of Signal Transduction

1. Most rapid responses - Involving change in protein/enzyme activity

1. Closing of leaf traps of Venus fly-trap upon contact with insect
2. Chloroplast movement in response to light

II. Rapid response involving electrochemical changes

1. Stomatal opening

III. Moderately fast responses involving gene expression modulation

1. Insect attack on plants resulting in release of volatile compounds to attract insect predators

IV. Long-term responses (involving chromatin remodeling)

1. Vernalization
2. Seed dormancy
3. Modulation of root branching in response tonutrition availability
4. Lateral bud outgrowth

Routes of Signal Perception

Neighboring cells communicate with each other both through

1. **Apoplast** (formed by the interconnection of cell walls)
2. **Symplast** (the cell-to-cell cytoplasmic continuum via plasmodesmata).
3. **Plasma membrane-** lipophilic signaling molecules (e.g., ethylene, auxin) can cross the plasma membrane and is perceived in the cytoplasm or nucleus to evoke a response.

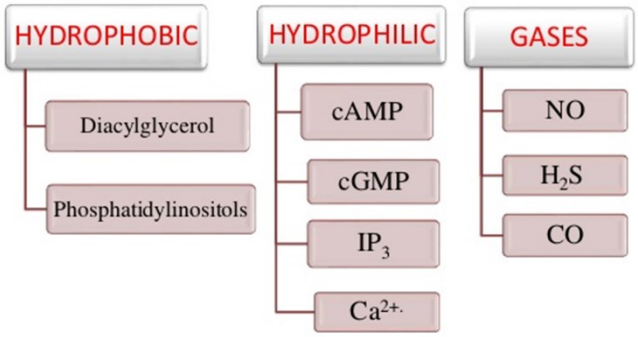
Dr.Roshni Rajamohan

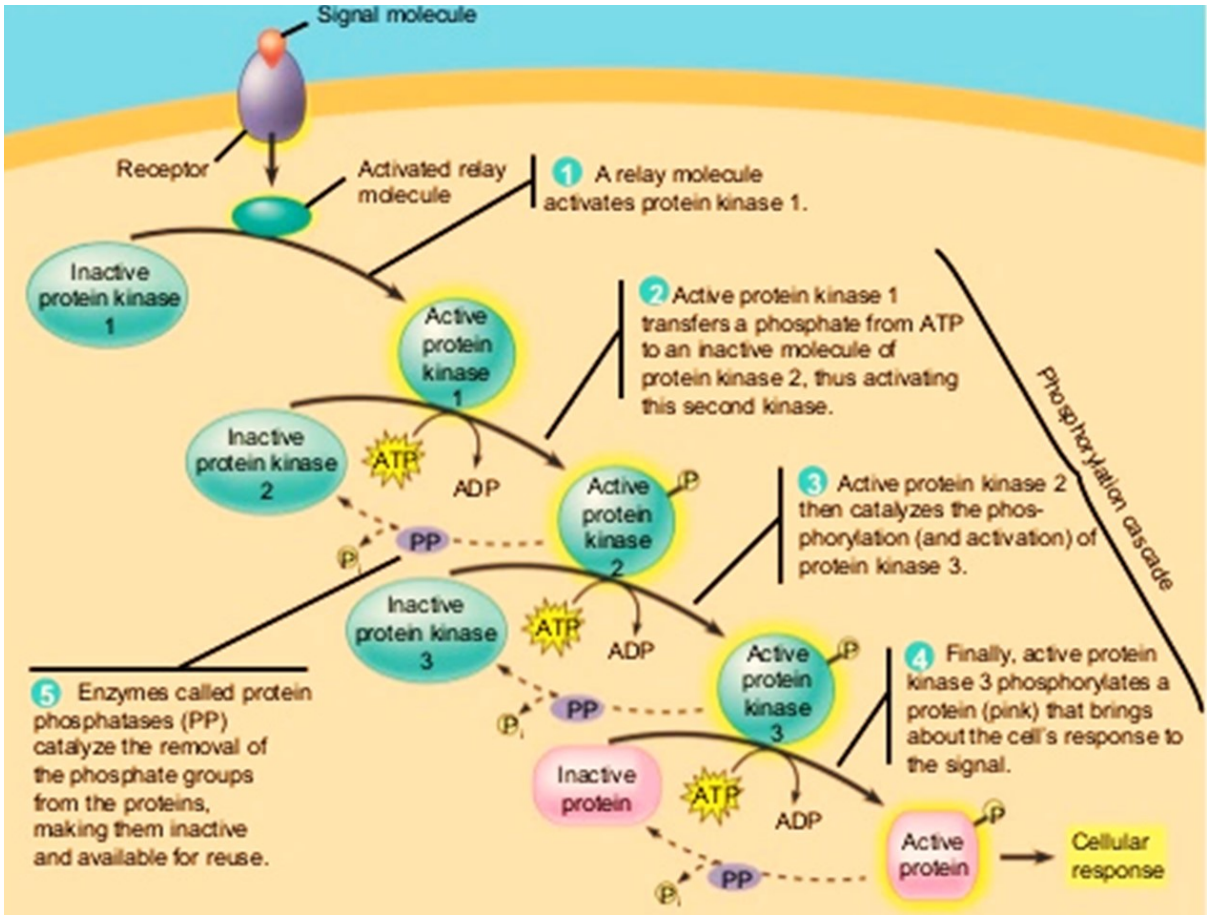
Deshbandhu College

SECOND MESSENGERS

- Second messengers are intracellular, diffusible small molecules and ions which are rapidly synthesized or released transiently as a concentrated pulse following signal perception by the receptors and modify the activity of target signaling proteins.
- Cyclic nucleotides (cGMP, Camp)
- Nitric Oxide
- Ca2+
- Lipid-signaling molecules

TYPES OF SECOND MESSENGERS





Dr.Roshni Rajamohan

Deshbandhu College

1. (cGMP)

Guanosine 3',5'-cyclic phosphate / Cyclic guanosine monophosphate (cGMP) is a nucleotide consisting of **three functional groups**: a sugar, a nitrogenous base (guanine) and a single phosphate group **forming a cyclic bond**. It is made from GTP in a reaction catalyzed by the enzyme guanylyl cyclase and is degraded by phosphodiesterases. **It is different from GMP (non-cyclic).**

In animals cGMP can act as an cyclic GMP is an important second messenger or signalling molecule involved in processes including smooth muscle contraction, phototransduction in the eye and blood vessel dilation. In all these cases nitric oxide (NO) is produced and this stimulates activity of a guanylate cyclase to produce cGMP from guanosine triphosphate (GTP).

cGMP in plants

cGMP is present in plant tissues, but,its role of the G-protein cascade in plants is still controversial. **In plants** cGMP has been implicated as a second messenger in the responses of phytochrome and gibberellin.
Some key genes (e.g., guanylylate cyclase) have not yet been identified in plant genomes. cGMP levels are vanishingly small in plants. Studies with inhibitors have implicated cGMPas a second messenger for the hormones gibberellin and ABA. So, a role for cGMP in phytochrome signaling, although controversial, remains a possibility. Phytochrome is now known to be a protein kinase- **serine/threonine kinase. Gibberellin has been reported to cause a transient rise in cGMP levels in barley aleurone layers, suggesting a possible role for cGMP in α-amylase production.**

Refer Hopkins and Huber for the 3 examples given below

Nitric Oxide

Ca2+

Lipid-signaling molecules

Suggested Reading:

1. Taiz, L. and Zeiger, E. (2010) Plant Physiology. 5th Edition, Sinauer Associates.
2. William G. Hopkins, Norman P. A. Hüner (2008) Introduction to Plant Physiology, 4th Edition, Wiley.

Dr.Roshni Rajamohan

Deshbandhu College

3. Bhatla, Satish C, Lal Manju A. (2018) Plant Physiology, Development and Metabolism, Springer.