3 - Defense and protection (integument)

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3 Defense and Protection (Integument)

In ticks, the integument (Figure 10 A-F) is an organ of vital importance, externally covering the body and acting as a physical barrier against environmental hazards. The integument plays a key role in the biological success of the ticks, due to its versatility, physiological aspects and interaction with all the ectoparasite systems, covering and sustaining the body, protecting against mechanical impacts and regulating the hydric balance (Coons; Alberti, 1999; Sonenshine; Roe, 2014).

Histologically, the integument is constituted of a cuticle comprised of several sublayers secreted by cells that form single epithelium, which secretes all the material that will constitute the exoskeleton, responsible for the formation of epidermal appendages and dermal glands (Coons; Alberti, 1999; Hackman, 1982; Sonenshine; Roe, 2014).
The cuticle is an acellular structure comprised of two layers: a) the epicuticle, outer and thinner, with distensible and deep folds, and b) the procuticle, inner and thicker (Coons; Alberti, 1999).

The distensibility of the integument allows the ticks (specially females in oogenesis) to increase the body volume during engorgement, accommodating the enlarged midgut, as well as the ovary in development, which contains oocytes in different stages of maturation (Bughdadi, 2008; Oliveira et al., 2009; Remedio; Nunes; Camargo-Mathias, 2014).

According to Coons and Alberti (1999), the epicuticle morphology does not present significant variations over the different developmental phases, being thinner or thicker in some species or regions of the body. Some cuticle characteristics are species-specific, e.g., argasidae ticks present a cement layer, while in Ixodidae this layer is absent. Additionally, according to Dillinger and Kesel (2002), *Ixodes ricinus* females have their body enlarged without ecdysis, once their epicuticle is highly resistant and distensible.

The procuticle is the layer between the epicuticle and the epidermis, in some cases, sclerotized. The sclerotized parts (sclerites, plates and shield) are harder and thicker than the non-sclerotized one, also called soft parts (aloscutum and membranes) (Coons; Alberti, 1999). The procuticle is subdivided into two layers: the exocuticle, in contact with the epicuticle, and the endocuticle, close to the epidermal cells (Coons; Alberti, 1999). Both sublayers contain pore channels, whose function is still nuclear; however, it has been suggested that they are involved in the exchange of gases, water and lipids between the internal compartments of the tick and the environment (Coons; Alberti, 1999). Cytoplasmic extensions can be found in the pore channels; however, these tunnels are commonly found empty. In *Rhipicephalus (Boophilus) microplus*
females, the pores are branched and less frequent (Beadle, 1972). In some cases, a subcuticular layer (deposition zone) is found between the epidermal cells and the stabilized procuticle, containing non polymerized precursors of chitin-protein complexes (Coons; Alberti, 1999).

Figure 10 – Histological sections of the integument of semi-engorged *R. sanguineus* s. l. females stained with: (A, D) Hematoxylin-eosin (HE); (B, E) stained with Ponceau Xylidine; (C, F) stained with Toluidine blue. ep = epicuticle; e = epidermis; sb = subcuticle; pr = procuticle

Bars: (A-C) 50 µm; (D-F) 10 µm

According to the literature, the morphology, sublayer division and the cuticle composition may undergo alterations in the different feeding stages (unfed, semi-engorged and fully engorged) and in the different phases of the
biological cycle (larva, nymph and adult); however, such alterations differ among the species. According to Remedio, Nunes, and Camargo-Mathias, (2014), the procuticle sublayer division is not observed in unfed *Rhipicephalus sanguineus* s. l. ticks, while this division is evident in the phase of full engorgement. In *R. (Boophilus) microplus*, the procuticle presents an inner and outer endocuticle during the four days of slow engorgement.

The single epithelium is constituted of cuboidal cells, with round-shaped nuclei, small nucleoli and condensed chromatin (Amosova, 1983; Coons; Alberti, 1999). However, during the feeding process the epithelial cells can undergo morphological alterations. The epithelial cells of *R. sanguineus* s. l. are larger in the stage of full engorgement. However, the opposite occurs in *R. (Boophilus) microplus*, i.e., the epithelial cells are larger in the initial phase of the feeding process (Beadle, 1972; Remedio; Nunes; Camargo-Mathias, 2014). Recent studies have demonstrated that morphological alterations occur when the ectoparasites are exposed to acaricides, confirming that these chemicals can pass through the cuticle and reach the epithelium, causing significant alterations in the cells (Lima-de-Souza et al., 2017).