Metamorphosis in Insects

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The process of transformation from an immature form to an adult form in two or more distinct stages is known as metamorphosis.

1. Different Types of Insect Metamorphosis:

A. Ametabola:

Members of this group undergo a series of postembryonic moults without any particular change in general appearance. They lack proper metamorphosis.

Example:

Springtails (Collembola).

B. Hemimetabola:

The young's of this group is called nymph. The nymphs have the same general appearance as the adults (Fig. 2.95A) but lack wings, which gradually appear through a series of nymphal moults. Aquatic nymphs are sometimes referred to as naiads.

The developmental stages are called instars. This type of metamorphosis is called incomplete or gradual type of development. The full expression of adult characters appears after the final moult.

Example:

Cockroaches (Orthoptara), grasshoppers, Rhodinus bugs (Hemiptera), dragon flies (Odonata), earwigs (Dermaptera).

These are collectively called as exoptrygote insects.

C. Holometabola:

The insects of this type of development show complete metamorphosis. In this development there are two stages in between egg and adult (Fig. 2.95B). The stages are larva and pupa. Larvae are very different in appearance from the adult. This stage is also named as maggots, caterpillars or grubs.

These are worm-like, bearing no resemblance to the adult and undergoes a series of moult in which the last instar is transformed into pupa. The pupa or chrysalis is a superficially quiescent, non-feeding stage, during which an active transformation of tissues leads to the emergence of the adult after final moulting.

Examples:

True flies (Diptera), moths and butterflies (Lepidoptera), ants, wasps and bees (Hymenoptera) and beetles (Coleoptera). These are commonly grouped as endopterygote insects. A number of insects enter into a resting stage called diapause as some point of their development to overcome environmental hazards.

2. Endocrine Glands in Insects

Endocrine Organs of Nervous Origin:

In insects, neurosecretory cells are numerous and have important functions. Recent work has revealed that there are two types of neurosecretory cells: type A which stain with para-aldehyde fuchsin, and type B which do not. All cells possess electron dense granules. The neurosecretory cells can produce blue colour from the reflected light due to the light scattering effect of colloidal-sized particles.

Protocerebrum:

It is the most complex part of the insect brain consisting of several distinct cell masses and regions of neuropile. The pars intercerebralis, part of protocerebrum is located in the dorsal median region above the proto-cerebral bridge and central body. It contains two groups of neurosecretory cells that transport their secretions to the corpus cardiacum.

Sub-esophageal and ventral chain ganglia:

Neurosecretory cells are also found to be located in sub-esophageal and ventral chain ganglia. The sub-esophageal ganglia are composed of three fused ganglia that innervate sense organs, and muscles associated with mouth parts, salivary glands and neck region.

Corpora cardiaca:

The corpora cardiaca arise from the nervous system and are situated behind the brain in close association with the dorsal aorta. They receive axons from the neurosecretory cells in the brain and serves as storage and release sites for their secretions. That is why it also acts as neuro-haemal organ.

Four cellular elements have been recognised in this organ:

(1) The bulbous endings of neurosecretory axons whose perikarya are located in the dorsum of the brain,

(2) The perikarya of neurosecretory cells that send axons into nerves that supply various peripheral organs,

(3) Glia-like cells and

(4) Intrinsic corpus cardiacum cells.

Although, the corpora cardiaca are storage release centres, there are evidences that their own cells are capable of producing secretions.

Endocrine Organs of Epithelial Origin:

Corpora allata:

Aggregation of ectodermal cells proliferated from the surface epithelium in the vicinity of the mouth parts are seen in the posterior margin of the brain. These cells form the gland, corpora allata. These glands are commonly paired and laterally placed (Periplaneta) or they may fuse to form a single structure (Rhodnius).

In the butterfly Pieris, few large cells with polymorphic nuclei are found in corpora allata. The corpus allatus of bug (Pentatoma rufipes) consists of almost syncytial mass of small cells with cell boundaries barely distinguishable. In phasmid (Bacillus rossii), a nearly columnar epithelium surrounding the embryonic lumen persists in the adult phasmids (Fig. 7.55).

Fig. 7.55 : Histological structure of corpora allata of different insects : A. *Pieris brassicae*, few large cells with polymorphic nuclei, B. *Pentatoma rufipes*, an almost syncytial mass of small cells, and C. *Bacillus rossii*, a nearly columnar epithelium surrounding the embryonic lumen

Thoracic gland:

These glands are found only in immature insects, with the exception of the Apterygotes. These are also called prothoracic glands or ecdysial glands. These glands consist of irregular masses of tissue of ectodermal origin that are usually intimately associated with tracheae.

The glands may or may not be innervated. Depending upon its final location, these glands are also identified as peri-tracheal or ventral glands. The cells of these glands show cyclic secretory activity, reaching a maximum between moults. The glands atrophy in the adults.

Ring gland:

The larvae of higher Diptera (true flies) contain a small ring of tissue, supported by tracheae, called the ring gland or Weismann's ring. The different cells that compose it are considered to be homologous with corpora allata, corpora cardiaca and the thoracic glands.

Some Other Endocrine Glands:

In Aeschnia cyanea, two types of endocrine cells were found to be located in midgut. One type is filled with dense granules and the other includes vesicles with an excentric core or has a loose filamentous appearance. These cells discharge their contents into the internal medium at the level of the basement membrane.

3. Neurohormones of the Brain:

Ecdysiotropin:

Protocerebrum secretes ecdysiotropin or prothoracicotropic hormone (PTTH) or brain hormone (BH) that acts on ecdysial glands.

Bursicon (Tanning hormone):

Neurosecretory cells within the brain produce a blood borne hormone which triggers the tanning or darkening of adult cuticle. It is a protein hormone with a molecular weight of about 40,000. It is released into the fused thoracoabdominal ganglia. Bursicon is released after the emerged fly has dug its way out of the soil, but in some insects this hormone may be secreted slightly before or during the loss of the old skin.

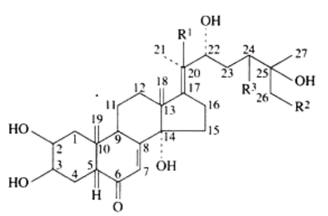
Eclosion hormone:

Median neurosecretory cells of the brain produce eclosion hormone, which collects in the corpora cardiaca and is released into the blood at the time of switchover from pupal to adult stage. In most insects it acts upon neurons within the abdominal ganglia to initiate the pre-eclosion behaviour. Other neurohormones released from the brain and their target organs, and their functions are mentioned in Table 7.21.

4. *Characteristics of Moulting Hormone (MH) in Insects:*

A. Chemical Nature:

Moulting hormone of insects is called ecdysone. This is of two types: α-ecdysone and β-ecdysone. These are formed from cholesterol (Figs. 99 and 100)



α – ecdysone (ecdysone)	: $R^1-R^2-R^3-H$
β – ecdysone, Ecdysterone, 20 – hydroxyecdysone, Crustecdysone	: R^1-OH, R^2-R^3-H
20, 26 – dihydroxyecdysone	: R^1-R^2-OH, R^3-H
26 – hydroxyecdysone	: R^1-R^3-H, R^2-OH
Mokisterone A	: R^1-OH, R^2-H, R^3-OH

Fig. 2.99 : Structures of ecdysones isolated from insects.

Cholesterol
↓
7-dehydrocholesterol
↓
2, 22, 25-trideoxy-α-ecdosyne
↓
22, 25-dideoxy-α-ecdysone
↓
22-deoxy-α-ecdysone
↓
α-ecdysone
↓
β-ecdysone

Fig. 2.100 : Plausible biosynthetic scheme of ecdysones in *Calliphora*.

B. Site of Synthesis:

Prothoracic glands.

C. Route of Transport:

Ecdysone, following its synthesis is transported to the haemolymph, via binding proteins to target tissues.

D. Control and Inactivation:

The titre of hormone is controlled by inactivating the hormone. MH is inactivated principally by formation of sulphate conjugates and to some extent glycoside derivatives (Fig. 2.98.).

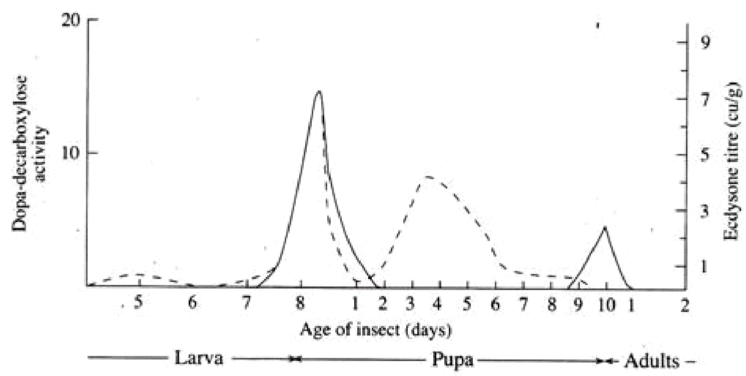


Fig. 2.98 : Ecdysone titre and dopa-decarboxylase activity during development of *Calliphora crythrocephala*. (············) Ecdysone titre in cu units/g. (———) DOPA decarboxylase activity (as percentage transformation of DOPA to dopamine). cu = Calliphora unit = amount of material necessary to produce 50 – 70% pupation, i.e., = 0.01 μg α ecdyzone.

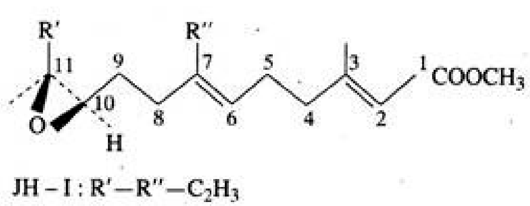
E. Function:

It not only functions during moulting but also during embryonic and adult stages of insect life cycle.

5. *Characteristics of Juvenile Hormone (JH) in Insects:*

A. Chemical Nature:

JH of two types, JH-I and JH-II. They arise from two homo- isoprenoid and one normal isoprenoid units (Figs. 2.101, 2.102).



JH – I : R′—R″—C_2H_3
[Methyl (2*E*, 6*E*) – (10*R*, 11*S*) – 10, 11 – epoxy – 7 – ethyl – 3, 11 – dimethyl – 2, 6 – tridecodienoate]
JH – II : R′—C_2H_3, R″—CH_3

Fig. 2.101 : Structures of juvenile hormones (JH).

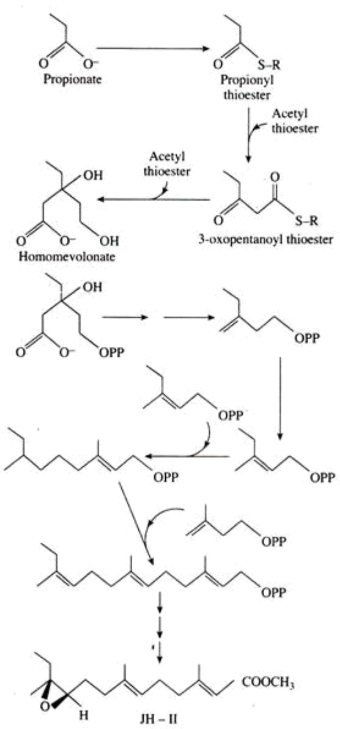


Fig. 2.102 : Possible biosynthetic pathway of JH–II.

Site of Synthesis:

Corpora allata of brain.

C. Route of Transport:

Following synthesis it is secreted into the haemolymph and via haemolymph it is transported to the target cells. The lipid soluble JH is transported by haemolymph in association with a hydrophilic carrier protein. Besides transporting, the protein also has a role in protecting the hormone from degradative enzymes.

D. Control and Inactivation:

After performing its functions, the JH undergoes inactivation through the activities of carboxyl-esterase and epoxidehydrase enzymes.

E. Functions:

The most important effects of JH include its morphogenetic role in maintaining the larval (or nymphal) state in immature insects. It also regulates, entirely distinct processes connected with reproductive maturation and activity in adults.

Endocrine Control of Moulting in Insects:

The hormonal control on development, in insect, can be broadly described by a 'classical scheme' (Fig. 2.96). Moulting and metamorphosis are controlled by endocrine hormones of the brain and associated glands innervated by the brain. Corpora cardiaca and corpora allata of the brain along with the paired protothoracic glands in proto-thorax are the site of hormone production.

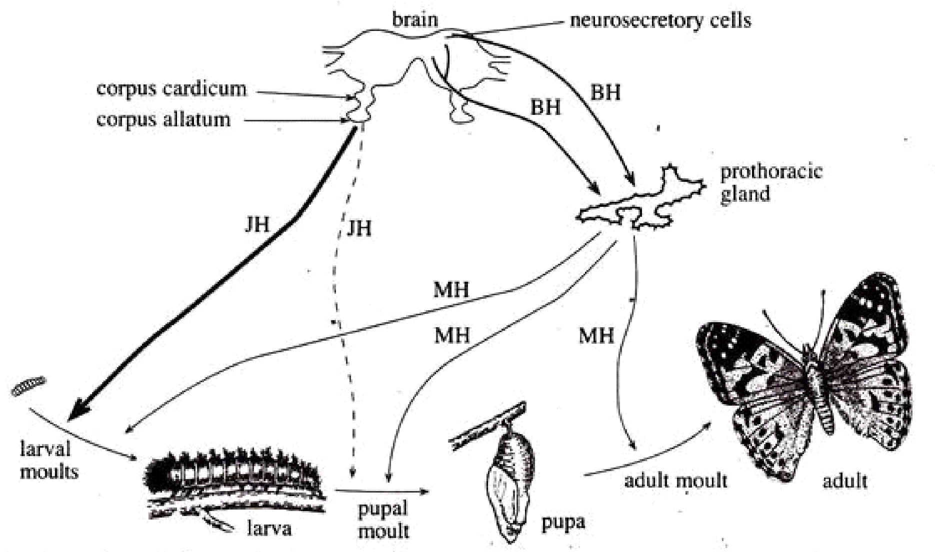


Fig. 2.96 : Classical scheme of the hormonal control of moulting and metamorphosis in a holometabolous insect. BH = Brain hormone, JH = Juvenile hormone, MH = Moulting hormone.

Pathway of Hormone Action:

In response to various stimuli (viz., temperature changes, photoperiod, distention of gut after feeding), the neurosecretory cells of the brain produce brain hormones (BH) [ecdysiotropin, protothoracicotropic hormone (PTTH)], which enter the haemolymph, via corpora cardiaca in many cases.

BH then stimulates the protothoracic gland to synthesise and /or release insect moulting hormone (MH). Under direct control of brain, the corpora allata secretes juvenile hormone (JH). Both JH and MH acts differently during various stages of development.

6. *Co-ordinated Action of Hormones during Metamorphosis in Insects:*

Normal development, including metamorphosis, is dependent on the relative amounts of the two hormones (JH and MH), available to the reacting tissues under the direct control of Brain. The BH along with corpora cardiaca hormone serves as tropic hormone.

This tropic hormone is needed by ecdysial/protothoracic gland for its activation to produce MH/ ecdysone. Under the influence of this hormone the moulting process of the insect is initiated. There are several factors which control the rate of secretion by ecdysial gland.

One of the control systems is the stimulation or inhibition by the JH. With the release of ecdysone into the haemolymph, the epidermis is stimulated to moult and at the same time, the body tissues start to differentiate in the direction of adult structures.

At this stage JH from corpora allata is released to retard the growth. If the amount of JH increases, the organism will not transform into adult but will remain juvenile in form (Fig. 2.97).

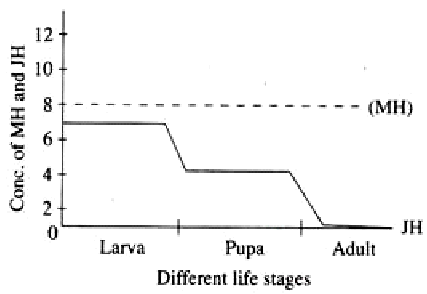


Fig. 2.97 : Level of moulting hormone (MH) and juvenile hormone (JH) in haemolymph during normal development in insects. MH maintains a steady state while the level of JH in haemolymph differentiates the developmental stages.

If prior to each moult a high level of JH is present then the resulting organism will be immature. If the JH is at a minimum, or completely absent, an adult will be formed. While with an intermediate level of JH the pupal period will be attained.

Therefore, from endocrinological point of view, the difference between moulting and metamorphosis is the concentration of JH in the haemolymph, prior to each moult in the immature stages. The moult which occurs without any juvenile hormone influence will produce metamorphosis leading to adult (Fig. 2.97).

7.Role of other hormones in metamorphosis:

Eclosion:

Eclosion hormone or EH is released from brain by a circadian clock and declining ecdysteroid titers. If ecdysone titer is artificially kept high, the release of eclosion and its activity are inhibited. This hormone influences many aspects of pupal-adult ecdysis, including the behaviour associated with ecdysis and subsequent degeneration of abdominal inter-segmental muscles used in the act of ecdysis.

Isolation of eclosion hormone gene from different insects suggested that EH hormone as well as the mechanism by which ecdysis behaviour is triggered is conserved among insects.

Ecdysis triggering hormone:

It is the most recent hormone discovered that plays an important role in ecdysis. This 26 amino acid peptide hormone is synthesised by the epitracheal glands that are located segmentally in larvae, pupae and adults of Manduca sexta. According to Zitnan (1996), this hormone may act upstream from the eclosion hormone in a series of cascade events leading to ecdysis.

Bursicon (Tanning hormone):

Bursicon, commonly found in neurohaemal organs associated with the ventral chain ganglia is suggested to stimulate tanning and sclerotisation of the cuticle following ecdysis.