Nutrition, Digestion, Excretion

- Nutritional Ecology
  - Essential nutrients
- The Digestive System
- The Excretory System

What nutrients are essential for insects?

Water

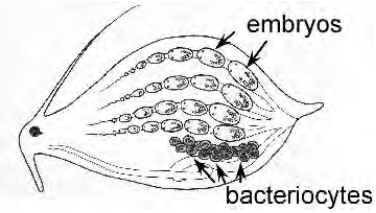
- This is the ultimate challenge for many terrestrial insects.
  - Drinking or moisture in food.
  - Oxidative metabolism.
  - Absorption of water vapor.

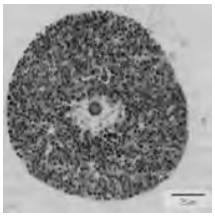
Energy

- Oxidation of carbohydrates, fats, organic acids, suitable amino acids.
- Each are variably available to different types of insects.
- Requirements can be quite high: Certain insect flight muscles convert more energy per unit weight than any other animal tissue.

Essential Amino Acids

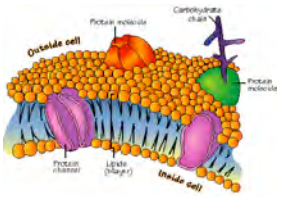
- Insects need at least the same 10 amino acids in their diet as we do.
  - Predators have little problem with this.
  - Phytophagous insects more of a problem.
  - Particularly sap-suckers.
  - Adam will talk more about this on Friday.





Essential Lipids

- Insects are unable to synthesize polyunsaturated fatty acids
  - Involved in formation of phospholipids of cell membranes.
- Also **sterols** (unlike mammals).
  - Required for many hormones.
  - Derived from cholesterols (animal food) or β-sitosterol (plant food)



Vitamins and Growth factors

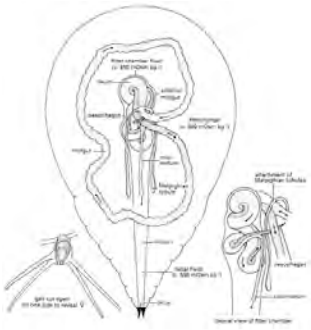
- Vitamin Bs particularly important.
- Vertebrate blood is particularly low in these (which insects care?)
- How do they get it?

Minerals

- Requirements essentially the same across animal kingdom (e.g. we cannot synthesize them).

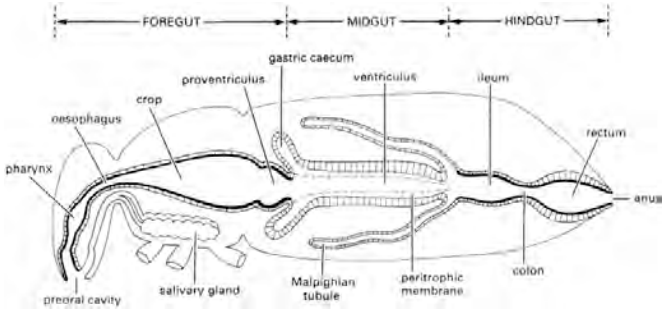
The Insect Gut

- The insect's digestive system & excretory system will reflect the diet in much the same way that mouthparts do.
- Considerable variation is built around a common theme.
- Many of these functional differences are analogous to differences we see across vertebrate diversity…



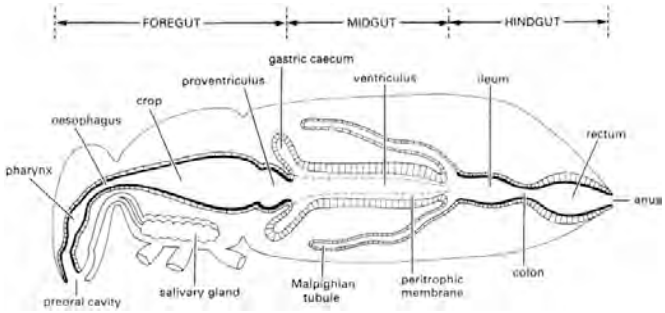
Gross Gut Morphology

- Foregut: Processing and storage of food.
- Midgut: Digestion and absorption of food.
- Hindgut: Absorption of water, salts, elimination of wastes.
- Sound familiar?



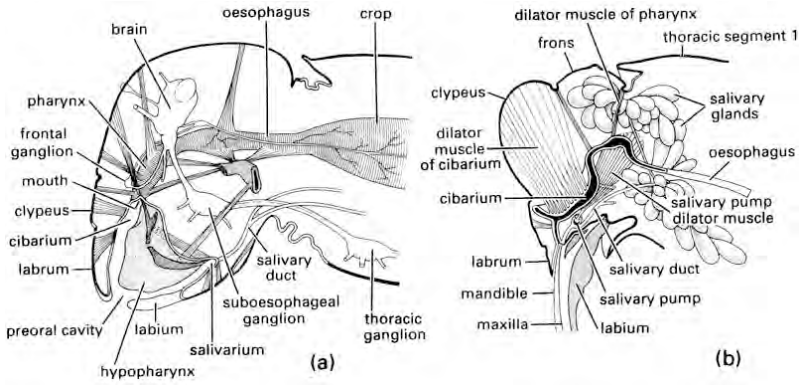
Gross Gut Morphology

- Note that the foregut and the hindgut are lined with cuticle (derived from ectoderm).
- **Midgut** is not, instead lined with **peritrophic membrane** (derived from endoderm).



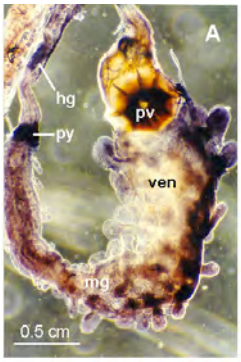
Foregut

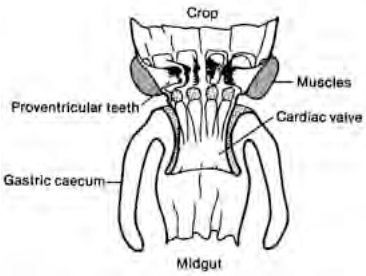
- Mouth and oral cavity: consumption of food.
  - Ventral glandular salivarium
  - Dorsal muscular cibarium



Foregut

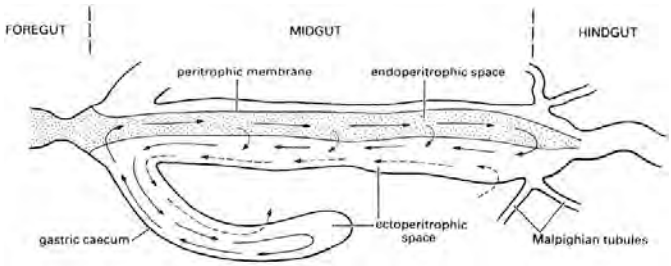
- Mechanical processing of food in pharynx and proventriculus (gizzard).
- Storage in crop.





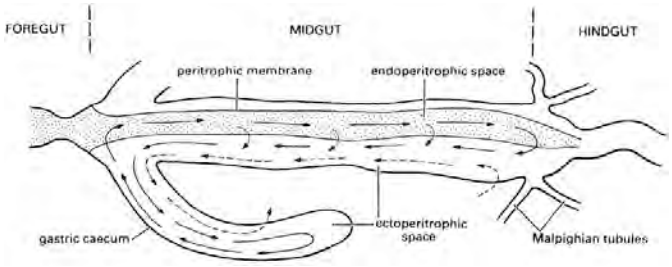
Midgut

- Most digestion of food occurs here.
- Two main areas:
  - **Gastric caeca** often house endosymbionts.
  - **Ventriculus** where most digestion occurs.

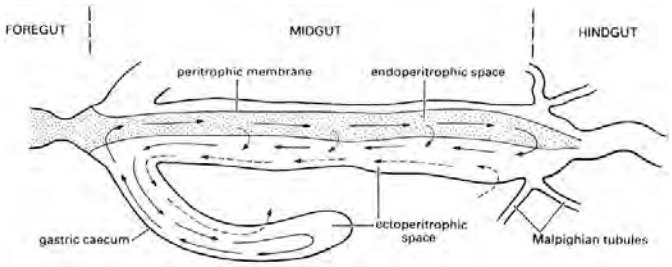


Peritrophic membrane

- Secreted by microvillate columnar epithelial cells.
- Made up of an amorphous sheet of polysaccharide, chitin, glycoprotein, and protein.
- Tubular film that surrounds the bolus and within which considerable digestion occurs.
- **Why would insects do this?**



Why?



Peritrophic membrane

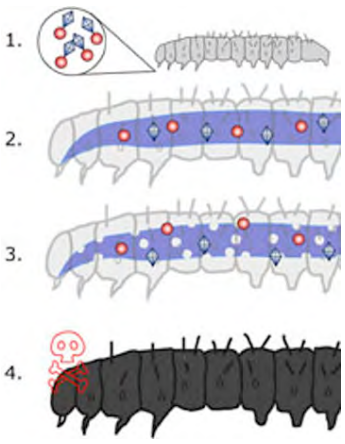
- Numerous insect pathogens center activity on peritrophic membrane.
- Including **Bt**: genetically derived insecticide from *Bacillus thuringiensis.*

A 12-day-old cotton bollworm larva raised on a diet containing Bt proteins. Source: USDA

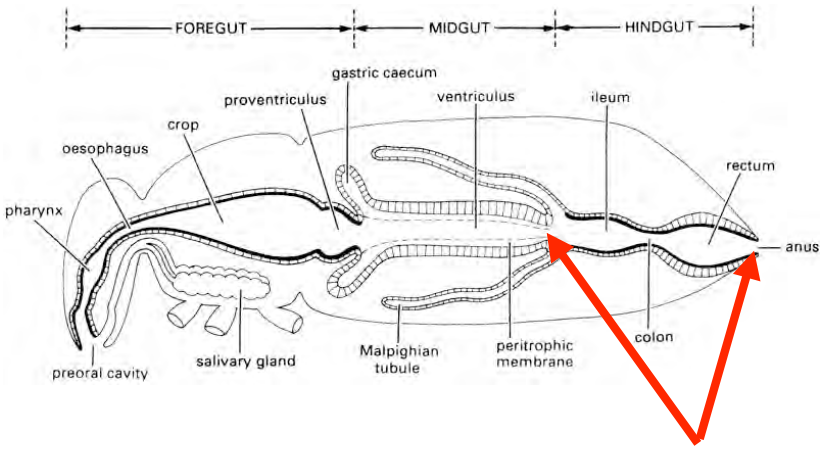
A 12-day-old cotton bollworm larva raised on a diet with no Bt. Source: USDA

Peritrophic membrane

1. Insect eats *Bt* crystals and spores. Enzymes are activated by proteolytic enzymes in the insect gut.
2. The toxin binds to specific receptors in the gut and the insects stops eating.
3. The crystals cause pores to open in the peritrophic membrane, allowing spores and normal gut bacteria to enter the body.
4. The insect dies as spores and gut bacteria proliferate in the body.



Hindgut & Malpighian Tubules: Water conservation and excretion.

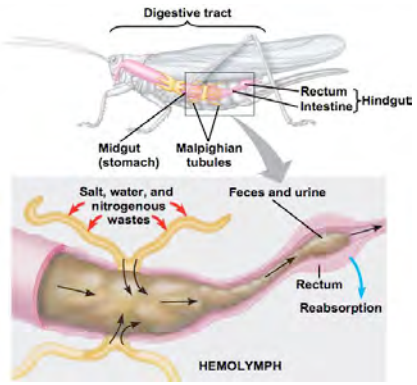


Hindgut & Malpighian Tubules: Water conservation and excretion.

- Intimately involved in **osmoregulation** and elimination of wastes (especially nitrogenous).
- Re: insects have open circulatory system, therefore, no kidney or nephridia.
- Aquatic insects also have chloride cells to actively pump in ions.

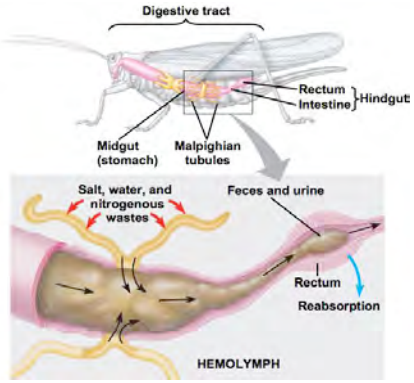
Malphigian Tubules

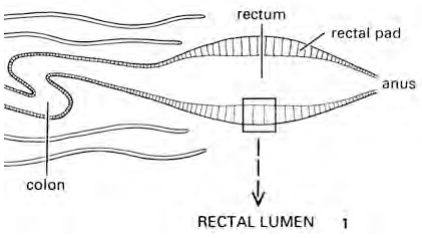
- Outgrowth of hindgut, ectodermal in origin.
- Dead end tips open into hemolymph
- Transport epithelium secretes nitrogenous wastes and solutes **into** tubules: the **filtrate**.
- Water follows, how?
- These are delivered to the hindgut.



The Hindgut

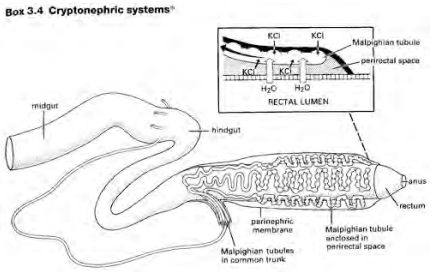
- Parts of rectal epithelium are thickened to form **rectal pads**.
- These are specialized for absorption of water from feces before defecation.
- Active transport of ions across these cells sets up osmotic gradient, water is reabsorbed.
- How are nitrogenous wastes excreted?





Cryptonephridia

- Some desert insects have intimate association between Malpighian tubules and hindgut.
- Bounded by **perinephric** membrane.
- Allows extreme conservation of water, including absorption of water from humid air in the rectum.



Some unusual diets…

- Insects can digest some abundant, yet resistant compounds.
- Some moths and beetles can feed on keratin.
  - Requires enzyme, low oxygen environment to reduce sulfur bonds, and reducing agent.

Clothes moths (Tineidae) are also known to scavenge horn, hooves, and even tortoise shells.

Some unusual diets…

- Beeswax is ordinarily resistant to digestion.
- But wax moths can eat it: have a highly **basic** gut.

Wax moths (Pyralidae) are considered a pest by beekeepers

Some unusual diets…

- Wood regularly consumed by some wood-boring beetles, termites, wood-feeding roaches, and silverfish.
  - Some endogenous production of cellulases (wood-roaches, termites).
  - Most endosymbiotic interactions with bacteria or fungi.
  - Some exogenous consumption of fungi to obtain cellulases.
  - Some only consume rare starch, sugar, or whole cell walls in wood tissue, not lignin itself.

Termites and wood-roaches are the only insects known to convincingly produce their own cellulotyic enzymes

Asian longhorn beetle house an endosymbiotic fungus that produces cellulolytic enzymes