INSECT INTEGUMENT

Read Chapter 16 in Chapman

* The insect integument is composed of the **CUTICLE, EPIDERMIS,** and the **BASEMENT MEMBRANE.**

Functions of the Integument
1. Protection for internal organs.
2. Skeleton for attachment of muscles.
3. Give the insect its form.
4. Give chemical and physical colors.
5. Regulates water loss.
6. Provides a metabolic reserve.
7. Protects against entry of foreign materials such as pesticides.
8. Allows for modifications which provide sensory input, eyes, chemoreceptors, etc.
9. Allows for movement and most important, flight.

General Components
Cuticle
  Epicuticle
    Cement layer
    Wax layer
      mono-layer
      thick layer
    Polyphenol layer (outer epicuticle in text)
    Cuticulin layer (inner epicuticle in text)
  Procuticle (chitinous cuticle in text)
    Exocuticle layer
    Mesocuticle layer
    Endocuticle layer
    Schmidt's layer
Epidermis
Basement Membrane (basal lamina)

- We are going to consider the integument at the intermolt. We'll leave molting to the physiologists

THE CUTICLE
The cuticle is divided into:
1. **EPICUTICLE** which is outer and has no chitin. It is up to 4 um thick.
2. **PROCUTICLE** (**chitinous cuticle** in your text) which is inner and contains chitin. It is of variable thickness.

EPICUTICLE
* The epicuticle is the outermost layer of the integument and it is also complex. The epicuticle consists of lipid and protein, but no chitin.

The epicuticle is divided into 4 layers:
1. **CEMENT LAYER** is the outermost layer. It is probably like shellac and is not always present.
2. **WAX LAYER** is the next layer. It is made up of as many as 3 layers:
    a. Outer Layer - not always present. (wax blooms)
    b. Middle Layer - largest.
    c. Mono Layer - imparts water protection.
3. **POLYPHENOL LAYER** (**outer epicuticle** in your text) is the next layer and is the part of the epicuticle that has been sclerotized. This is the first-formed layer of new cuticle produced at each molt, protecting the new procuticle from the molting enzymes.

4. **CUTICULIN LAYER** (**inner epicuticle** in your text) is the innermost layer of the epicuticle. Chemically complex, consisting primarily of tanned lipoproteins. During its production, phenolic substances and phenoloxidase are also present. Very important layer.
   - It extends over the entire body including the ectodermal invaginations.
   - It is a selective barrier allowing important chemicals through during molting and allows the resorption of the digested products of the endocuticle of the old cuticle.
   - Because it is inelastic, it limits growth.

PROCUTICLE

* Is 20 to 60 percent chitin. Most of the rest consists of protein.

Chitin - a nitrogenous polysaccharide similar to cellulose:

N-acetyl-D-glucosamine residues, Glucosamine residues, and ß 1,4 linkages

The protein of the procuticle is of 2 types:
1. Watersoluble - sometimes called **ARTHROPODIN**, really a class of proteins.
2. Water insoluble proteins that bind to chitin and each other.

* The procuticle is divided into 4 layers based on staining characteristics.
   1. **EXOCUTICLE** - In the exocuticle proteins are linked together by a quinone molecule. The resulting molecule is called **SCLEROTIN** and is very tough and non-yielding. It is tanned procuticle.

   {Sclerotized = hardened = tanned ≠ darkened - darkening involves the deposition of melanin}
   These are independent processes.

   - exocuticle is absent from areas where flexibility is needed as in joints, intersemental membranes, and along ecdysial lines.

   * Another special protein is **RESILIN** which is a terrific natural rubber found in wing joints and places where energy must be conserved.
   2. **MESOCUTICLE** - transition layer based upon staining. Chemically similar to endocuticle.
   3. **ENDOCUTICLE** - 10-200 um thick. The endocuticle is composed of lamellae made up of masses of microfibrils arranged in succession of planes, all fibers in one plane being parallel to one another. Extensive hydrogen bonding holds it together. Covalent bonding holds chitin together with protein in the endocuticle.
   4. **SCHMIDT'S LAYER** = subcuticle; very thin. Located above the epidermis, below the endocuticle, originally thought to be an adhesive layer, now believed to represent newly secreted cuticle that is less well-stabilized endocuticle. The chitin fibers in this region are not ordered.

EPIDERMIS

* The epidermis is the outermost cellular layer of the insect. It is sometimes called the hypodermis but this isn't a very good term as the insect has no dermis.

* It is one-cell thick.

* When inactive, its cell boundaries are indistinct.

* When active, as during the deposition of a new cuticle, the previously flattened cell bodies become more or less cuboidal and their plasma membranes are very distinct. **Plasma membrane plaques** - secrete outer epicuticle and chitin fibers (see fig. 16.1a in text).

* At this time one or more nucleoli are evident and RNA synthesis is evident by the presence of much endoplasmic reticulum.

* Epidermal cell densities range from about 3000/mm^2 to 11000/mm^2.

* In the cyclorrhaphan Diptera, epidermal cells do not divide but grow in size as the larva grows. In *Calliphora erythrocephala*, they grow to 11 times their 1st instar size by the time they are in their 3rd instar.

* In contrast, in the Nematocera, epidermal cells divide as the larva grows. They also increase in size.

* The shape of both outer and inner borders changes with secretory activity and within the molting cycle. Folding and the appearance of many microvilli on the plasma membrane is evident during cuticle deposition and resorption of the endocuticle via the molting fluid.

* Pigments occur in the epidermis, usually orange and red.

* **Oenocytes** - cells produced by epidermal cells. Synthesize hydrocarbons and possibly other lipids that contribute to the epicuticle.

BASEMENT MEMBRANE (**basal lamina** in text)
* Contains connective tissue, collogen, and mucopolysaccharide.
* Defined as the continuous layer ca. 0.5 mu thick beneath the epidermis.

* Just before molting, it thickens by the deposition of more mucopolysaccharide from the hemocytes which can often be seen adhering closely to its surface.

* Secreted in part by the hemocytes but the epidermis may also be involved in its formation.

* Tracheoles, nerves and various sensory structures pass to or through it.

* Where muscles are attached it is continuous with the sarcolemma. It is attached to the epidermis by hemidesmosomes.

* Function isn't clear from my reading but may act as sort of a base for support while the outer layer of the cuticle (epicuticle) is being laid down. May also act as a molecular sieve.

MOLTING AND ECDYSIS
* Snodgrass equates molting and ecdysis. This is not the case however, they are independent processes. The process leading up to the shedding of the old cuticle and distinct from the final act of shedding is called **MOLTING.** The process of casting off the old cuticle is **ECDYSIS.**

* One of the main problems insects encounter is the fact that muscles have to attach to an exoskeleton which is renewed at the molt. Therefore the attachments also have to be renewed. During this period of time the insect is vulnerable.

* Muscles pass through the procuticle to the base of the cuticulin where they are anchored by some unknown mechanism.

* The base of the epidermis and the muscle interdigitate which also helps in anchoring the muscles to the cuticle. **MICROTUBULES (TONOFIBRILLAE)** extend outward through the epidermis to the base of the cuticle. From here, **MUSCLE ATTACHMENT FIBERS** pass through the cuticle to base of the cuticulin layer through pore canals. These fibers are not contractile and continue to grow with the increase in thickness of

the procuticle. As the cuticulin layer is one of the earliest formed during molting, the muscle attachments are maintained almost always.

CUTICULAR PROTUBERANCES

* These have been variously classified on the basis of:
    1. Movability - Spines are non-movable; spurs are movable.
    2. Relationship to underlying epidermal cell - setae and scales are unicellular; microtrichia are subcellular; and spines and spurs are multicellular.

* On the basis of TEM and cytological evidence, morphologists recognize 4 basic types of cuticular protuberances. In contrast, taxonomists recognize a vast array of different protuberances.

    1. **MULTICELLULAR** with cells similar in appearance to cells of the remainder of the epidermis. [1, 2, and 5 in overhead] These are **SPINES** and **SPURS**. In the broad sense, legs and antennae conform to this definition. Also eversible glands, the endophallus, eversible pouches of butterflies and moths, the ptilinum of the cyclorrhapha Diptera, tracheae, tendons, large "teeth" in the proventriculus of acridids.

    2. **MULTICELLULAR** with specifically differentiated cells. These are **SETAE**. The most basic type is the trichoid sensillum which originates from three specific cell types:

        a. Trichogen cell - hair-forming cell. The **TRICHOGEN CELL** actually makes the protuberance and secretes the cuticle on it.
        b. Tormogen cell - socket-forming cell. The **TORMOGEN CELL** is considered to make the socket and secrete its cuticle.
        c. Sense cell - nerve cell or neuron. The **SENSE CELL** differentiates into a bipolar sense cell with dendrites extending peripherally and an axon growing into the CNS.

        * At maturity, the trichogen and tormogen cell usually degenerate.

    3. **UNICELLULAR - ACANTHAE** - unicellular projections with no nerve cell; one projection. There are 2 types:

        a. **TYPE A ACANTHAE** - the process is nearly as large in cross-section as the underlying cell that produced it.
        b. **TYPE B ACANTHAE** - the process is small relative to cell. [examples: proventriculus of Mecoptera; tenent hairs on feet of Diptera].

    4. **SUBCELLULAR** - more than one projection per cell. These are called **MICROTRICHIA**. Projections that are many per cell. Common on abdomen, taenidia of trachea, on setae, on wings.