INSECT METAMORPHOSIS

Zoo 514

Dr. Reem Alajmi

Definition

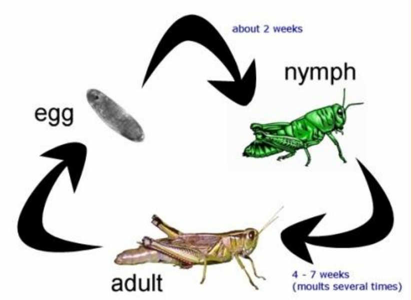
- **Metamorphosis** is the changes that occur in the transformation of the larva to the adult.
- It may be more or less extensive depending on the degree of differences between the larva and the adult. According to that different types of metamorphosis are present.

1- Hemimetabolous insects

2- Holometabolous insects

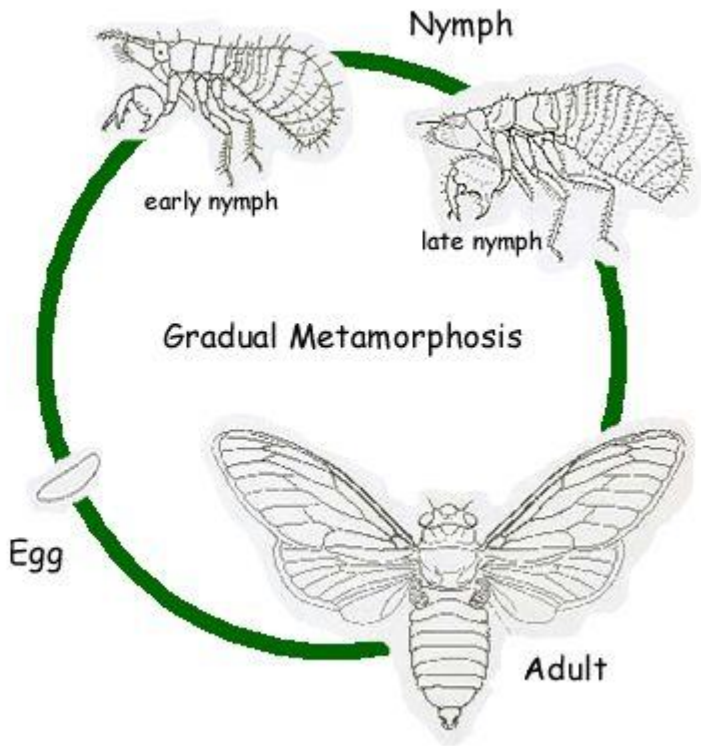
- The onset of metamorphosis generally is associated with the attainment of a certain body size, which is through to program the brain for metamorphosis, resulting in altered hormone levels.
- In most insects, a reduction in the amount of circulating juvenile hormone (as a result of reduction of corpora allata activity) is essential to the initiation of metamorphosis.

HEMIMETABOLOUS INSECTS

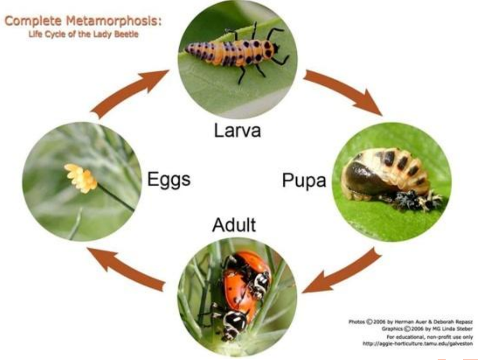


- Three life stages occur: egg, nymph, and adult. Insects with gradual metamorphosis are said to be hemimetabolous (hemi = part). Some entomologists refer to this type of transformation as incomplete metamorphosis.
- Growth happens during the nymph stage. The nymph resembles the adult in most ways, particularly in appearance. Usually, the nymph also shares the same habitat and food as the adults, and will exhibit similar behaviors. In winged insects, the nymph develops wings externally as it molts and grows. Functional and fully-formed wings mark the adult stage
- Epidermal mitosis and expansion only occurs at the time of a molt and, in hemimetabolous insects, progressive development of the wing buds occurs at each molt.
- The genitalia develop progressively by modification of the terminal abdominal segments, but with a more marked alteration at the final molt.

- Some hemimetabolous insects include grasshoppers, mantids, cockroaches, termites, dragonflies, and all true bugs.



Holometabolous insects



- Each stage of the life cycle: egg, larva, pupa, and adult – looks different from the others. Entomologists call these insects holometabolous (holo = total).
- The larvae of holometabolous insects bear no resemblance to their adult parents. Their habitats and food sources may be entirely different from the adults as well. Larvae grow and molt, usually multiple times. Some insect orders have a unique name for their larval forms: butterfly and moth larvae are caterpillars; fly larvae are maggots, and beetle larvae are grubs.
- The development of adult features in holometabolous insects varies with the degree of modification of larval features involved.
- In Diptera, the tissues are almost completely rebuilt following histolysis and phagocytosis of the larval tissues. This reconstruction occurs in the pupa.

Larva(e)

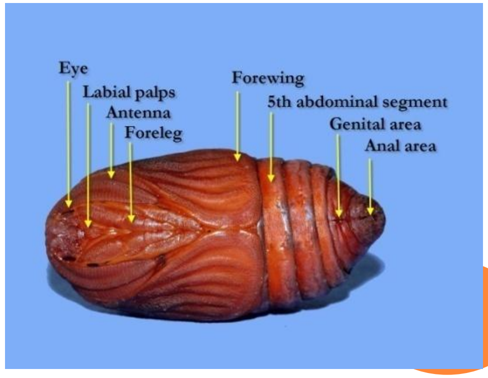
- Larvae hatch from the eggs.
- The larvae do not look like the adults.
- They usually have a worm-like shape.
- Larvae molt their skin several times and they grow slightly larger.
- Larvae eat A LOT of food.
- Different types of larvae are present.
- Examples of larvae: mealworms, maggots, caterpillars, grubs

Pupa

- All the features of the adult become recognizable in the pupa .
- At the larva/pupa molt the wings and other features that up to now have been developing internally are everted and become visible externally although not fully expanded to the adult form.
- Different types of pupae are recognized:

1- Exarate: In this type of pupa the appendages (e.g. legs, wings, mouthparts and antennae) are extend freely from the body.

2- Obtect: Appendages are glued down by a secretion produced at the larva-pupa molt. This type of pupa is usually more heavily sclerotized than the exarate pupae.



a- Decticous: when pupae have articulated mandibles, that the pharate adult uses to cut through the cocoon. Decticous pupae are always exarate.

B- Adecticous: pupae with a non articulated mandibles, in which case the adult usually first sheds the pupal cuticle and then uses its mandibles and legs to escape the cocoon or cell (Some adecticous pupae may be obtect)

Prepupa

- The last stage larva is often quiescent for two or three days before the ecdysis to a pupa.
- During this period, the insect is sometimes referred to as a prepupa, but it does not usually represent a distinct morphological stage separated from the last stage larva by a molt.

Protection of the pupa

- Most insect pupae are immobile, and most insects pupae in a cell or cocoon which affords them some protection.
- Many larval Lepidoptera construct an underground cell in which to pupate, cementing particles of soil with a fluid secretion.
- Some moth families construct a chamber of wood fragments glued together to form a hard enclosing layer.
- Many larvae produce silk which may be used to hold other structures, such as leaves, together to form a chamber for the pupa, but in other species a cocoon is produced wholly from silk.

Pupae of aquatic insects

- The behavior of aquatic insects on pupation varies considerably.
- Some larvae, such as the beetle Hydrophilus, leave the water and pupate on land.
- Many others particularly the aquatic Diptera, pupate in the water.
- Sometimes the pupae are fastened to the substratum (such as stones or rocks) to protect them form water currents.
- Chironomidae pupate in the larval tubes or embedded in the mud.
- Other aquatic pupae obtain oxygen from the air, either directly or indirectly.

- The pupae of most Culicidea are free-living and active. They are buoyant so that, when undisturbed, they rise to the surface and respire via prothoracic respiratory horns.
- The pupae of some Culicidae and Ephydridae have their respiratory horns embedded in the tissues of aquatic plants, obtaining their oxygen via the aerenchyma.

Significance of the pupa

- It is a stage during which major internal reconstruction occurs and is of particular importance in permitting the development and attachment of adult muscles to the cuticle and the full development of the wings.
- Most of the adult thoracic muscles are different from those of the larva. It has been suggested that muscles will only develop in an appropriate form and length if they have a mold in which to do so. The pupa provides a mold for the adult muscles.
- Development of the wings internally within the larva is restricted by lack of space and this problem becomes more acute as the insect approaches the adult condition and the flight muscles also increase in size.

- Thus development can only be completed after the wings are everted, for this reason, two molts are necessary in the transformation from larva to adult.
- At the first, from larva to pupa, the wings are everted and grow to some extent. Further growth occurs and the adult cuticle is laid down at the pupa-adult molt.

Control of moulting

- Molting is a complex process involving hormonal, behavioral, epidermal and cuticular changes that lead up to the shedding of the old cuticle.
- Ecdysis commences with the remnants of the old cuticle splitting along the dorsal midline as a result of increase in hemolymph pressure.
- The newly ecdysed insect expands the new cuticle by swallowing air or water and/or by increasing hemolymph pressure in different body parts .

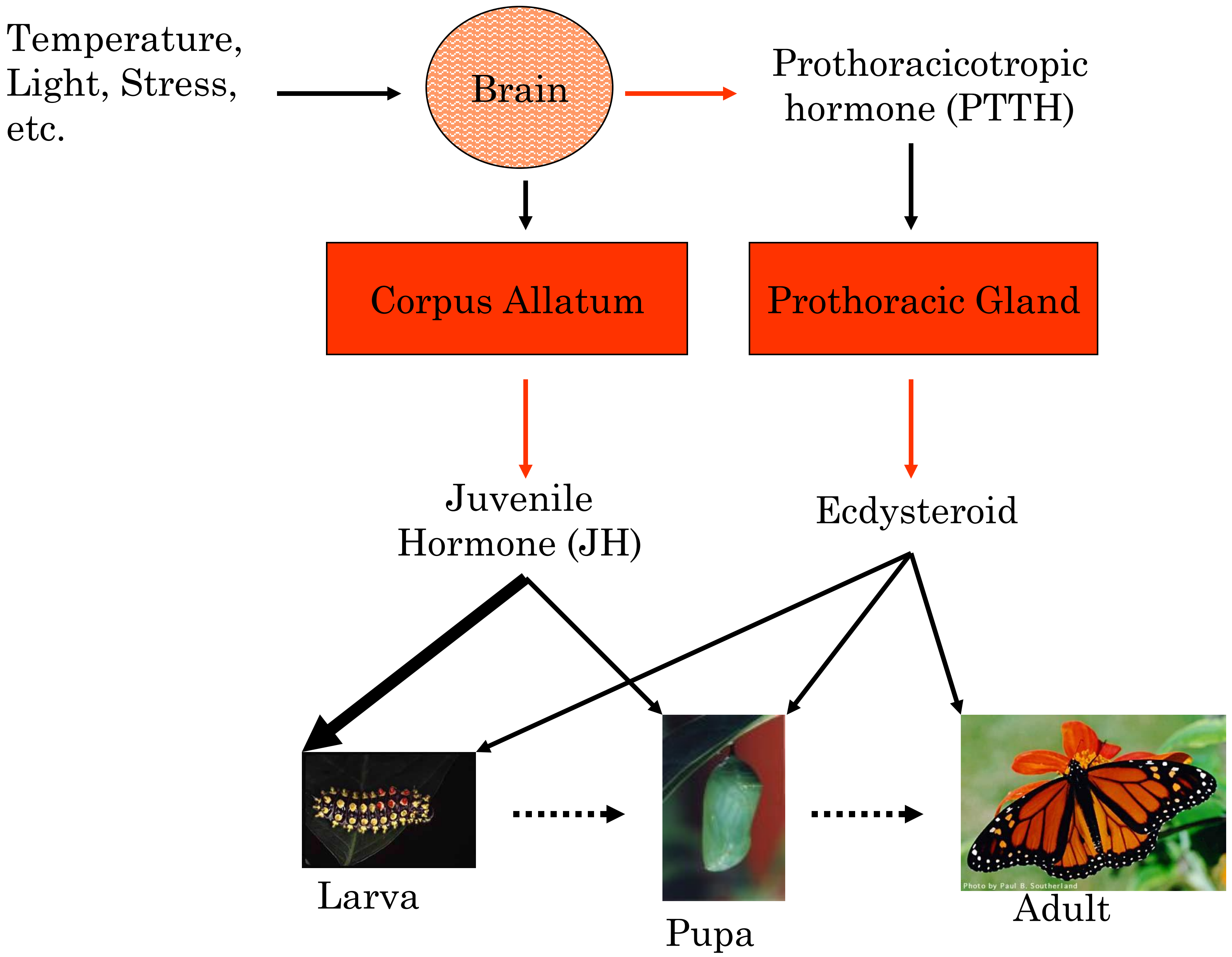
- Three main types of hormones control molting and metamorphosis:

- Neuropeptides including PTTH, ecdysis triggering hormone (ETH) and eclosion hormone (EH).
- Ecdysteroids
- Juvenile hormone (JH), which may occur in several different forms even in the same insect.

- Neurosecretory cells in the brain secrete PTTH, which passes down to corpora allata and sereated their into the haemolymph.
- The PTTH stimulates ecdysteroid synthesis and secretion by the prothoracic or moulting glands.

- Ecdysteroid initiates the changes in the epidermal cells that lead to the production of the new cuticle.
- The characteristics of molt are regulated by JH form the corpora allata.
- JH inhibits the expression of adult features so that high haemolymph level (titer) of JH is associated with a larval-larval moult, and a lower titer with a larval-pupal molt, JH is absent at the pupal-adult molt.
- Ecdysis is mediated by ETH and EH.

Hormonal Control of Insect Metamorphosis



CONTROL OF METAMORPHOSIS BY INTERNAL AND EXTERNAL FACTORS

Temperature, Light, Stress, etc. → Brain

Temperature (day degrees)

Critical size matched (**availability of food**)

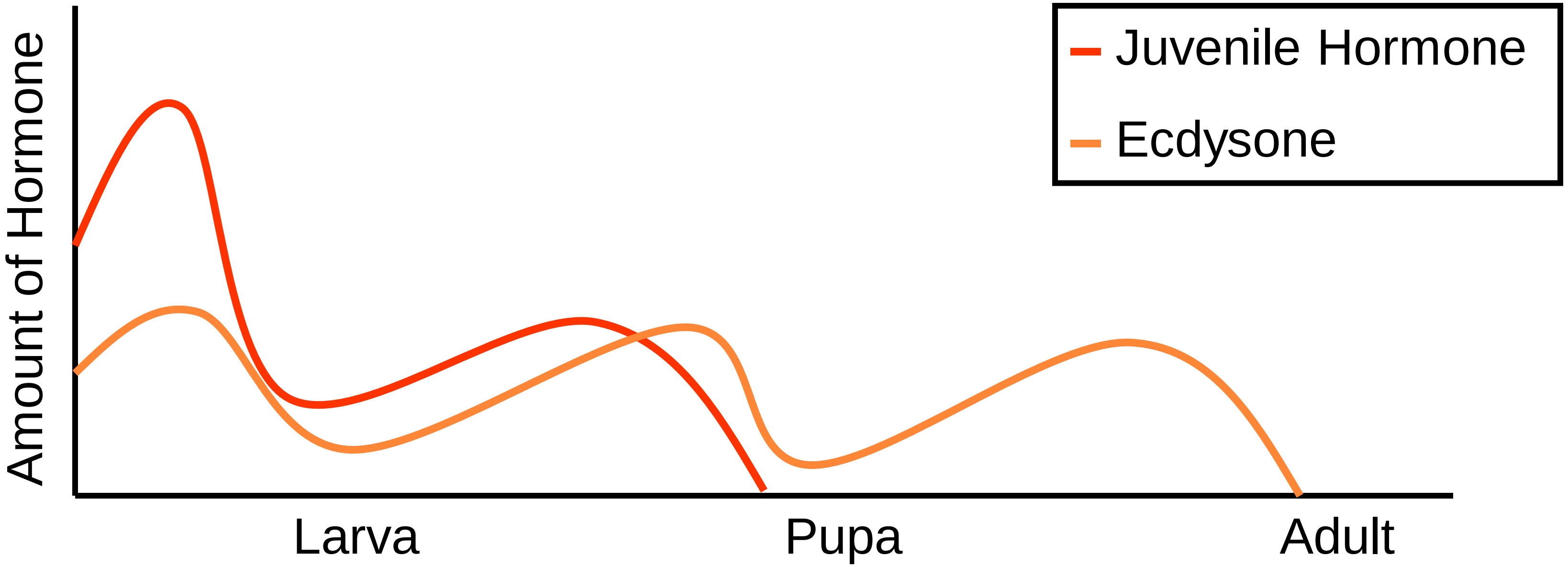
Light (photoperiod)

Chemicals

Amount of **moisture**

Stress: mutagens, predators, etc.

REGULATION OF JH LEVELS



Eclosion

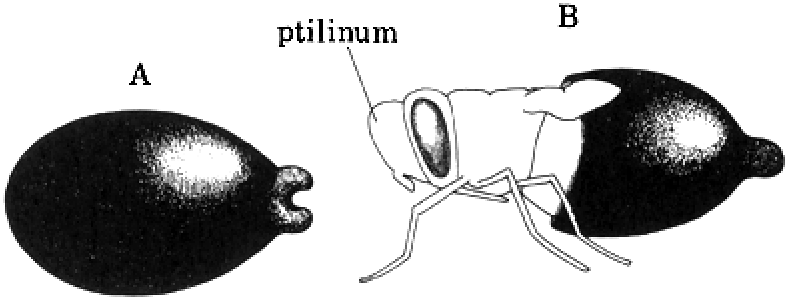
- The escape of the adult from the cuticle of the pupa or, in hemimetabolous insects, of the last larval stage is known as eclosion.

Escape from the cocoon or cell

- Sometimes the pharate adult is sufficiently mobile to make its escape from the cocoon or cell while still within the pupal cuticle. This is the case in species with decticous pupae which use pupal mandibles, actuated by the adult muscles, to bite through the cocoon).
- Sometimes, as in Trichoptera, the adult mouthparts are non-functional, so pupa moves away from the cocoon before the adult emerges, aided by its freely moveable appendages and backwardly directed spines on the pupal cuticle.
- In some Lepidoptera, the pupa works its way forwards with the aid of backwardly directed spines on the abdomen, forcing its way through the wall of the cocoon with a ridge or tubercle known as a cocoon cutter on the head. The pupa does not escape completely from the cocoon, but is held with the anterior part sticking out by forwardly directed spines on the ninth and tenth abdominal segments. With the pupal cuticle fixed in this way the adult is able to pull against the substratum and so drag itself free more readily.

- In many insects with adecticous pupae, the adult emerges from the pupa within the cocoon or cell, making its final escape later, often while its cuticle is still soft and unexpanded. Their escape is facilitated by the flimsiness of the cocoon or the presence of a valve at one end of the cocoon through which the insect can force its way out while the ingress of other insects is prevented.
- Some Lepidoptera produce secretions which soften the material of the cocoon. This enables the adult insect to push its way out protected by the remnants of the pupa cuticle.

- Cyclorrhaphous Diptera have an eversible sac called the ptilinum at the front of the head which assists in their escape from the puparium. It can be expanded by blood forced into the head this pressure of the ptilinum splits off the cap of the puparium and, if the puparium is buried in the soil, the ptilinum is also used by the fly to digs way to the surface. Once the fly's cuticle has hardened, the ptilinum is no longer visible and the muscles associated with it degenerate.



- The degree of hardening that insects undergo before escaping form the cocoon varies according to insect specie.

- In some, most of the cuticle remains soft until after eclosion, but some parts, particularly those involved in locomotion, harden before that.
- Other insects emerge from the pupa and harden fully before making their escape from the cocoon. Some species use their mandibles to bite their way out. Other have an appendage, known as the false mandible, on the outside of the mandible which is used in escaping from the cocoon and then, in most species, falls off.
- The escape of fleas from their cocoon is stimulated by mechanical disturbances and in many species is facilitated by a cocoon cutter on the frons.

Eclosion of aquatic insects

- Some emerge under water and swim to the surface as adults, while in others, the pupa rises to the surface before the adult emerges.
- The pupae of Culicidae are buoyant, while other insects, whose pupae are normally submerged, increase their bouyancy just before emergence by forcing gas out of the spiracles into the space beneath the pupal cuticle, or by increasing the volume of the tracheal system.
- Many Trichoptera swim to the surface as pharate adults, the middle legs of the pupae of these species being fringed to facilitate swimming, and the insect may continue to swim at the surface until it finds a suitable object to crawl up to the surface.
- The act of eclosion at the surface, in mosquitoes, results from the pharate adult swallowing air. The air is probably drawn from the space between the adult and pupal cuticles and is derived from air drawn into the tracheal system through the respiratory horns of the pupa.

Time of eclosion

- The time of eclosion is synchronized with suitable environmental conditions.
- Many factors affecting the time of eclosion including:

- Temperature.
- Season.
- Light cycle (Day/night).
- Sex of insects (males insects tend to emerge as adults a little before the females).
  This probably reflects, in part, the smaller size of many male insects.

Initiation of molting and metamorphosis

- The factors responsible for initiating molting are poorly understood.
- In general, insect responds to reaching a certain size, but how it measures size is not known in most cases.
- Abdominal stretch due to blood meal may stimulate molting.
- The size at which molting occurs is not absolute, but depends on the insects size at the beginning of the stage.
- Some species molt if they are starved and they may become smaller.
- In others its is related to head size at the beginning of larval stage.
- Metamorphosis occurs when ecdysteroids are produced in the absence of juvenile hormone.

Production of ecdysteroid hormones

- The prothoracic gland is stimulated to produce ecdysone by the prothoracicotropic hormone (PTTH). Release of this hormone, usually via the corpora cardiaca (or from corpora allata in Lepidoptera), results form the presumed neural signal produced by size.
- Each period of ecdysteroid production is proceeded by a peak of PTTH.
- The release of PTTH is inhibited by a high titer of juvenile hormone in the hemolymph, although in the earlier larval stages PTTH is released in the presence of juvenile hormone.
- The secretion of PTTH is photoperiodic (secreted during specific period) usually within a certain period of the day.
- Ecdysteroid hormones regulate many other activities.

Control of ecdysis

- Three neruropeptieds are involved in the control of eclosion. They are:

- Ecdysis triggering hormone (ETH), form preitracheal glands. It act directly on cells in the ventral ganglia to witch on pre-ecdysis behavior. It also stimulate the release of eclosion hormone.

- Elosion hormone (EH) (ecdysone) form neurosecretory cells in the brain. It is probably accounts for the specific times of eclosion. It stimulate the release of CCAP. It also regulates sclerticization of the cuticle of the wings, the release of bursicon, and breakdown of the eclosion muscles in silkmoths.

- Crustacean cardioactive peptide (CCAP) from cells in the ventral nerve cord. This hormone switches off pre-eclosion hebavior and switch on eclosion behavior. It also accelerate heartbeat.

- The previous neuropeptides interact to induce the behaviors that culminate in eclosion.
- The pre-eclosion behavior consists of a series of abdominal rotations, which serves to free the adult abdomen from the overlying pupal cuticle. Followed by a period of quiescence then eclosion behavior begin.
- Eclosion behavior consists of waves of abdominal contraction and of shrugging of the wing bases that continuous until eclosion is complete.