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# Peritrophic Envelope: A Non-Cellular Envelope of Midgut in Insects

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## Abstract

There is a fluid film surrounding the food bolus in most insects which is known as peritrophic envelope. The peritrophic envelope is composed of chitin and proteins, of which peritrophins proteins are the most important composition. Since peritrophic envelope is differentiated into two compartments in the midgut, which adds new physiological roles. These new roles are observed on envelope permeability and on enzyme compartmentalization, fluid fluxes, and ultrastructure of the midgut. Insects lacking peritrophic envelope have a special structure called perimicrovillar membrane. Moreover the function of peritrophic envelope provides barrier against various pathogens in other way it can be called that it provides immunity to various viral diseases too.

## Introduction

The midgut of most insects is differentiated from the main volume of the gut lumen by a non-cellular structure called the peritrophic envelope otherwise called the peritrophic layer or peritrophic membrane. It generally comprises a proteoglycan gel on a framework of chitin microfibrils. The chitin chains in the peritrophic envelope are mostly α-chitin, which comprises antiparallel microfibrils and is aggregated into larger bundles that confer considerable tensile strength. The protein associated with the envelope is known as peritrophins which have chitin-binding domains and six, eight or ten cysteine residues that form disulfide bridges, creating a binding pocket in which hydrophobic residues from hydrogen bind with the chitin microfibrils. Some peritrophins are broadly glycosylated, with the sugar representing up to half of the absolute sub-atomic mass. These proteins are called invertebrate intestinal mucins (IIMs).

Peritrophic envelopes are apparently not produced by some insects. They are absent from adult mosquitoes, except after a blood meal ingested by females, and unknown among nectar-feeding adult Lepidoptera, some adult ants (Hymenoptera), lice (Pthiraptera), book lice (Psocoptera), Zoraptera, Raphidoptera, Megaloptera, adult fleas (Siphonaptera), and Bruchid beetles (Peters, 1992). Exceptionally among insects, the Hemiptera and Thysanoptera lack peritrophic envelope but posses, instead a lipoprotein layer called the perimicrovillar membrane, which lies external to the midgut cells. In most hemipterans, the perimicrovillar film structures complex folds, so showing up as different layers in cross area, and expand both into the gut lumen and between individual microvilli of the midgut cells. In aphids it is joined to the zenith of midgut cells by structures like septate intersections. It is believed to be derived from membrane synthesized in the Golgi vesicles of midgut cells. In all species tested, the perimicrovillar membrane bears α-glucosidase activity.

## Types of Peritrophic Membrane

***Type I***

It is present in Coleoptera, Blattodea, Ephemeroptera, Hymenoptera, Odonata, Orthoptera, Phasmida, larval Lepidoptera and adult Diptera. It is produced by the whole gut epithelium or by only a part of it (anterior or posterior regions) in patches that join together. Peritrophic envelope is produced by the whole midgut or anterior midgut epithelium envelops the food along the whole midgut. Sometime it is observed that peritrophic envelope is produced only by the posterior part and the anterior midgut epithelium which is usually covered with a viscous material which can be called as the peritrophic gel and it is observed in carabid beetles and bees. This gel is also observed in the anterior part of midgut caeca in some insects and along the whole midgut of others. Peritrophic gel differs from peritrophic envelope in two important aspects: lack of mechanical resistance and permeability properties.It is observed that in some species the microfibrils which form the laminae are assembled at the bases of the microvilli forming a template for the developing grid of chitin microfibrils, and the whole process is known as delamination. Type I peritrophic envelope may be synthesized only after food ingestion, without affecting digestion efficiency, because this envelope may be formed quickly due to the cooperation of a large number of cells.

***Type II***

It is found in Dermaptera, Isoptera, some Lepidoptera and larval Diptera. It is secreted by a few rows of cells at the entrance of the midgut (cardia). In larvae of the mosquito, *Aedes*, the most anterior 8-10 rings of cells in the midgut epithelium produce the entire peritrophic envelope, which comprises a single lamina with outer and inner granular layers bounding the chitin microfibrils.

## Functions of Peritrophic Envelope

- The peritrophic envelope acts as a barrier, separating the midgut cells from the ingested food. In this way it protects the gut wall from the damage by Ingested food material, including abrasive food particles, pathogens and certain toxins.
- The peritrophic envelope is permeable to inorganic ions, small organic molecules (sugars, amino acids, etc.), peptides and small proteins, but is an effective barrier to the passage of lipids, large proteins and polysaccharides.
- Chemical protection is seen in different phytophagous insects, including *Schistocerca* locusts and some larval Lepidoptera, in which the peritrophic envelope shapes a barrier against tannins.
- The peritrophic envelope also protects against many potential microbial pathogens. For instance, young honey bee larva, in which the envelope is not yet developed, are highly susceptible to American foulbrood- a disease caused by *Paenobacillus larvae* but older larvae are resistant, halfway in light of the fact that the microscopic organisms are limited by very much created peritrophic envelope, forestalling their admittance to the midgut epithelium.
- It is also illustrated by an experiment that the peritrophic envelope is eliminating the calcofluor, an inhibitor of chitin synthetase.

## Functions of Peritrophic Envelope Other Than Gastrointestinal Mucous

***Primary Functions:*** those probably evolved under selective pressures. It is present in all orders of class Insecta.

- Prevention of non-specific binding onto cell surface.
- Prevention of discharge by permitting enzyme recycling.
- Removal of oligomeric molecules from inside Peritrophic envelope.

***Panorpoidea (Diptera and Lepidoptera)***

- Limitation of oligomer hydrolases to ectoperitrophic space.
- Production of monomer restricting to cell surface.

***Secondary functions:*** These are consequences of the chemical properties of peritrophic envelope components.

- Enzyme immobilization
- Toxin binding

***Compartmentalization of Peritrophic Envelope***

- Endo-peritrophic space which is present between the peritrophic envelope and the midgut cells. It is the space where the food is located.
- Ecto-peritrophic space which is present in the gut lumen.

Compartmentalization of enzyme exercises and a generation of a countercurrent allow the progression of liquids that increases the effectiveness of absorption.

***Synthesis and Secretion***

The secretion of peritrophic envelope consists of six steps:

- Synthesis by ribosomes on rough endoplasmic reticulum (ER).
- Segregation of the product into cisternae of the ER.
- Intracellular transport to Golgi areas.
- Concentration in vesicles associated with the Golgi.
- Intracellular storage in secretory granules or vacuoles that get moved to the cell surface.
- Discharge through the surface.

## Permeability of Peritrophic Envelope

The capacity of the peritrophic envelope to compartmentalize the luminal digestive enzymes depends on its permeability. Pore sizes of the peritrophic envelope may be determined by comparing molecular weights of enzymes restricted to the ectoperitrophic fluid (e.g., luminal aminopeptidase) with those of enzymes present in the endoperitrophic space (e.g., trypsin and amylase). Amylase and trypsin, known to occur in major amounts inside peritrophic envelope (activities in peritrophic envelope contents are about 70% of activities in midgut homogenates, have specific activities in peritrophic envelope substance higher or equivalent to explicit activities in ectoperitrophic fluid. Peritrophic envelope may have a huge scope of pore measures: some small or very large and greater part of them in the middle range. Enzymes bigger than the determined pore sizes may periodically be found inside peritrophic envelope, yet in non-huge sums. In this manner, the referenced pores are those answerable for keeping up various sorts of digestive enzymes inside and outside peritrophic envelope. Pore sizes were likewise decided utilizing changed atoms of known sub-atomic loads with various strategies. The majority of the information concur with those acquired from protein circulation considers. Pore sizes of 300–800 nm are surprisingly large and may be due do damage of peritrophic envelope. The chitin-peritrophin matrix of peritrophic envelope may be responsible for the strength and elasticity of this membrane, in addition to the role in defining its permeability. In accordance with this hypothesis, inhibition of protein synthesis resulted in disturbed formation of peritrophic envelope, whereas inhibition of chitin synthesis resulted in a pronounced enhancement of permeability (Zimmermann and Peters, 1987) during its manipulation.

## Functional Effects of Peritrophic Envelope Absence or Modification

Calcofluor inhibits the formation of chitin containing microfibrils by binding the polysaccharide (Maeda and Ishida, 1967). It enhances the permeability of peritrophic envelope when injected into Dipteran species and in Lepidoptera it increases the baculovirus infection. In larvae of moth *Trichoplusia ni* it is observed that peritrophic envelope is inhibited and there is high larval mortality when fed with calcoflour. Mosquito which lacks peritrophic envelope are digesting the blood meal. It is also proven that lack of peritrophic envelope have no effect on quantitative nutritional parameters (digestibility, efficiency of conversion of food into body mass and growth rate).

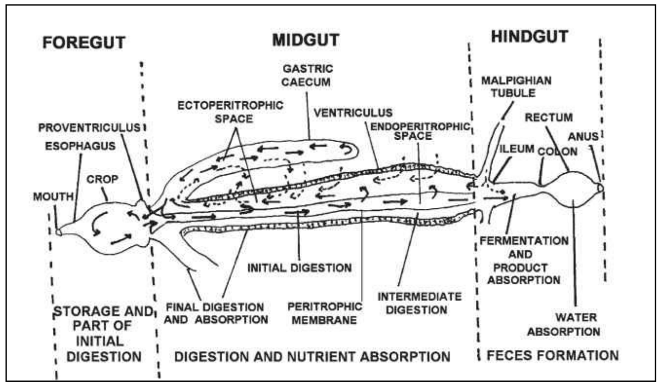


Figure 1: Foregut, Midgut & Hindgut (Source: sciencedirect.com)

## Conclusion

Peritrophic envelope in insects is like a physical immunity to various disease causing pathogen. This structural variation present in insect midgut not only protect from pathogen but also from the mechanical damage by the ingested food by phytophagous insects. The permeability of the envelope determines the type of particles to be absorbed. So it can be concluded by saying that this non cellular layer which present in the insect midgut plays a very important role in digestion point of view. In pest management point of view it determines the size of the toxins should be made so that it can enters into the gut epithelium and cause lysis of cell.

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