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Role of Heat Shock Proteins in Insects

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Introduction

Insects respond to elevated temperature and to a variety of chemical and physical stresses by a rapid increase in the synthesis of a set of conserved polypeptides collectively referred to as heat shock proteins (Hsps). *Hsps*, named according to their molecular weight, such as Hsp100, Hsp90, Hsp70, Hsp60, Hsp40, small Hsp (sHsp) and Hsp10, are a class of functionally related proteins involved in the folding and unfolding of other proteins. Ritossa first reported that heat and the metabolic uncoupler dinitrophenol induced a characteristic pattern of puffing in salivary gland chromosomes in the fruit fly, *Drosophila busckii* (Ritossa, 1963). This discovery eventually led to the identification of Hsps which were represented by these puffs. Increased synthesis of selected proteins in the cells of *Drosophila* following stresses such as heat shock was first reported in 1974 (Tissieres *et al.*, 1974). An enormous literature has now accumulated that describes a wide variety of events in a cell's response to a wide array of biotic and abiotic sources of stress in a variety of insects. Hsps are found in practically all living organisms, from bacteria to humans.

HSP

Called as molecular chaperone directs the folding, oligomerization, secretion and degradation of proteins and protect against their denaturation.

Chaperone: a protein that interacts with and influences the activity of heat shock proteins.

- Chaperonsare the proteins which assist the unfolding or folding and assembling or dis-assembling of the newly produced polypeptides and old proteins.

Functions of Chaperone

- Prevents the segregation of newly synthesized polypeptides & already synthesized polypeptides.
- Heat shock chaperons have tendency to aggregate the denatured proteins in cytoplasm & refolding of the denatured proteins.
- Some chaperons act as enzymes.

Classification of HSPs based on molecular mass, amino acid sequence and function

- In insects – 4 major families; small heat shock proteins (sHsps), Hsp60, Hsp70 and Hsp90
- sHsp are ATP independent, prevents irreversible denaturation of substrate proteins when cells are stressed (Basha *et al.,* 2012)
- Others are ATP dependent, cause structural rearrangement of the HSPs, protein folding, degradation, disaggregation, and cell localization, thereby influencing essential processes such as protein synthesis, cell signalling and transcription.

Hsp90 family

- Most abundant proteins in Eukaryotes accounting for ~1% of the total soluble protein
- Unlike other chaperones, Hsp90 does not act in nascent protein folding. It binds to substrate proteins, which are in a near native state, at a later stage of folding
- Highly conserved.

Interacts with HSP40, HSC70/HSP90 organizing protein (HOP), and co-chaperones to bind and stabilize newly synthesized substrate/client proteins

Hsp70 family

- Strongly upregulated by heat stress and toxic chemicals
- In the eukaryotic organisms, express Hsc70 in Cytosol, Hsp70, Grp78 in endoplasmic reticulum and Grp75 in mitochondria.
- Assists in protein transport into mitochondria and the endoplasmic reticulum. Protects proteins under stress. Stabilizes proteins prior to complete folding and transports across membranes and proteolysis
- Works with co-chaperones such as Hsp40/J-proteins and Hip which aid in Hsp70 function and nucleotide exchange factors.

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Hsp60 family

- Referred as Chaperonins
- They are the most conserved and ubiquitous class of a molecular chaperone present in the plastids, mitochondria, and cytoplasm of all eukaryotes.
- Complex topologies of polypeptides require assistance of these specialized folding machines.
- Mediate the native folding of proteins through cooperation of HSP70 and HSP60

Functions of Heat Shock Proteins

- Housekeeping functions in the cell
- Prevention of aggregation of damaged proteins,
- Transportation
- Folding and unfolding of protein,
- Assembly and disassembly of multi-structured units
- Degradation of misfolded or aggregated proteins

Abiotic stress and Biotic stress responses

Insects respond to elevated temperatures and to chemical and other stresses by an increase in the synthesis of Hsps. Hsps appear to serve a significant role in the insect's responses to abiotic stressors such as Heat, Cold, Heavy metals, Uv radiation, Dehydration and Hypoxia

Biotic stressors such as Pathogens and Cross protection

Hsps can protect cells and organisms from thermal damage. High temperature can alter gene expression including Hsps and other genes in a vector mosquito population using suppression subtractive hybridization (Zhao *et al.*, 2009). In the red flour beetle, *Tribolium castaneum*, the expression of *Hsp83* gene could be induced with heat stress at 40 ºC for 1 h in teneral and mature beetles (Xu *et al.*, 2010). *AeaHsp26* and *AeaHsp83* are important markers of stress and may function as critical proteins to protect and enhance survival of *Aedes aegypti* larvae and pupae (Zhao *et al.*, 2010).

Hsp genes are induced and modulated in insects in response to environmental factors including abiotic and biotic stresses. *Hsp* genes are also developmentally regulated, which is important for insects to survive and adapt to their environments. The very widespread occurrence of Hsp activity in insects will have a significant bearing on insect adaptability as our climate changes. It may be likely that via Hsp activity, many pest and beneficial species will be able to adapt to global warming more than

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previously thought. Changes in environmental conditions can rapidly shift allele frequencies in populations of species linked to evolutionary responses to pollution, global warming and other changes.

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