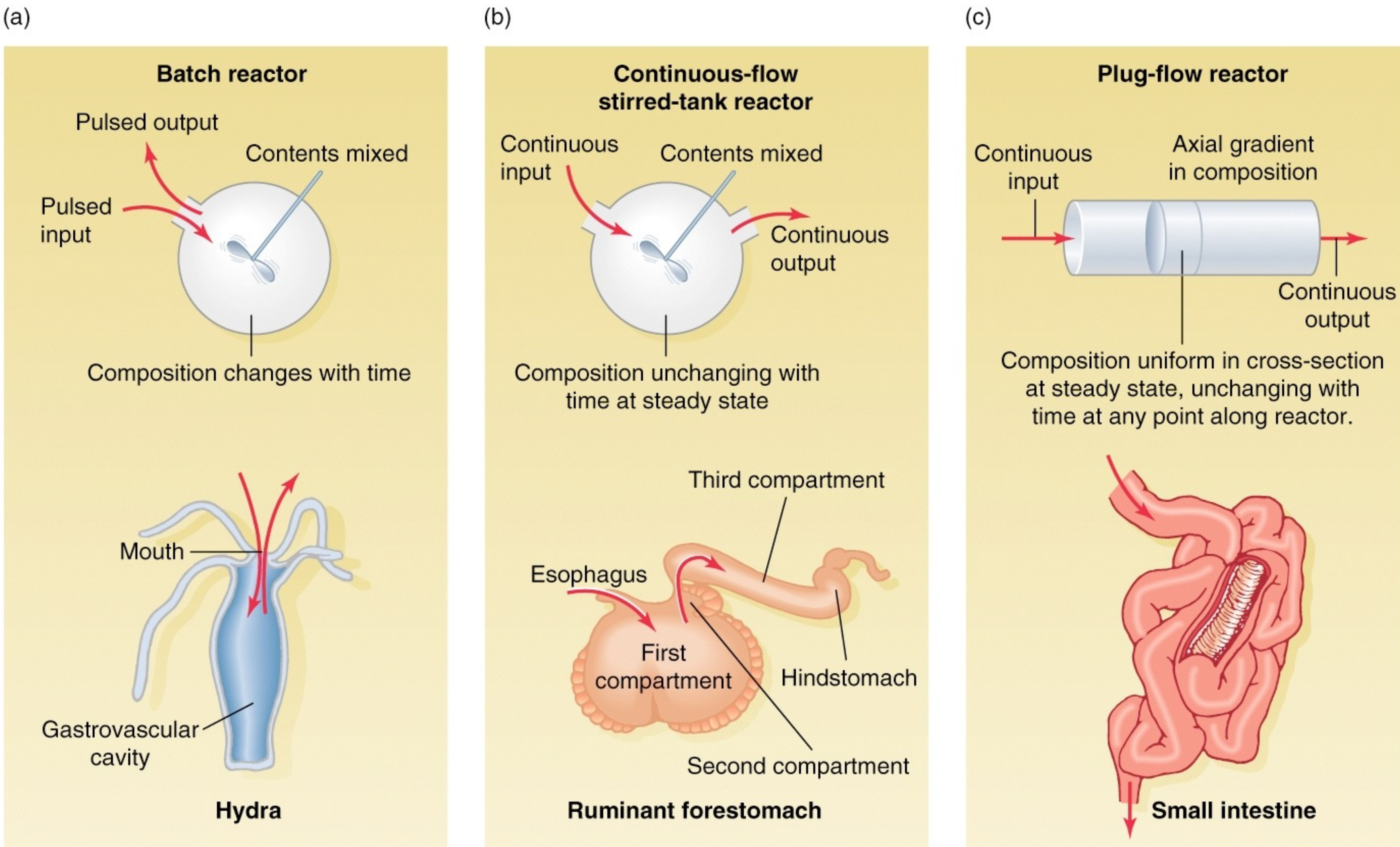
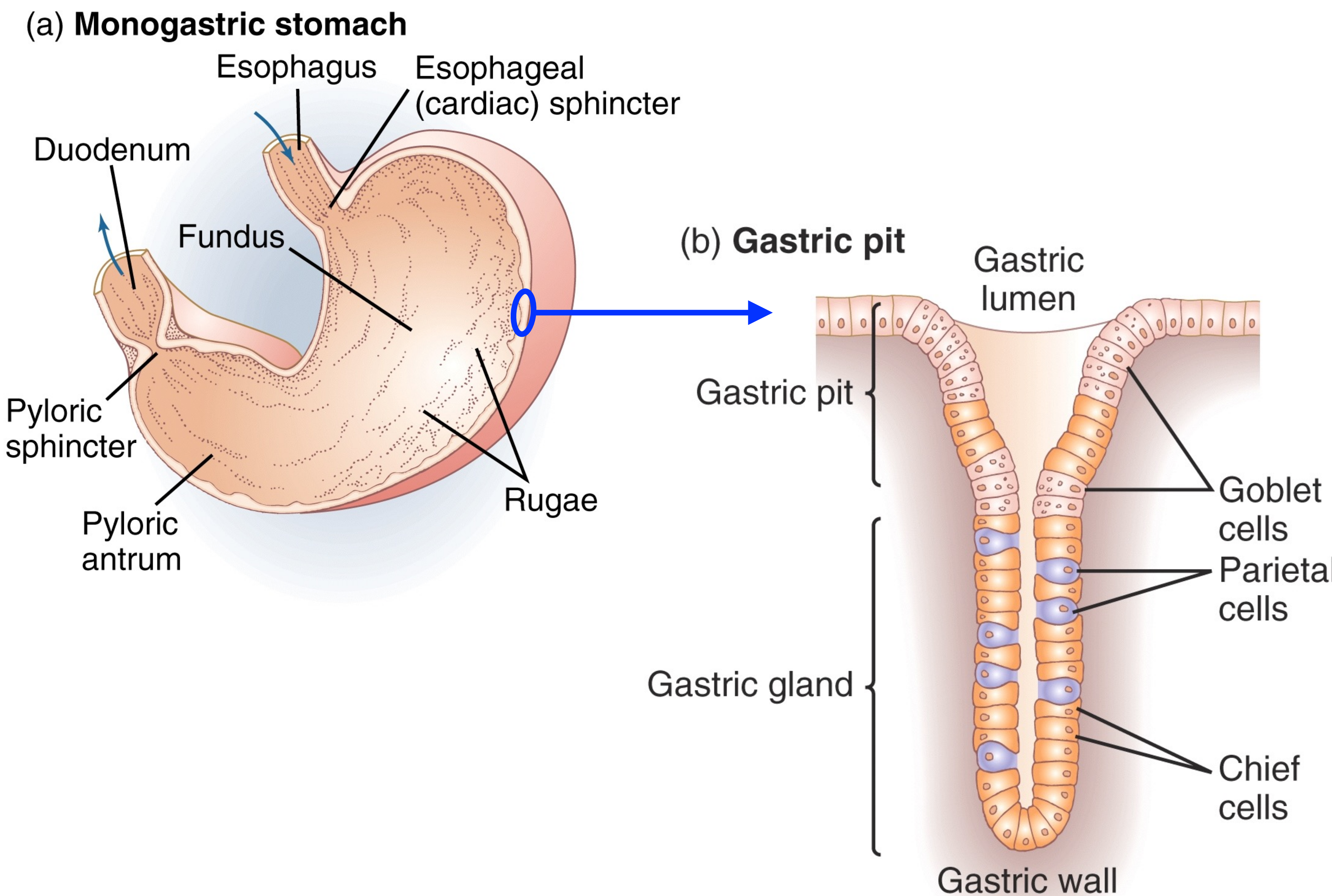
Alimentary systems - Three Models



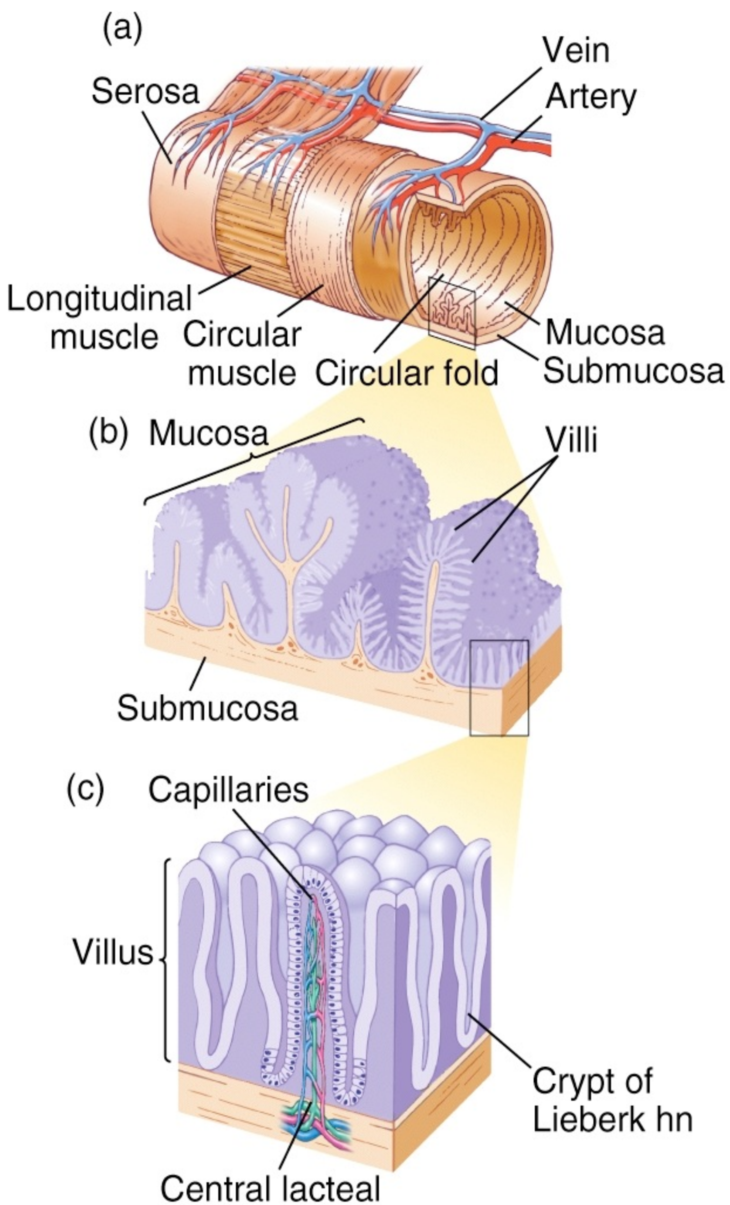
Many stomachs; Ruminants have very motile rumen; mixes food

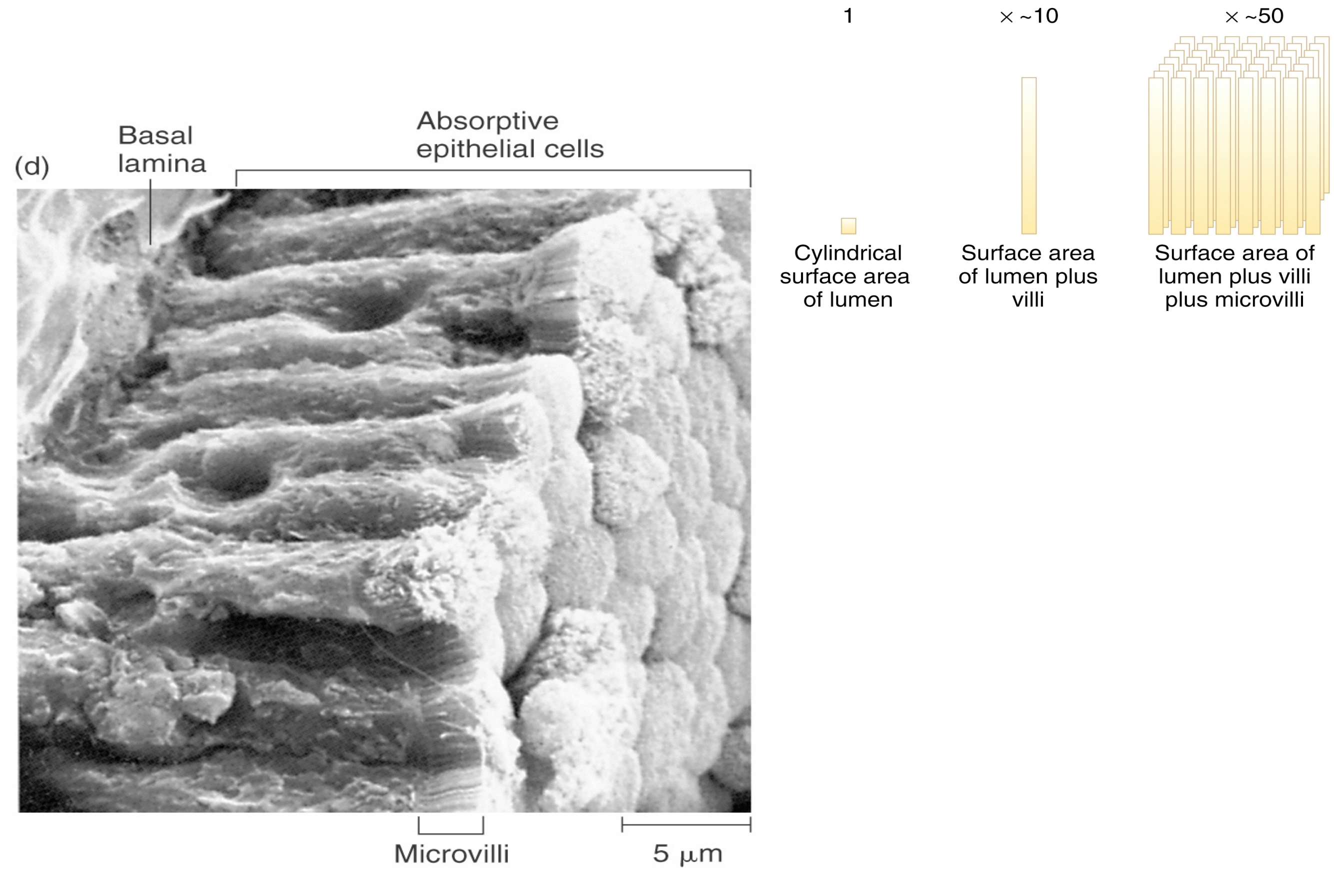
Typical vertebrate midgut; increase transit time -> increased absorption

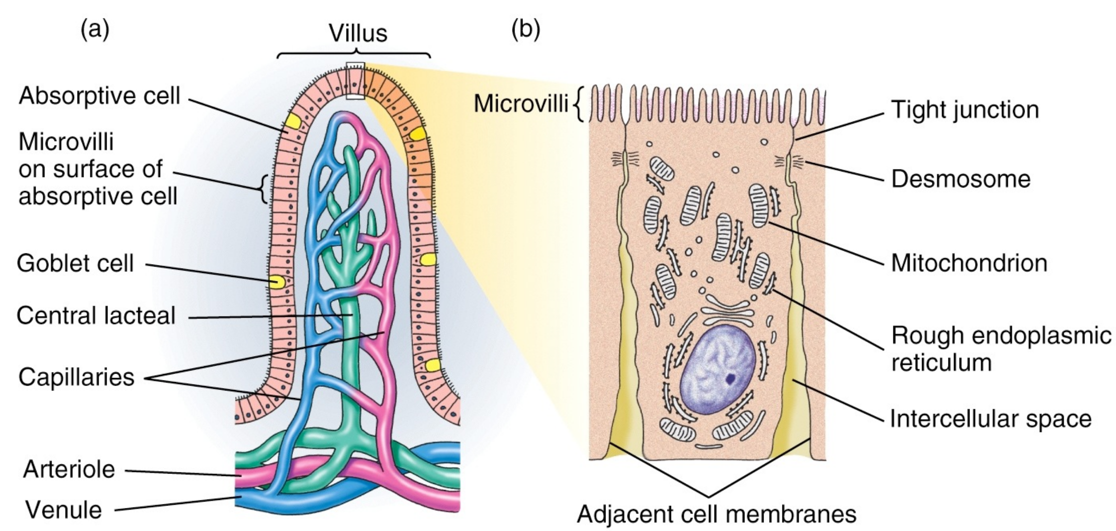
Typical Vertebrate Stomach



Small Intestine







Small Intestine

Carbohydrates Proteins Fats

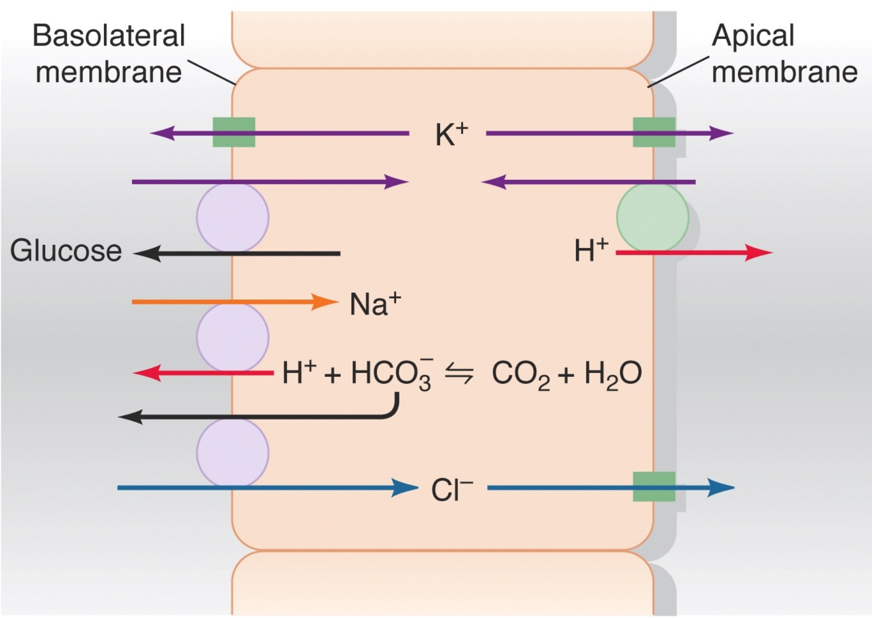
broken down

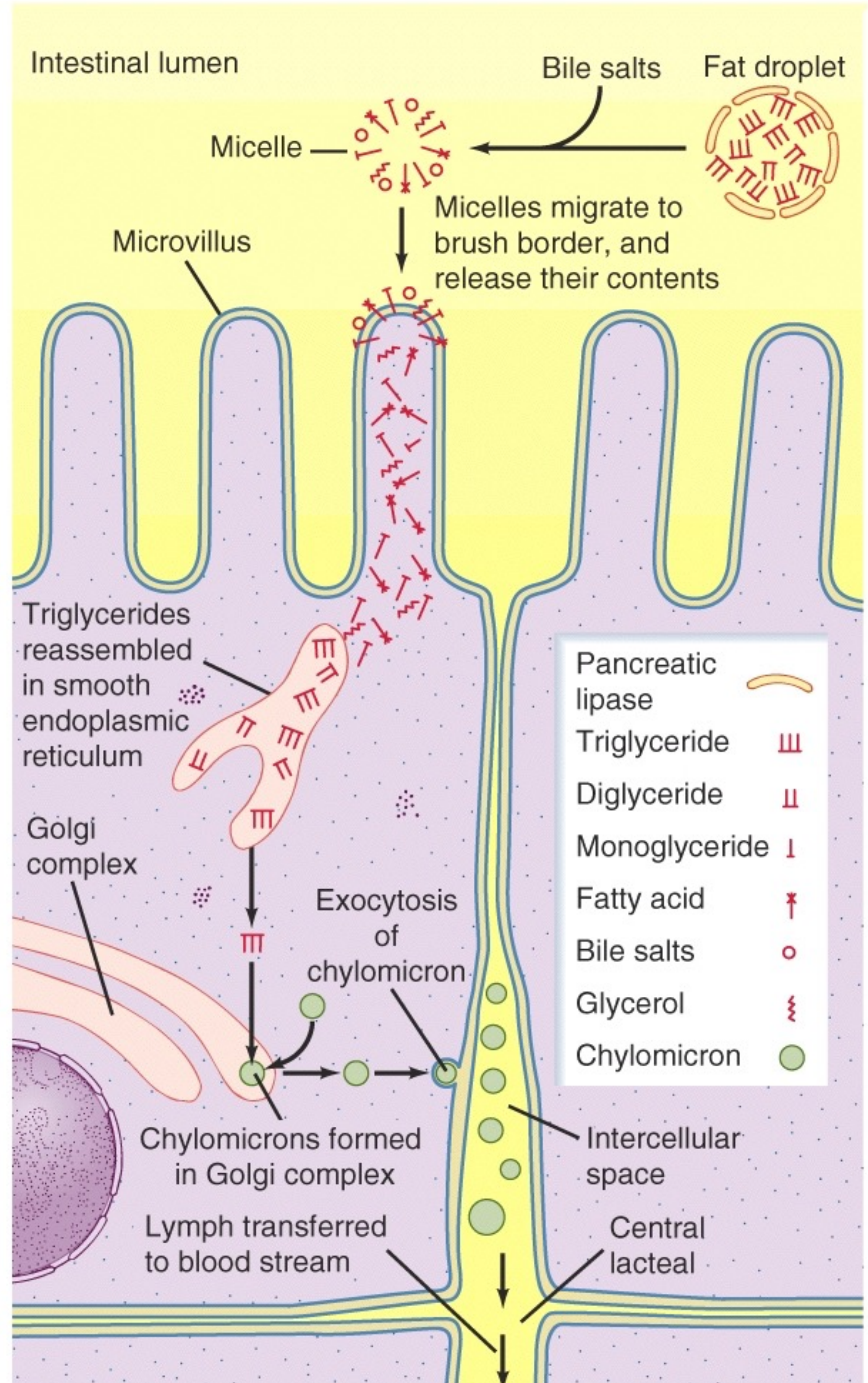
monosaccharides amino acids fatty acids

cross cell membrane via

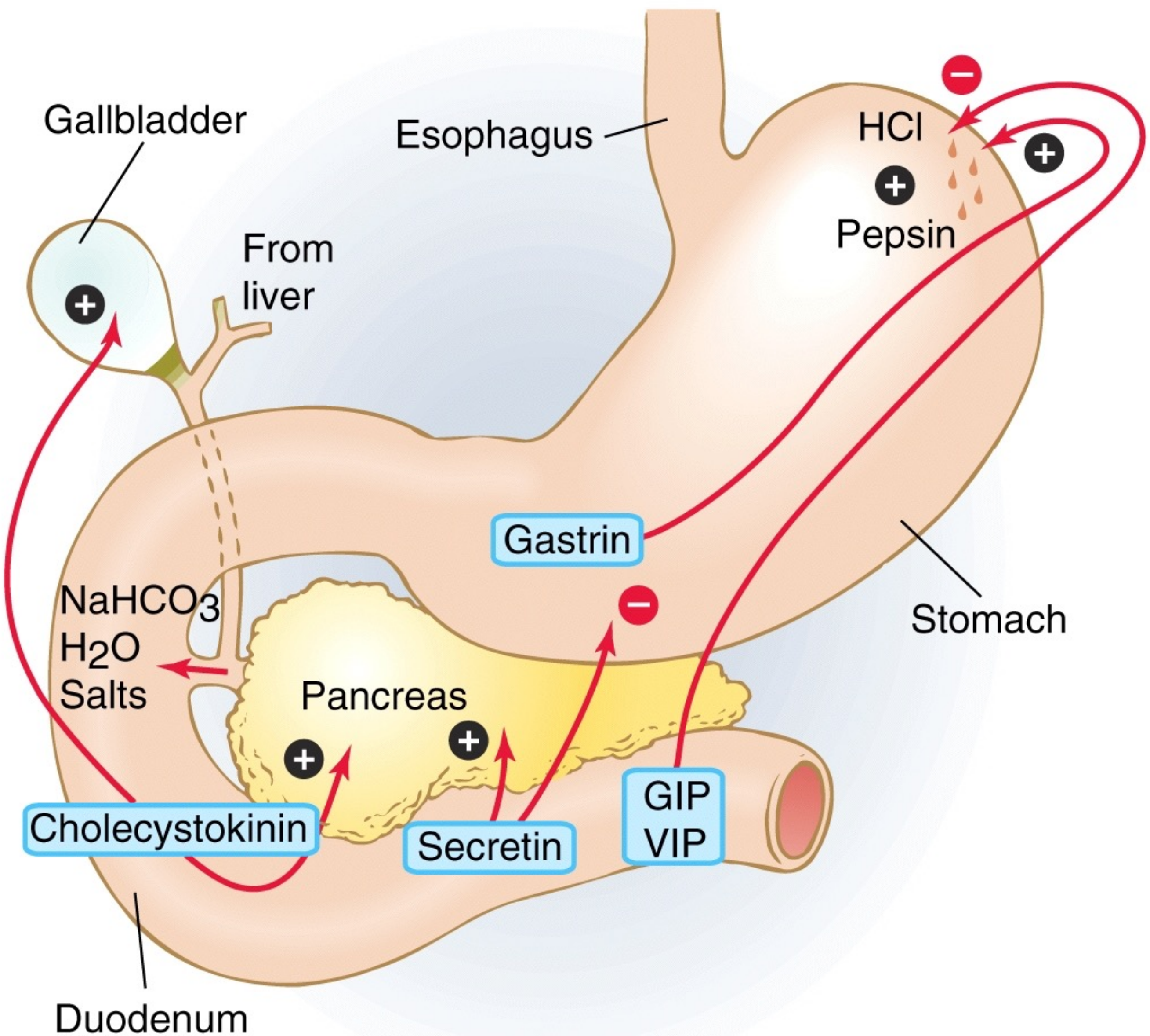
transport proteins
(active transport)

diffusion
(no transporter)





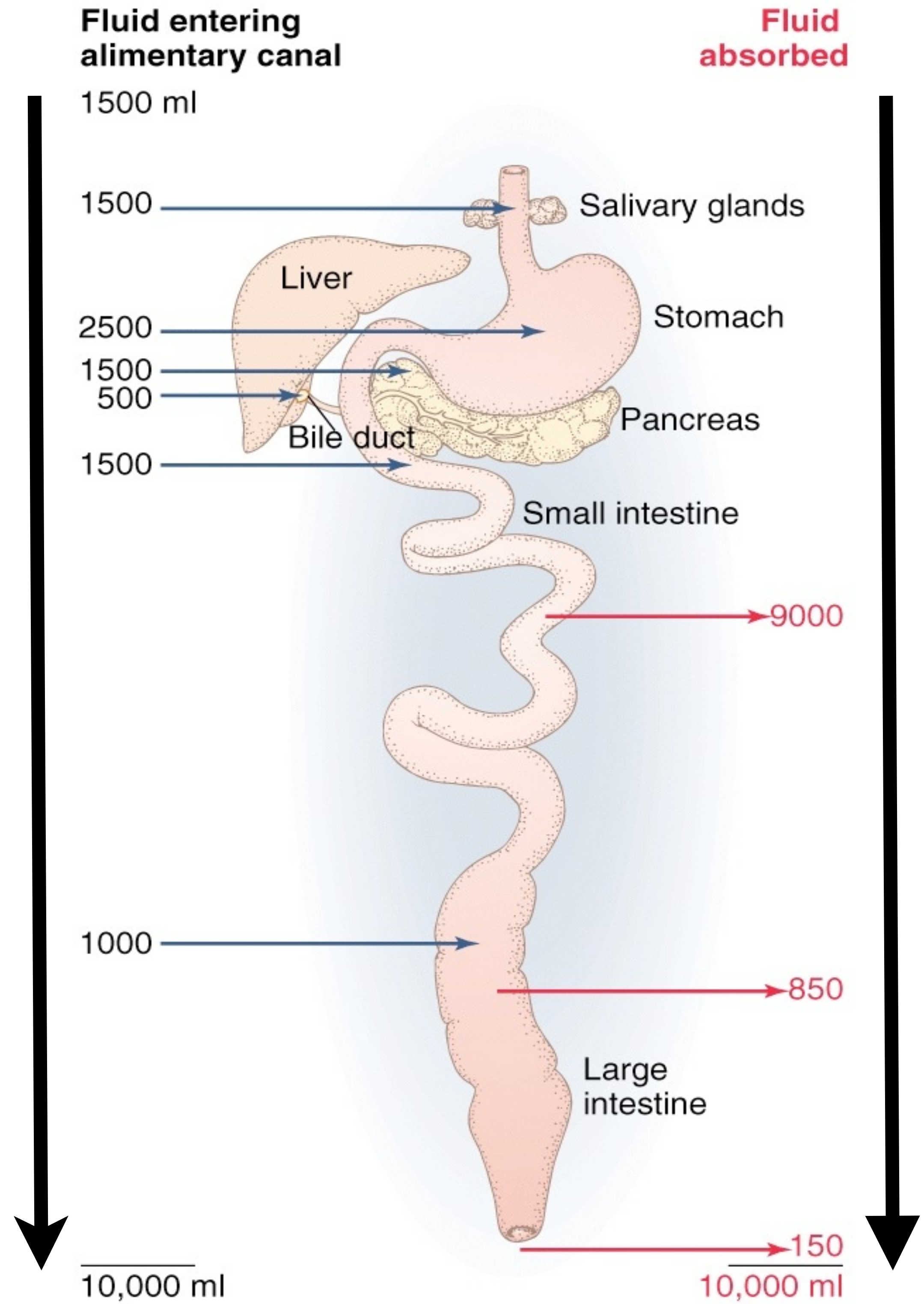
Stomach is regulated by hormones (and stretch)



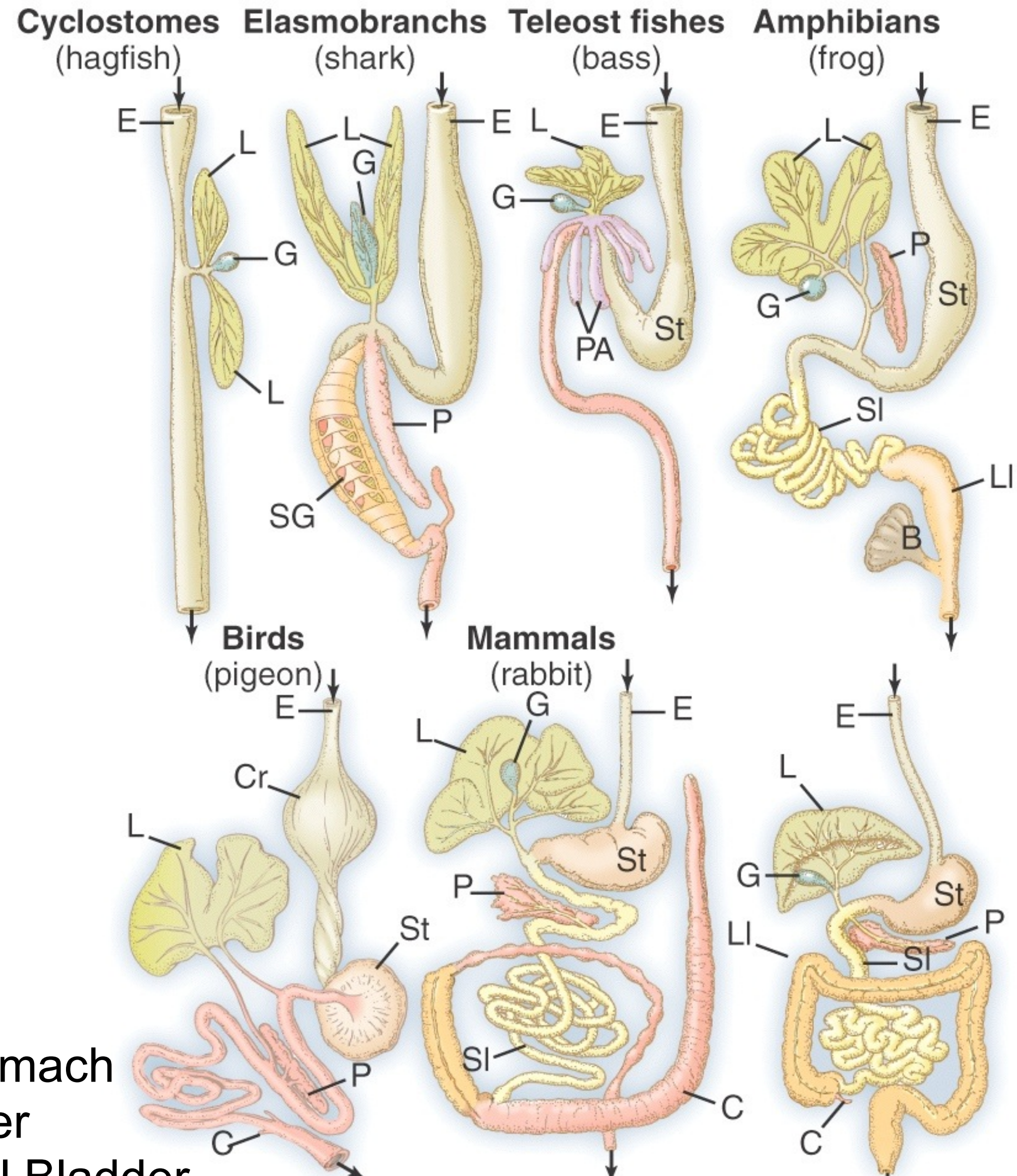
Fluid Resorption

Lots of Fluids necessary for Digestion! ->

Need major resorption to maintain fluid balance



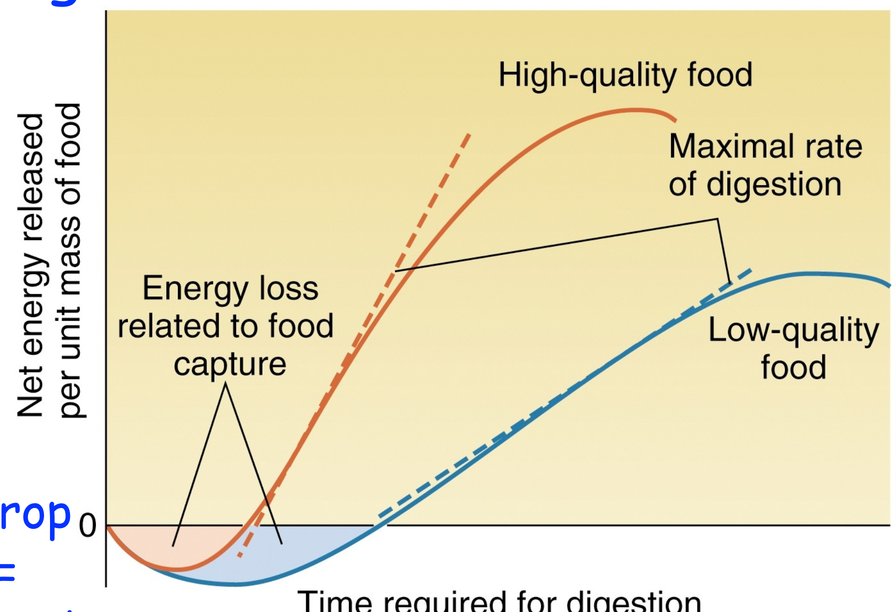
Digestive systems of vertebrates



All else equal, absorption proportional to gut transit time.

Predators eat energy dense food, tend to have shorter, straighter gut

Herbivores have longer gut/ specializations to aid with hard-to-digest foods



Stomach
Liver
Gall Bladder
Pancreas
Small intestine
Large intenstine (colon)

Birds have no teeth!: gizzard/crop (muscular pocket pre-stomach)= swallow stones&sand, help to grind seeds&grain

Polysaccharides

Polysaccharides are sugar polymers that serve many functions:

- **energy storage** and
- **structural** functions.

Polysaccharides can consist of several thousand monosaccharides joined by glycosidic linkages.

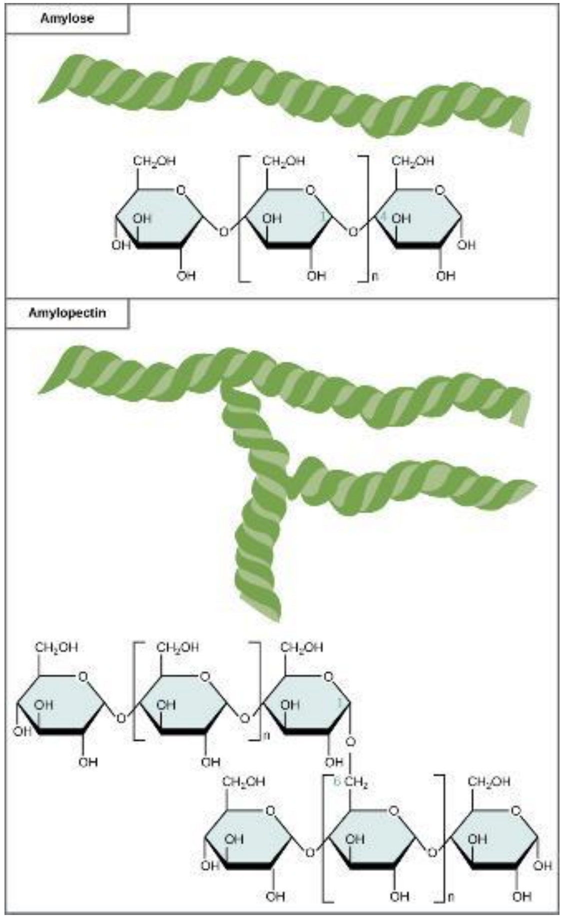
Polysaccharides

Polysaccharides are sugar polymers that serve many energy storage and structural functions.

Polysaccharides can consist of several thousand monosaccharides joined by glycosidic linkages.

Two forms of **starch**

Starch is the major storage form of glucose in plants



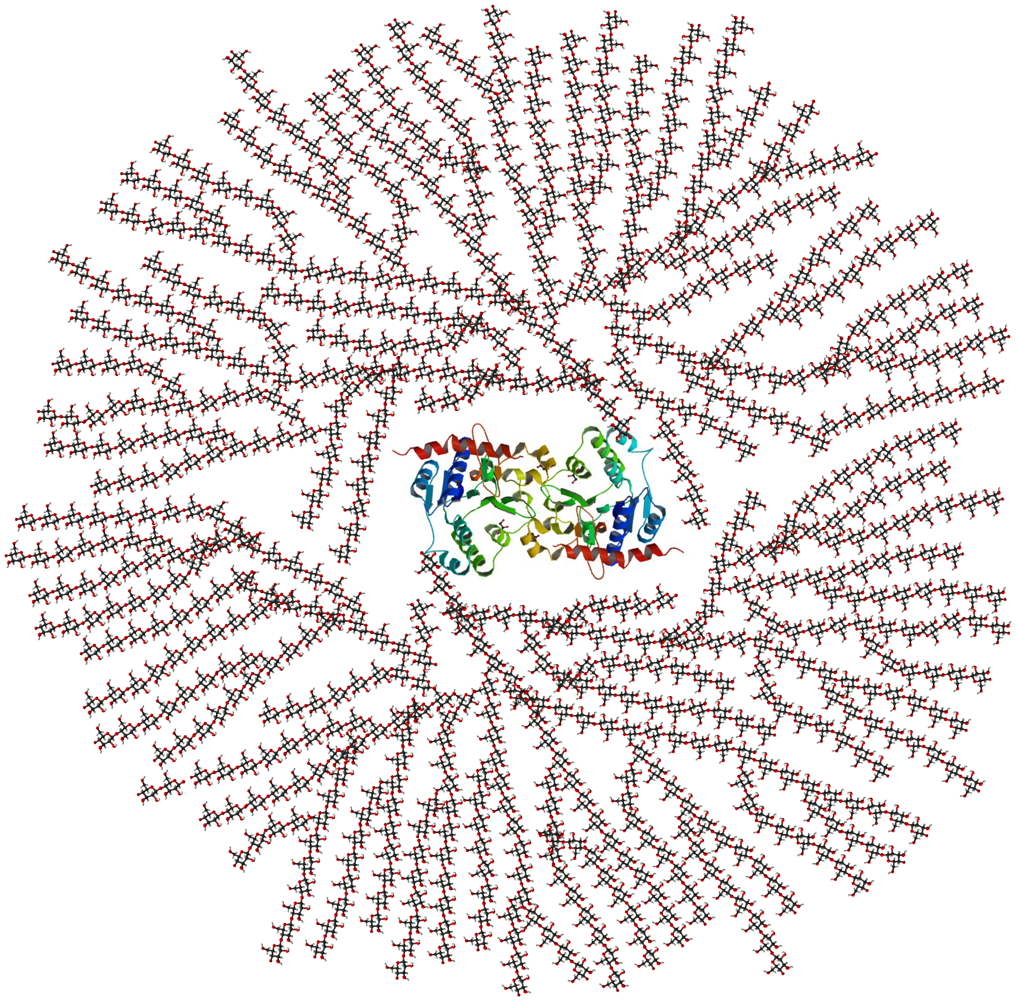
Amylose: α 1-4 glycosidic linkages.

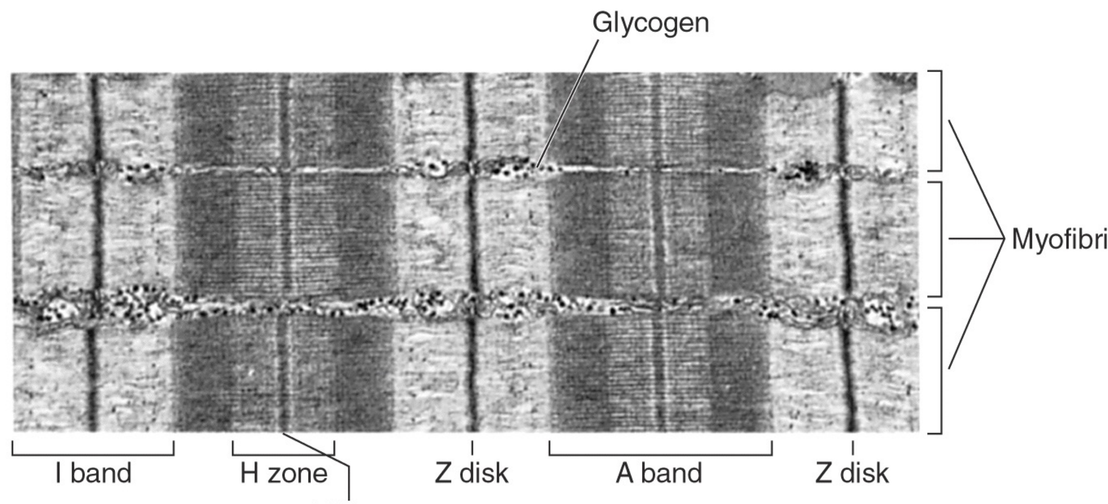
Amylopectin: α 1-4 and α 1-6 glycosidic linkages.

Because of the way the subunits are joined, the glucose chains have a helical structure.

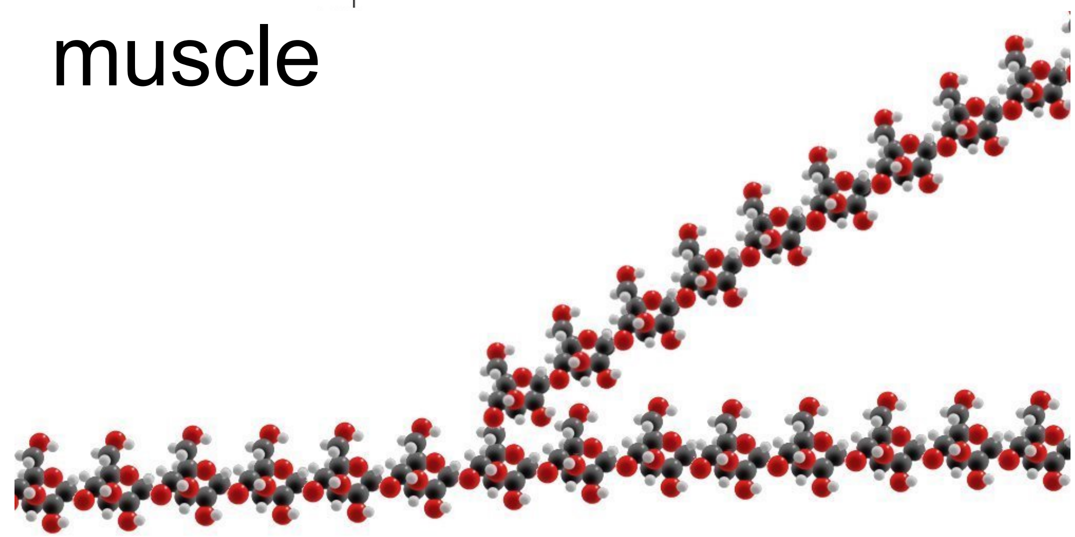
Polysaccharides - Glycogen

Glycogen is the major storage form of glucose in animals





muscle

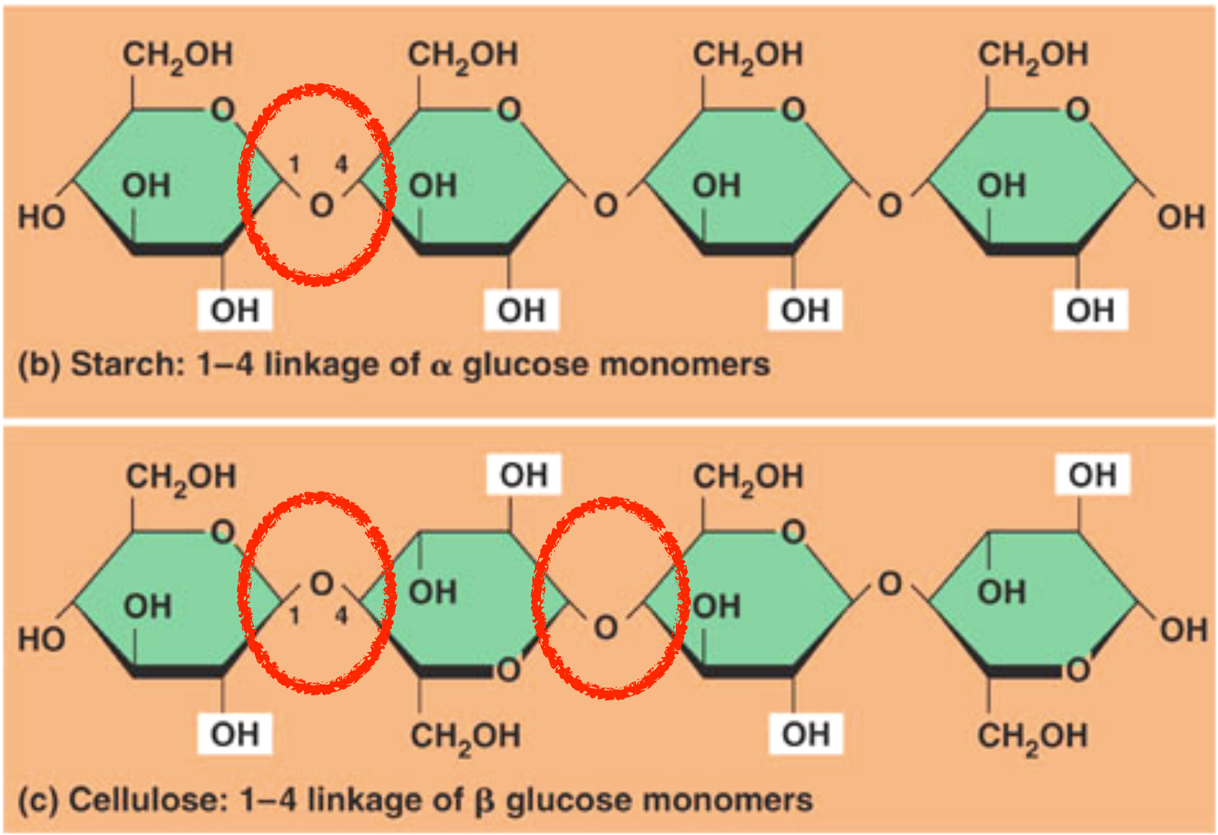


By CeresVesta at English Wikipedia - Transferred from en.wikipedia to Commons., Public Domain, https://commons.wikimedia.org/w/index.php?curid=53007229

Polysaccharides - Cellulose

Cellulose is the most abundant structural polysaccharide in plants - gives plant cell walls their rigidity

Cellulose has different glycosidic linkages than starch



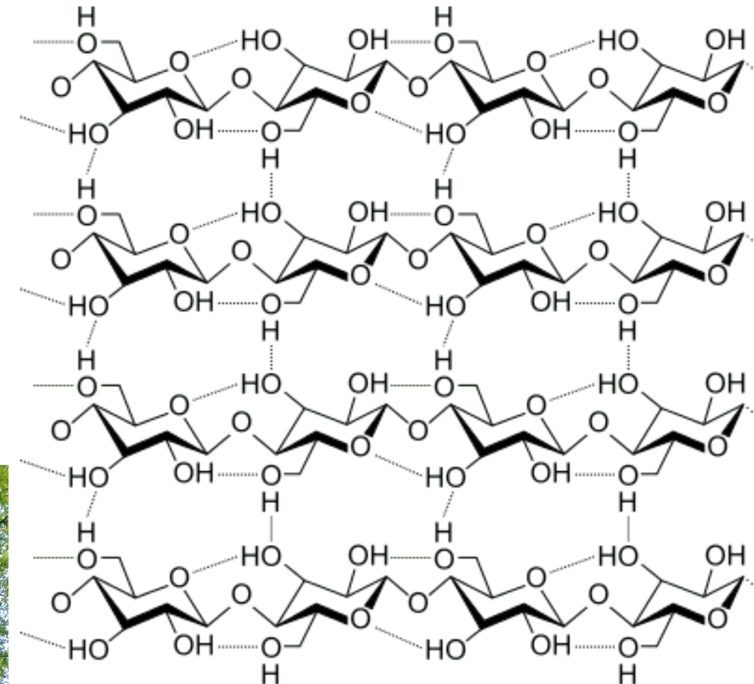
Animals cannot digest cellulose.
Need symbionts to help digest the β linkages via fermentation.

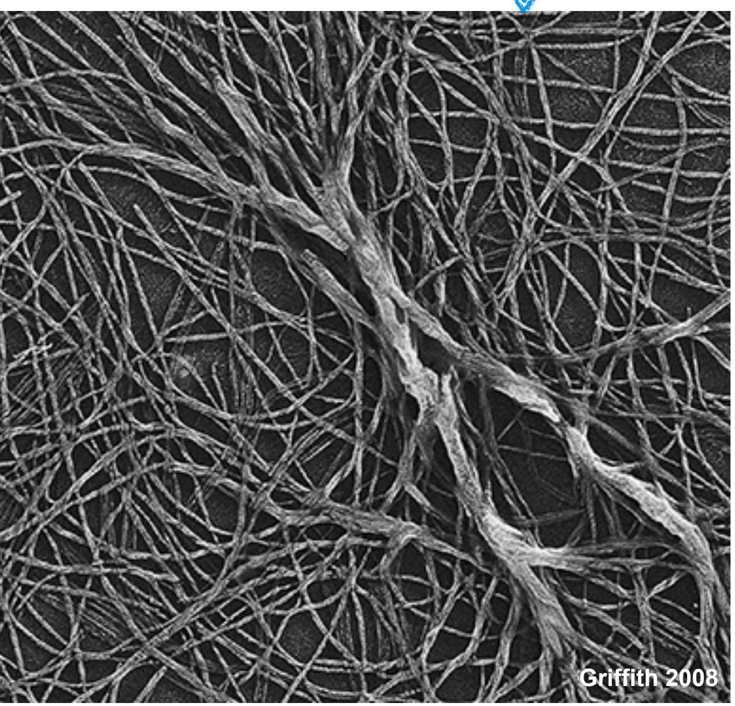
Each monomer is "flipped" relative to the next

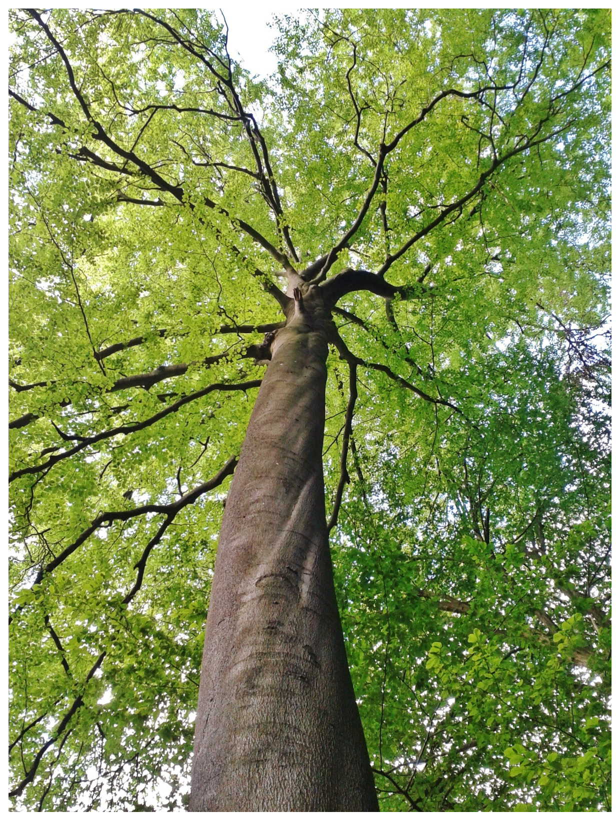
Polysaccharides - Cellulose

Cellulose is not branched.

Hydrogen bonding across the chains produce cable-like units called microfibrils.



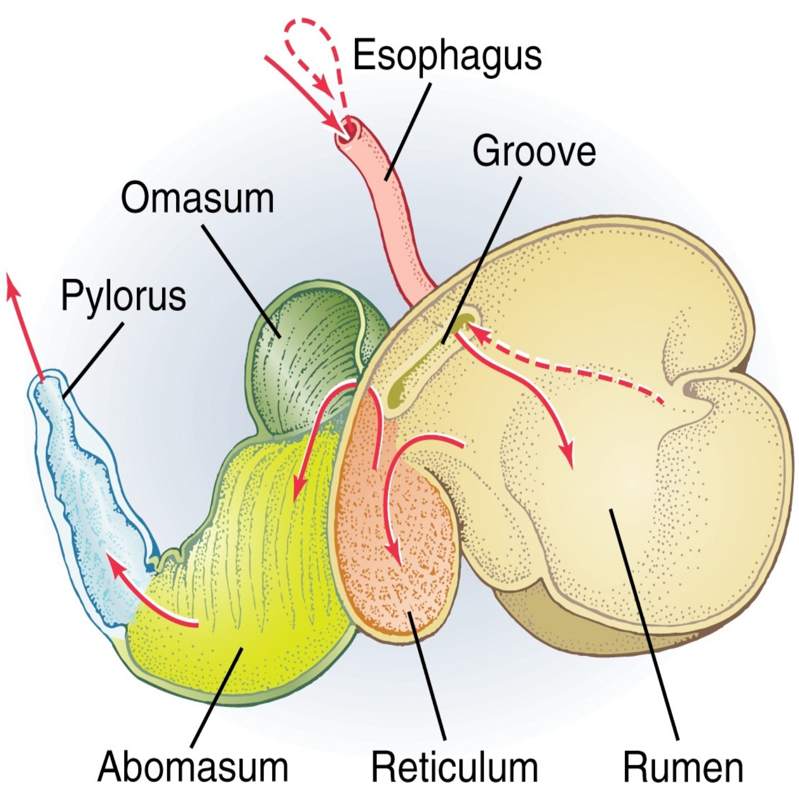


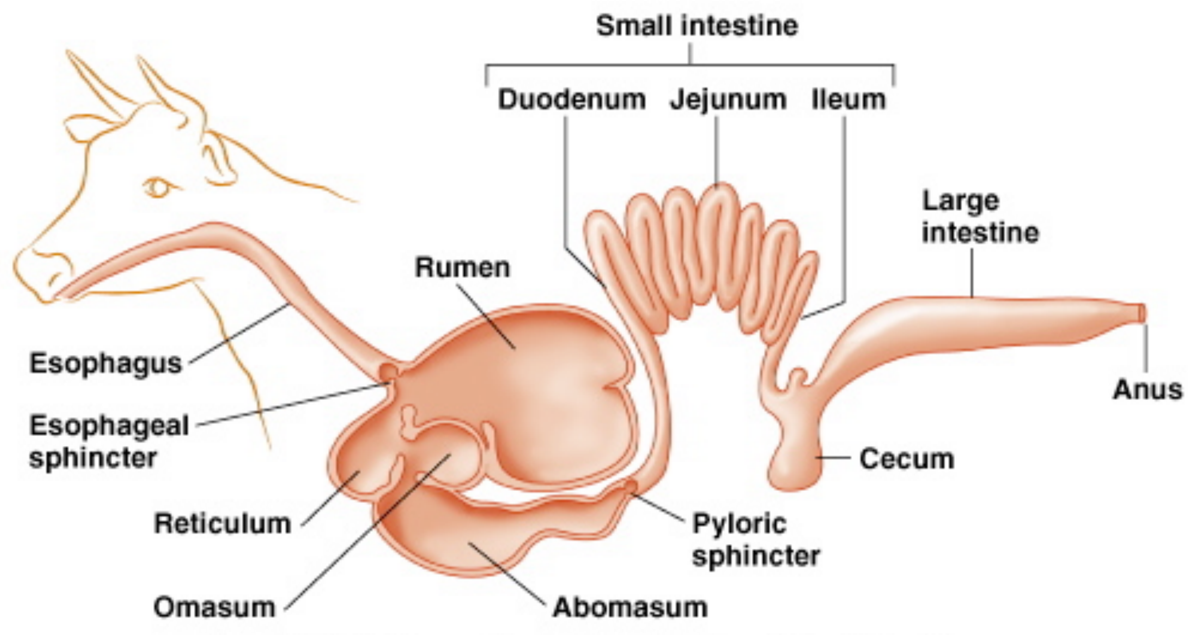


Cellulose provides structure for plants to grow tall even without a skeleton

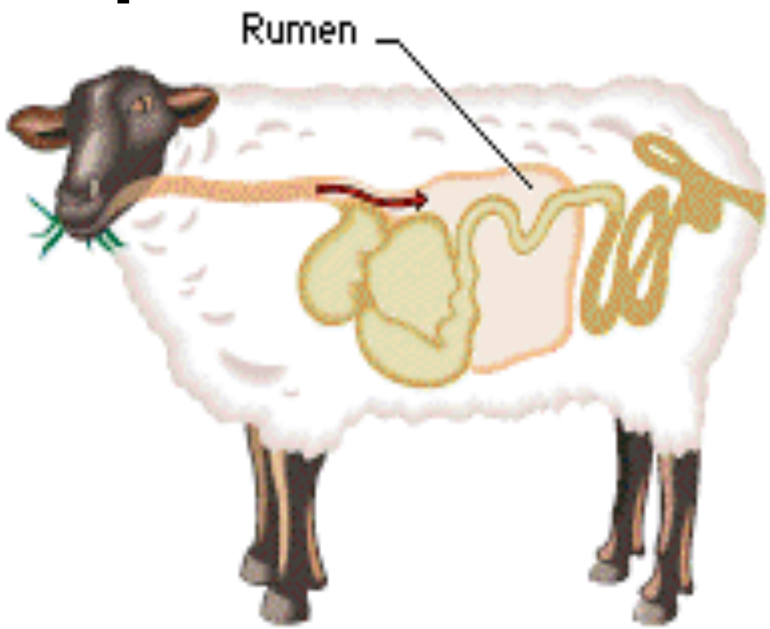
Digastric (multichambered) stomach: Foregut Fermentation - Cow

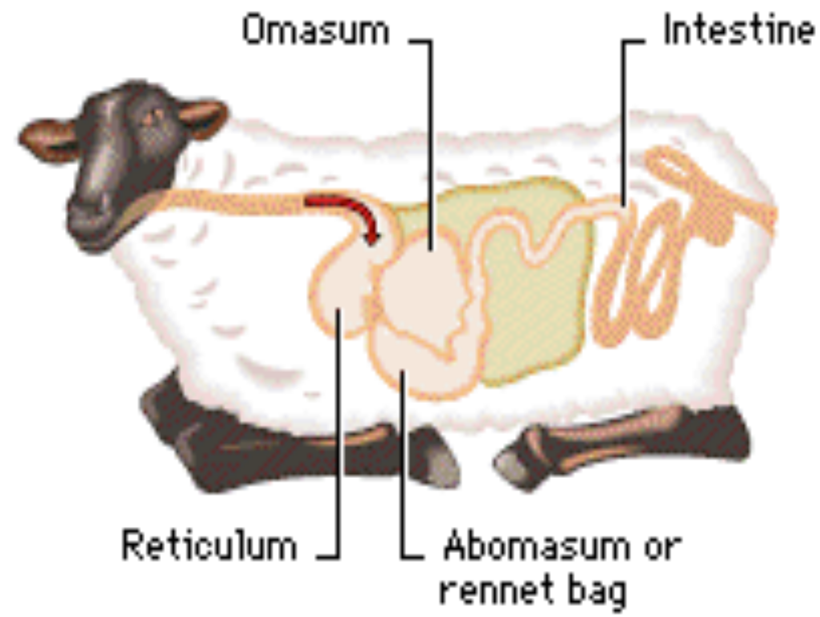
Rumination: “Chew cud”





Sheep





Grazing

Plant material is chewed a little before being swallowed.

Part-digested food is stored in the rumen where it is broken down into cud by bacterial action.

Ruminating

Cud is regurgitated and chewed again while the ruminant is lying down.

Food swallowed for the second time bypasses the rumen.

Food is finally processed by acids and digestive enzymes in the other stomach chambers.

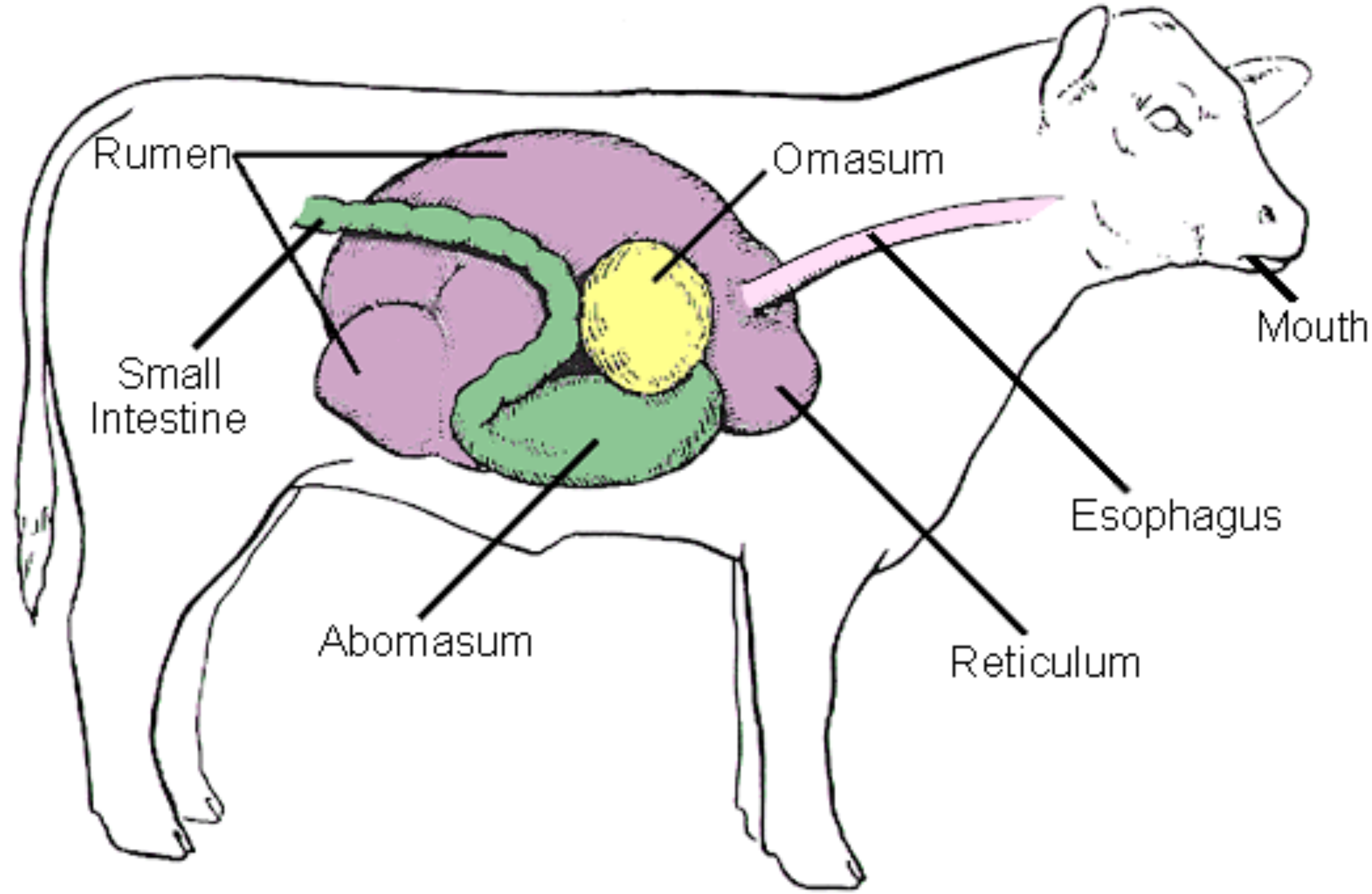
- **Rumen** - large fermentation vat; also called the "paunch"

1. anaerobic
2. Temperature = 39°C (103°F)
3. saturated with gasses
4. constant motion

Rumen Size

Species	Maximum	Normal Content
1000 lb cow	~55-60 gallons	25-30 gallons
150 lb ewe	~5-10 gallons	3-5 gallons

Rumen is HUGE!



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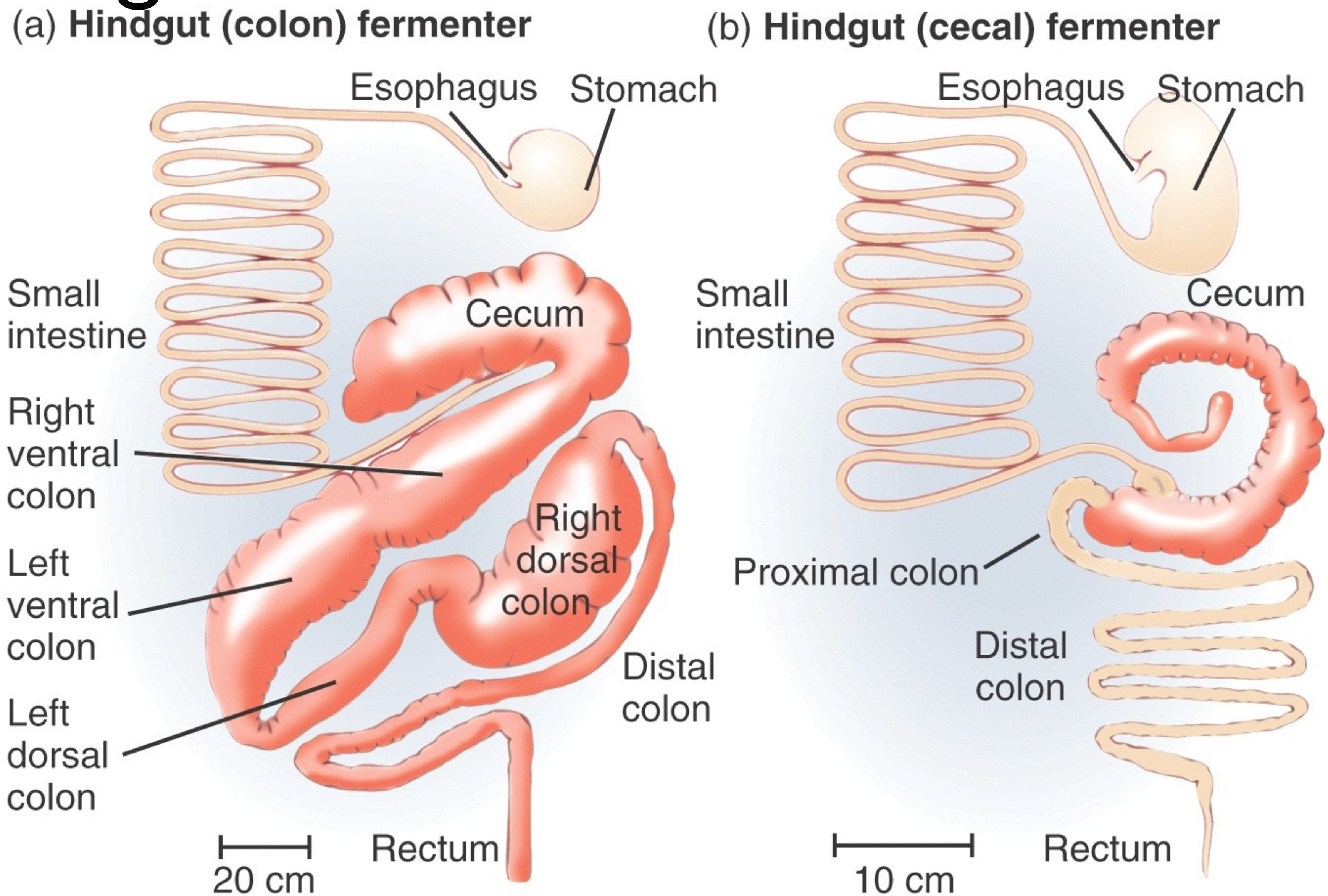
Hindgut Fermentation: in Cecum



-fermentation takes up a lot of space, in non-ruminant animals this is an enlarged portion of colon (head or anterior end) called Cecum

Fermentation in a Ruminant (sheep)

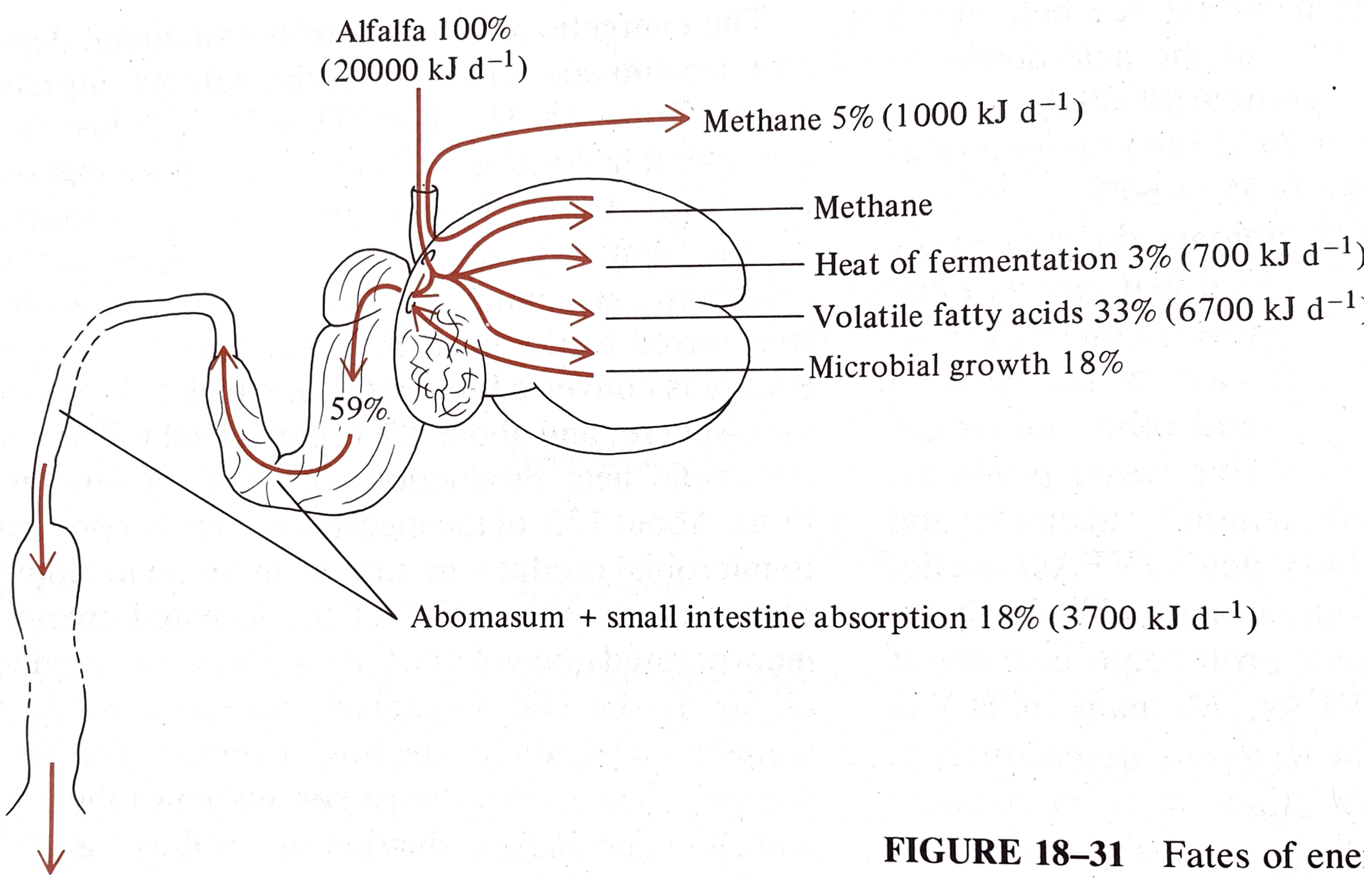
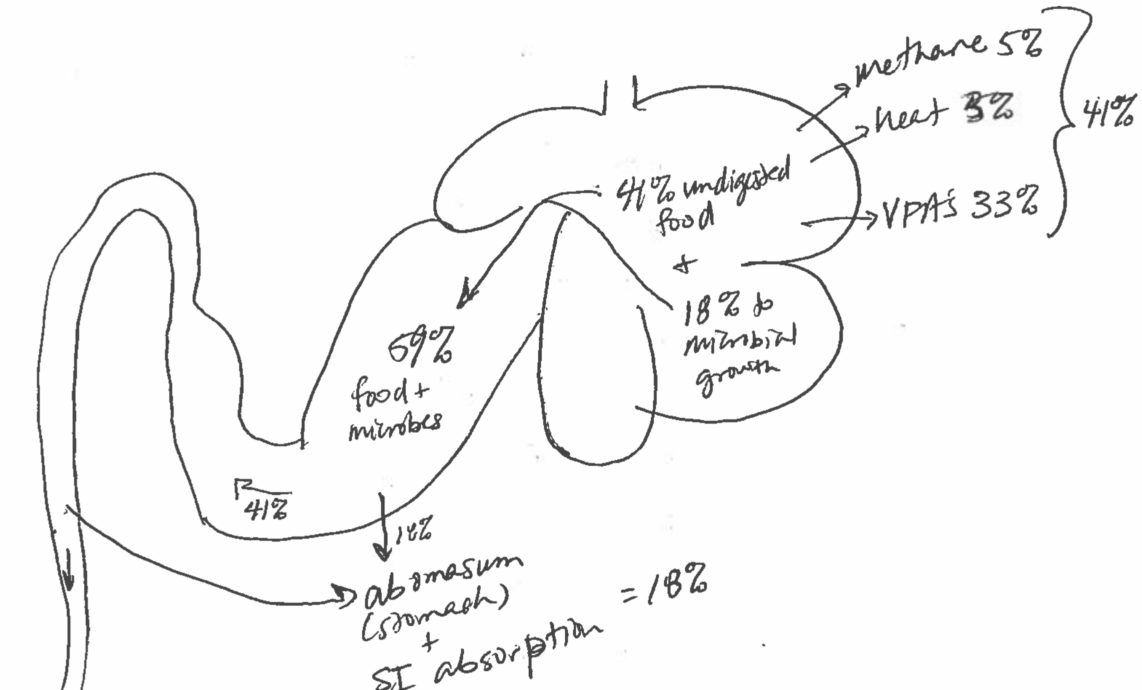


FIGURE 18–31 Fates of energy ingested as an alfalfa diet by a ruminant mammal, the sheep *Ovis*.

The major advantage of ruminant and ruminant-like fermentative digestion is the ability to assimilate

have extensive vitamin and sterol requirements (Dadd 1970). Blood-sucking insects rely on their



Fermentation: — waste — methane
— heat
— VFA's
— Microbial growth → to digestion.

Only 41% of ingested food is available to direct digestion,

but 18% is added by microbial growth.

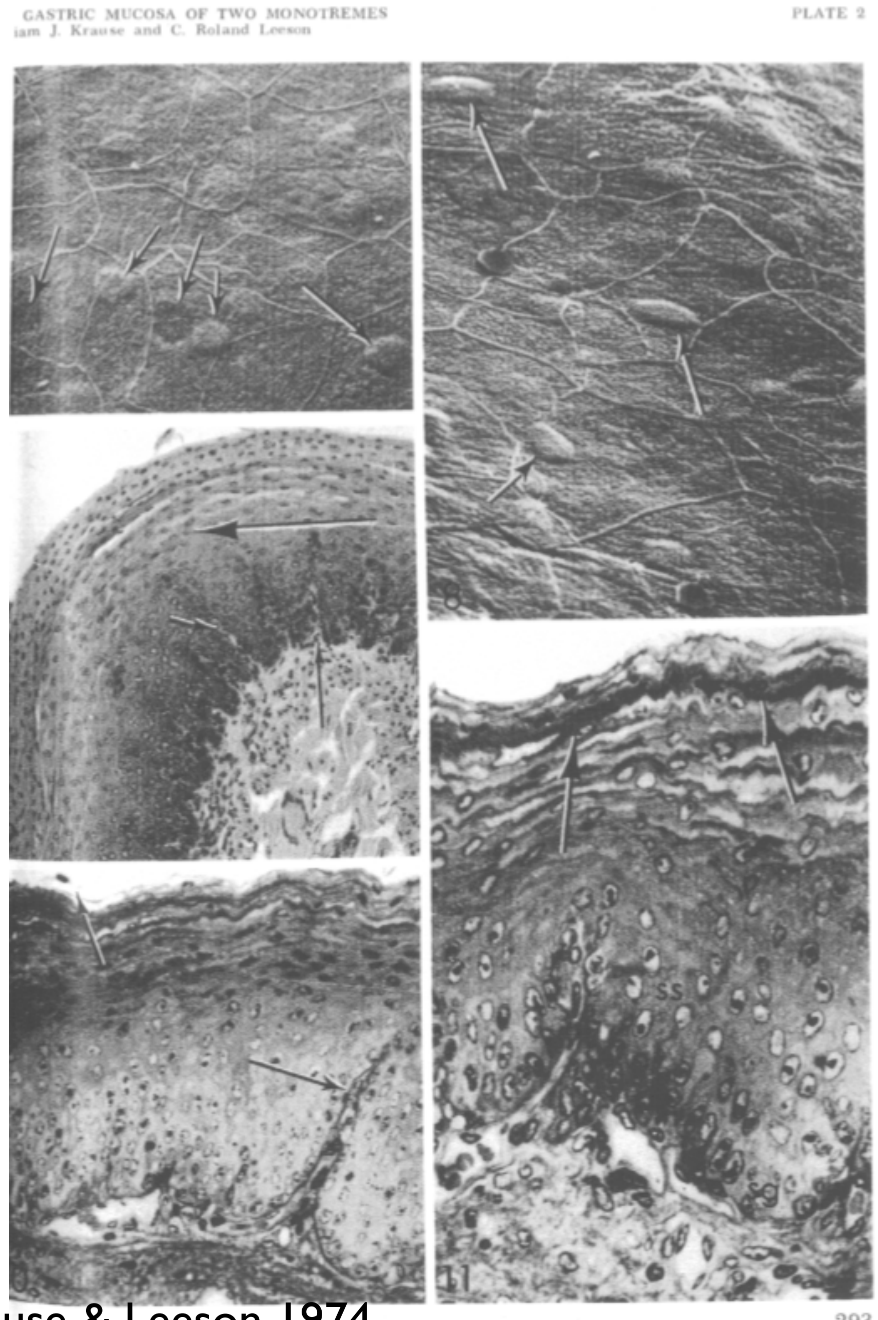
so to simplify, say 59% of food is directly digested

How is DMR supported? 33% of Food E comes from Fermentation
18% from direct digestion.

∴ $\text{Fermentation} = \frac{33}{33+18} = 65\%$ of E from Food or DMR. $\text{Direct digestion} = \frac{18}{33+18} = 35\%$

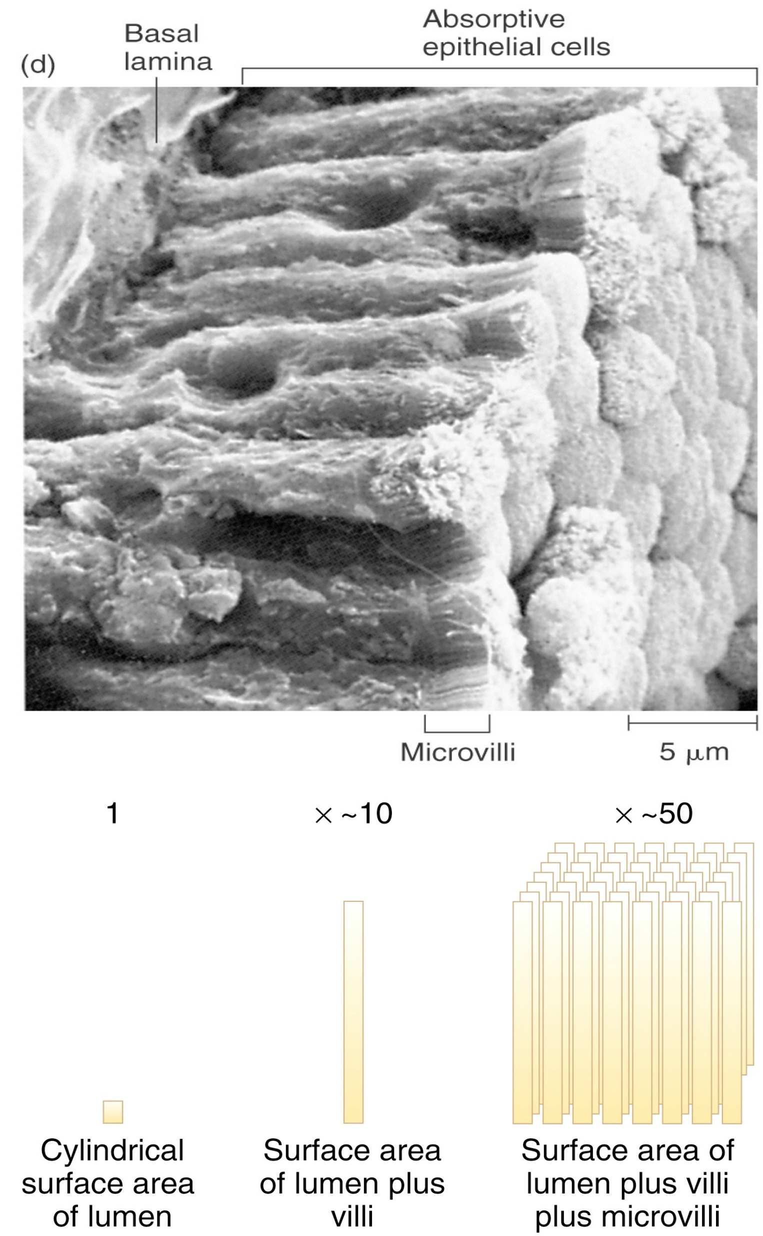
.35 × DMR = E from direct digestion — must assimilate this much!

Squamous Epithelial Cells of Platypus Gut!



Krause & Leeson 1974

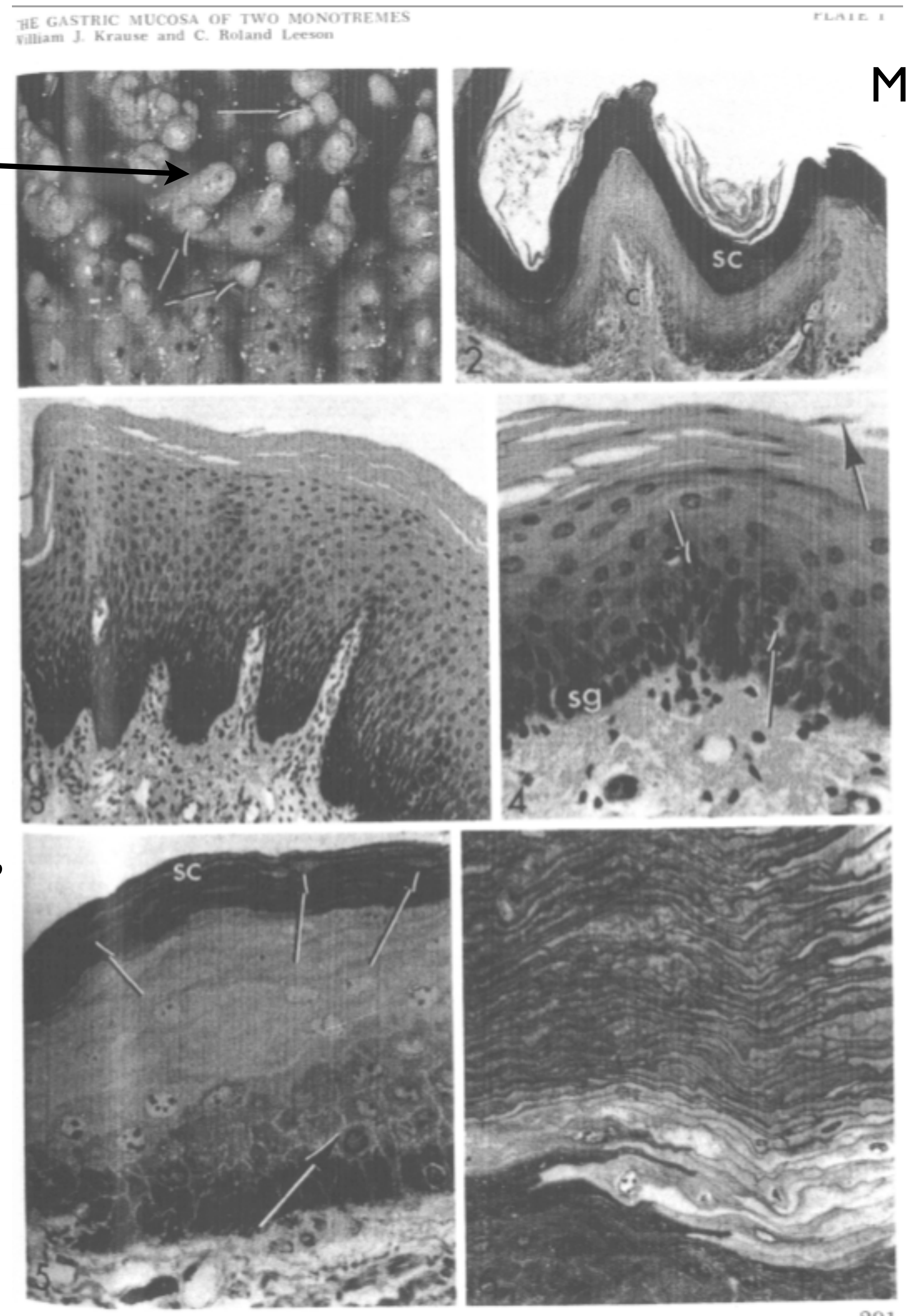
Typical Columnar Epithelial Cells of Vertebrate Gut



Monotreme Gastric Mucosa

Krause & Leeson 1974

Projections into lumen



Mechanical breakdown of food?

Stratum corneum

Connective tissue cores

Duck-billed platypus
Eats shrimp, river inverts, mud?

http://www.animalfactguide.com/blog/2008/12/

Echidna
Eats termites, small insects

http://curiousanimals.net/animals/monstrous-animal-echidna/

Genome Biol. 2008; 9(5): R81.
Published online 2008 May 15. doi: 10.1186/gb-2008-9-5-r81.
PMCID: PMC2441467

Loss of genes implicated in gastric function during platypus evolution

Gonzalo R Ordoñez,[1] LaDeana W Hillier,[2] Wesley C Warren,[2] Frank Grützner,[3] Carlos López-Otín,[1] and Xose S Puente[1]

Monotreme guts are basic (pH 6.8)!

Genome sequencing reveals that the genes for pepsidases and HCl secretion have been lost or inactivated.

Abstract

Background

The duck-billed platypus (*Ornithorhynchus anatinus*) belongs to the mammalian subclass Prototheria, which diverged from the Theria line early in mammalian evolution. The platypus genome sequence provides a unique opportunity to illuminate some aspects of the biology and evolution of these animals.

Results

We show that several genes implicated in food digestion in the stomach have been deleted or inactivated in platypus. Comparison with other vertebrate genomes revealed that the main genes implicated in the formation and activity of gastric juice have been lost in platypus. These include the aspartyl proteases pepsinogen A and pepsinogens B/C, the hydrochloric acid secretion stimulatory hormone gastrin, and the α subunit of the gastric H^+/K^+-ATPase. Other genes implicated in gastric functions, such as the β subunit of the H^+/K^+-ATPase and the aspartyl protease cathepsin E, have been inactivated because of the acquisition of loss-of-function mutations. All of these genes are highly conserved in vertebrates, reflecting a unique pattern of evolution in the platypus genome not previously seen in other mammalian genomes.

Conclusion

The observed loss of genes involved in gastric functions might be responsible for the anatomical and physiological differences in gastrointestinal tract between monotremes and other vertebrates, including small size, lack of glands, and high pH of the monotreme stomach. This study contributes to a better understanding of the mechanisms that underlie the evolution of the platypus genome, might extend the less-is-more evolutionary model to monotremes, and provides novel insights into the importance of gene loss events during mammalian evolution.