The peritrophic matrix

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4.1 INTRODUCTION

Two historical motivations for the study of insects involves their competition with human beings for the same food supply and their influence on human health. The insect midgut has pivotal roles in both of these aspects of the relationship between humans and insects (see also Chapters 6–8 and 16). In particular, the functions of the peritrophic matrix (PM) which lines the gut of most insects, is intimately associated with the digestive process in insects and the cycle of invasion and transmission of many insect-borne pathogens. Despite its central importance in these events, there is relatively little known of the detailed molecular structure and functions of the PM. In part, this deficiency is caused by the wide variety of insect PM structures and the multiple functions of this matrix. Because of this variety, it is impractical to comprehensively describe all PM structures. Rather, examples will be cited which illustrate general aspects of the PM structure, recent advances in the understanding of its molecular structure and unifying concepts relating to the functions of this matrix.

4.1.1 Definition of peritrophic matrix

First observed last century in insects, the PM was described as a ‘membranous sac which directly surrounds the food in the lumen of the intestine’ (Balbiani, 1890). Since then the name has also included any
membranous layer which lines the insect gut (e.g. Figure 4.1). Peters (1992) emphasized the point that most insect midguts contain a number of discrete PMs and suggested that these membranes collectively should be called a peritrophic envelope. There has been criticism of the term peritrophic membrane because of the inference that it is related to the cytoplasmic membrane of cells whereas the PM is acellular being principally composed of chitin, glycosaminoglycans and proteins. Consequently, the term peritrophic matrix is used here. Richards and Richards (1977) listed a number of features which are indicative of a PM:

1. a positive test for chitin;
2. a membrane(s) forming a tube or sac around ingested food and capable of being physically separated from the rest of the gut;
3. a line separating the food from the digestive epithelia in histological sections;
4. any recognizable layer around the food;
5. any membranous or filamentous secretion of midgut cells whether or not it is concerned with food.

Peters (1992) has remarked on the great variety of PM types and their lack of absolute conformity to these characteristics. The semipermeable nature of the matrix may be a common functional characteristic which could be added to the above list. In most cases, the original description given by Balbiani (1890) is adequate with the provision that the PM may have evolved to include many divergent structures and functions.

4.1.2 Species range

Although the PM is often thought to be only associated with insects, Peters (1992) in a comprehensive review, described the presence of PM-like structures in many arthropod classes as well as several other phyla. He also noted the presence of a mucoid-type layer in the gut of many animals including vertebrates and suggested that this layer may be functionally analogous to a PM. The majority of the Insecta contain PMs, at least at some stage of their life cycle. There is a minority of insects which do not contain a PM in any of their life stages, e.g., some lice species (Phthiraptera) (Waterhouse, 1953a; Peters, 1992). The PM is developmentally expressed in different life stages of many insects. For example, the adult flea (Siphonaptera) does not contain a PM whereas its larval stage does (Peters, 1992). The structural form and number of PMs can also be very different between the various life stages of the same insect. Some PMs are continually expressed whereas others are induced by the ingestion of a meal. One of the best examples of the latter is the production of PMs in adult female mosquitoes which occurs after ingestion of a blood meal. Consequently, the establishment of the