Digestion Notes

Digestion Overview
- The body uses a variety of small molecules (amino acids, fatty acids, glucose) for its metabolic needs - food is mechanically and chemically broken down into thesis molecules during digestion, after which they can be taken up by body cells through the separate process of absorption
- Food travels in a one-way path from mouth to esophagus to stomach to small intestine to large intestine to anus
- Organs and structures in the digestive system are specialized for specific functions in digestion
- Digestive enzymes are specific hydrolytic enzymes that have an optimal functioning temperature and pH
- Proper nutrition is necessary for health. After all, you are what you eat!

What happens during the digestive process?
1. **Digestion**: the mechanical and chemical breaking down of ingested food into particles, then into molecules small enough to move through epithelial cells and into the internal environment
   - mechanical digestion uses teeth, tongue, roof of the mouth, and stomach to physically breakdown food into smaller pieces; this precedes chemical digestion
     ➡ Why? To increase surface area for enzymes to work on food (the substrate)
   - chemical digestion uses hydrolytic enzymes to breakdown macromolecules into unit molecules
2. **Absorption**: the passage of digested nutrients from the gut lumen into the blood or lymph, which distributes them through the body
3. **Elimination**: the expulsion of indigestible (ex. cellulose) material from the body

1. **DIGESTION**
- During digestion, carbohydrates are broken down into monosaccharides (ex. glucose), proteins into amino acids, fat into glycerol and fatty acids, and nucleic acids into nucleotides
- Digestion is an extracellular process.
  ➡ What type of transport is needed for the hydrolytic enzymes to be excreted out of the cell that produces them? **Exocytosis**

A. **Mouth**
- **Structure**
  - divided into an anterior hard palate (contains several bones) and a posterior soft palate which is composed of muscle tissue
• **Function**
  a. receives food
  b. mechanical digestion of food
  c. chemical digestion of starch

• There are three sets of **salivary glands** that produce **saliva** for digesting starch:
  1. parotid (below ears)
  2. sublingual (below tongue)
  3. submandibular (under lower jaw)

• **Saliva**
  - consists of water, mucus and a hydrolytic enzyme called salivary amylase which functions to breakdown starch into maltose
  - Once food has been chewed, it is called **bolus**
  - Food is then passed through the back of the mouth when you swallow
    - the first region it enters is called the **pharynx (throat)** which is simply the region between mouth and esophagus where swallowing food and air meet
    - Swallowing is a reflex action (requires no thought)

  ![Diagram of the mouth and throat]

  Why is it impossible to breathe and swallow at the same time?
  - when you swallow, the following happens in order to block air passage:
    1. the **soft palate** moves back to cover openings to nose (nasopharyngeal opening)
    2. **Uvula (end of soft palate)** covers the internal nares
    3. the **trachea** moves up and a flap of tissue called the **epiglottis** which prevents food from entering the respiratory tract

  What happens when food goes down the “wrong way” (ex. down the trachea)? **You cough it up**

• **Esophagus**
  - long and muscular (smooth muscle)
  - lined with mucus membrane (for lubrication)
  - has circular and longitudinal muscle for peristalsis, **rhythmic contractions of the esophageal muscles** (analogy: squeezing a tube of tooth paste)

  What is **reverse peristalsis**? **Vomiting**

• Food bolus reaches the end of the esophagus and arrives at the **cardiac sphincter** connecting to the stomach
  - Made of muscles that encircle tubes, open them when they relax, close them when they contract

• **Stomach**
  • **Functions**
    a. temporary food storage (2-6 hours)
b. mechanical digestion
   c. chemical digestion of proteins
   • three layers of muscle to contract to churn and mix its contents
   • “hunger pains” are felt when an empty stomach churns
   • the mucus lining of the stomach contains inner gastric glands (interstitial glands) which produce gastric juice
   - Components of gastric juice:
     a. Pepsinogen (pepsin = active form)
       ▪ proteins and water - peptides
     b. Hydrochloric acid (pH 2-3)
       ▪ kills bacteria, activates pepsinogen to pepsin by cleaving off a part of it to expose the active site
     c. Mucus
       ▪ prevents HCl from digesting stomach wall

Why is it important to keep pepsin in its inactive form, pepsinogen, when there is no food in the stomach? Saves energy, prevents self-digestion
What is an ulcer? How does it form? Open sore in stomach lining; formed from too much gastric juice and not enough mucus
   - could be due to stress (over stimulation of nervous system) or due to bacterial infection (ex. Helioabacter pylori)
• after 2-6 hours (depending on the type of food), the food has been turned into a semi-liquid food mass called acid chyme, and the stomach empties into the first part of the small intestine (called the duodenum)
   - This emptying is controlled by the pyloric sphincter at the bottom of the stomach

2. ABSOPTION

D. Small Intestine
   • Functions
     a. completing the chemical digestion of proteins, carbohydrates, and lipids
     b. absorption of unit molecules into blood (circulatory system) or lymph (lymphatic system)
   • Total length is approximately 6 metres (2.5 cm diameter)
   • 3 sections: duodenum, jejunum, and ilium
   • Duodenum
      ▪ first 25 cm
      ▪ receives bile and pancreatic juice
      ▪ site of major chemical digestion of proteins, carbohydrates, and lipids
- **Jejunum & ileum**
  - completion of chemical digestion and absorption of nutrients into circulatory or lymphatic system
  - walls of duodenum and small intestine are lined with millions of interstitial glands that produce juices containing enzymes that finish the digestion of proteins and starch
  - secretions from the interstitial glands contain digestive enzymes: **peptidases** digests peptidase to amino acids, **maltase** digests maltose to glucose
    - other enzymes made here digest other disaccharides (ex. lactase digests lactose [the sugar in milk], and **sucrase** digests sucrose)
  - the small intestine’s structure is specialized for its function of digestion and absorption
    1. long
    2. convoluted
    3. has villi (each with microvilli)
    4. mitochondria for ATP production (needed for active transport)
  - the structure of the small intestine is well related to its function of absorption
    - long and convoluted walls increase surface area
    - surface area is further increased by presence of finger-like projections called villi (singular one is called a "villus")
      - Interstitial glands are at the base of each villi
    - Each villi contains blood vessels and lymph vessels
  - Absorption takes place across the walls of each villus
    - This can happen actively or passively
      - Recall that active transport across cell membranes require ATP
    - The nutrient can now enter the blood or the lymphatic system, depending on what type it is
      - Ex. lipids vs. proteins vs. carbohydrates
  - **Fatty acids and glycerol** are absorbed across the villi, are recombinined into fat molecules in the epithelial cells of the villus
    - The fats then move into the lacteal of each villus and enter the lymphatic system
    - Why? Lipids are not readily soluble in H2O, making it more difficult to transport via blood, therefore found more in lymph. Lymph is also bigger and non polar
  - **Glucose** and **amino acids** enter the blood through the capillary network
  - The blood vessels from the villi in the small intestine merge to form the hepatic portal vein which leads to the liver

  - Functions of the liver
1. Keeps blood concentrations of nutrients, hormones, etc. **constant** (ex. converts glucose to glycogen and back to keep blood glucose levels constant)
2. **Interconversion of nutrients** (ex. carbohydrates to fats, amino acids to carbohydrates and fats)
3. Removes toxins from the blood = **detoxifies** (ex. breaks down alcohol using alcohol dehydrogenase)
4. Production of **bile** (up to 1.5 litres of bile per day!)
5. **Destroy**s **old red blood cells** (Red blood cells can live approximately 120 days)
6. Production of **urea** (deamination of amino acids and excretion of resulting ammonia as urea, uric acid, etc.)
7. **Manufacture of plasma proteins** such as fibrinogen and thromboplastin (for blood clotting) and albumin
8. **Manufacture of cholesterol**
   - cholesterol is needed for making steroid hormones such as estrogen and testosterone, and helps with membrane permeability
   - Produces **bile** which is sent to the duodenum via bile duct
     - Bile is thick, **green** liquid
     - produced in liver
     - stored in gall bladder
     - contains bile salts which break fat into **fat droplets**
     - Why are fat droplets better? **Increased the surface area of fat (substrate) so that lipase can work on digesting it.**

• **The pancreas**
  1. Pancreatic juice enters duodenum through the **pancreatic duct**
  2. **Components of pancreatic juice**
     c. hydrolytic enzymes
        ▪ **Pancreatic amylase**: starch + H₂O = maltose
        ▪ **Trypsin (trypsinogen)**: protein + H₂O = peptides
        ▪ **Lipase**: fat + H₂O = glycerol + fatty acids
        ▪ **Nuclease**: nucleic acid = nucleotides
        ▪ **Nucleotidase**: nucleotides = sugar (pentose) + phosphate + base
        ▪ **Peptidase**: peptides = amino acids
d. Sodium bicarbonate (NaHCO₃)
   ▪ pH 8.5
   ▪ neutralizes **acid chyme** so that enzymes are at optimal pH

3. **ELIMINATION**

E. **Large Intestine**
   • Consists of the **colon** and **rectum** (last 10-20 cm of colon)
   • Opening of the rectum is called the **anus**
   • **Anal** sprinter is a circular muscle that you learn to control
• Function of the rectum is to store feces until elimination
• **Reabsorption** of H2O (approximately 95%) from indigestible food matter
• Absorption of certain vitamins
• Feces also contain **bile pigments, heavy metals**, and billions of **E. coli**
  - E. coli are parasites, but they provide a valuable service to us: this bacteria break down some indigestible food, and in the process produce some vitamin K, amino acids, and other growth hormones that are in turn absorbed by the colon
  - Feces is made mostly of cellulose (fibre) not bacteria

Why do feces smell? H2S = hydrogen sulphide produced by bacteria

Why do you fart? Methane gas provided by E. coli as a by product

**Common Disorders of the Digestive System**

• **Diarrhea**
  - Too much H2O is expelled in the feces
  - Usually caused by **infection** (in food, polluted water, etc.) or stress (increased peristalsis moves content through digestive track quicker, allowing for less H2O to be reabsorbed)
  - Symptom is actually a body defence against pathogen (an attempt to “flush it out”)
  - Loss of H2O can lead to severe **dehydration**
    * Causes millions of deaths per year in Developing Nations

• **Constipation**
  - Feces are **dry**, hard, difficult to expel
  - Leading cause is lack of **fibre**
    * Diet can be supplemented by fiber or natural fiber supplements
    * Most chemical laxatives are irritants - cause increased peristalsis. They may weaken intestinal wall such that their continued use is perpetuated (you grow to “depend” on them)

What does your poop say about your health?

**Bristol stool chart**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Separate hard lumps, like nuts (hard to pass)</td>
</tr>
<tr>
<td>2</td>
<td>Sausage-shaped but lumpy</td>
</tr>
<tr>
<td>3</td>
<td>Like a sausage but with cracks on its surface</td>
</tr>
<tr>
<td>4</td>
<td>Like a sausage or snake, smooth and soft</td>
</tr>
<tr>
<td>5</td>
<td>Soft blobs with clear-cut edges (passed easily)</td>
</tr>
<tr>
<td>6</td>
<td>Fluffy pieces with ragged edges, a mushy stool</td>
</tr>
<tr>
<td>7</td>
<td>Watery, no solid pieces, <strong>Entirely liquid</strong></td>
</tr>
</tbody>
</table>
How Well Do You Know Your Shit?

When you poop, the little brown blob in your toilet bowl is what’s left of the food after your body has absorbed all the nutrients it needs from it.

Pooping is vital to your health as it’s your body’s natural way of expelling the waste that it doesn’t need. That’s why how your poop looks and smells can also give clues to what’s going on inside your body.

Textures of poop

Separate hard lumps, like nuts
You’re lacking fibre and fluids. Drink more water and chomp on some fruits and veggies.

Sausage-shaped, smooth and soft
Optimal poop! You’re doing fine!

Watery, no solid pieces, all liquid
You’re having diarrhoea! This is probably caused by some sort of infection and diarrhoea is your body’s way of cleaning it out. Make sure you drink lots of fluids to replace the liquids lost or otherwise you might find yourself dehydrated.

Sausage-shaped but lumpy
Not as serious as separate hard lumps, but you need to load up on fluids and fibre.

Soft blobs with clear-cut edges
Not too bad. Pretty normal if you’re pooping multiple times a day.

Soft and sticks to the side of the toilet bowl
Presence of too much mucus, which could mean that your body isn’t absorbing the fats properly. Diseases like chronic pancreatitis prevent your body from properly absorbing fat.

Fluffy pieces with ragged edges, a mushy stool
You’re on the edge of normal. This type of poop is on its way to becoming diarrhoea.

Shades of poop

Brown: You’re fine. Poop is naturally brown due to bile produced in your liver.

Green: Food may be moving through your large intestine too quickly. Or you could have eaten lots of green leafy veggies, or green food colouring.

Yellow: Greasy, foul-smelling yellow poop indicates excess fat, which could be due to a malabsorption disorder like celiac disease.

Black: It could mean that you’re bleeding internally due to ulcer or cancer. Some vitamins containing iron or bismuth subsalicylate could cause black poop too. Pay attention: if it’s sticky, and see a doc if you’re worried.

Light-coloured, white, or clay-coloured: It’s not what you’re normally seeing. It could mean a bile duct obstruction. Some meds could cause this too. See a doc.

Blood-stained or red: Blood in your poop could be a symptom of cancer. Always see a doc right away if you find blood in your stool.

Quick facts about poop

- The food you eat usually takes 5 days from the time you eat it till it ends up in your poop.
- Poop is made up of undigested food, bacteria, mucus, and dead cells, that’s why it smells.
- Healthy poop sinks slowly.

How often should you poop?

On average, people go once or twice a day, but some may go more and some may go less. According to doctors, there’s no normal frequency, as long as you’re constipated, you’re fine.

How to keep your poop healthy?

- Eat a diet high in fibre (20 – 25g), lots of water, regular exercise.
- If you’re having trouble pooping (constipation), dietary fibre can help make the passage smoother.
- Proper hydration helps ensure your colon is slippery enough for the poop to move through.

When to see a doctor?

The first time you see anything out of the ordinary in your poop, don’t panic yet. See if it happens again. If symptoms persist, then go talk to a doc. Pay attention to what your body is telling you, and whenever you feel uneasy, it’s time to go to a doctor.