MOULTING

The process of casting or shedding of old cuticle from the insect body is called moulting. The casted cuticle known as exuviae and the stages between moultings are called instars.

All insects shed and replace the cuticle a number of times during postembryonic development and the process is known as the moulting. Moulting is a complex process involving first separation of the old cuticle from the hypodermis (apolysis) followed by a shedding of the old cuticle (ecdysis). Immediately after ecdysis, tanning of cuticle (sclerotization), takes place.

Insect exoskeletons are hard and protect the body. Because the exoskeleton is hard and rigid, an arthropod cannot grow unless it sheds its old exoskeleton and secretes a new one. This process is called moulting.

STEPS OF MOULTING

APOLYSIS

The apolysis starts with increase in the number and size of the epidermal cells of the hypodermis due to repeated mitotic divisions. The epidermal cells become tall, columnar in shape and are closely packed. They exert marked tension at the cuticular surface and as a result separate themselves from the cuticle (Figure 1).

Due to the separation of the hypodermis from the cuticle, formation of a subcuticular space takes place. The epidermal cells or modified moulting glands discharge the moulting fluid in subcuticular space. The moulting fluid is a granular gelatinous fluid and contains chiefly, two enzymes - the proteinase and chitinase, which are specifically digesting the endocuticle of old cuticle. Initially the moulting fluid is inactive but as soon as the cuticulin layer of a new cuticle is secreted, it becomes active.

As the moulting fluid digests the endocuticle of old cuticle, the subcuticular space increases gradually. On the other hand, the cuticulin layer moves forward with the synthesis of wax and polyphenol layers. After the formation of definite epicuticle, the successive layers of procuticle are deposited beneath and the subcuticular space is gradually occupied by the newly synthesized cuticle.

The moulting fluid is capable of digesting almost all endocuticle of the old cuticle except some indigested material which later persists in the form of the ecdysial membrane below the old cuticle.
The oenocytes secrete the cuticulin layer of new cuticle which is impermeable to the moulting fluid. The other epicuticular layers, the wax, polyphenol and cement layers are formed from the substances transported by the epidermal cells through the pore canals. The procuticle is also a product of epidermal cells which is discharged via the pore canals. The cement layer, in some insects, is secreted by the dermal glands. It is deposited over the wax layer at the last, i.e., just before the ecdysis.

Figure 1: Moulting cycle
ECDYSIS

The insect body is enclosed with an old cuticle consisting of epi- and exo-cuticle on a newly synthetized epi- and procuticle. The old cuticle is known as exuviae and the developmental stage bearing exuviae is called the pharate instar. Due to digestion of old endocuticle, the ecdysial lines develop on various parts exuviae. Due to the muscular activities of the inner developing insect, the exuviae splits along the ecdysial lines. Besides the muscular activity, the insect swallows air or water and as a result, the gut is distended causing increase in haemolymph pressure. The blood is subsequently pumped from the abdomen into the thorax by muscular activity. Due to enhanced blood pressure ultimately the thoracic old cuticle splits along the lines of weakness. After breaking up of exuviae along the ecdysial lines, the new instar comes out with bringing out its head and thorax first followed by the abdomen and appendages.

Not only the integumental cuticle (exuviae) but all the old cuticular structures are cast off including the endphragmal skeleton, tracheal linings and intima of foregut and hindgut.

At the time of ecdysis, the new cuticle is very soft and milky white providing substantial mechanical support to the insect body. At this stage, the blood acts a hydrostatic skeleton.

Ecdysone is a major hormone concerned with moulting which is secreted from the prothoracic glands of insect. It initiates apolysis and cuticle production. Insect molting hormones (ecdysone and its homologues) are generally called ecdysteroids.

SCLEROTIZATION

Sclerotization or tanning is the last process of moulting which involves differentiation of the procuticle into outer hard exocuticle and inner soft endocuticle. The exocuticle represents a tanned part of the cuticle.

It is simply a conversion of the protein arthropodin into sclerotin by initiating formation of cross links between the adjacent protein molecules. The cross-links are formed by quinones.

The concentration of tyrosine increases highly in the haemolymph just before the ecdysis. Tyrosine is converted to dihydroxyphenylalanine (DOPA) - dopamine to N-acetyldopamine and variety of quinones. The N-acetyldopamine (diphenol) is transported via pore canals into the outer part of the epicuticle where it is oxidized to a quinone by an enzyme, phenoloxidase. The quinone diffuses across the epicuticle into the outer part of
**procuticle** and after forming cross-links among the protein molecules, produces the **exocuticle** (Figure 2).

Quinone always forms links with terminal amino groups of the protein molecules having dibasic amino acid like **lysine**. It results into the formation of a **catechol-type protein** which is later on oxidised to a **quinonoid protein**. This quinonoid protein links to another protein molecule.

Sclerotization or tanning process is controlled by a hormone known as **bursicon**.

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**Figure**: Diagram showing the sclerotization process after ecdysis