The digestive system in humans involves the chemical breakdown of food and its absorption from the gut

Digestions of Food: The Alimentary Canal (Gut)

1) MOUTH where food is chewed and swallowed

- Hydrolysis of starch to maltose by salivary amylase
- Alkaline conditions assist to break the glycosidic bonds in starch

2) Food travels down the **OESOPHAGUS** by peristalsis

3) To the **STOMACH**

1. Acidity kills bacteria / Inhibits salivary amylase
2. Gastric glands are stimulated by gastrin to secrete gastric juice
    a. Contains HCl and pepsinogen (inactive pepsin)
    b. Active pepsin digests proteins → would damage glandular tissue
3. Damage to stomach wall by acidic gastric juice is prevented by mucus
4. Stomach digests proteins by hydrolytic endopeptidase
    a. pepsinogen + HCl + pepsin → pepsin
    b. Endopeptidases (pepsin/trypsin) break peptide bonds in the middle of polypeptides

SUBSTRATE	PRODUCTS	ENZYME	PRODUCED BY
Proteins	Smaller polypeptides	Endopeptidase: Pepsin	Gastric glands

4) To the **SMALL INTESTINE** (duodenum → ileum)

1. Liver in the upper abdomen secretes bile
    a. Liver detoxifies blood by removing poisonous substances / destroys old red blood cells / converts Hb to bilirubin (present in bile) / produces bile / produces urea from amino groups and ammonia
    b. Gall bladder stores bile
    c. Secreted into small intestine by bile duct
2. Muscles in wall of small intestine mix H_2O and oil forming small droplets/emulsion
. Larger surface area / higher lipase activity
a. Bile prevents droplets from running together
3. Exocrine gland of the pancreas secretes pancreatic juice into the duodenum
. Contains amylase, lipase, exopeptidase, trypsinogen (inactive trypsin)
a. Exopeptidases break peptide bonds **at the end** of smaller polypeptide chains
4. Intestinal brush border contains enterokinase
. Trypsinogen + enterokinase → trypsin

5. Intestinal brush border contains peptidase
6. Intestinal brush border contains maltase
    . Maltose in lumen of small intestine binds to maltase
    a. Resulting glucose diffuses into the cytoplasm of epithelial cells

b. Glucoseis also released back into the intestinal lumen and absorbed further down

∴ Duodenum digests food by HYDROLYTIC enzymes (→H_2O)

SUBSTRATE	PRODUCTS	ENZYME	PRODUCED BY
Starch	Maltose	Pancreatic amylase	Pancreas
Maltose	Glucose	Maltase	Intestinal cells
Proteins	Smaller polypeptides	Endopeptidase: trypsin	Pancreas
Smaller polypeptides	Amino acids; Dipeptides	Exopeptidase	Pancreas
Dipeptides	Amino acids	Peptidase	Intestinal cells
Triglycerides	Glycerol; Monoglycerides; Fatty Acids	Lipase	Pancreas

7. Ileum absorbs food
    a. Last and longest part of small intestine
    b. Microvilli (brush border) increase surface area

5) To the **LARGE INTESTINE** (cecum → colon → rectum) to anus

1. Larger in diameter than small intestine but shorter in length
2. Stores undigested food before it is egested as faeces

Lactose and Lactose Intolerance

- Lactase splits lactose into β-glucose and galactose
- Lactose intolerant person lacks lactase → lactose is neither digested nor absorbed
- High levels of soluble lactose remain in small intestine
    - Supports large populations of bacteria / ferment lactose producing gas / causing discomfort
    - Water potential becomes more negative / H_2O moves into small intestine / not reabsorbed / diarrhoea
- Adults rarely produce lactase / gene is switched off in adulthood

Absorption of Products of Digestion

Histology of the Ileum in Relation to its Secretory and Absorptive Functions

- Na^+, Cl^-, digestive juice secreted into **duodenum** → LOWERS water potential
- ∴ H_2O moves from epithelial cells into lumen by osmosis
- Increases efficiency of digestion (hydrolytic reactions) and absorption
- **Ileum** absorbs ions by active transport → INCREASES water potential

- ∴ H_2O moves back into epithelial cells

The Layers of the Gut Wall and the Ultrastructure of the Epithelium

- Hollow organs with a layer of epithelial cells surrounding the lumen
- Walls of the lumen contain muscles and blood vessels
- Small change in structure has a specific function
    - Small intestine
        - Tube with a thick wall surrounding a hollow lumen
        - Epithelial cells have microvilli on their surface
        - Epithelial cells secretes mucus

Absorption And Active Uptake Of The Products Of Digestion In Small Intestine

Glucose

1. Absorbed by epithelial cells using a protein carrier
2. This protein carrier works by secondary active transport (co-transport system)
3. Glucose **and** Na^+ are transported across the membrane into the intestinal cell
4. Further transport of glucose into blood capillaries by facilitated diffusion
5. **NOTE:** Fructose moves entirely by facilitated diffusion!

Amino Acids

1. Absorbed by epithelial cells by secondary active transport
2. Co-transport carrier proteins absorb amino acids **and** Na^+ across the membrane
    a. Different carrier molecules transport different types of amino acids
    b. Carriers are associated with peptidase
3. Passes from the epithelial cells into capillaries by facilitated diffusion
4. Newborns don't produce trypsin, HCl → proteins are not digested before small intestine is reached
    . Whole proteins may be transported by endocytosis and exocytosis
    a. Uptake by endocytosis, release into blood by exocytosis
    b. Often occurs in newborns due to their immature mucosa
    c. Allows passage of antibodies from mother's milk - provides passive immunity for the infant

d. Accounts for many early food allergies as the protein is recognized as "foreign"

Lipids

1. Triglycerides digested into monogylcerate + glycerol + fatty acids by lipase
2. Monoglycerides combine with bile to form micelles
    - 5mm in diameter / forms an emulsion / contains fatty acids and glycerol
3. Micelles move to membrane of epithelial cells
4. Monoglycerides + glycerol + fatty acids dissolve in bilayer
5. Triglycerides re-synthesise in cytoplasm / move into lymph capillaries (→lacteals)

6. Bile stays in small intestine

Oral Rehydration Therapy In The Control Of Gastro-Intestinal Infections

- High amounts of semi-liquid faeces result form toxins produced by microorganisms
  - Toxins block Na^+ channels in cells lining small intestine
  - Stop reabsorption / conc. of Na^+ ions in small intestine increases
  - Water potential gradient is in the opposite way (into small intestine)
  - Water is drawn out of epithelial cells and added to the contents of the gut
  - This results in diarrhoea
- Toxins have little effect on glucose co-transport carrier proteins
- TREATMENT: measured amounts of glucose and mineral salts are mixed with H_2O
  - Drinking the solution stimulates Na^+ and glucose uptake by co-transport proteins
  - H_2O is absorbed from small intestine
  - ORT increases performance of co-transport proteins / adequate amounts of glucose and Na^+ pass into intestinal cells / clears up attack of diarrhoea
- $\therefore$ Na^+ is absorbed by Na^+ channels AND mainly by glucose-Na^+-co-transport carrier proteins

Control Of Digestive Secretions

Nervous And Hormonal Control Of Salivary, Gastric And Pancreatic Secretions

Mammal has 2 communication systems → nervous and endocrine system

- Nervous system is based on electrical impulses passing along nerve cells
  - Short-lasting effects, can be switched on or off rapidly
  - Secretes salvia when food enters mouth
- Endocrine system is based on hormones
  - Travel in blood to target organ
  - Produce **long**-lasting effects
  - Trigger secretion of bile and pancreatic juice
- Endocrine system is only activated with large amounts of food intake
  - Food takes a **long** time to reach small intestine
  - Food stays there for a **long** time
  - Digestive juice can be secreted as large amounts of food are present
  - Digestive juice contains trypsin and pepsin → both enzymes are peptidases which damage proteins → they would damage epithelial cells if only small amounts of food would be present

Importance Of Simple And Conditioned Reflexes And The Hormones

Gastrin, Secretin And Cholecystokinin-Pancreozymin

Nervous reflexes

- Nerve pathway involving small number of nerve cells (2/3) → rapid response
- Automatic response → particular stimulus has same effect

Condition reflex

- Salvia and gastric juice are secreted
- By various stimuli associated with food (smell/sight/sound)
- By contact of substances in food with taste buds on tongue

Hormones

- Secreted in response to presence of food in particular region of gut
- Hormones travel in blood to glands / in glands, stimulate secretion of digestive juices
- **GASTRIN** stimulates exocrine glands in stomach to release gastric juice
- Acids (chyme) from stomach, fatty acids in duodenum stimulate release of **SECRETIN**
    - Stimulates secretion of alkali (bicarbonate ions) from pancreas
        - Neutralises acidity from intestinal contents
        - When pH reaches neutrality, secretion of secretin is inhibited
    - Inhibits gastric gland secretion
- Acidic chyme from stomach, fat, amino acids in **duodenum** stimulate release of **CHOLECYSTOKININ-PANCREOZYMIN CCK-PZ**
    - Activates smooth muscle contraction/emptying of gall bladder (to release bile)
    - Triggers secretion of enzymes from pancreas
    - Stimulates Medulla oblongata which give a satiety signal
    - Once molecules stimulating CCK are digested → CCK inhibited again
- **SOMATOSTATIN**
    - Acts on stomach, duodenum, pancreas
    - Inhibits release of gastrin, secretin, and CCK-PZ