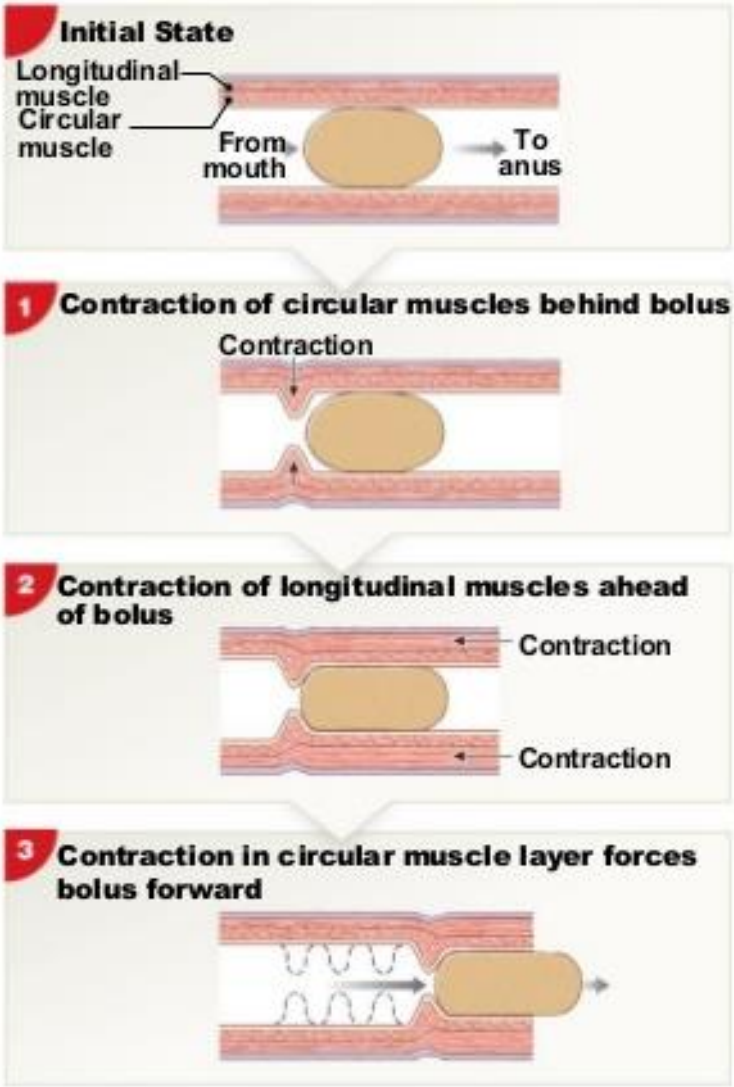
Understandings:

1. Explain peristalsis and how it works.

- "Peri" means "to wrap around" (as in perimeter) and "stallein" means "to place" in Latin. Essentially, it is a wave-like movement of continuous, involuntary contraction of muscles in our digestive "tube". Our tube includes of course our esophagus and small intestine and large intestine. In addition, this movement is also used in ejaculation and earthworms.

It is important to realize that there are two main muscles in work: circular and longitudinal. What is the difference? Basically, circular is the muscle around the tube that enables 1 way direction, while longitudinal is the vertical muscle that moves the bolus to the anus (it rhymes!).



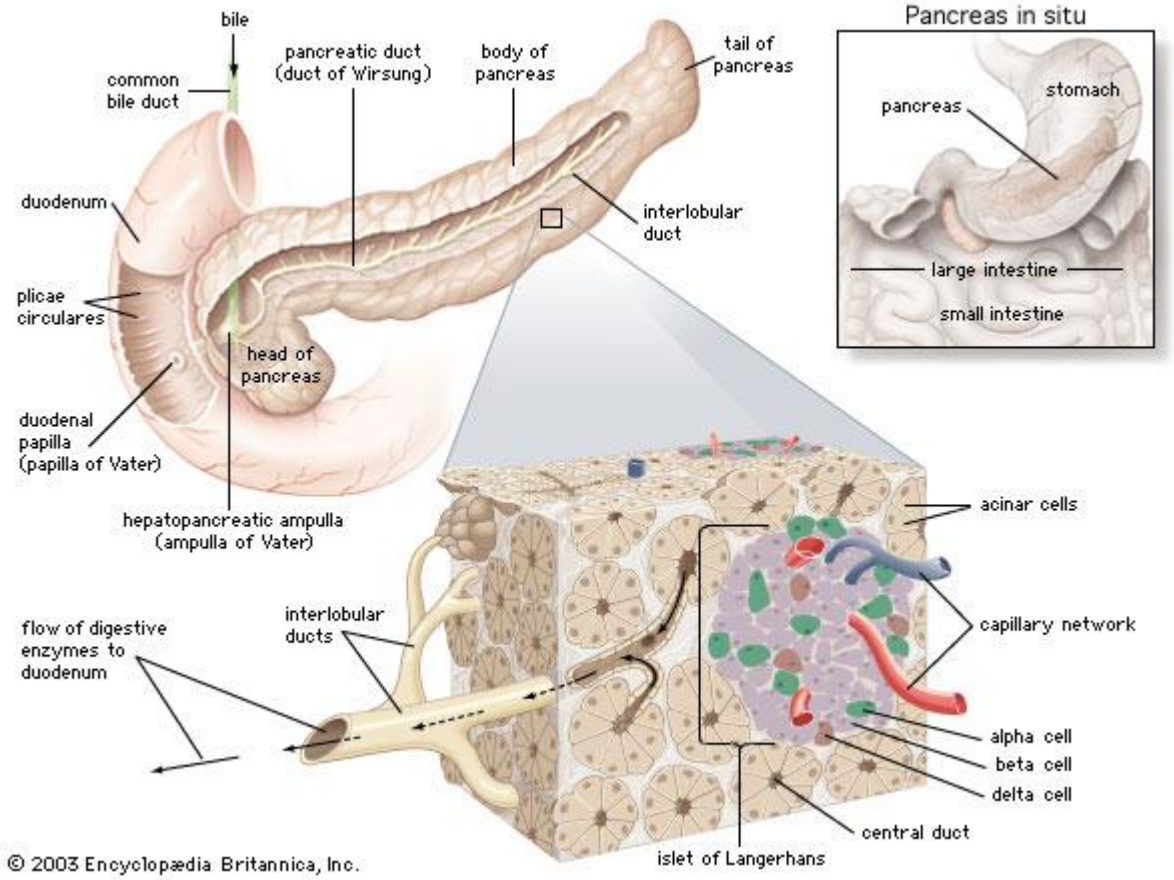
But why have this function? Well, there are two main reasons.

1. Food travels in one direction only. It would not be so nice to have your digested food up in your throat, unless you puke. But then abdominal muscles are used.

2. In the intestine, it enables the chyme to mix and churn with enzymes. The overall process is slow at a few centimeters/contraction, but it enables effective absorption.

2. Explain what, how and where pancreatic juice is.

- Pancreatic cells can either do the insulin/glucagon hormone production (endocrine pancreas) or secrete digestive enzymes (exocrine pancreas). They include amylase, lipase and protease (also hydrogen carbonate to neutralize the acid in stomach). But the question is how?



We can see from the picture above that the interlobular ducts lead to these paprika shaped islands. Those are a group of secretory cells, and one group of them is called one acinus. These cells basically produce the enzymes like all cells through transcription, translation, to rough ER, to Golgi apparatus and then secreted to the ducts by exocytosis.

Extra notes

- Be aware that there are many different types of what we simply call amylase. There are α-amylase, β-amylase and γ-amylase. Animals only have α-amylase and luckily, this is topic is *human physiology* so we just need to worry about one amylase. But the optimum conditions in which these amylases operate are different, so it is important that we know that different amylases exist.

3. Explain what happens in the small intestine.

- Once we have the enzymes, these ducts connect to duodenum – start of small intestine. These enzymes split macromolecules with hydrolysis.

Step 1.

Macromolecule	Enzyme	Polymer	Optimum pH
Starch	α-Amylase	Maltose (2x α glucose)	≈7
Triglycerides	Lipase	Glycerol and fatty acids. Mono glycerides.	≈8
Phospholipids	Phospholipase	Glycerol, fatty acids and phosphate.	Depends which phospholipase
Proteins	Protease	Oligopeptides and dipeptides.	≈1.6

But hey, these are not monomers yet! We enter step 2. This time, enzymes are secreted by the walls of small intestine.

Macromolecule	Enzyme	Monomer
Maltose	Maltase	α glucose
Lactose	Lactase	Glucose and galactose
Sucrose	Sucrase	Fructose and glucose
DNA and RNA	Nuclease	Nucleotides
Oligopeptides	Exopeptidase	Dipeptide (not monomer yet)
Dipeptide	Dipeptidase	Amino acids

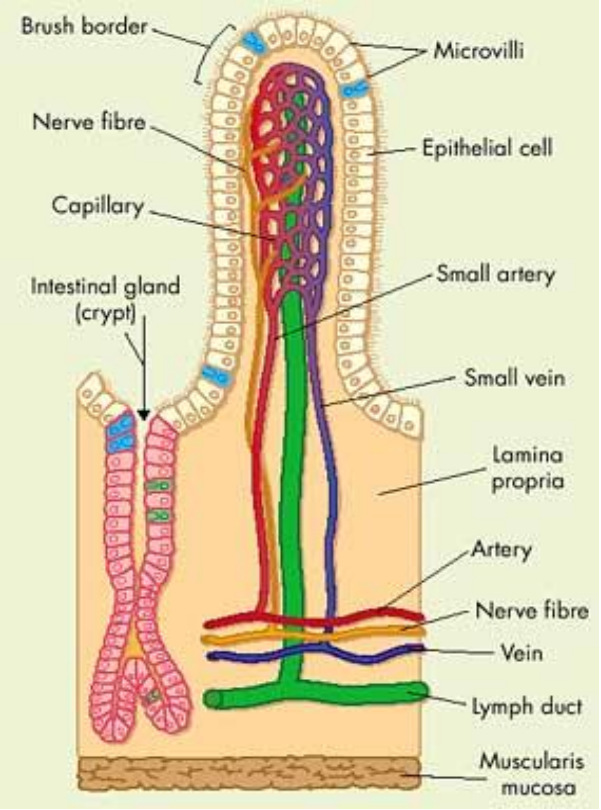
This takes from 8 – 24 hours.

There are molecules we cannot digest due to not compatible enzymes, like cellulose.

4. Explain the function of villi.

- Villi are very small finger-like folds on the small intestine. Villi are not a thing but merely a folding. The reason it folds is to increase surface area of epithelial cells. These are the ones that absorb the digested macromolecules and are only 1 cell thick to maximize efficiency.

The blood that passes through via capillaries obviously doesn't have many nutrients.



Most digested macromolecules are passively digested into the blood stream. The blood stream has now high concentration of digested macromolecules.

Lacteal is very important structure and is a type of lymph vessel (the green structure). Large molecules like fat is absorbed to the lacteal and then sent in to the blood.

Note that lymphatic system is not only a help for circulatory system, but also immune system. Substances that are pathogens or toxic are taken down the lymph duct/lacteal and taken to glands that can detoxicate. We have several lymphatic glands in our body. That is why our throat is sometimes swollen when we are sick, because lymphatic system is at full work.

The blood is taken directly to liver to further remove the pathogens or toxic substance.

5. Explain what villi absorbs.

- As mentioned, it is actually not the villi itself that absorbs. It is the epithelial cells that cover the villi that absorb it. The obvious 4 main molecules carbohydrates, protein, fats and nucleic acids are absorbed (they are broken down before absorption of course).

But they also absorb mineral ions, such as sodium, calcium and potassium that are used in neurotransmitters and potential gradient proteins. Vitamins are also absorbed.

Harmful substances may enter, but we have a system that takes care of it as seen previously. Even if some pathogens do enter, phagocytes will quickly remove them.

6. Explain in a molecular detail how absorption is done.

- Now we know that nutrients simply get absorbed via microvilli (villi on cells), epithelial cells and into the blood capillaries and lacteal (branch of lymphatic duct). But there are many ways in which nutrients may be absorbed, so exactly how are they absorbed?

This differs dramatically depending on whether the molecule is hydrophobic (lipids) or hydrophilic (the rest).

For hydrophobic molecules (taking lipid as an example):

1. Triglycerides are broken down into fatty acids, glycerol and monoglycerides.

2. They are absorbed in the epithelium by simple diffusion.

3. Once in the cell, the molecules recombine into triglyceride so it is no longer permeable to diffuse back to intestine.

4. Triglyceride is stored in a lipoprotein. Remember that without lipoproteins, triglyceride cannot be dissolved in water.

5. By exocytosis, these lipoproteins get transported to either to lacteal or the blood capillaries.

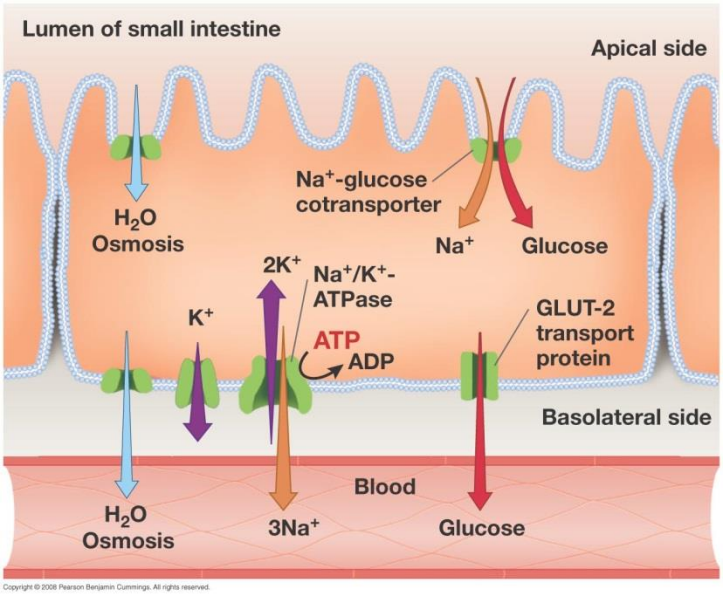
For hydrophilic molecules (taking glucose as an example):

1. Glucose cannot enter by simple diffusion because it is polar and membrane layers are hydrophobic in the middle.

2. In order to solve the problem, sodium-potassium actively pumps out $3Na^+$ to blood capillaries and pumps in $2K^+$. This makes the potential gradient of Na^+ low in the epithelial cells.

3. Na^+ from the small intestine will like to diffuse in and using this movement, a co-transporter transports sodium and glucose together. This is a form of facilitated diffusion.

4. From the epithelial cells, glucose uses facilitated diffusion into the blood capillaries.



Applications and Skills:

1. Explain how starch is digested in the small intestine.

- We have previously learnt that starch can be in amylose (unbranched with only 1,4 carbon bonds) or amylopectin (branched with both 1,4 and 1,6 carbon bonds).

Interestingly, amylase can only break down 1,4 bonds thus amylopectin is not fully digested right up to the point it meets microvilli. Microvilli have the function to break down 1,6 bonds using 3 enzymes. Finally, glucose may get absorbed.

2. Be able to make a model of small intestine using a dialysis tube.

- Done in class

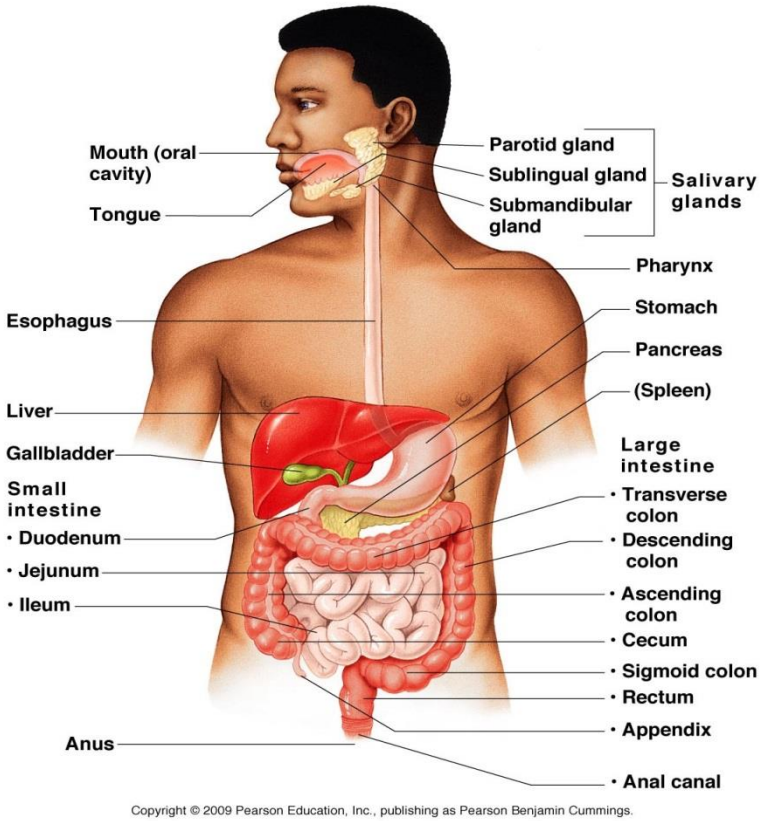
3. Be able to draw an annotated diagram of the digestive system.

- The path of food is also called alimentary canal.

In order, the process will be:

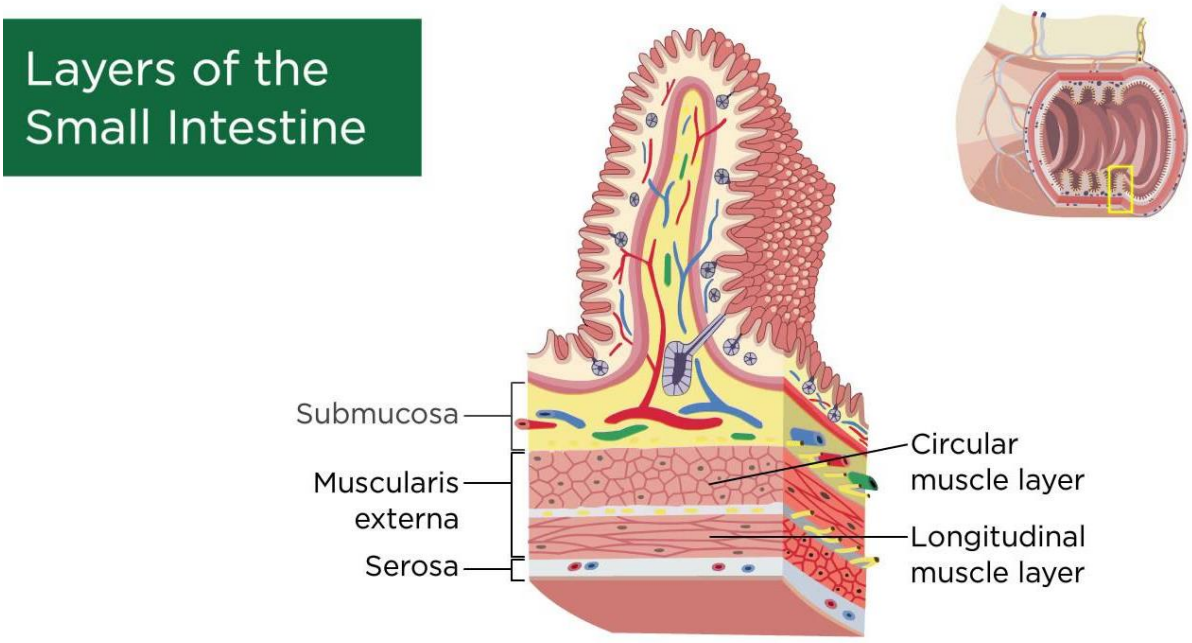
Ingestion → Digestion → Absorption → Transportation → Assimilation

Mouth → Esophagus → Stomach → Pancreas and gall ballder→ Small intestine → Large intestine → Rectum



4. Identify layers of the small intestine.

-



1. Serosa

2. Longitudinal

3. Circular muscle

4. Submucosa

5. Mucosa (the section right above submucosa with the layer of epithelial cells).