Diploma in Human Nutrition Assignment 2

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Abstract

The gastrointestinal tract (GIT) consists of a hollow muscular tube starting from the oral cavity, where food enters the mouth, continuing through the pharynx, oesophagus, stomach and intestines to the rectum and anus, where food is expelled.

Lipids or fats are digested and absorbed in the small intestine, bile salts emulsify fat so pancreatic lipase can digest it and the fats first enter lymphatic capillaries called lacteals before entering our blood circulation.

Minerals such as zinc, iron, magnesium and sulfur all serve critical functions in the human body, and can be got in a healthy, balanced diet or by taking supplements for specific deficiencies. The body absorbs the bulk of its nutrients through the intestinal wall during digestion. The rate of absorption depends upon a number of factors including our overall diet, the presence of other minerals in the meal and whether or not we are getting enough vitamins. Sometimes, our body determines whether or not a mineral is absorbed for use. If one is iron-deficient, for example, he/she will absorb iron from his/her diet at a higher rate than someone who is not.

Amino acids are classified into 4 types: Classification based on the position of “-NH2”, classification based on the composition of “-R’ side chain, classification based on the nutritional requirement and classification based on the metabolic Fate.

This paper examines the description of functions of each region of the gastro intestine tract, Explanation of the digestion and absorption of lipids, the role of bile salts and the formation of chylomicrons, Description of the absorption of minerals, especially iron and Description and explanation on the classification of amino acids according to their chemical and nutritional properties.

Keywords

Gastro intestine tract, Absorption, Lipids, Bile salt, Chylomicrons, Minerals, Iron, Classification, Amino acids and Nutritional properties.

1. **Introduction**

This coursework;

1. Describes the functions of each region of the gastro intestine tract.
2. Explains the digestion and absorption of lipids, the role of bile salts and the formation of chylomicrons.
3. Describes the absorption of minerals, especially iron.
4. Describes and explains the classification of amino acids according to their chemical and nutritional properties.

**Q1. Functions of the three regions of the gastro intestine tract.**

The gastrointestinal tract (GIT) consists of a hollow muscular tube starting from the oral cavity, where food enters the mouth, continuing through the pharynx, oesophagus, stomach and intestines to the rectum and anus, where food is expelled. There are various accessory organs that assist the tract by secreting enzymes to help break down food into its component nutrients. Thus the salivary glands, liver, pancreas and gall bladder have important functions in the digestive system. Food is propelled along the length of the GIT by peristaltic movements of the muscular walls. (**Martini 5th edition 2001).**

The major components of the diet are starches, sugars, fats and proteins which have to be hydrolyzed to their constituent smaller molecules for absorption and metabolism.

Starches and sugars are absorbed as monosaccharides while fats are absorbed as free fatty acids and glycerol (plus a small amount of intact triacylglycerol) and proteins are absorbed as their constituent amino acids and small peptides.

The major functions of each region of the gastrointestinal tract are:

**The Mouth**

* does starch hydrolysis catalyzed by amylase which is secreted by the salivary glands;
* does fat hydrolysis catalyzed by lingual lipase which is secreted by the tongue;
* does the absorption of small amounts of vitamin C and a variety of non-nutrients (including nicotine).

**The Stomach**

* does the denaturation of dietary proteins and the release of vitamin B12, iron and other minerals from protein binding, for which gastric acid is important;
* does protein hydrolysis which is catalyzed by pepsin;
* does fat hydrolysis which is catalyzed by lipase.
* does the secretion of intrinsic (Essential) factor which is required for the absorption of vitamin B12

**The Small intestine (duodenum, jejunum and ileum)**

* does starch hydrolysis catalyzed by amylase which is secreted by the pancreas;
* does hydrolysis of disaccharides within the brush border of the intestinal mucosa;
* does fat hydrolysis catalyzed by lipase which is secreted by the pancreas;
* does protein hydrolysis catalyzed by a variety of exo- and endopeptidases secreted by the pancreas and small intestinal mucosa;
* does the hydrolysis of di- and tripeptides within the brush border of the intestinal mucosa;
* does the absorption of the products of digestion;
* does the absorption of water (failure of water absorption, as in diarrhea, can lead to serious dehydration

**Large intestine (caecum and colon)**

* does bacterial metabolism of undigested carbohydrates and shed intestinal mucosal cells;
* does the absorption of some of the products of bacterial metabolism;
* does absorption of water.

**Rectum**

* does the storage of undigested gut contents prior to evacuation as faeces;

Throughout the gastrointestinal tract, and especially in the small intestine, the surface area of the mucosa is considerably greater than would appear from its superficial appearance. The intestinal mucosa is folded longitudinally into the lumen and the surface of these folds is covered with villi: finger like projections into the lumen, some 0.5–1.5 mm long. There are some 20– 40 villi per mm2, giving a total absorptive surface area of some 300 m2 in the small intestine. Each villus has both blood capillaries, which drain into the hepatic portal vein, and a lacteal, which drains into the lymphatic system. Water- soluble products of digestion (carbohydrates and amino acids) are absorbed into the blood capillaries, and the liver has a major role in controlling the availability of the products of carbohydrate and protein digestion to other tissues in the body. **According to Moore, Dalley 4th edition, 1999**, lipids are absorbed into the lacteals; the lymphatic system joins the bloodstream at the thoracic duct, and extrahepatic tissues are exposed to the products of lipid digestion uncontrolled by the liver, which functions to clear the remnants from the circulation. There is rapid turnover of the cells of the intestinal mucosa; epithelial cells proliferate in the crypts, alongside the cells that secrete digestive enzymes, and migrate to the tip of the villus, where they are shed into the lumen. The average life of an intestinal mucosal epithelial cell is about 48 hours. **Per Lippencott Williams & Wilkins. 1999**, this rapid turnover of epithelial cells is important in controlling the absorption of iron, and possible other minerals. The rapid turnover of intestinal mucosal cells is also important for protection of the intestine against the digestive enzymes secreted into the lumen. Further protection is afforded by the secretion of mucus, a solution of proteins that are resistant to enzymic hydrolysis and which coats the intestinal mucosa.

**Q2. Digestion and absorption of lipids, the role of bile salts and the formation of chylomicrons.**

Lipids or fats are digested and absorbed in the small intestine, bile salts emulsify fat so pancreatic lipase can digest it and the fats first enter lymphatic capillaries called lacteals before entering our blood circulation.

**Lipids**

Foods, such as meats, dairy products, seeds, nuts, and oils, contain dietary fat. Fat is a common example of a lipid, and there is a unique way lipids such as fats are broken down and absorbed out of the digestive tract.

A lipid is defined as a fat-like molecule that does not have the ability to dissolve in water. This inability to dissolve in water adds an element of difficulty to fat digestion. Because fat does not like water, it tends to clump together and form large droplets called emulsion droplets as it moves through our digestive system. By the time fat reaches our small intestine, it has not been digested at all. So, dietary fat in the small intestine looks like a fairly large glob of fat**. (Rebecca Gillaspy)**

**The role of bile salts**

These globs remain until bile that is produced in the liver and stored in the gallbladder mixes with the large fat droplets. Bile contains bile salts which act as an emulsifier of lipids. The term 'emulsify' means to break large fat droplets into smaller droplets (Emulsion droplets). And, that is exactly what is seen happening in the small intestine. The bile salts break up and coat the fat to form much finer droplets. These finer droplets have more surface area, and this aids digestion because the fat-digesting enzyme pancreatic lipase can only act on the surface of the fat droplet.

The enzymes of the small intestine are responsible for almost all of the fat digestion. When pancreatic lipase acts on the lipid, it breaks it down, which results in free fatty acids and monoglycerides, the two digestive products of lipids. These products are much easier for our small intestine to handle, and they have very little trouble being absorbed out of our digestive tract.

Absorption takes place through the mucosal lining of the small intestine and when these products pass through the mucosa, they enter the epithelial cells. Once inside the epithelial cells, the free fatty acids and monoglycerides enter the endoplasmic reticulum, which is a system inside the cell whose functions include synthesis and transport of lipids. Here, the digested products are resynthesized into triglycerides. Triglycerides are the major form of fat stored by the body. So, an important fact to point out is that fats are reassembled in the epithelial cells of the small intestine. This makes fat absorption different than absorption of proteins and carbohydrates. With protein and carbohydrate absorption, we see their basic units, which are amino acids and monosaccharides, are able to pass through the intestinal epithelial cells without being altered. (**Rebecca Gillaspy)**

**The formation of Chylomicrons**

Chylomicrons are small globules composed of protein and lipid. Before triglycerides leave the epithelial cells, they're coated by proteins, which results in the formation of chylomicrons. The coating of protein gives the triglyceride a water-soluble coat, and this allows the chylomicron to travel outside of the cell. The newly formed chylomicrons leave the epithelial cell and enter the lymphatic which are called lacteals. The lacteals are found in the fingerlike projections of the intestinal wall, called the villi. The lacteals represent another unique way fats are absorbed because lipids pass through the lymphatic system before they make their way back to our bloodstream. (**Rebecca Gillaspy)**

**Q3. Absorption of minerals, especially iron.**

Minerals such as zinc, iron, magnesium and sulfur all serve critical functions in the human body, and can be got in a healthy, balanced diet or by taking supplements for specific deficiencies.

The body absorbs the bulk of its nutrients through the intestinal wall during digestion. The rate of absorption depends upon a number of factors including our overall diet, the presence of other minerals in the meal and whether or not we are getting enough vitamins. Sometimes, our body determines whether or not a mineral is absorbed for use. If one is iron-deficient, for example, he/she will absorb iron from his/her diet at a higher rate than someone who is not. [**(Rachel Casiday and Regina Frey**](http://www.chemistry.wustl.edu/~edudev/LabTutorials/Vitamins/vitamins.html)**)**

The rate of absorption is called “bioavailability,” and it’s a measure of how much of each mineral our body is able to process. Some minerals compete against each other for our body’s digestive resources. For example, large amounts of zinc in our diet will lower the absorption rate of iron and copper. Other minerals work together. Calcium, phosphorus and magnesium combine to give rigidity to our teeth and bones. ([**American Chiropractic Association)**](http://www.acatoday.org/content_css.cfm?CID=1347)

Sources of minerals

Plants and their derivatives are rich in minerals, but they are sometimes bound in forms that make them unavailable. Phytates, or the salts of phytic acids, are present in many plants, and they can block absorption of some key nutrients, particularly for vegetarians. Minerals from animal sources such as calcium from dairy and iron from red meat are not bound by phylates and so are said to be more bioavailable than plant-based minerals. [**(Sunitha Jasti**](http://www.faqs.org/nutrition/Met-Obe/Minerals.html)**)**

Role of vitamins in absorption of minerals

Although some minerals compete with each other for our body’s attention, vitamins are helpful in ushering necessary nutrients into the bloodstream. Vitamin deficiencies can lower the bioavailability of some minerals. For example, vitamin C helps our body absorb iron efficiently while vitamin D aids in calcium, phosphorous and magnesium digestion. Milk is often fortified with vitamin D for this reason.

**Digestion and absorption of minerals;**

* Calcium

Calcium is absorbed from the intestinal lumen by two distinct mechanisms, and their relative magnitude of importance is determined by the amount of free calcium available for absorption:

1. *Active, transcellular absorption* occurs only in the duodenum when calcium intake is low. This process involves import of calcium into the enterocyte, transport across the cell, and export into extracellular fluid and blood. Calcium enters the intestinal epithelial cells through voltage-insensitive (TRP) channels and is pumped out of the cell via a calcium-ATPase.

The rate limiting step in transcellular calcium absorption is transport across the epithelial cell which is greatly enhanced by the carrier protein calbindin, the synthesis of which is totally dependent on vitamin D.

2. *Passive, paracellular absorption* occurs in the jejunum and ileum, and, to a much lesser extent, in the colon when dietary calcium levels are moderate or high. In this case, ionized calcium diffuses through tight junctions into the basolateral spaces around enterocytes, and hence into blood. When calcium availability is high, this pathway responsible for the bulk of calcium absorption due to the very short time available for active transport in the duodenum.

* Phosphorus
* Phosphorus is predominantly absorbed as inorganic phosphate in the upper small intestine. Phosphate is transported into the epithelial cells by cotransport with sodium and expression of this/these transporters is enhanced by vitamin D. (**Bronner F, 1998).**
* Copper

There are two processes responsible for copper absorption; a rapid, low capacity system and a slower, high capacity system which may be similar to the two processes seen with calcium absorption. Many of the molecular details of copper absorption remain to be elucidated. Inactivating mutations in the gene encoding an intracellular copper ATPase have been shown responsible for the failure of intestinal copper absorption in Menkes disease.

A number of dietary factors have been shown to influence copper absorption. For example, excessive dietary intake of either zinc or molybdenum can induce secondary copper deficiency states.

* Zinc

Zinc homeostasis is largely regulated by its uptake and loss through the small intestine. Although a number of zinc transporters and binding proteins have been identified in villus epithelial cells, a detailed picture of the molecules involved in zinc absorption is not yet in hand.

Intestinal excretion of zinc occurs via shedding of epithelial cells and in pancreatic and biliary secretions.

* A number of nutritional factors have been identified that modulate zinc absorption. Certain animal proteins in the diet enhance zinc absorption. Phytates from dietary plant material (including cereal grains, corn, rice) chelate zinc and inhibit its absorption. Subsistence on phytate-rich diets is thought responsible for a considerable fraction of human zinc deficiencies. (**Lonnerdal B, 2000).**
* Iron

Iron homeostasis is regulated at the level of intestinal absorption and it is important that adequate but not excessive quantities of iron be absorbed from the diet. Inadequate absorption can lead to iron-deficiency disorders such as anaemia. On the other hand, excessive iron is toxic because mammals do not have a physiologic pathway for its elimination.

Iron is absorbed by villus enterocytes in the proximal duodenum. Efficient absorption requires an acidic environment, and antacids or other conditions that interfere with gastric acid secretion can interfere with iron absorption. **Andrews NC, 1986/1999.**

Ferric iron in the duodenal lumen is reduced to its ferrous form through the action of a brush border ferrireductase. Iron is cotransported with a proton into the enterocyte via the divalent metal transporter DMT-1. This transporter is not specific for iron but also transports many divalent metal ions.

Once inside the enterocyte, iron follows one of two major pathways. Which path is taken depends on a complex programming of the cell based on both dietary and systemic iron loads:

* *Iron abundance states*: iron within the enterocyte is trapped by incorporation into ferritin and hence not transported into blood. When the enterocyte dies and is shed, this iron is lost.
* *Iron limiting states*: iron is exported out of the enterocyte via a transporter (ferroportin) located in the basolateral membrane. It then binds to the iron-carrier transferrin for transport throughout the body.
* Iron in the form of heme from ingestion of hemoglobin or myoglobin, is also readily absorbed. In this case, it appears that intact heme is taken up by the small intestinal enterocyte by endocytosis. Once inside the enterocyte, iron is liberated and essentially follows the same pathway for export as absorbed inorganic iron. Some heme may be transported intact into the circulation. (**Miret S, Simpson RJ, 2003).**

**Q4. classification of amino acids according to their chemical and nutrition al properties**

Amino acids are classified into 4 types:

1. Classification based on the position of “-NH2”
2. Classification based on the composition of “-R’ side chain
3. Classification based on the nutritional requirement
4. Classification based on the metabolic Fate

**a) Classification based on the position of “-NH2”:**

These amino acids are classified into THREE types:

i) **α-amino acid:** This are amino group attached to the next carbon of the carboxyl group called “α-amino acid”. All naturally occurring amino acids are in “α-L-amino acids”.

ii) **β-amino acid:** The are amino group attached to the third carbon (numbering from Carboxyl group) of the amino acid called “β-amino acid”. Eg: β-alanine, it is one of the end product of Pyrimidine catabolism.

iii) **γ-amino acid:** This are amino group attached to the fourth carbon (numbering from Carboxyl group) of the amino acid called “γ-amino acid”. Eg: GABA (Gamma Amino Butyric Acid)

**b) Classification based on the composition of “-R’ side chain:**

These amino acids are classified based on the composition of ‘R’ side chain, they are categorized into 8 types: **(Fairley & Kigour, 1966)**

**a) Neutral Amino Acids or Simple amino acids:**

They have no functional group in the side chain. Eg:

*Table 1: Examples of neutral or simple amino acids.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name of the Amino acid** | **Single letter symbol** | **Three letter symbol** | **IUPAC name** | **Source** |
| **Glycine** | G | Gly | a-amino acetate | Animal source are: Scleroproteins, Gelatin and silk fibroin. Plant source are: Glycine Max (Soya been) |
| **Alanine** Isolated from Silk Fibroin in 1888. | A | Ala | a-amino propionate | Alanine is present in Silk fibroin alone with Glycine |
| **Valine** | V | Val | a-aminoisovalarate |  |
| **Leucine** Isolated from Cheese by Proust in 1819. | L | Leu | a-aminoisocaproate | Isolated from cheese, but later it was obtained in purer form from hydrolysates of wool. |
| **Isoleucine** Discovered by Paul Erhlish (LT 1854 to 1915) | I | Ile | a-amino-β-methylvalarate |  |

**b) Hydroxyl Group containing amino acids:**

They contain a hydroxyl group in their side chain. Eg:

*Table 2: Examples of hydroxyl group containing amino acids.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name of the Amino acid** | **Single letter symbol** | **Three letter symbol** | **IUPAC name** | **Source** |
| **Serine** Derived from the Serum | S | Ser | a-amino-B-hydroxyl propionate | Silk protein, Sericin, and Fibroin |
| **Threonine** Discovered by Meyer & Rose in 1936 | T | Thr | a-amino-B-hydroxyl butyrate | Threonine is less abundant than serine in most proteins. |

**c) Sulphur Containing amino acids:**

These amino acids posse a sulfur atom in the side chain. Eg:

*Table 3: Examples of Sulphur containing amino acids.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name of the Amino acid** | **Single letter symbol** | **Three letter symbol** | **IUPAC name** | **Source** |
| **Cysteine** Isolated from Urinary stones in 1843 | C | Cys | a-amino-B-mercaptopropionate | Fibrous proteins such as Keratin from hair are especially rich in cysteins (12%) |
| **Methionine** | M | Met | a-amino-B-methylmercaptobutyrate |  |

**d) Acidic amino acids:**

These have a Carboxyl group in the side chain. E.g:

*Table 4: Examples of acidic amino acids.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name of the Amino acid** | **Single letter symbol** | **Three letter symbol** | **IUPAC name** | **Source** |
| **Aspartic acid** Discovered by *Ritthausen* in 1868. | D | Asp | a-aminosuccinate | It is the parent compound of aspargine. |
| **Glutamic acid** Discovered by *Ritthausen* in 1866 | E | Glu | a-aminoglutarate | It is found in Gluten. It is the parent compound of Glutamine. |

**e) Basic amino acids:**

These possess an amino group in the side chain. Eg:

*Table 5: Examples of basic amino acids.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name of the Amino acid** | **Single letter symbol** | **Three letter symbol** | **IUPAC name** | **Source** |
| **Arginine** | R | Arg | a- amino-g-guanidinovalarate (Guanidonium group is present) | It is abundant in highly basic proteins of the cell nucleus (histones) and in Sperm proteins. |
| **Lysine** | K | Lys | a, e- diaminocaproate | It is present in plant proteins like Corn and Wheat. |

**f) Heterocyclic amino acid:**

These amino acids have in their side chain a ring which possess at least one atom other than the carbon. Eg:

*Table 6: Examples of heterocyclic amino acids.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name of the Amino acid** | **Single letter symbol** | **Three letter symbol** | **IUPAC name** | **Source** |
| **Tryptophan**It was discovered in the laboratory of F.G.Hopkins | W | Trp | a-amino-B-3-indolepropionate or B–indolylalanine |  |
| **Histidine** | H | His | a-amino-B-Imidazolepropionate | Hemoglobin, Protamines and Histones |

**g) Aromatic amino acid:**

These have a benzene ring in the side chain. Eg:

*Table 7: Examples of aromatic amino acids.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name of the Amino acid** | **Single letter symbol** | **Three letter symbol** | **IUPAC name** | **Source** |
| **Phenylalanine** | F | Phe | a-amino-B-phenylpropionate |  |
| **Tyrosine**Isolated from Cheese in 1857 | Y | Tyr | a-amino-B-(p-hydroxy phenyl) propionate | Cheese |

**h) Imino acid:**

These are also heterocyclic compounds, which have “imino group” (-NH-) instead of amino group (-NH2).

*Table 8: Examples of imino acids.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name of the Amino acid** | **Single letter symbol** | **Three letter symbol** | **IUPAC name** | **Source** |
| **Proline** | P | Phe | 2-pyrrolidinecarboxylate | Zein from Corn and Gelatin |
| **Hydroxy Proline** | – | Hy.Pro |  |  |

**c) Classification based on the Nutritional requirement:**

Based on Nutritional requirement, amino acids are divided into 3 types.

1. Essential Amino acids (EAA)
2. Non-Essential Amino acids (NEAA)
3. Semi-Essential Amino acids (SEAA)

**1. Essential Amino acids (EAA):**

Some of the amino acids don’t synthesize in the human body. It should be supplied through diet. They are required for proper growth and maintenance of the individual.

**Eg:**

**MATT VIL PHLy** **or** **PVT TIM HALL**

**M**= Methionine **A**=Arginine **T**=Threonine **T**=Tryptophan **V**=Valine

**I**=Isoleucine **L**=Leucine **P**=Phenylalanine **H**=Histidine **L**=Lysine

**2. Non-Essential Amino acids (NEAA):**

The body can synthesize about 10 amino acids to meet the biological needs; hence they need not be consumed in the diet.

**Eg:** Gly, Ala, Ser, Cys, Asp, Asn, Glu, Gln, Tyr and Pro.

**3. Semi-Essential Amino acid:**

Histidine and Arginine are semi-essential amino acids. Growing children require them in food. But they are not essential for the adult individual.

**d) Classification based on the Metabolic Fates**

These amino acids can be classified based on the metabolic fate:

i) Purely ketogenic amino acids

ii) Ketogenic and Glucogenic amino acids

iii) Purely Glucogenic amino acids

**i) Purely ketogenic amino acids:**

Leucine is purely ketogenic because it is converted into ketone bodies.

**ii) Ketogenic and Glucogenic amino acids:**

During metabolism, part of the carbon skeleton of these amino acids will enter the ketogenic pathway and the other part of the glucogenic pathway.

**Eg:** Lys, Ile, Phe, Tyr & Trp are partially ketogenic and partially glucogenic.

**iii) Purely Glucogenic amino acids:**

All the remaining 14 amino acids are purely glucogenic as they enter only into the glucogenic pathway.

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