Plant Signal Transduction

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As living organisms, we are constantly receiving and interpreting signals from our environment. These signals can come in the form of light, heat, Odors, touch or sound. The cells of our bodies are also constantly receiving signals from other cells. These signals are important to keep cells alive and functioning as well as to stimulate important events such as cell division and differentiation.

Signal transduction is the process by which an extra cellular signaling molecule activates a membrane receptor, which in turn activate internal molecules creating a response.

Single Transduction Pathways in Plants

Plant cells, due to their sessile nature, are able to interact with its surrounding environment. Plants use various environmental signals to alter their mode of developmental morphology. Throughout their life cycle, plant and plant cells respond to both internal and external signals, such as nutrients, organic metabolites, water availability, light, temperature, germination, growth and flowering.

Sometimes plants respond to harsh environmental stresses at cellular and molecular level, as well as at physiological levels to confer tolerance of the stress and ensure better survival. The genome sequences of Arabidopsis and rice have now been determined and have revealed the presence of complex gene families that encode signalling molecules and transcription factors (TFs). There are as many as 1800 genes that encode transcription factor, more than 600 genes that encode protein kinases and major junk of 600 genes that encode F-box proteins particularly in Arabidopsis genome.

The participation and stability of signalling factors and TFs is necessary for the regulation of signal pathways. In addition, post transcriptional regulation at RNA level also leads to various other signalling pathways (Fig. 1).

Mechanism of Signal Transduction

Generally, signal transduction is initiated by sensing of signal by a receptor. These receptors are either located in the plasma membrane or in the cytoplasm or restricted to cellular compartments. The receptors happen to be a protein. The plasma membrane by virtue of its membrane potential can act as receptor by employing proteinaceous pores, called channels, to control in and out flux of ions through the cell.

As a consequence of alteration in membrane potential opens a group of voltage gated channel that allow Ca2+ to enter and initiate transduction sequence. Several signals such as light wavelength (red < blue), fungal elicitors or growth regulators can modify membrane potential. Several unique receptors have been characterized in the cells.

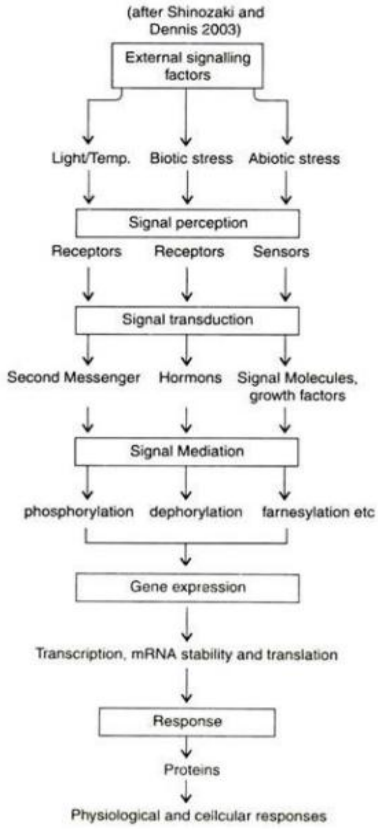

Fig. 1 Signal Transduction Pathway

Some transmembrane protein receptors are phosphorylated by protein kinases. In plants, receptor-like protein consists of a large extra cytoplasmic domain with active site of a protein kinase involves in signal transduction process. Binding of ligand leading to dimerization of the receptor and brings protein domains into very close proximity of the cytoplasm.

This receptor complex is then activated by phosphorylation. The active RLK complex interacts with membrane bound or soluble transduction proteins to initiate the signal transduction in a different direction. Several RLKs have been characterised in plant cells including protein kinases which are implicated in incompatibility process and precludes fertilization.

Cell signalling can be divided into 3 stages

1. **Reception:** A cell detects a signalling molecule from the outside of the cell. A signal is detected when the chemical signal (also known as a ligand) binds to a receptor protein on the surface of the cell or inside the cell.

2. **Transduction:** When the signalling molecule binds the receptor it changes the receptor protein in some way. This change initiates the process of transduction. Signal transduction is usually a pathway of several steps. Each relay molecule in the signal transduction pathway changes the next molecule in the pathway.

3. **Response:** Finally, the signal triggers a specific cellular response.

Reception

Membrane receptors function by binding the signal molecule (ligand) and causing the production of a second signal (also known as a second messenger) that then causes a cellular response. These types of receptors transmit information from the extracellular environment to the inside of the cell by changing shape or by joining with another protein once a specific ligand binds to it. Examples of membrane receptors include G Protein-Coupled Receptors and Receptor Tyrosine Kinases.

Intracellular receptors are found inside the cell, either in the cytopolasm or in the nucleus of the target cell (the cell receiving the signal). Chemical messengers that are hydrophobic or very small (steroid hormones for example) can pass through the plasma membrane without assistance and bind these intracellular receptors. Once bound and activated by the signal molecule, the activated receptor can initiate a cellular response, such as a change in gene expression.

Transduction

Since signalling systems need to be responsive to small concentrations of chemical signals and act quickly, cells often use a multi-step pathway that transmits the signal quickly, while amplifying the signal to numerous molecules at each step.

Steps in the signal transduction pathway often involve the addition or removal of phosphate groups which results in the activation of proteins. Enzymes that transfer phosphate groups from ATP to a protein are called protein kinases. Many of the relay molecules in a signal transduction pathway are protein kinases and often act on other protein kinases in the pathway. Often this creates a phosphorylation cascade, where one enzyme phosphorylates another, which then phosphorylates another protein, causing a chain reaction.

Also important to the phosphorylation cascade are a group of proteins known as protein phosphatases. Protein phosphatases are enzymes that can rapidly remove phosphate groups from proteins (dephosphorylation) and thus inactivate protein kinases. Protein phosphatases are the "off switch" in the signal transduction pathway. Turning the signal transduction pathway off when the signal is no longer present is important to ensure that the cellular response is regulated appropriately. Dephosphorylation also makes protein kinases available for reuse and enables the cell to respond again when another signal is received.

Kinases are not the only tools used by cells in signal transduction. Small, nonprotein, water-soluble molecules or ions called second messengers (the ligand that binds the receptor is the first messenger) can also relay signals received by receptors on the cell surface to target molecules in the cytoplasm or the nucleus. Examples of second messengers include cyclic AMP (cAMP) and calcium ions.

Response

Cell signalling ultimately leads to the regulation of one or more cellular activities. Regulation of gene expression (turning transcription of specific genes on or off) is a common outcome of cell signalling. A signalling pathway may also regulate the activity of a protein, for example opening or closing an ion channel in the plasma membrane or promoting a change in cell metabolism such as catalyzing the breakdown of glycogen. Signalling pathways can also lead to important cellular events such as cell division or apoptosis (programmed cell death).

References

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