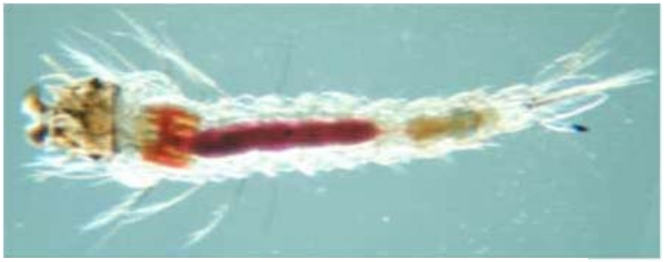
Alimentary Canal

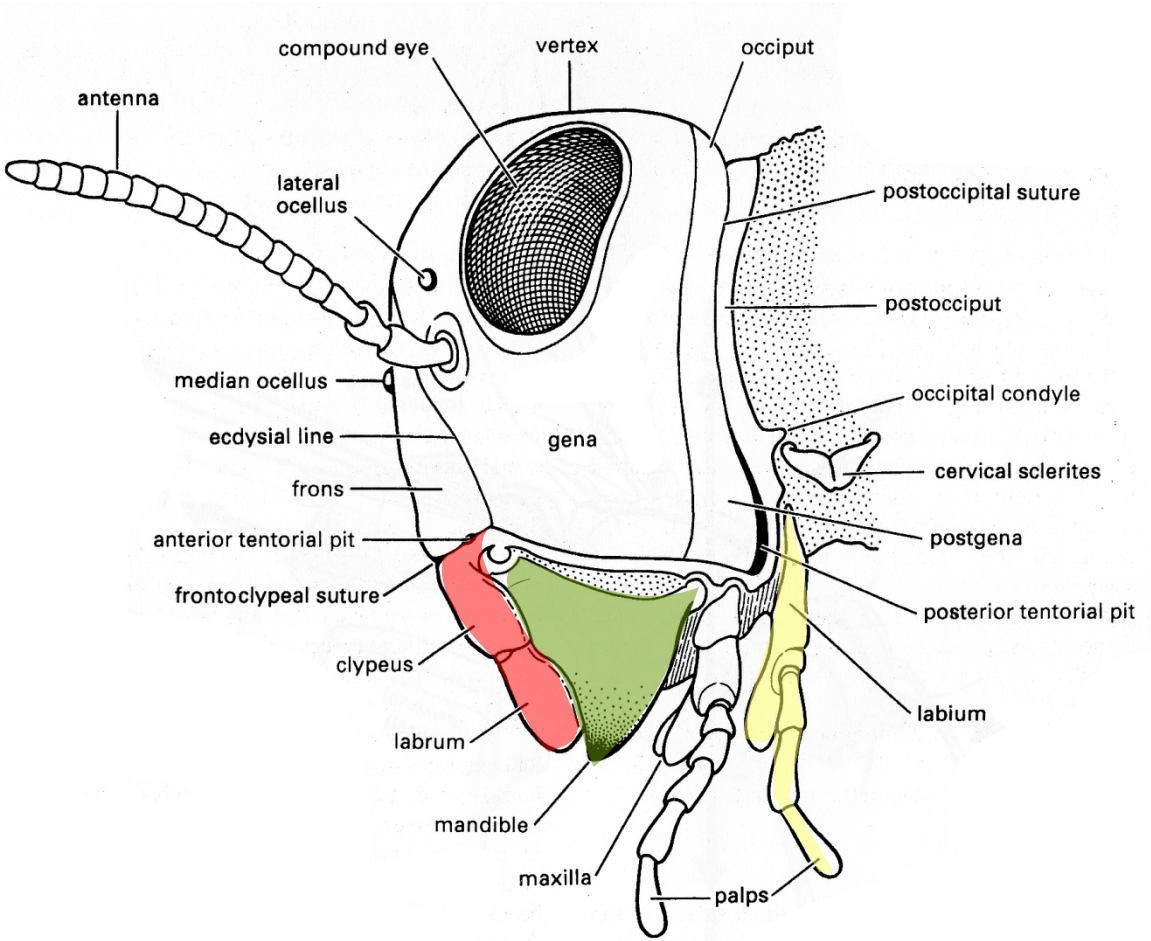


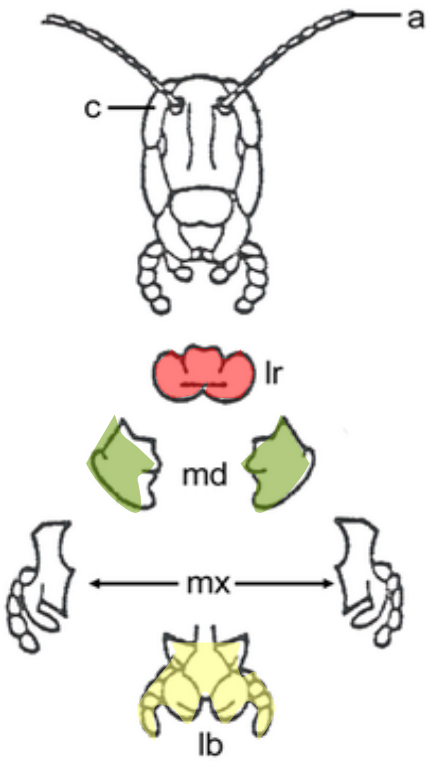
Alimentary canal

Digestive system

Function and associated modifications to
- Mouthparts*
- Digestive tract
- Excretory system*

Head side view





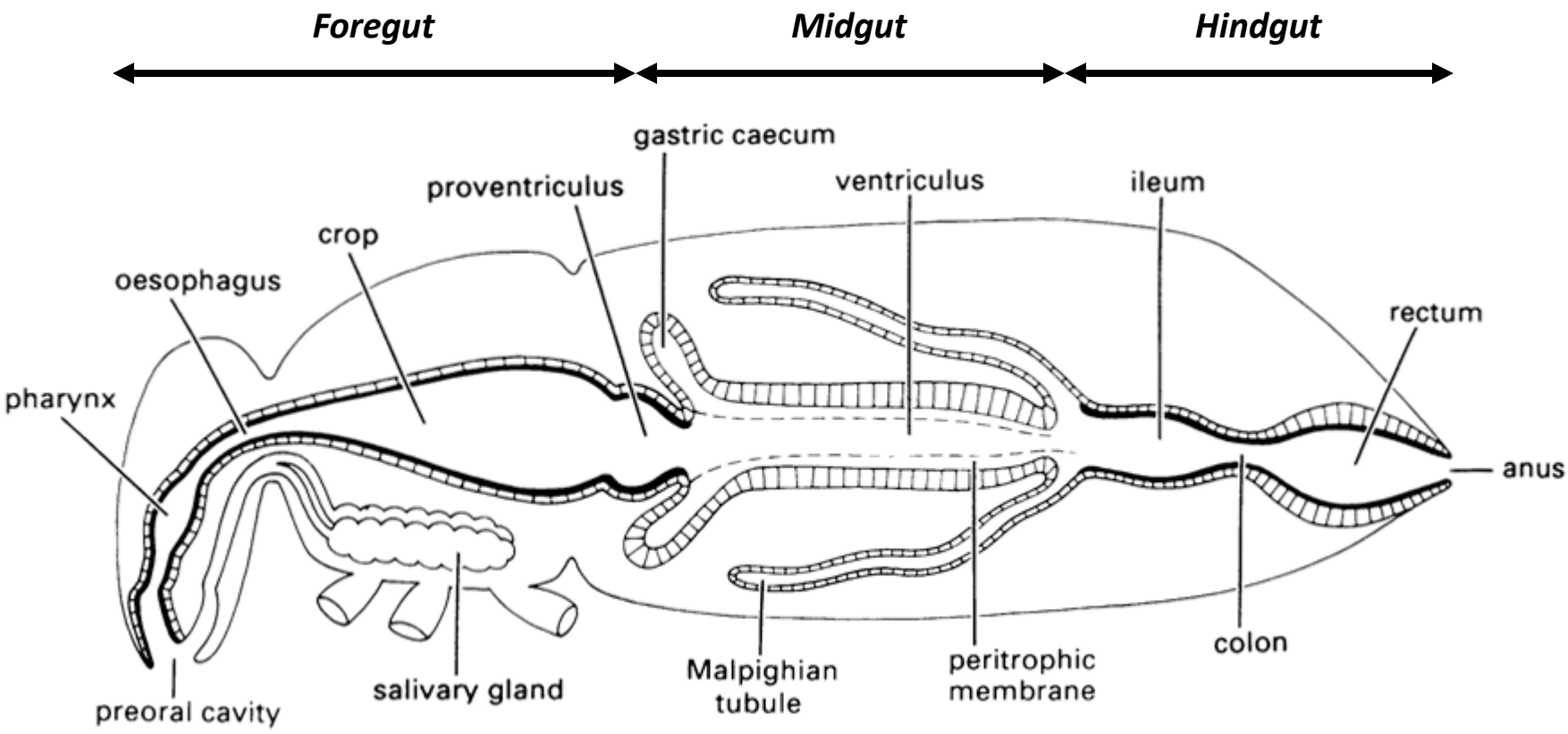
labrum

mandibles

maxillae

labium

Gullan and Cranston, 2005



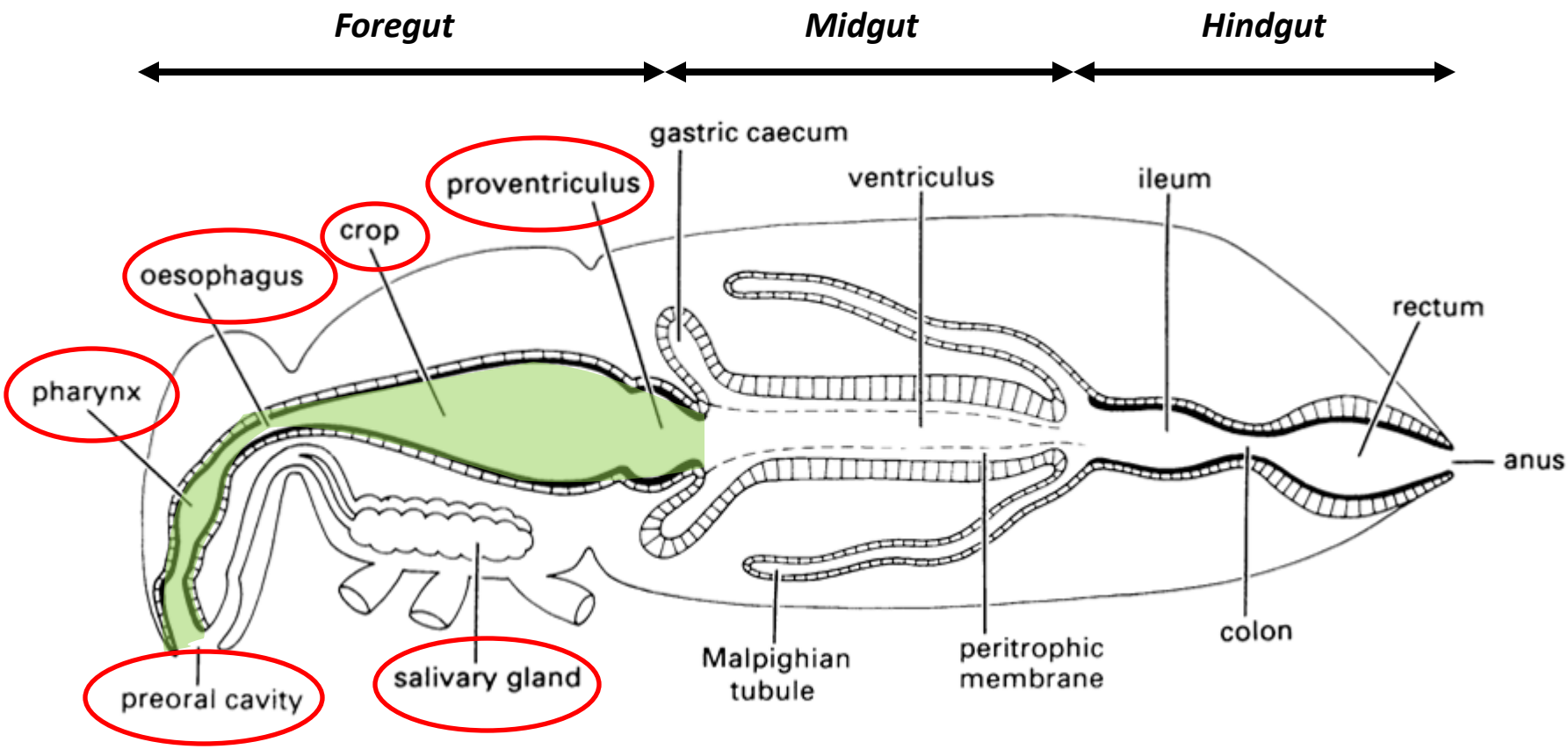
After Dow 1986; Adv. Insect Physiol. 19:187-328

Partitioning gut function

- Foregut
  - Ingestion, storage and digestion
- Midgut
  - Digestion and absorption
- Hindgut
  - Excretion and osmoregulation

[Gut epithelium one cell layer thick]

Foregut

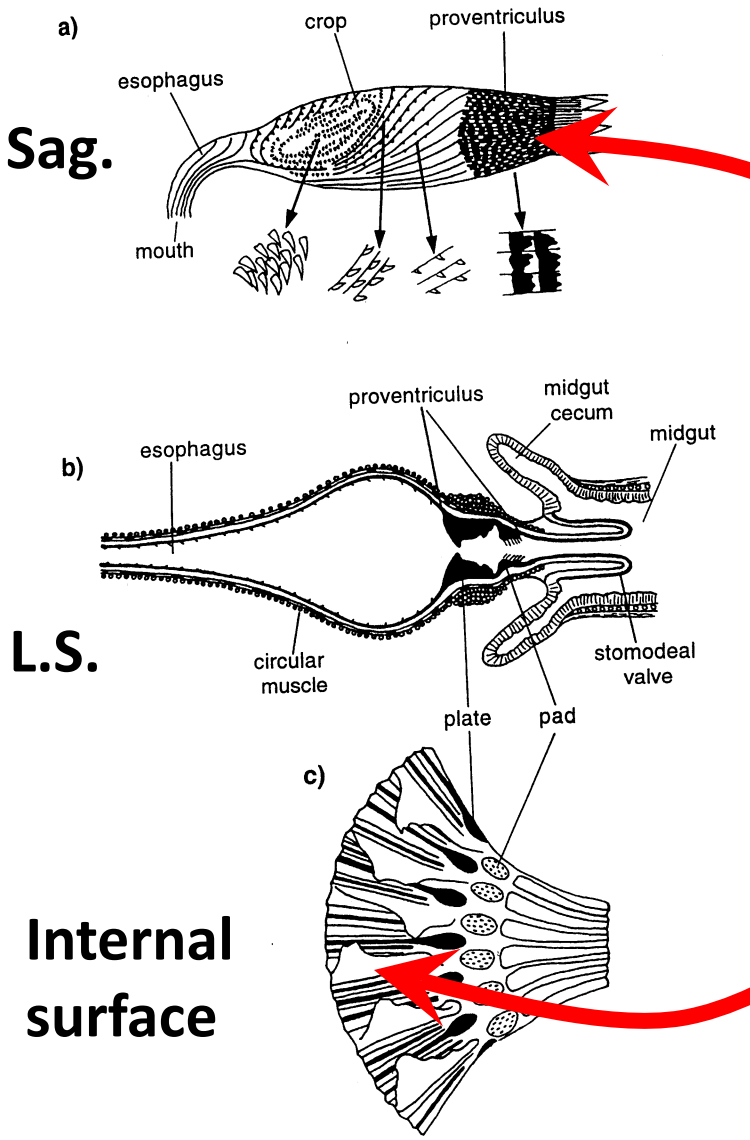


After Dow 1986; Adv. Insect Physiol. 19:187-328

Foregut

- Ingestion, storage and digestion
- Lined with cuticle
  - generally unsclerotised although many bear spines
  - varies in different regions
- Some permeability (e.g. fatty acids for cockroaches)
- Salivary glands – digestive enzyme secretion (mostly amylase, proteases, chitinases in carnivores), blood-feeders produce anticoagualants and modified to produce silk in some lepidopterans

Foregut morphology



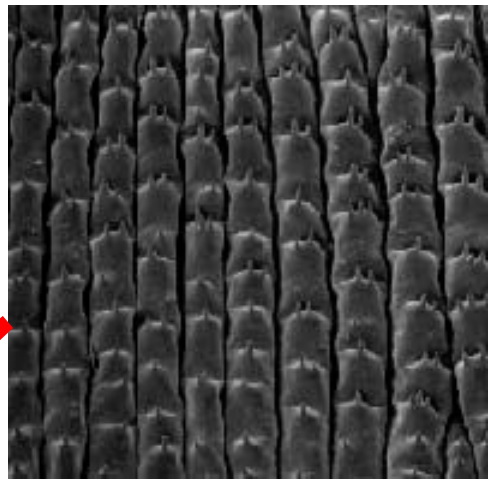
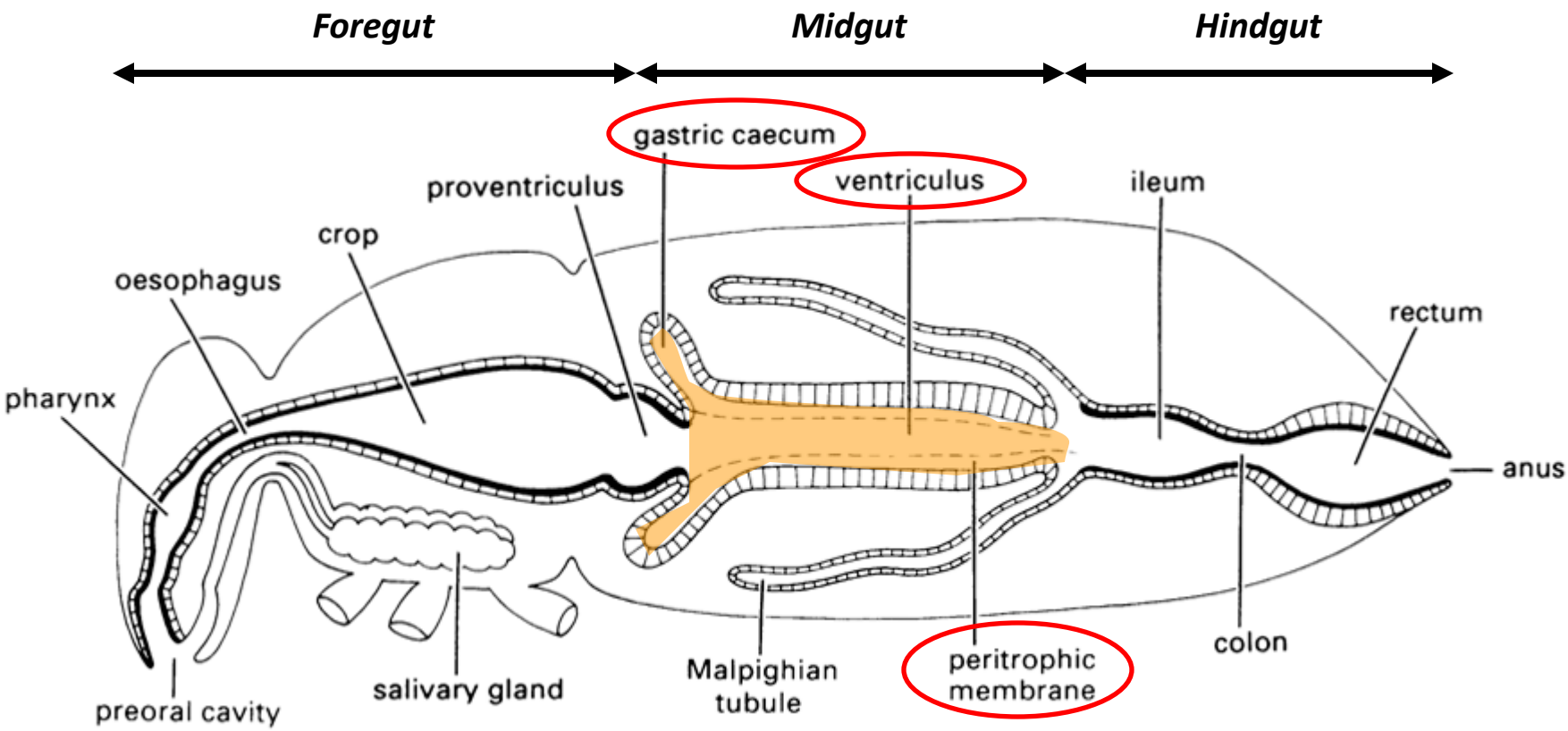


Fig. 3.2. Foregut armature. **(a)** Sagittal section through the foregut of a locust showing the pattern of cuticular spines on the intima. Enlargements show details of the spines. In the proventriculus, the spines are replaced by larger sclerotized plates with backwardly directed teeth at the posterior edges (after Williams, 1954). **(b)** Longitudinal section of the foregut of *Periplaneta* showing the development of the proventriculus to form a grinding apparatus (after Snodgrass, 1935). **(c)** Proventriculus of a cockroach slit open and laid flat showing the hexaradial symmetry (after Miller and Fisk, 1971).

Chapman 1998, Fig 3.2 & Hochuli et al. 1992

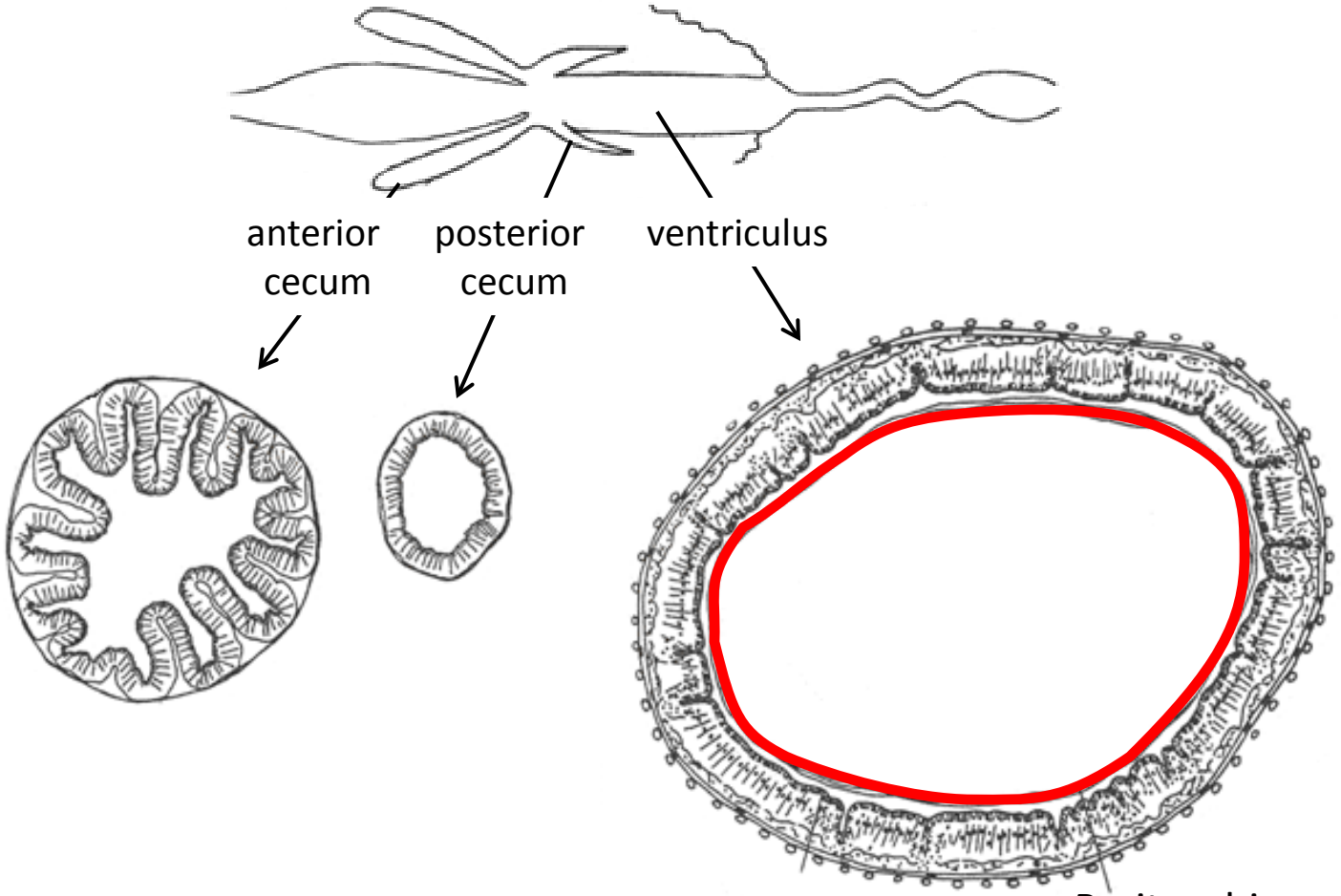
Midgut



After Dow 1986; Adv. Insect Physiol. 19:187-328

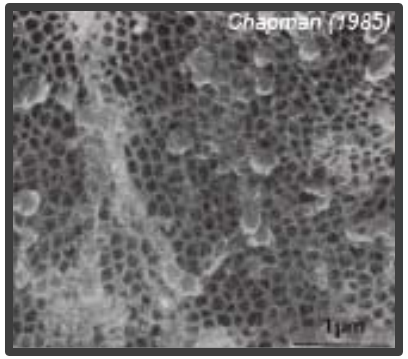
Midgut

- Digestion and absorption
- No cuticular lining
- Production and secretion of digestive enzymes
- Cell types
  - Columnar cells, absorption of digestion products and secretion of enzymes
  - Regenerative cells, grow new cells
  - Goblet cells, control fluid exchange between gut lumen and haemocoel, contains proton pumps
- Absorption – increased surface area by microvilli mostly in caeca
- Midgut epithilium and food separated by a thin sheath – Peritrophic membrane



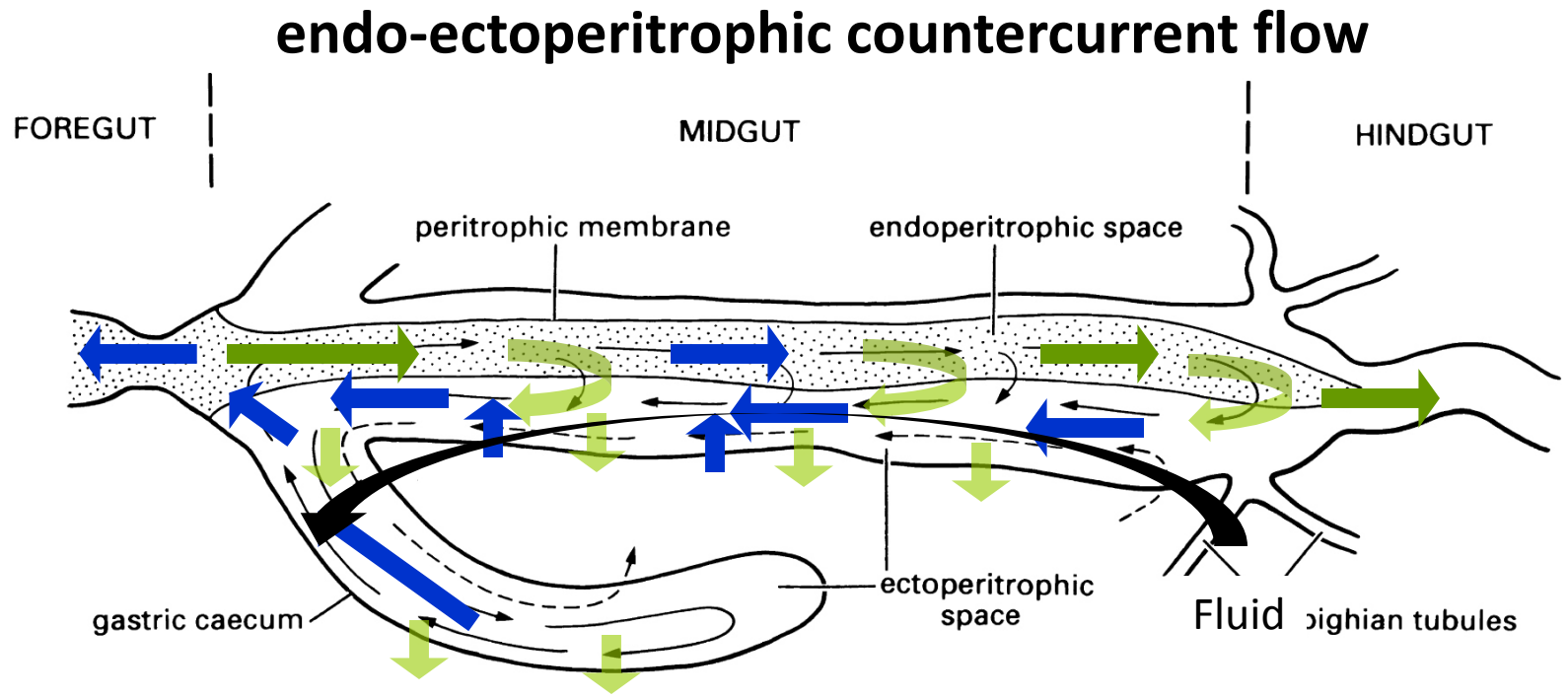
Chapman 1988

Peritrophic membrane



- Separates midgut epithelium from food
- Formed from
  - Chitin, proteins and glycoproteins
- Two types (based on mode of secretion)
  - Related to diet – robust in herbivores, lost in hemipterans and hompterans
- Functions
  - Efficient high flux sieve - pores allow passage of small molecules, restrict large molecules
  - Barrier
    - Mechanical protection from food
    - Chemical protection from allelochemicals
    - Barrier to infection from pathogens, viruses, bacteria, parasites
  - Compartmentalization of the midgut lumen
    - countercurrent fluid fluxes – **endo-ectoperitrophic countercurrent flow** that increases enzyme efficiency and decreases enzyme excretion(recycling)

Peritrophic membrane

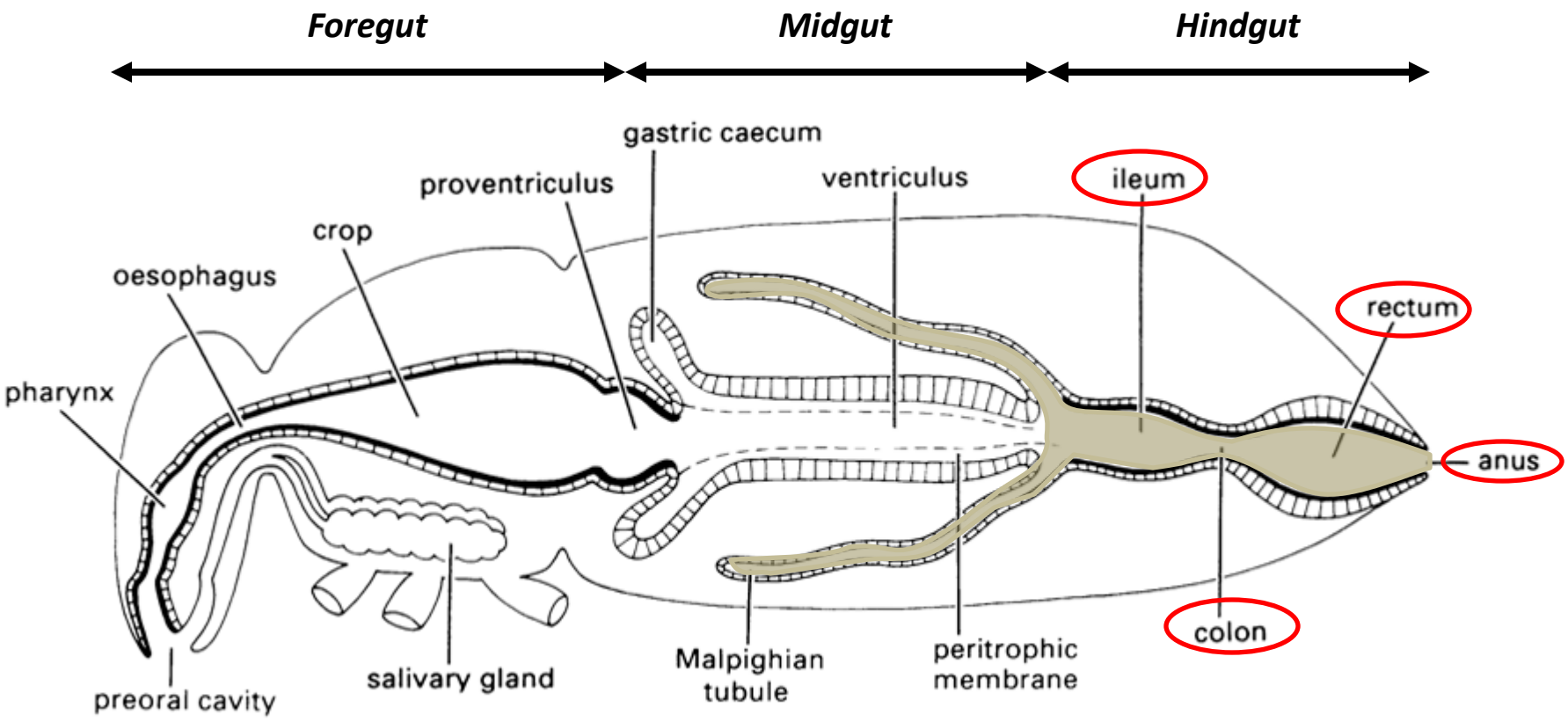


Increase digestive efficiency

- Conserve nutrients and enzymes and reuse enzymes that may be lost due to rapid passage through the midgut
- Allow absorption of digested products along the entire length of the midgut and in the caeca

Gullan and Cranston, 2005

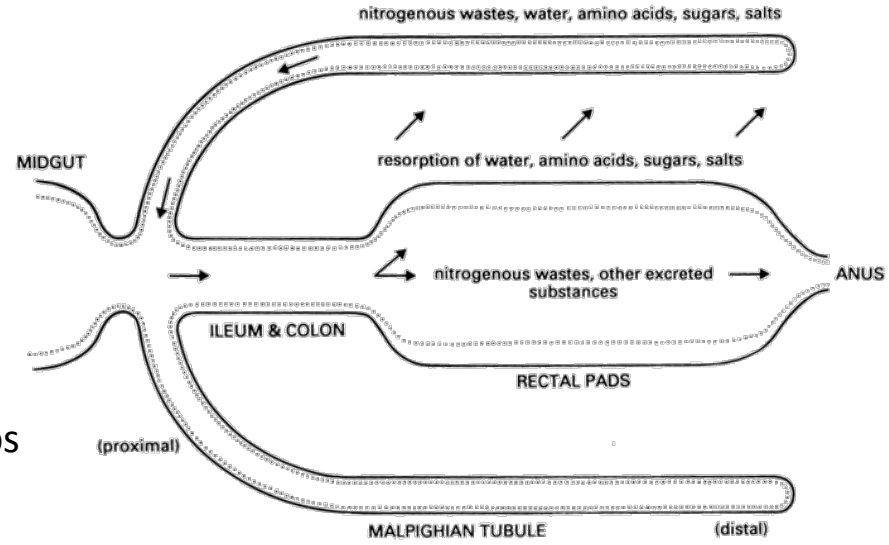
Hindgut

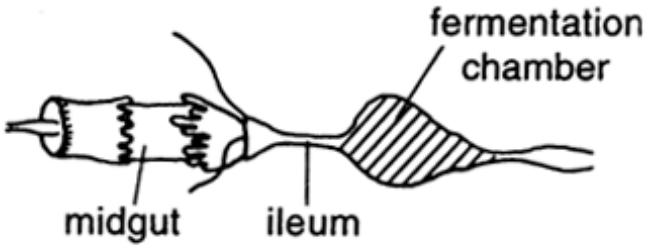


After Dow 1986; Adv. Insect Physiol. 19:187-328

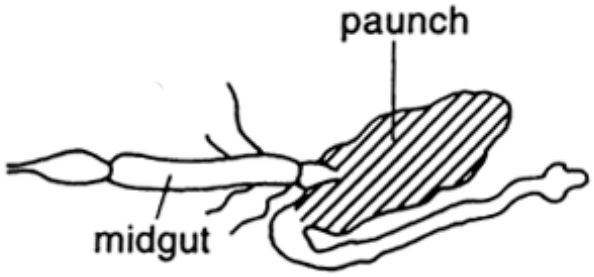
Hindgut

- Excretion and osmoregulation
- Malpighian tubules form junction
- Lined with cuticle
  - Highly permeable
- Modified to assist nutrition
  - e.g. symbionts in termites and scarabs





Scarab larva – bacteria to digest cellulose



Termite – protists to digest cellulose

Chapman, 1998; Gullan and Cranston, 2005

Malpighain tubules

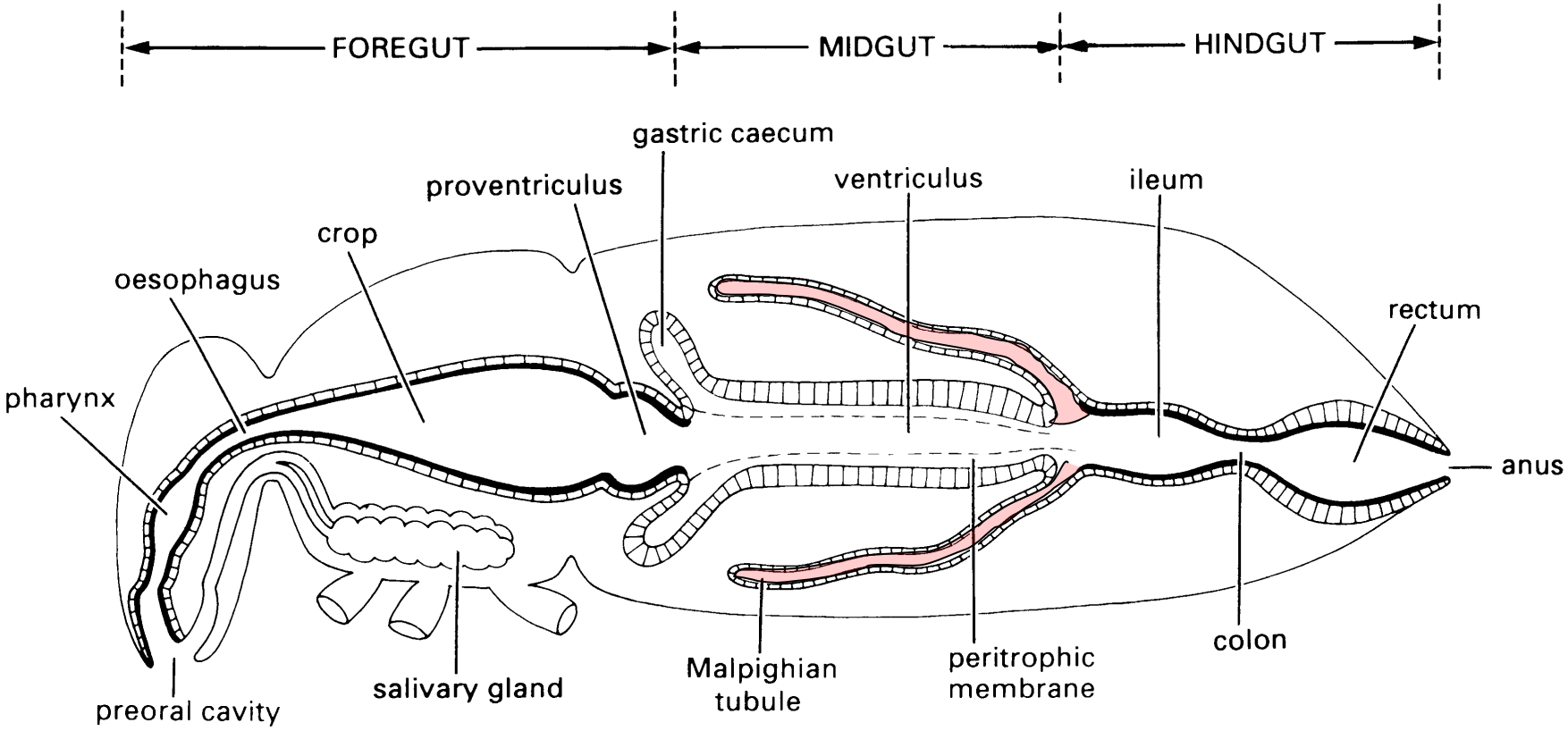


Fig. 3.13 Generalized insect alimentary canal showing division into three regions. The cuticular lining of the foregut and hindgut are indicated by thicker black lines. (After Dow, 1986.)

Gullan and Cranston, 2005

Malpighain tubules

- Produce a filtrate ionically dissimilar to haemolymph
- Active transport of ions generated osmotic pressure gradient and water passively follows (as do sugars and most amino acids)
- Hindgut selectively resorbs water, sugars and certain solutes but eliminates others
- Continuous secretory activity of each MT leads to flow of primary urine from its lumen into the gut

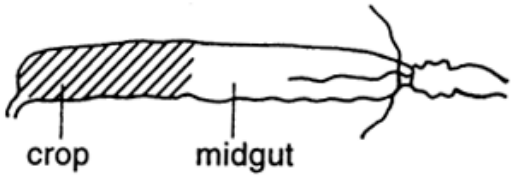
Gut morphology

- *Solid feeder*: wide, straight, short gut, strong musculature & protection from abrasion

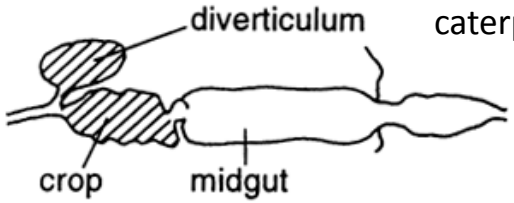
- *Liquid feeder*: long, narrow, convoluted gut, less musculature & protection

Solid feeder

caterpillar

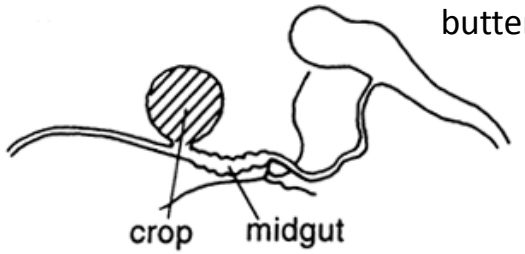


caterpillar-*Myrascia*

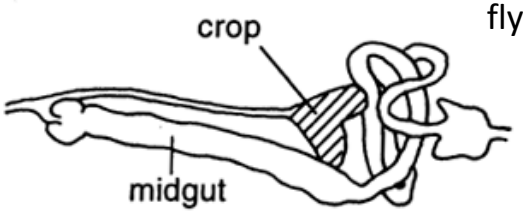


Liquid feeder

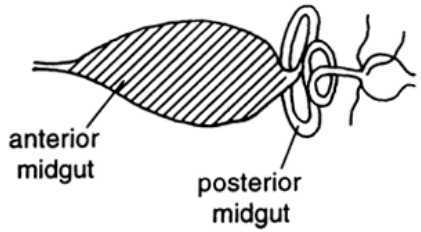
butterfly



fly



Bug - *Rhodnius*

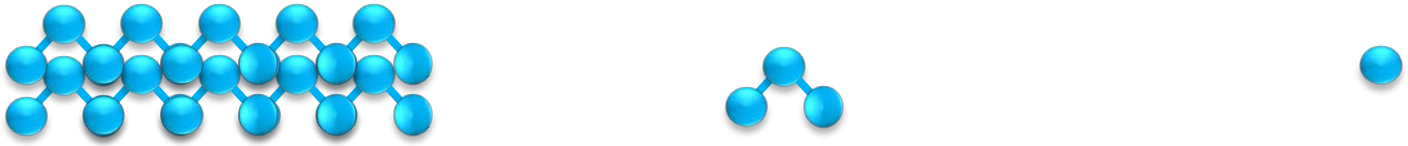


Chapman 1998

Digestion

large molecules ⟹ small molecules

Proteins —(Chymotrypsin, Trypsin)→ polypeptides —(Aminopeptidases, Carboxypeptidases)→ amino acids



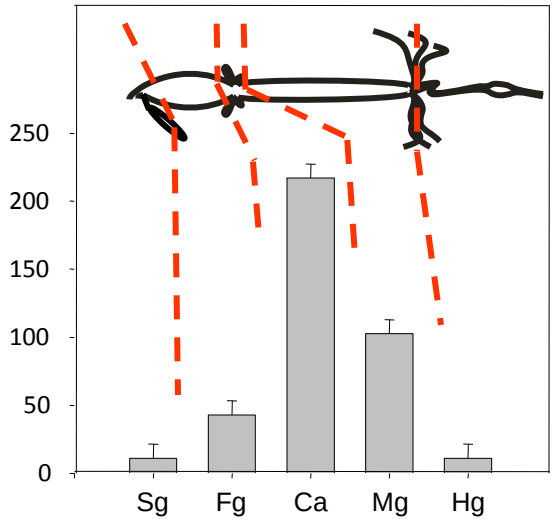
Starch —(Amylase)→ disaccharides, oligosacchirides —(Glucosidases)→ sugar monomers

Triacylglycerols —(Lipases)→ Fatty acids & glycerol

Tissues

All enzymes except amylase

Caeca > midgut > foregut > hindgut = salivary glands

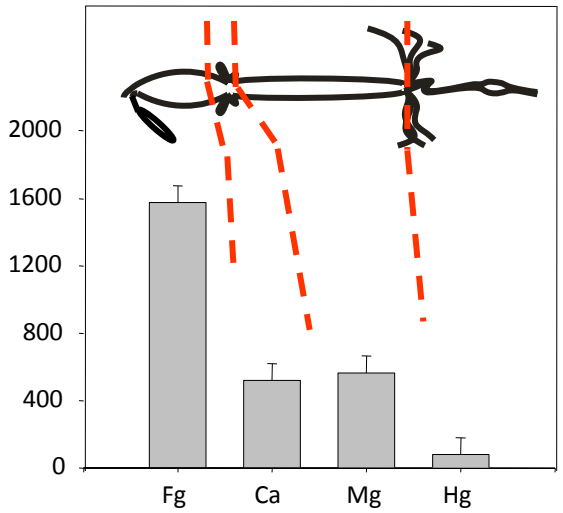


Tissues

Contents

All enzymes

foregut > cacea = midgut > hindgut



Contents

Clissold et al. 2010

Absorption – midgut

Products of digestion

Organic compounds

- Amino acids
- Simple sugars
- Fatty acids/glycerol

Inorganic compounds

- Sodium
- Potassium
- Chloride

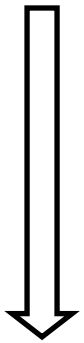
Water

Very important

Concentrates food which

- improves digestion efficiency
- And maintains concentration gradients for absorption

Gut lumen



Hemocoel

Passive - diffusion from higher to lower concentration

e.g. K^+, Cl^-, sugars, fatty acids & glycerol, cholesterol, lipid soluble vitamins, water

- carrier-facilitated transport (pinocytosis or phagocytosis)

Active - proton pump (move compounds against a concentration gradient). Pumps H^+ ions into the gut and protons exchanged for potassium.

e.g. sugars, amino acids, Mg^{2+}, Ca^{2+}, Na^+

Absorption

Depends on

- Permeability of the intestinal epithelium
- pH
- Temperature
- Relative concentrations of nutrients, e.g. Ca and Mg compete for same ion pump

Summary

The structure of the alimentary canal

- specialization of the three regions
- role of the peritrophic membrane

The process of digestion and absorption

Further reading

Chapman, 1998; Ch 3

Klowden, 2007; Ch 6

Nation, 2008; Ch 2

References

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