

Preface

Extracellular Composite Matrices in Arthropods

The book contains comprehensive contributions on extracellular composite matrices in arthropods. The building blocks of such matrices are formed in and secreted by single-layered epithelial cells into exterior domains where their final assembly or transformation takes place. Emphasis is placed largely on insects, due to the extensive body of published research that in part is the result of available whole genome sequences of several model species (in particular *Drosophila melanogaster*) and accessible ESTs for other species. Such advances have facilitated fundamental insights into genomic, proteomic, and molecular-based physiology. The book includes also chapters on noninsect arthropod biocomposites such as the mineralized crustacean cuticles (Chap. 5), spider silks (Chaps. 12 and 13), and salivary gland secretion of ticks (Chap. 17). However, it is appropriate to acknowledge that the book excludes arthropod toxins and venoms that merit a sizable separate volume.

The phylum Arthropoda that arose about 550–600 MYA is the biggest and most diverse in the animal kingdom. Arthropods show a remarkable and insuperable adaptation to survive, colonize, and essentially thrive, in a plethora of aquatic and terrestrial habitats. Basically, the cuticular structures have been pivotal for their successful adaptations to the external environment and thus have been conserved through eons. It is noteworthy that extracellular matrices of arthropods amount to a large inert biomass. The global organic biomass of chitin from insects and crustaceans is regarded as second only to cellulose. The first seven chapters of the book are dedicated to these highly organized and super-complex composite matrices.

The cuticular matrix has been explored from diverse viewpoints, thus providing useful perspectives related to function and biological significance. Different morphologies of external surfaces that affect appearance; various colors that may function for camouflage, recognition, heat absorption, mating, and defense; and mechanical properties such as strength, rigidity, elasticity, or plasticity are

determined by specific chitin-protein interactions and architectural assemblies, degree of protein sclerotization and hydration, or types of proteins.

One example is the pliant resilin with its characteristic amino acid sequences and intermolecular di- and tri-tyrosine cross-linking (Chap. 4). Due to its superlative energy storage efficiency and high fatigue lifetime, resilin is crucial in activities including legged locomotion, flight, jumping, attachment to substrates, and sound production (in cicadas).

The diverse composite assemblies of chitin filament systems and proteins, which form the architectural matrix of skeletal procuticles and peritrophic membranes, dictate their varied functional properties (Chaps. 1, 2, 3 and 8). Basically, the chitin-protein matrix is formed by interactions between a single aminosugar biopolymer (largely the antiparallel α -chitin allomorph) and a large number of highly diverse proteins. Furthermore, cuticular diversity may be amplified by a later intermolecular cross-linking of proteins and different stacking configurations. Nucleophilic reactions, by low molecular weight oxidation products of catecholamine derivatives, stabilize (sclerotize) the proteinaceous exocuticular layer and overall contribute strength and rigidity to the cuticle (Chap. 6). In addition to such cross-linking, the crustacean chitin-protein layers are primarily rigidified by calcification (Chap. 5).

Cuticular hydrocarbons and lipids are integral parts of the epicuticular layer where their hydrophobic nature functions as waterproofing components. It is reasonable to perceive that involvement of cuticular hydrocarbons has been essential to solve ecophysiological constraints during the transition of arthropods from aquatic to terrestrial habitats. Existing on or near the cuticle surface, volatile hydrocarbons have also evolved to serve in defense, reproduction, and communication (Chap. 7). In the context of waterproofing, eggs of oviparous insects, which normally face the major problem of desiccation, are protected by certain waterproofing chorionic layers. Moreover, the embryonic layer of serosal cuticle is paramount in protecting developing embryos from dehydration (Chap. 9).

The dynamic spatial and temporal events that accompany synthesis (and degradation) of the cuticular complex structure are comprehensively covered in chapters dealing with the integumental matrices (Chaps. 1, 2 and 3). It includes specific genes and the interplay of genes, specific structural proteins and enzymes that are involved *inter alia* in biosynthesis, and degradation of the cuticular matrix. In addition, intercalation of low molecular weight components essential for waterproofing (like hydrocarbons) or quinone-based compounds that are used as stabilizing elements (sclerotization, melanization) or as pigments are included. Colors of cuticles are varied, depending on insect species and in anatomical regions of the same species. Pigmentation/melanization also plays important roles in wound healing and encapsulation of invading parasites (Chap. 6).

The dynamic events and sequential assembly of cuticular layers as well as the secretions of enzymes and low molecular weight component are cued and synchronized by sets of hormonally regulated genes (Chaps. 1, 2, 3, 4, 5, 6 and 7).

The eggshell structural complex shares many similarities to the cuticular matrix. It is largely an organized multilayered composite structure assembled according to

an idiosyncratic spatial and temporal program (Chap. 9). The largely proteinaceous layers of eggshells are secreted by sets of monolayered follicular cells inherently equipped with a predetermined genetic plan for the complex structural design. Chorionic eggshells provide protection against desiccation and/or flooding and against predation or invasion of pathogenic microorganisms, as well as resistance to mechanical stresses or temperature fluctuations. Several eggshell chorionic layers are stabilized by intermolecular cross-linking such as disulfide bridges, di- and tri-tyrosine bonds, and quinone-based sclerotization.

Silks, which are biopolymeric composite natural fibrous materials spun from protein secretions, occur in various lepidopterans, hymenopterans, beetles, flies, thrips, lacewings, spiders, and acari. Another part of the book (Chaps. 12, 13 and 14) is limited to glandular secretions of silk moths and spiders. Spiders, for example, produce different types of fibers with remarkable properties, compositions, and morphologies that serve various functions like locomotion, signaling the presence of caught prey, web construction, wrapping pray, or creation of cases for protecting developing eggs. The cocoon silk of *Bombyx mori* (the only domesticated arthropod), which is known for over 5000 years, has been commercialized into valuable textiles.

A cluster of three Chaps. (15, 16 and 17) is dedicated to saliva which is water or oily oral secretions of mostly labial salivary glands. Its various functions include lubrication of mouthparts, predigestion and digestion of plant materials, water balance, and antimicrobial and antipredator actions as well as in host-vector interactions. Saliva of plant sap feeders plays a role in transmitting viral and protozoan pathogens. The pharmacologically active saliva of hematophagous arthropods blocks host antibleeding defense, serves as an analgesic in tick bites, and affects inflammatory and immune systems of vertebrate hosts, in addition to transmitting debilitating pathogens.

The *Drosophila* salivary glands are well known for the exocrine secretion of a glue material that attaches their puparia to the substrate (Chap. 15). Additionally, this chapter deals with apocrine secretion of salivary gland cells where they lose part of their cytoplasm into the lumen. In contrast to the exocrine glue proteins, a large number of cytoskeletal, cytosolic, mitochondrial, ribosomal, and Golgi apparatus components are released and exposed to the exterior.

Chapter 11 is dedicated to *Drosophila melanogaster* female and male secretory products of accessory glands that play critical roles in fertility and overall reproduction. It involves the complicated network of interactions of the multiple secreted components that target multiple receptors which are involved in preparation for mating, during mating, and through postmating events.

A number of Chaps. (4, 5, 12, 13 and 14) cover commercially applicative aspects related to extracellular matrices. There is a worldwide market for chitin, its deacetylated form chitosan, and for their chemical modifications. Such products are biodegradable, biocompatible, and nontoxic with a large range of useful applications in the textile and pharmaceutical industries, in agriculture, water treatment, cosmetics, food, and photography products.

Blocking chitin synthesis by commercial acylurea insecticides or inhibition of acarine chitin synthase by the acaricide etoxazole indicates the applicative value of

chitin as target in pest control. The physiologically essential processes of chitin synthesis and degradation have been regarded as useful selective targets for interference, and their potent inhibitors were subjected to further scrutiny of successful lead compounds in the hope of developing commercial pharmaceuticals and pest control agents (Chap. 10).

Genes of cuticular protein and chitin synthesis and degradation, which are expressed at transition stages, are regulated by growth hormones. Interfering juvenile hormone analogs and juvenile hormone mimetics, as well as ecdysterone agonists, were developed and commercialized as highly successful insecticides.

Natural biocomposites like crustacean mineralized cuticle, the pliant resilin, or the insect and spider silks have generated much interest and have inspired basic and applied research that yield sophisticated functional biomimetics, biomaterials, and structural hybrids. The rigid calcified crustacean cuticle stimulated development of organic/inorganic hybrid materials and motivated the use of synthetic polymer templates that generated ceramic and fiber-reinforced composites. Resilin with its outstanding elasticity, energy storage, resilience, and high fatigue lifetime has opened avenues for various polymer designs leading to potential applications for biorubbers, biosensors, and biomedical scaffolds. Spider silks, which have unique mechanical properties in terms of strength, extensibility, and toughness, offer exciting opportunities for the design of biomaterials for tailor-made applications in medicine, engineering, and defense.

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