3.3.3 Digestion independent Pack

**Specification**

During digestion, large biological molecules are hydrolysed to smaller molecules that can be absorbed across cell membranes. Digestion in mammals of:

• Carbohydrates by **amylases** and **membrane-bound disaccharidases**

• Lipids by **lipase**, including the action of **bile salts**

• Proteins by **endopeptidases, exopeptidases** and **membrane-bound dipeptidases**.

Mechanisms for the absorption of the products of digestion by cells lining the ileum of mammals, to include:

• **Co-transport** mechanisms for the absorption of **amino acids** and of **monosaccharides**

• The role of **micelles** in the absorption of lipids.

**Previous GCSE Knowledge**

* The hierarchical organisation of cells into tissues, organs and organ systems, exemplified by the stomach and digestive system
* The role of amylase, protease and lipase enzyme in the digestion of large insoluble food molecules, and their sites of production.
* The role of Bile in emulsifying fats and neutralising acid from the stomach, and the site of its production and storage
* Diffusion in the movement of molecules from a region of high to low concentration

Read the following article by the National Geographic Society to give you an overview of digestion and watch the following video.

<https://www.youtube.com/watch?v=yIoTRGfcMqM>

The digestive system is the series of tube like organs that convert our meals into body fuel. In all there's about 30 feet (9 meters) of these convoluted pipeworks, starting with the mouth and ending with the anus. Along the way, food is broken down, sorted, and reprocessed before being circulated around the body to nourish and replace cells and supply energy to our muscles.

Food on the plate needs to become a mashed-up, gooey liquid for the digestive system to be able to split it up into its constituent parts: proteins, carbohydrates, fats, vitamins, and minerals. Our teeth start the process by chewing and grinding up each mouthful, while the tongue works it into a ball-shaped **bolus** for swallowing.

Moistening saliva fed into the mouth from nearby glands starts the process of chemical digestion using specialized proteins called **enzymes**. Secreted at various points along the digestive tract, enzymes break down large molecules of food into smaller molecules that the body is able to absorb.

Once we swallow, digestion becomes involuntary. Food passes down the throat to the **esophagus**, the first of a succession of hollow organs that transport their contents through muscular contractions known as **peristalsis**.

The esophagus empties into the **stomach**, a large, muscular chamber that mixes food up with digestive juices including the enzymes pepsin, which targets proteins, and lipase, which works on fats. Hydrochloric acid likewise helps to dissolve the stomach contents while killing potentially harmful bacteria. The resulting semifluid paste—**chyme**—is sealed in the stomach by two ring like sphincter muscles for several hours and then released in short bursts into the **duodenum**.

The first of three sections of the **small intestine**, the duodenum produces large quantities of mucus to protect the intestinal lining from acid in the chyme. Measuring about 20 feet (6 meters) in length, the small intestine is where the major digestion and absorption of nutrients take place. These nutrients are taken into the bloodstream, via millions of tiny, fingerlike projections called villi, and transported to the liver.

What's left in the digestive tract passes into the **large intestine**, where it's eaten by billions of harmless bacteria and mixed with dead cells to form solid feces. Water is reabsorbed into the body while the feces are moved into the rectum to await expulsion.

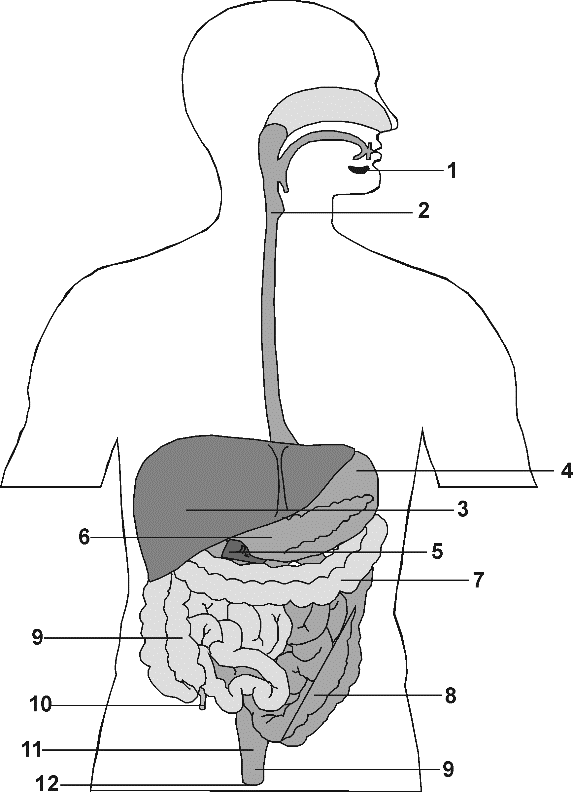
**Key Players**

Other organs that play a key role in digestion include the liver, gallbladder, and pancreas. The **pancreas** is a gland organ located behind the stomach that manufactures a cocktail of enzymes that are pumped into the duodenum. A duct also connects the duodenum to the **gallbladder**. This pear-shaped sac squeezes out green-brown bile, a waste product collected from the liver that contains acids for dissolving fatty matter.

The **liver** itself is the body's main chemical factory, performing hundreds of different functions. It processes nutrients absorbed into the blood by the small intestine, creating energy-giving glycogen from sugary carbohydrates and converting dietary proteins into new proteins needed for our blood. These are then stored or released as needed, as are essential vitamins and minerals. The liver also breaks down unwanted chemicals, such as any alcohol consumed, which is detoxified and passed from the body as waste.

**Major parts of the digestive system**

Label the diagram below using the following website http://www.biology-innovation.co.uk/pages/human-biology/the-digestive-system/ showing all the organs involved in the digestive system of a human or the slides on GoL.

[](http://www.google.co.uk/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwj9-PqKjeXRAhVBWRQKHf57BOgQjRwIBw&url=http://bloggakuten.com/worksheet/label-the-digestive-system-worksheet.html&psig=AFQjCNEgWTbQgcxePFvn8iE6uT8eqKeG_A&ust=1485701902912337)

The main stages of food processing are ingestion, digestion, absorption and egestion. The alimentary canal is a system made up of organs.

What is meant by a system? (link topics 3.2)

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What is an organ?

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What are organs made up of?

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Please can you define the following terms (use slides on GoL)

Ingestion

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Digestion

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Absorption

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Egestion

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The major parts of the digestive system are the mouth, oesophagus, stomach, duodenum, liver, pancreas, ileum, large intestine and rectum. Using the following websites and the slides on GoL fill in the table below describing the function of organs and enzymes found in each organ if any.

<http://www.biology-innovation.co.uk/pages/human-biology/the-digestive-system/>

<https://www.youtube.com/watch?v=wzmtgIbRBFg>

| Organ | Function | Enzymes/secretions |
| --- | --- | --- |
| Mouth |  |  |
| Oesophagus |  |  |
| Stomach |  |  |
| Duodenum |  |  |
| Liver |  |  |
| Pancreas |  |  |
| Ileum and small intestine |  |  |
| Large intestine |  |  |
| Rectum |  |  |

**Digestion**

Digestion takes place in two stages:

1. Physical breakdown
2. Chemical digestion

Use the slides on GoL to fill in the gaps:

Physical breakdown

Fill in the following paragraph using the terms surface area, stomach, slicing, chemical digestion, chewing

* The physical breaking up of large pieces of food into smaller pieces
* Starts in the mouth with the \_\_\_\_\_\_\_\_and \_\_\_\_\_\_\_\_\_\_ action of the teeth
* Increases the \_\_\_\_\_\_\_\_\_\_\_for enzyme action (chemical digestion)
* Continues in the \_\_\_\_\_\_\_\_\_\_\_\_\_\_by the churning action caused by the contraction of muscles in the stomach wall
* This increases the surface area for enzymes to act (\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_)

Chemical digestion

* The chemical breakdown of food molecules into smaller, soluble molecules by enzymes
* Occurs in a number of stages
* All digestive enzymes are **hydrolases** -they break chemical bonds by the addition of water

There are three types of enzymes involves in digestion. These are:-

1. **Carbohydrases** whichhydrolyse carbohydrates ultimately to monosaccharides
2. **Lipases** which hydrolyse lipids into glycerol and fatty acids
3. **Proteases** which hydrolyse proteins ultimately to amino acids

**Enzymes and their action**

Using a flow chart describe the digestion of lipids and proteins. Use flow diagram of digestion and absorption found on GoL (resources), slides on GoL and/or Toole and Toole book p152-154. Carbohydrate digestion given as an example.

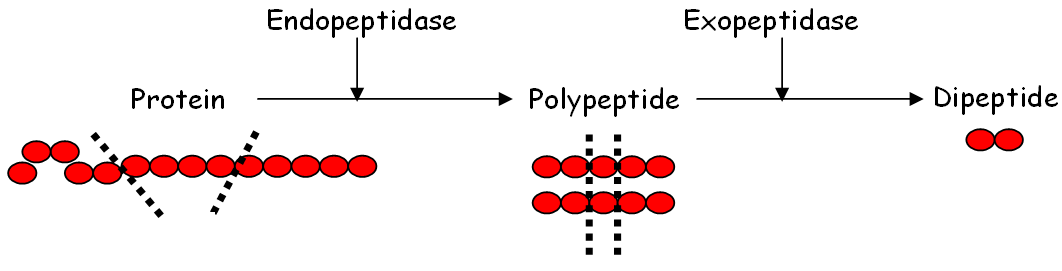
1. Carbohydrate Digestion

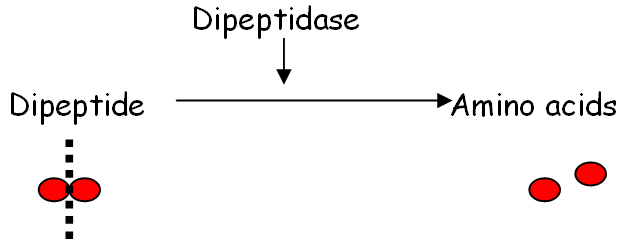
|  |  |
| --- | --- |
| Mouth, Pharynx and oesophagus. Mineral salts to maintain optimum pH for amylase (around pH7) | Polysaccharides Disaccharides  Salivary Amylase  Smaller Maltose  polysaccharides  Pancreatic Amylase  Disaccharides  Maltase, sucrase and lactase |
| Stomach acid denatures amylase (no digestion) |  |
| Small intestine (enzymes from pancreas). Alkaline salts maintain pH near neutral so amylase can function |  |
| Small intestine (enzymes from epithelium known as membrane-bound disaccharidase) | Monosaccharides (alpha glucose, fructose and galactose) |

1. Protein Digestion

Proteins are large complex molecules that are hydrolysed by a group of enzymes called peptidases (proteases). These are:-

1. **Endopeptidases** which hydrolyse peptide bond between amino acids in the central region of the molecule forming a series of peptide molecules. Found in the stomach eg. Pepsin
2. **Exopeptidases** which hydrolyse the peptide bonds on the terminal amino acids of the peptide molecules to release dipeptidases and single amino acids (found in duodenum e.g Trypsin
3. **Dipeptidases** whichhydrolyse the bond between the dipeptide to release amino acids-these enzymes are **membrane bound** and found on epithelial cells lining the ileum

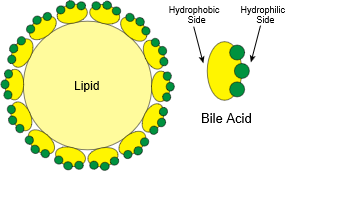




|  |  |
| --- | --- |
| Mouth, Pharynx, oesophagus | No protein digestion occurs in the mouth |
| Stomach |  |
| Small intestine (enzymes from pancreas) |  |
| Small intestine (enzymes from epithelium) |  |

1. Lipid Digestion

Bile is a yellow-green liquid that is produced in the liver and stored in the gall bladder.Bile enters the duodenum through the **bile duct** where it neutralises the pH of the partially digested food that has come from the stomach. Bile contains bile salts which play a key role in the digestion of fatty acids. Bile salts are amphiphile compounds i.e. have one end that is hydrophillic and one end that is hydrophobic and act like a surfactant, emulsifying the lipids.



Bile salts aggregate around droplets of lipids to form **micelles (4-7nm)** with the hydrphobic sides towards the fat and hydrophillic side facing outwards. This prevents fat droplets re aggregating together. Leaving a **larger surface area** for the action of pancreatic **lipase**.

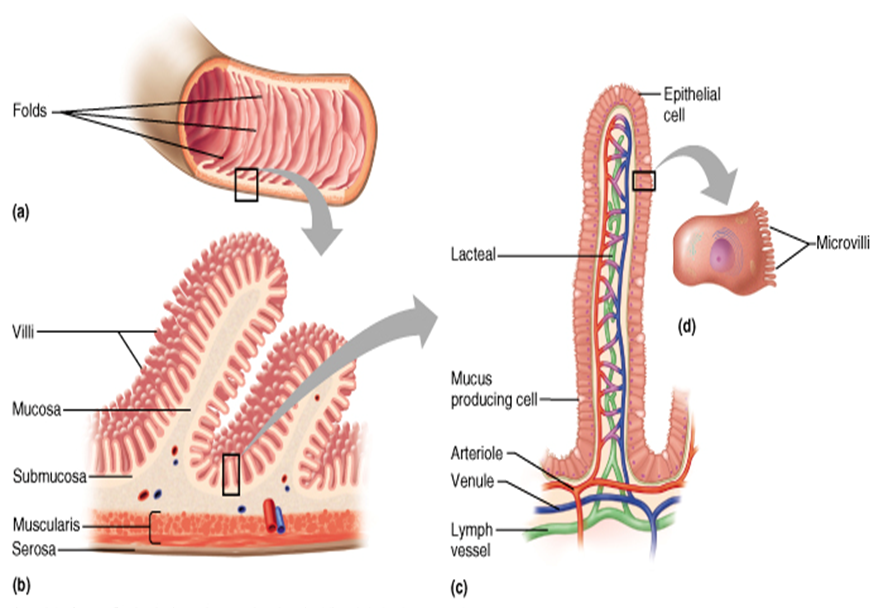
|  |  |
| --- | --- |
| Mouth, Pharynx, oesophagus | No lipid digestion occurs in the mouth |
| Stomach | No lipid digestion occurs in the stomach |
| Small intestine (enzymes and salts from pancreas) |  |

**Absorption**

Absorption of proteins, lipids and carbohydrates occurs in the ileum which is adapted for this function. The wall of the ileum is folded and possess finger like projections, about 1mm long called villi. They have thin walls, lined with epithelial cells on the other sifde of which is a rich network of blood capillaries. The villi increase surface area which in turn increases rate of absorption.

Villi are situated at the interface of the Lumen (cavity of the intestines and the blood and other tissues of the body. They are a specialized exchange system adapted for the absorption of the products of digestion.

Structure of the small intestine



The ileum is well adapted to its function. Use the slides on Gol to list the 5 things that increase the efficiency of villi for absorption of digested products:-

1.

2.

3.

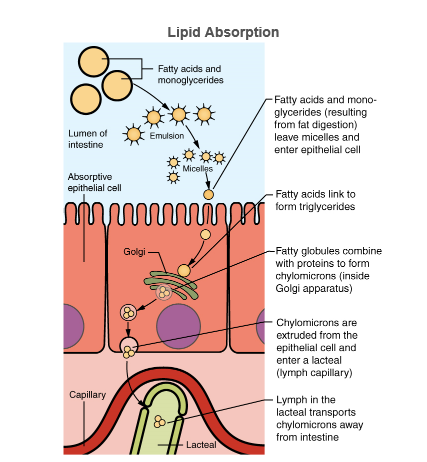
4.

5.

**Lipid absorption**

Watch the following video <https://www.youtube.com/watch?v=3J5pNwLYZ7w>

Unlike amino acids and simple sugars, fatty acids and monoglycerides are transformed (changed) as they are absorbed through epithelial cells. Remember lipids are digested by lipases which act on lipids to hydrolyse them to monoglycerides and fatty acids. Once inside the cell they reform to form triglycerides and are then transformed into Chylomicrons inside the Golgi and Endoplasmic reticulum.



Using the AQA textbook if you have it p156 –This page is on Gol in the Folder 3.3, resources and nutrition. You can also use the slides on GoL. Fill in the missing gaps using the following words.

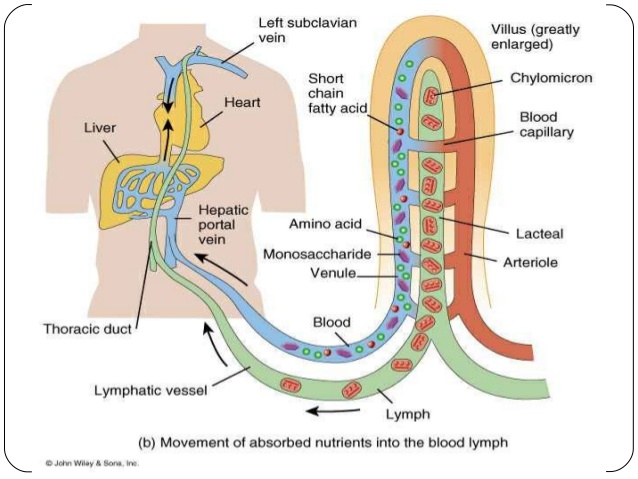
**Monoglyceride, micelle, endoplasmic reticulum, lacteal, exocytosis, thoracic duct, triglycerides, water soluble, and diffuse,**

Triglycerides once digested to \_\_\_\_\_\_\_\_\_\_\_\_\_ and fatty acids by pancreatic lipase remain in association with the bile salts. The structures formed are called \_\_\_\_\_\_\_\_\_\_\_.

Once the micelle comes into contact with the epithelial cell lining the ileum they break down and release the non-polar monoglycerides and fatty acids which\_\_\_\_\_\_\_\_\_\_\_\_\_across the cell-surface membrane into the epithelial cells.

They are then transported to the \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_where they are recombined to form \_\_\_\_\_\_\_\_\_\_\_\_\_. In the endoplasmic reticulum and Golgi apparatus the triglycerides associate with cholesterol and lipoproteins which become surrounded by a protein coat to form structures called **chylomicrons.** The chylomicrons are \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_lipoproteins and are too big to pass into blood capillaries but can enter the large pores of the\_\_\_\_\_\_\_\_\_\_. Thus the chylomicrons move out of epithelial cell by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_and enter the lymphatic capillaries called l**acteals.** They are then transported in the lymphatic vessels which eventually empty through the \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_and into circulatory system.

A diagram to show the lymphatic system (in green). Lipids are transported into the lacteals found at the centre of the villi in the ileum. They enter the blood stream via the thoracic duct.

[](http://www.google.co.uk/url?sa=i&rct=j&q=&esrc=s&frm=1&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwiH0dri7urKAhVGUhQKHQGyBTUQjRwIBw&url=http://www.slideshare.net/asrulicerole/the-lymphatic-system-08&psig=AFQjCNFviAWmVd7ejVuIgGGQKqkYrs6l6A&ust=1455113513972532)

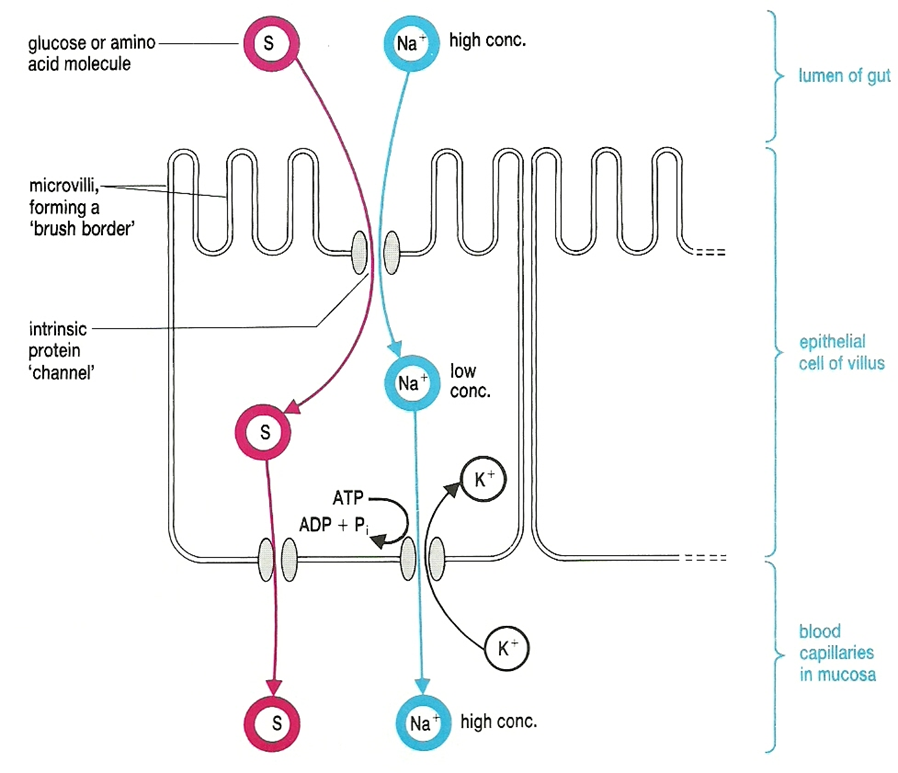
**Absorption of amino acids and monosaccharides**

Digestion of proteins produces amino acids while the digestion of carbohydrates produces monosaccharides such as fructose, glucose and galactose. The method of absorbing these products are the same namely **diffusion** and **co-transport**. Glucose and amino acids are absorbed by co transport into the epithelial cells lining the ileum while facilitated diffusion moves glucose and amino acids from the ileum epithelial cell to the blood. The blood maintains a concentration gradient.

Write a definition of diffusion

Write a definition of Co Transport

Using the information you learnt in Topic 3 Transport across cell membranes fill in the boxes in the diagram. Please state whether the concentration of amino acid/glucose is high or low (p96 AS Toole and Toole AQA textbook, GoL).



Type of transport-

Type of transport

Type of transport-

Facilitated diffusion

Describe and explain the transport of amino acids/glucose (Topic cross Link 3.2)

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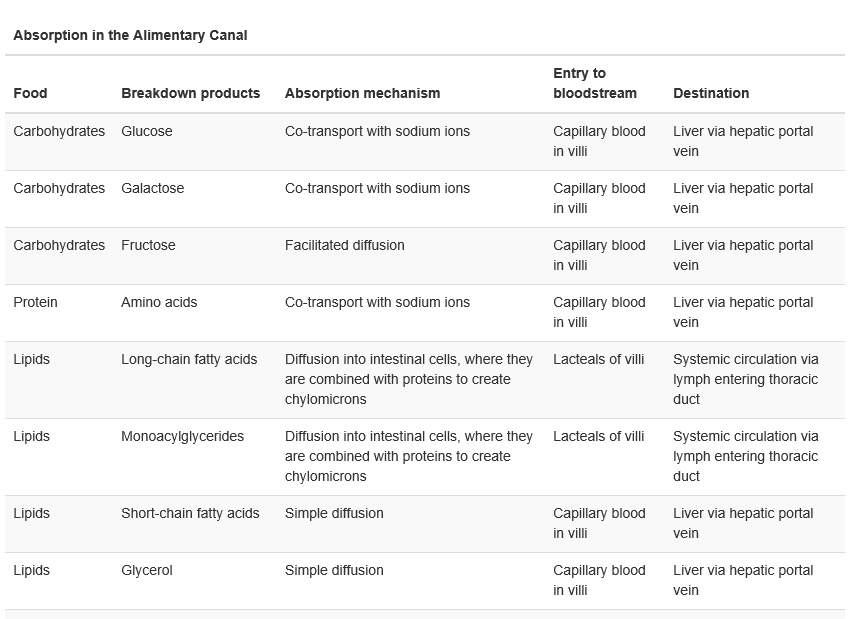
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**Summary of Absorption**



**Common diseases of the digestive system**

Please do some research and make notes on the following diseases. You will need to bring these with you for a class discussion:-

1. Lactose Intolerance
2. Coeliac Disease

Add a paragraph on each disease to the end of your booklet or use the space below to make notes.

Answer the following questions using precise and concise language. Remember to use diagrams and reference.

* Who is at risk?
* What are the causes?
* What are the symptoms?
* What are the effects on the digestive system?

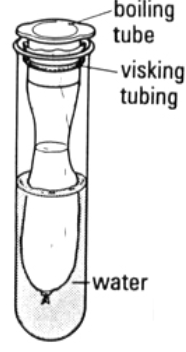
Some great videos:

<https://www.youtube.com/watch?v=_i2cclGYPx0> (lactose intolerance)

<https://www.youtube.com/watch?v=nXzBApAx5lY> (Coeliac disease)

**Digestion Experiment**

Visking tubing is commonly used to model gut digestion because it is semi permeable. The tubing is soaked and a knot is tied at one end. It is then placed into a boiling tube containing water as shown in the diagram below.



Watch the demonstration:

<http://sciencedemo.org/2014/01/modelling-digestion-using-visking-tubing/>

**Experiment**

In another experiment three model guts were set up labelled 1, 2 and 3. In each model gut **rice** was added to the visking tubing. Then:-

1. 5 cm3 of water was added to model gut 1.
2. 5 cm3 of amylase was added to model gut 2.
3. 5 cm3 of boiled amylase was added to model gut 3.

All the boiling tubes containing the model guts were placed in a water bath at 37ºC. The model guts were left for at least 15 minutes. After 15 minutes, a teat pipette was used to remove some of the water surrounding the model guts in the boiling tubes and then each solution was tested for starch and glucose.

How do you test for starch?

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How do you test for glucose?

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What do you think your results would show for:-

1. Model Gut 1

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2. Model Gut 2

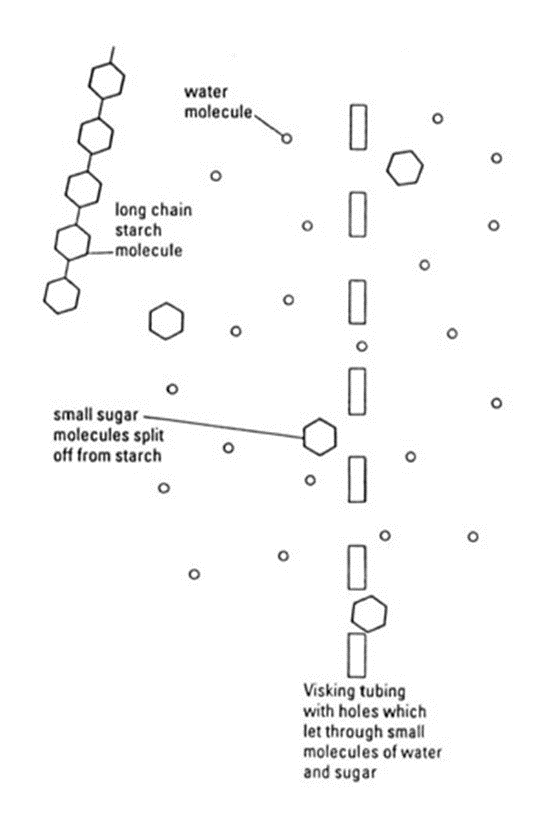
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3. Model Gut 3

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Please answer the following questions:

1. What does the Visking tubing of the model gut represent?
2. What does the water in the boiling tube, outside the model gut, represent?
3. How is this model different from the situation in a real gut?
4. Use the diagram to explain what is happening in each of the 3 model guts.



1. Why does the body need enzymes to digest food?
2. What would be the result with boiled amylase? Try to explain this.
3. How could you adapt this experiment to test for protein digestion?

**Exam Questions**

A student investigated the effect of chewing on the digestion of starch in cooked wheat.

He devised a laboratory model of starch digestion in the human gut. This is the method he used.

1.      Volunteers chewed cooked wheat for a set time. The wheat had been cooked in boiling water.

2.      This chewed wheat was mixed with water, hydrochloric acid and a protein-digesting enzyme and left at 37 °C for 30 minutes.

3.      A buffer was then added to bring the pH to 6.0 and pancreatic amylase was added. This mixture was then left at 37 °C for 120 minutes.

4.      Samples of the mixture were removed at 0, 10, 20, 40, 60 and 120 minutes, and the concentration of reducing sugar in each sample was measured.

5.      Control experiments were carried out using cooked wheat that had been chopped up in a blender, not chewed.

(a)     What reducing sugar, or sugars, would you expect to be produced during chewing?  
Give a reason for your answer.

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**(2)**

(b)     In this model of digestion in the human gut, what other enzyme is required for the complete digestion of starch?

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**(1)**

(c)     What was the purpose of step 2, in which samples were mixed with water, hydrochloric acid and pepsin?

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**(1)**

(d)     In the control experiments, cooked wheat was chopped up to copy the effect of chewing.

Suggest a more appropriate control experiment. Explain your suggestion.

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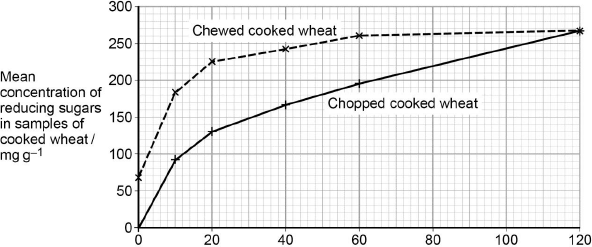
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**(2)**

(e)     The figure below shows the student’s results.

  
                               Incubation time / minutes

Explain what these results suggest about the effect of chewing on the digestion of starch in wheat.

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**(3)**

**(Total 9 marks)**

**Q2.**Some people have a medical condition called pancreatitis. This can lead to their pancreatic duct becoming blocked. As a result, a high concentration of amylase is found in their blood.

At 12-hour intervals, a doctor measured the concentration of amylase in the blood of a person suffering from a blocked pancreatic duct. He also measured the concentration of amylase in the blood of a healthy person.

The figure below shows his results.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Concentration of amylase in the blood / arbitrary units** | |
|  | **Time / hours** | **Person with blocked pancreatic duct** | **Healthy person** |
|  | 0 | 1800 | 800 |
|  | 12 | 2200 | 750 |
|  | 24 | 2500 | 700 |
|  | 36 | 2000 | 750 |
|  | 48 | 1400 | 800 |

(a)     (i)      The changes in concentration of amylase in the blood of a person with a blocked pancreatic duct are different from those of a healthy person during the period shown in the figure above.

Describe **two** of these differences.

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2 ............................................................................................................

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**(2)**

(ii)     In a person with a blocked pancreatic duct, starch digestion is affected.  
Explain how.

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**(2)**

(b)     Healthy people have amylase in their blood. This does not cause any harmful effects in the body.  
Explain why.

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**(2)**

(c)     Pancreatitis can lead to the release of protein-digesting enzymes into the blood. This is harmful to the body.  
Suggest **one** reason why.

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**(2)**

**(Total 8 marks)**

**Q3.**          Read the following passage.

Gluten is a protein found in wheat. When gluten is digested in the small intestine,  
the products include peptides. Peptides are short chains of amino acids. These  
peptides cannot be absorbed by facilitated diffusion and leave the gut in faeces

Some people have coeliac disease. The epithelial cells of people with coeliac disease do not absorb the products of digestion very well. In these people, some of the peptides from gluten can pass between the epithelial cells lining the small intestine and enter the intestine wall. Here, the peptides cause an immune response that leads to the destruction of microvilli on the epithelial cells.

Scientists have identified a drug which might help people with coeliac disease.  
It reduces the movement of peptides between epithelial cells. They have carried out trials of the drug with patients with coeliac disease.

Use the information in the passage and your own knowledge to answer the following questions.

(a)     Name the type of chemical reaction which produces amino acids from proteins.

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**(1)**

(b)     The peptides released when gluten is digested cannot be absorbed by facilitated diffusion (lines 2 – 3). Suggest why.

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*(Extra space)* .................................................................................................

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**(3)**

(c)     The epithelial cells of people with coeliac disease do not absorb the products of digestion very well (lines 4 – 5). Explain why.

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**(3)**

(d)     Explain why the peptides cause an immune response (lines 7 – 8).

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**(1)**

(e)     Scientists have carried out trials of a drug to treat coeliac disease (lines 10 – 11).  
Suggest **two** factors that should be considered before the drug can be used on patients with the disease.

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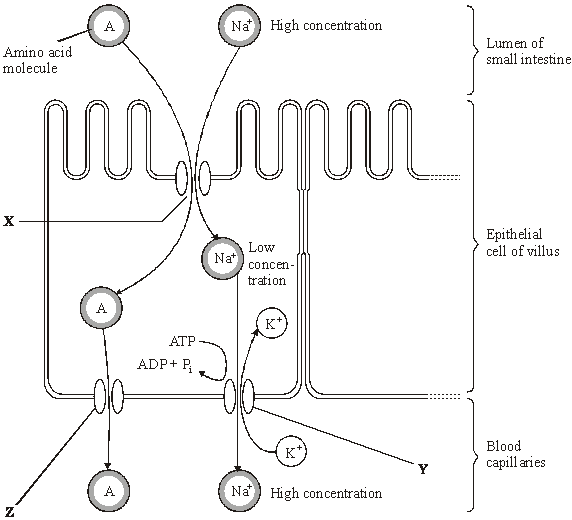
2 .....................................................................................................................

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**(2)**

**(Total 10 marks)**

**Q4.**   The diagram shows one method by which amino acids are absorbed from the small intestine into the blood. They are co-transported into the epithelial cell with sodium ions (Na+) at point **X** on the diagram. Normally, the concentration of sodium ions inside the epithelial cell is low.



*Source*: adapted from M. ROWLAND,  
*Biology (University of Bath Science 16-19)* (Nelson Thornes) 1992.

Dinitrophenol (DNP) prevents ATP production. When treated with DNP, the sodium-potassium pump at **Y** no longer works. As a result, the concentration of sodium ions in the cell rises and amino acid absorption stops.

(i)      Explain why pump **Y** will **not** work in the presence of DNP.

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**(2)**

(ii)      Explain why sodium ions and amino acids are **not** absorbed from the lumen of the small intestine in the presence of DNP.

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**(2)**

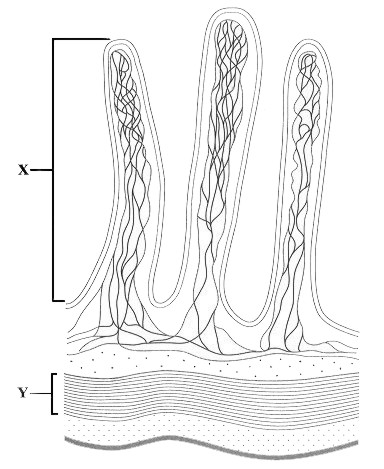
(iii)     By what mechanism would amino acids leave the epithelial cell at point **Z**?

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**(1)**

**(Total 5 marks)**

**Q5.**          The diagram shows part of the gut wall of an animal.



(a)     (i)      Name the structure labelled **X**.

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**(1)**

(ii)     Describe the function of the layer labelled **Y**.

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**(2)**

(b)     Describe and explain how **two** features shown in the diagram increase the rate of absorption of digested food.

Feature 1

Description

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Explanation

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Feature 2

Description

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Explanation

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**(4)**

**(Total 7 marks)**

**Q6.**(a)     Describe the role of the enzymes of the digestive system in the complete breakdown of starch.

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**(5)**

(b)     Describe the processes involved in the absorption of the products of starch digestion.

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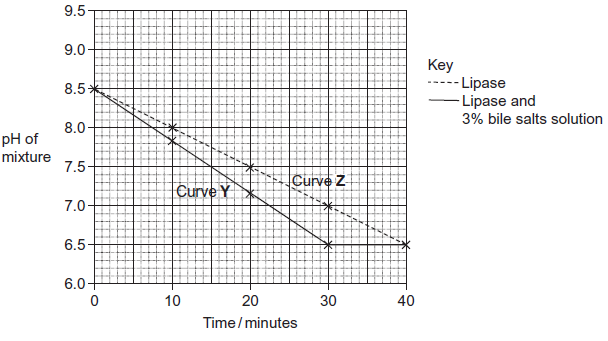
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**(5)**

**(Total 10 marks)**

**Q7.**Scientists investigated the effect of lipase and a 3% bile salts solution on the digestion of triglycerides. The graph below shows their results.



The scientists also incubated triglycerides with different concentrations of bile salts. After 30 minutes they measured the diameter of the triglyceride droplets. They used the results to calculate the mean radius of the droplets at each concentration. The table below shows their results.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Concentration of bile salts /% | 0 | 1 | 2 | 3 | 4 | 5 |
|  | Mean radius of triglyceride droplet / μm | 6 | 5 | 4 | 3 | 2 | 1 |

(a)     Describe how you would use a microscope to find the mean diameter of triglyceride droplets on a slide.

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**(3)**

(b)     (i)      The ratio of mean radius of triglyceride droplets in bile salts at a concentration of 0% to the mean radius in bile salts at a concentration of 3% is 2 : 1.

What is the ratio of their surface areas? Show your working.

You can calculate the surface area of a droplet from the formula

A = 4*π*r2

Where  A = surface area  
    r = radius  
   *π* = 3.14

**(2)**

(ii)     Use the data in the table to explain the difference between curves **Y** and **Z** in the graph.

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**(3)**

**(Total 8 marks)**