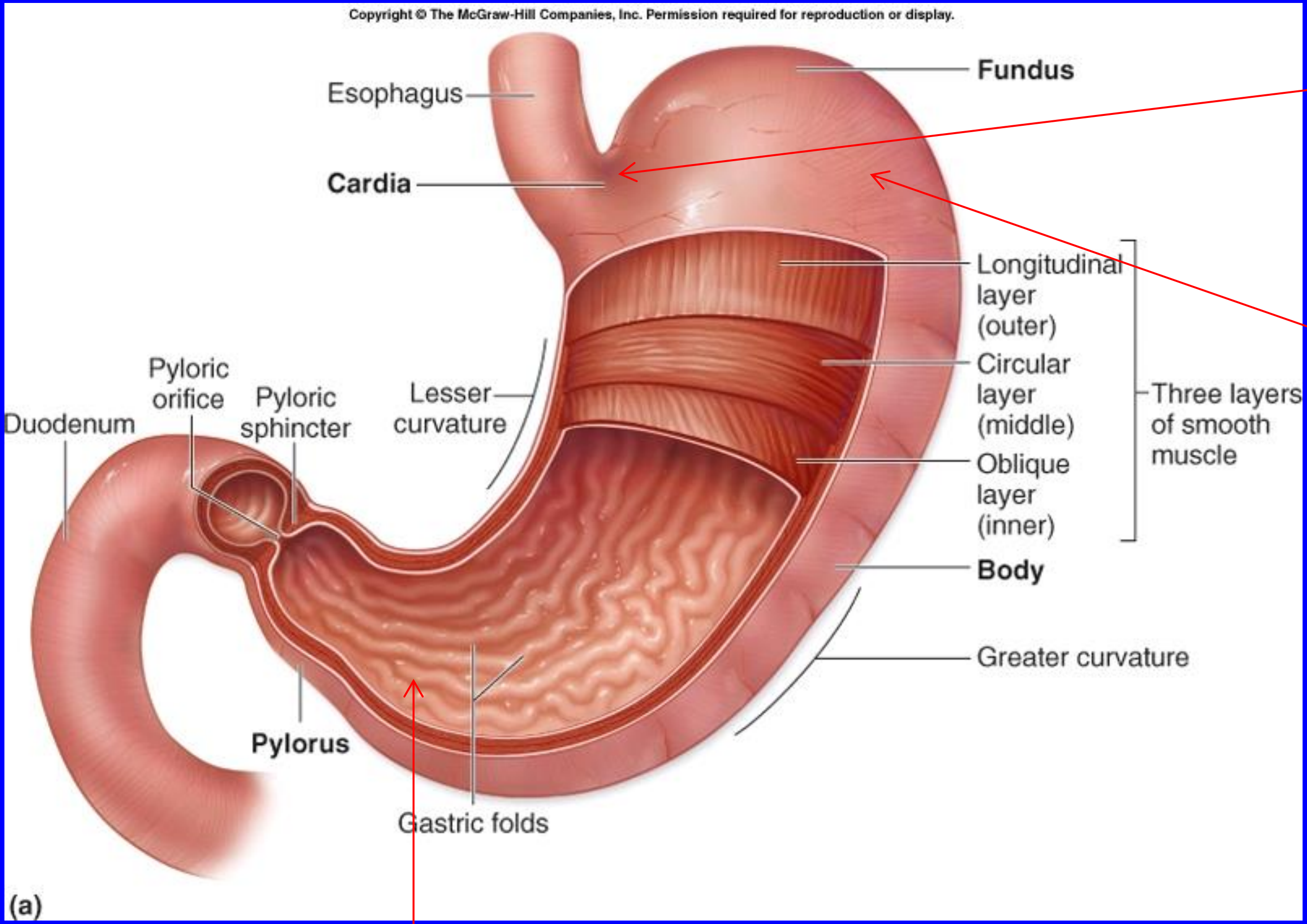
Mammalian digestive tracts

- Mouth: mastication, some digestive enzymes
- Esophagus: simple transport tube
- Stomach: most initial digestion, some physical processing
- Small intestine: digestion continues, some absorption
- Caecum: diverticulum at junction of small and large intestines, digestion continues
- Large intestine: absorption
- Rectum: final absorption

Relative proportions and size differ according to diets

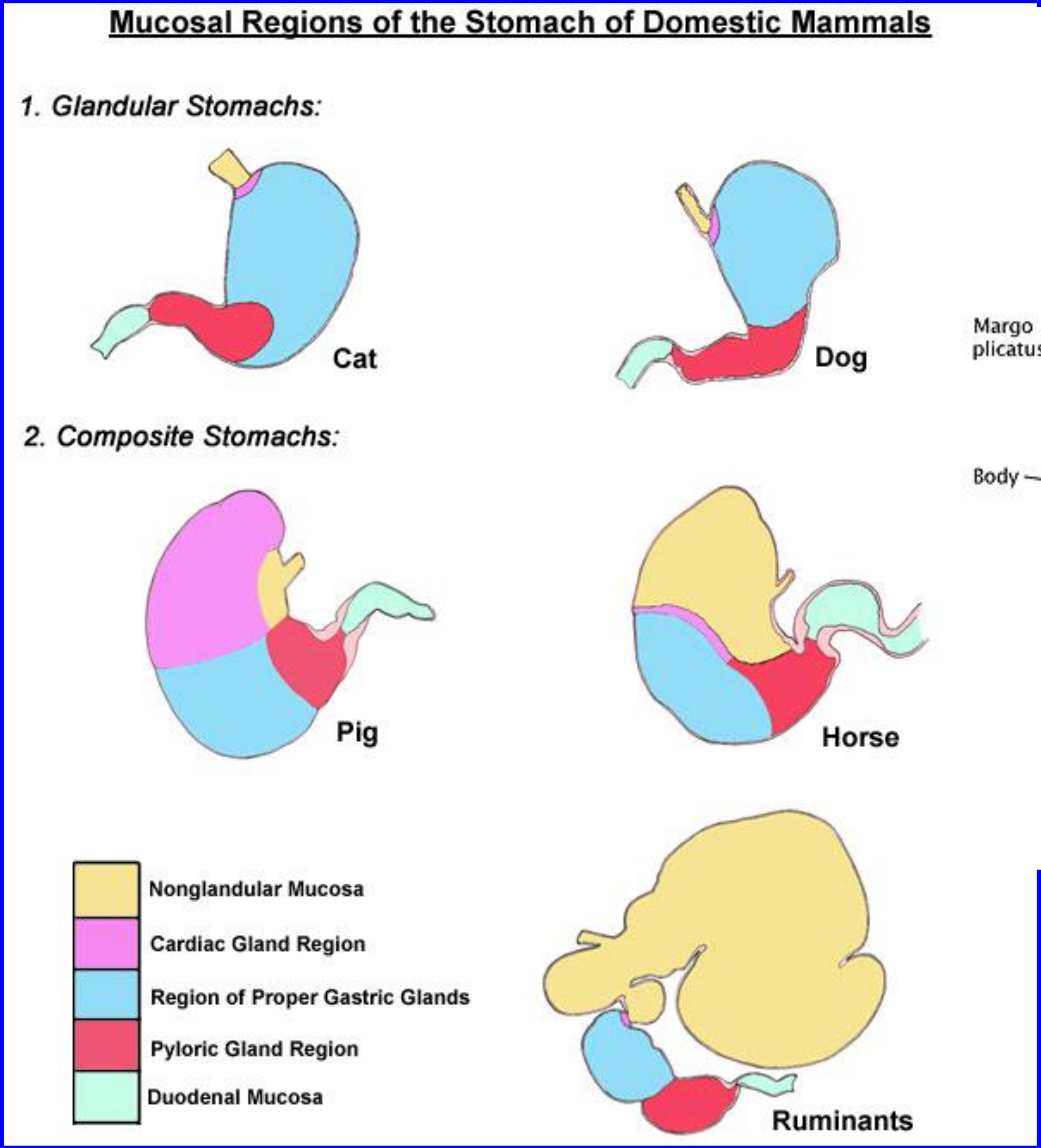
Generalized stomach



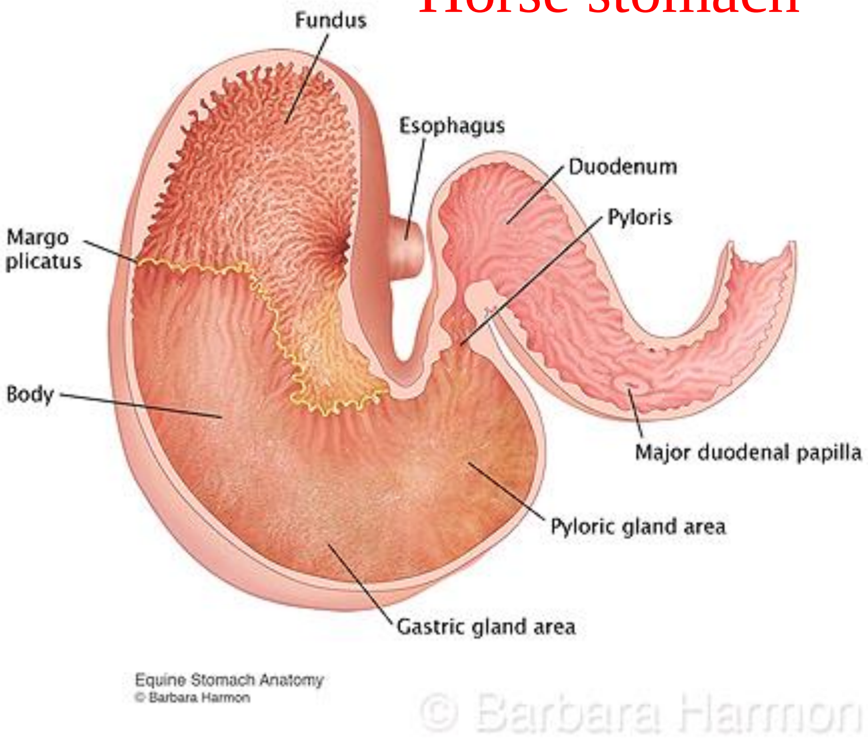
Cardiac glands - mucus

Fundic glands – pepsin, renin, HCl

Pyloric glands – mucus, gastrin (controls HCl secretion), electrolytes (buffers)



Horse stomach



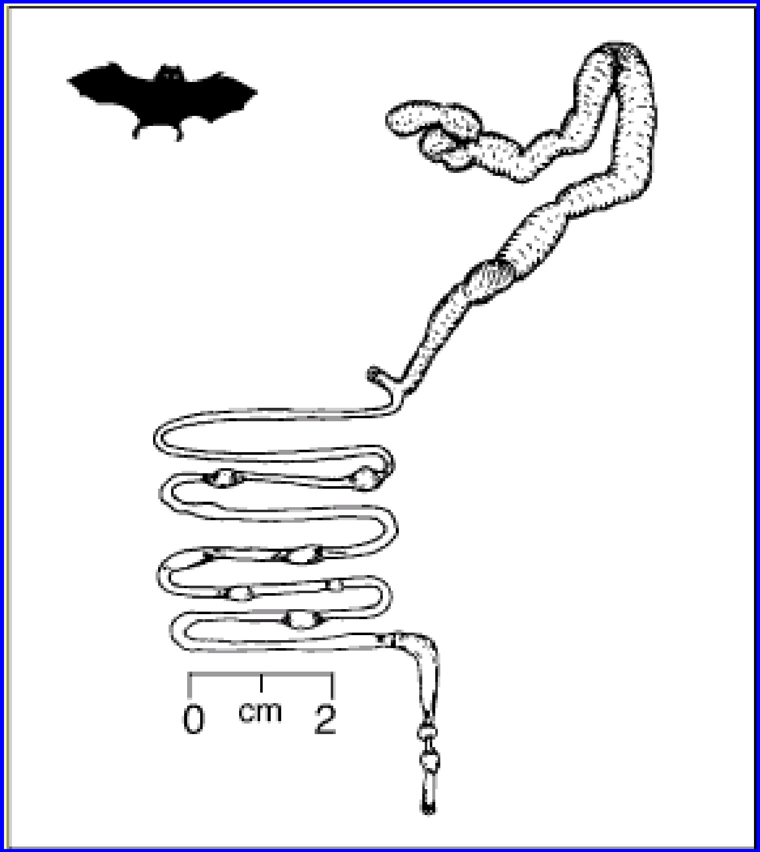
Tougher food = more area with ridged, cornified (non-glandular) lining

Some of the most important differences among dietary types shown in length of gut relative to body size, and relative proportions of digestive and absorptive regions:

Carnivores/insectivores: food (meat) is easy to process and digest, so

1. Relatively short post-gastric tract (2-6 X HBL)
2. Caecum reduced or absent
3. Little differentiation between small and large intestines

(See examples of carnivores and insectivores on handout)



Vampire bats have large stomachs and simple post-gastric digestive tracts.

Stomachs fill up with blood, very dilute food. Water must be extracted to condense food, then passed to intestines.

Herbivores faced with more difficult diet to digest:

1. Most E in leaves, grass not stored as starch, but locked up in structural carbohydrates like cellulose.
2. No enzyme produced by mammals can break down cellulose or lignin into simple sugars. But some bacteria and protozoans can!
3. Herbivorous mammals evolved symbiotic relationship with bacteria and protozoans to tap into E in structural carbohydrates.

4. Special compartments in gastrointestinal tract develop to serve as refuges for microbial symbionts.
5. Two basic ways: Foregut fermenters (ruminants, rely on large complex stomach with rumen) and hindgut fermenters (rely on enlarged caecum).

Advantages of microbial fermentation:

1. Breaks down cellulose into volatile fatty acids that can be digested or absorbed by mammals.
2. Microbes grow and reproduce, plus can fix inorganic N (from urea) into protein, namely their bodies, which also can be digested (yielding all essential amino acids, vitamins except A + D, about 100-180 g protein per day from low quality food).
3. Can conserve water because urea (waste product of protein digestion) gets converted to more protein instead of excreted.

(foregut fermenters benefit more from 2 and 3... some hindgut use coprophagy to run food through a second time to better digest and absorb the work of those microbes, YUCK)

4. Microbes also can break down many plant defensive compounds.

So, what do the microbes need?

1. Normal stomach acidic – pepsin functions best around pH 2.0.
2. Microbes need pH 5.9 – 7.0, more neutral.

Hindgut fermenters store microbes in caecum. Initial digestion in stomach, portions of digesta introduced to caecum and further acted upon my microorganisms there, then returned to large intestine where fermentation and absorption continues.

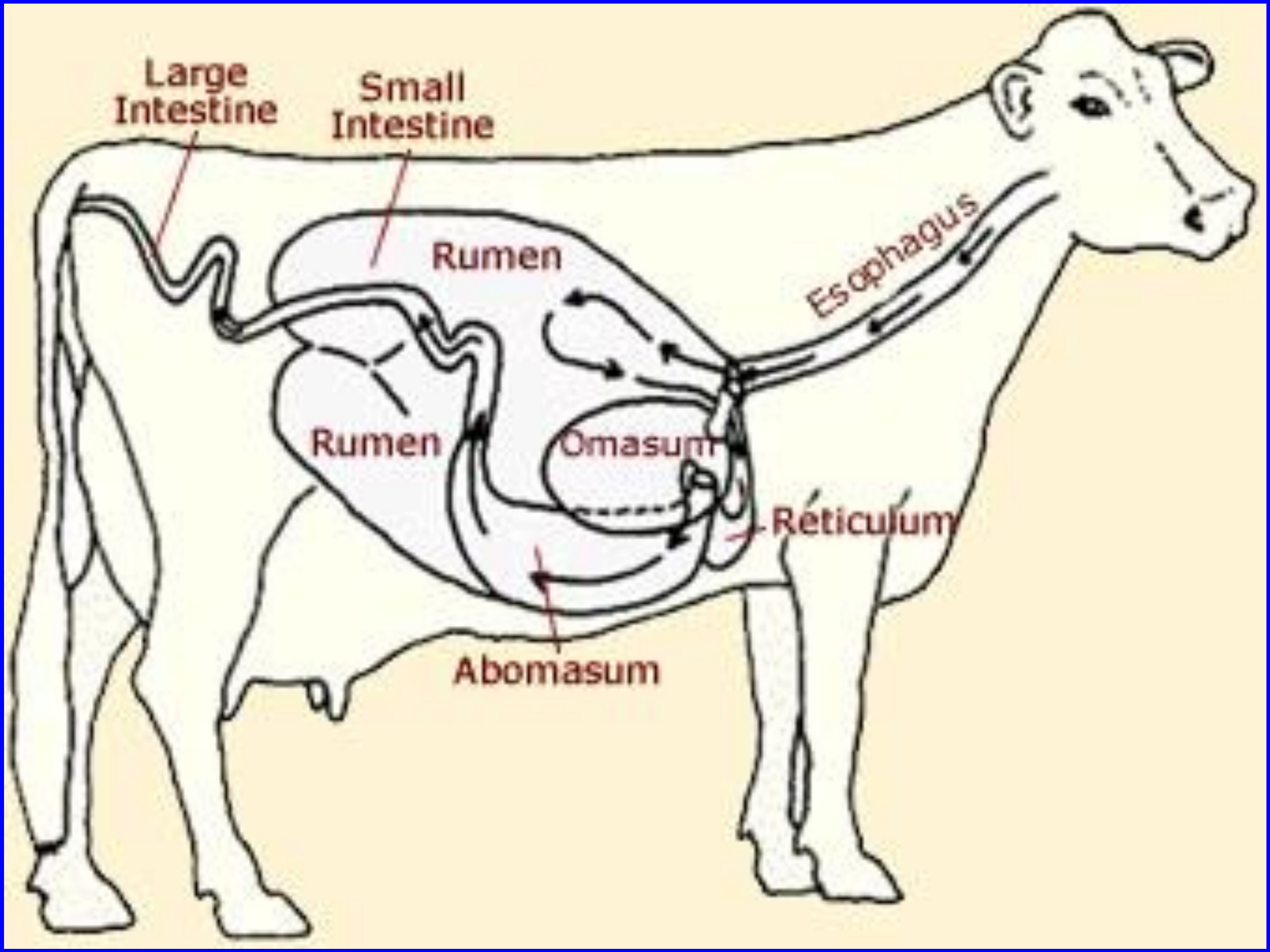
Examples: many rodents, perissodactyls, rabbits, sirenians, hyraxes, elephants, some marsupials

Foregut fermenters house microbes in enlargement of forestomach. Initial receptacle for plant material called rumen. “Soup” in rumen contains microorganisms that break down cellulose.

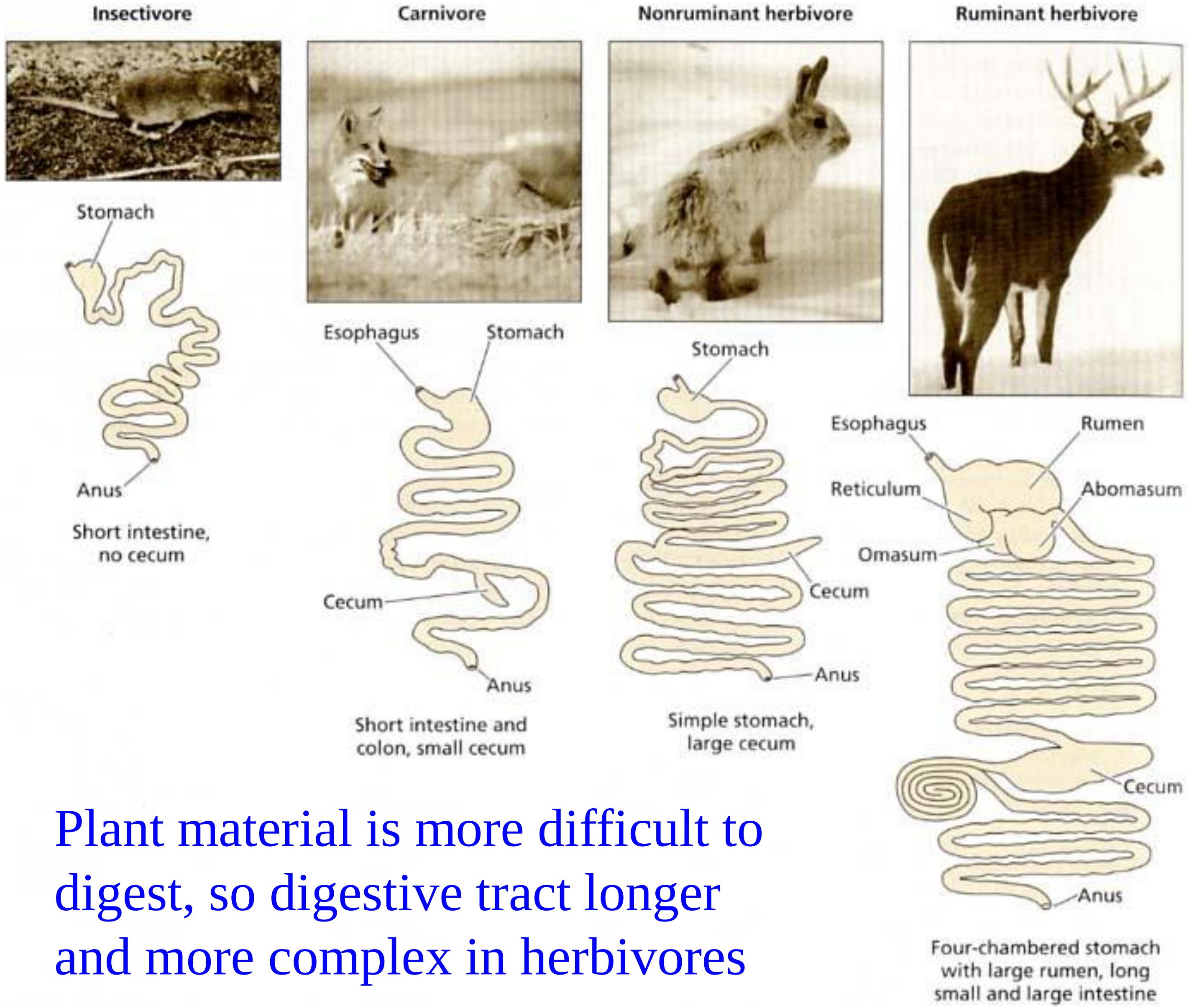
Large particles float to top or collect in reticulum, regurgitated to mouth to be re-chewed (cud), cycle repeated until chemical and physical breakdown reach point where particles sink down in fluid, get passed on to next chambers and eventually intestine.

Ruminants salivate greatly – saliva high in calcium carbonate to keep pH in rumen high and buffer acids produced during fermentation.

Examples: artiodactyls, sloths, macropod marsupials

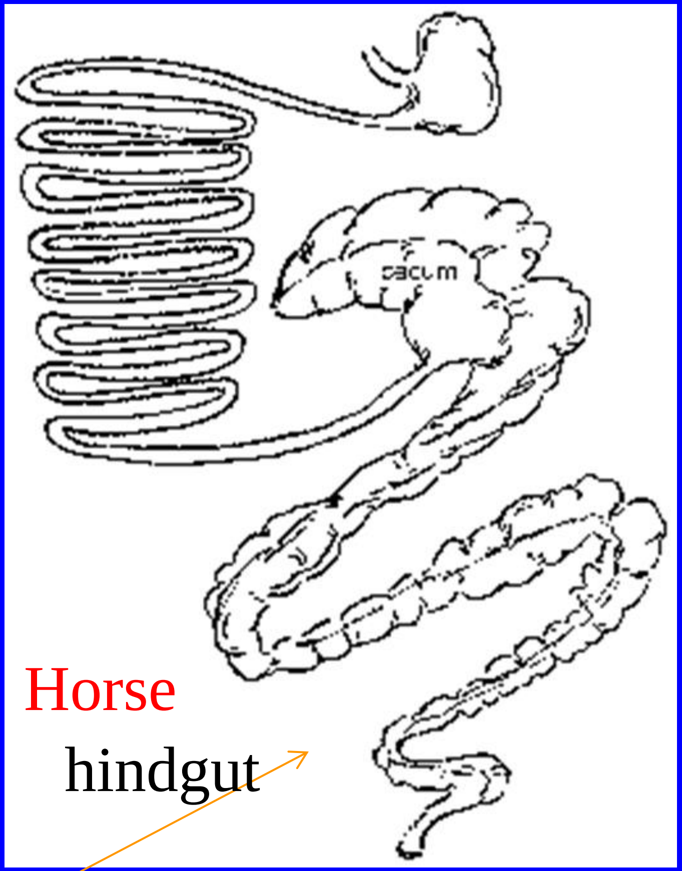


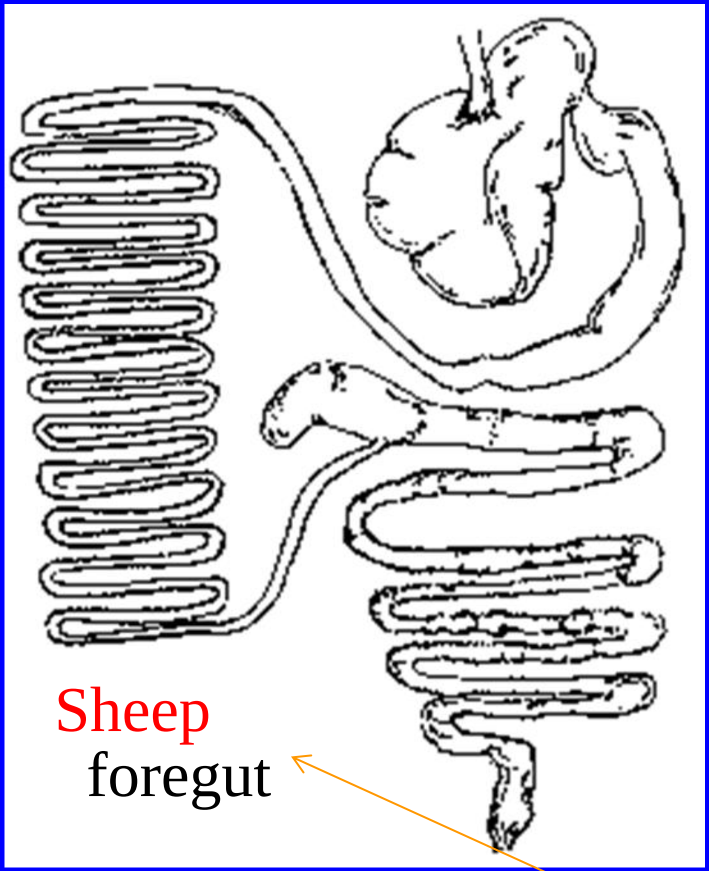
How a cow works (small and large intestine under-represented, mainly showing stomach).



Plant material is more difficult to digest, so digestive tract longer and more complex in herbivores

Figure 7.2 Digestive system. The digestive systems of mammals, illustrating the differences in morphology that correspond to different diets. *Adapted from Hickman et al., 1995,* Integrated Principles of Zoology, *10th ed., Wm. C. Brown Publishers.*





post-gastric = 10-15 X HBL	lg., compartmentalized stomach
large caecum	longest post-gastric = 20-27 X HBL
long, sacculated lg. intestine	reduced caecum, lg intestine not sacculated

% volume of digestive tract

	Carnivore (dog)	Hindgut F (horse)	Foregut F (sheep)
stomach	65	9	67*
small intestine	20	30	20*
caecum	<1	16*	3
large intestine	15	45*	10

*Note different emphasis between hindgut and foregut fermenters

Folivores: specialize on eating leaves... very low quality diet!

Koalas have the largest relative caecum of any mammal

Folivores generally have lower metabolic rates, sometimes lower body temperatures, and spend a LOT of time sleeping (to conserve E) and digesting.

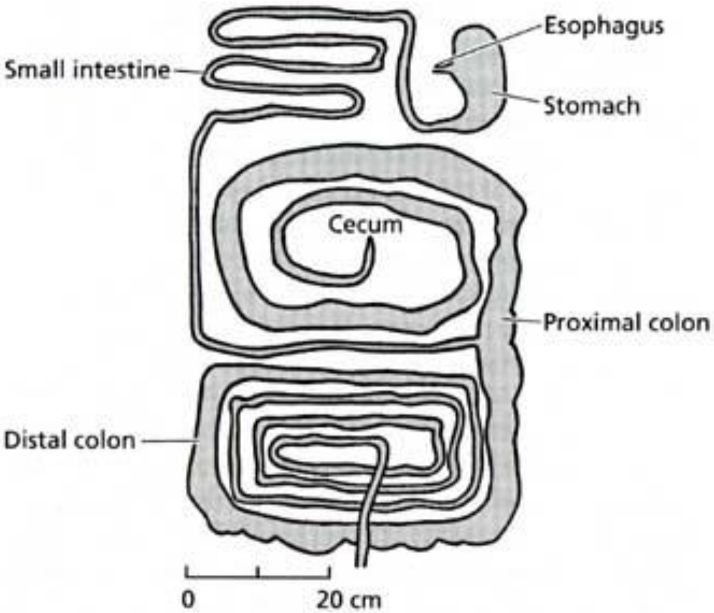


Figure 7.14 Koala digestion. The digestive tract of the koala is well adapted for digesting fibrous leaves of *Eucalyptus*, the staple in its diet. The cecum, measuring up to 2.5 m (8 ft), is the site of microbial fermentation. *Adapted from Harrop and Hume, 1980,* Comparative Physiology: Primitive Mammals, *Cambridge Univ. Press.*

Hindgut fermenters process food about 2X faster

Foregut fermenters about 3/2 X more efficient at extracting nutrition; longer time for fermentation allows more production of protein and breakdown of toxic compounds by symbionts

So, when food is abundant and good quality (conditions optimal), hindgut fermenters can obtain more energy per day.

When food becomes limiting, ruminants can extract more from it, and therefore obtain more energy per day.

Ruminants feed in bouts, however, which is why the smallest (like voles) and largest (like rhinos and elephants) herbivores are foregut fermenters.

Mammal Math:

Hindgut fermenter 2/3 as efficient but 2X faster; can process 2X as much food in a given time if conditions optimal.

So, 2/3 efficient times 2X faster = 4/3 more E and protein.

Optimum conditions same for both, but tolerances differ.

Hindgut can support itself better on diet of low quality if food is abundant,

BUT if both compete for nutritious food that is limited in supply, ruminant can extract more from smaller quantity.

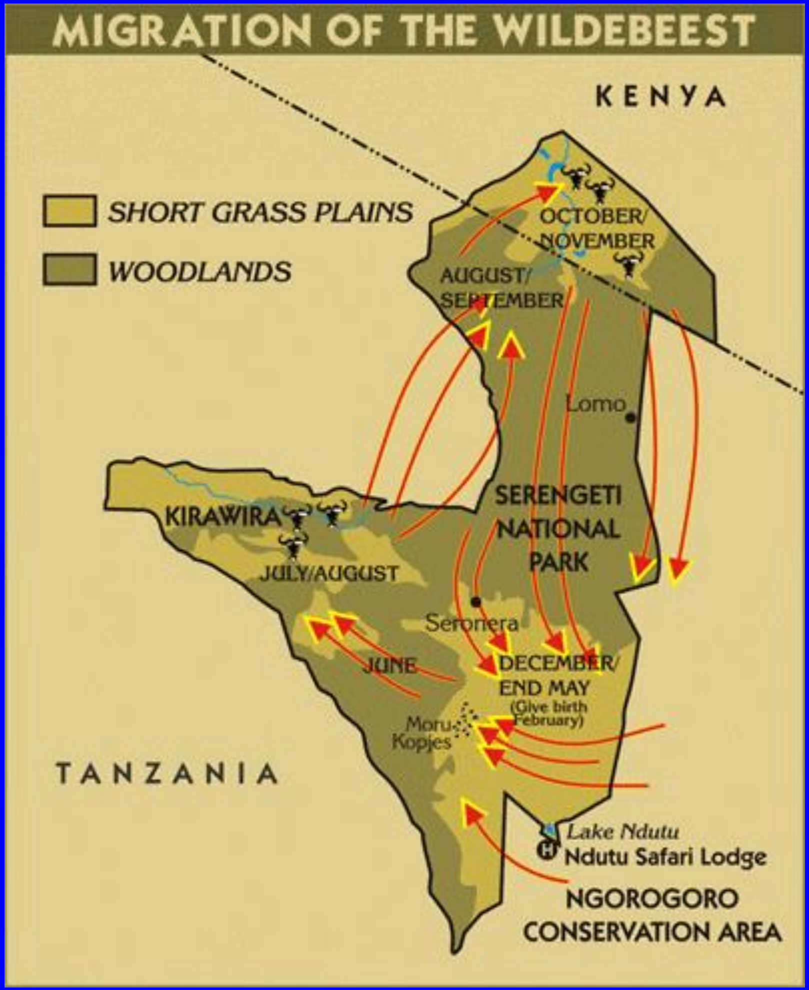
Wildebeest – 230 -275 kg, ruminant

Zebra – 350 kg, hindgut

Thompson's gazelle – 20 kg, ruminant

3 most numerous species during Serengeti migrations

Serengeti migrations: digestive systems at work



1. Body size and digestive systems.
2. Structure of the herb layer.
3. Local topography and regional migrations.
4. Follow the "green wave."

Study questions:

1. How do a carnivore, hindgut fermenter, and foregut fermenter differ in the relative length, emphasis on different components, and general morphology of their digestive tracts?
2. What are the advantages to a herbivore of using microbial fermentation?
3. How do hindgut and foregut fermenters differ in their passage rates of food during digestion? In extraction efficiency? How do ecological conditions (food quality and abundance) affect the ability of each to get enough E and nutrients?