Digestion and Absorption of Fat

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Dietary fat Composition

- More than 85-95% are triglycerides (Triacylglycerols).
- The other includes:
  - Cholesterol,
  - Cholesteryl esters,
  - Phospholipids,
  - Essential unsaturated fatty acids, and
  - Fat soluble vitamins, etc.
Fats

- The lipids, present in the various cells of the human body, constantly undergo changes.
- They are continually being oxidized for energy, converted to other essential tissue constituents or stored as reserve fat in adipose tissue.
- An adult takes about 60-150gm of lipids per day.
- Fat is energy rich compounds and provides 9 kcal/gm.
- Normally essentially all (98%) of the fat consumed is absorbed, and most is transported to the adipose for storage.
Dietary sources of Lipids

- **Animal Sources**
  - Dairy products- Milk, butter, ghee.
  - Meat and Fish, Pork, eggs.

- **Vegetable Sources**
  - Cooking oils- Sunflower oil, Mustard oil, Ground nut oil, etc.
  - Fats from other vegetable sources.
Digestion in the mouth and stomach

Digestion in mouth:
The lingual lipase is secreted by the Ebner’s glands on the dorsal surface of tongue. Its action continues in the stomach but action is negligible at mouth.

Digestion in stomach:
- **Lingual lipase** from the mouth enters stomach along with the food.
- It acts on short chain triglycerides (present in milk, ghee and butter; more significant in newborn infants)
- **Gastric lipase** (acidstable) secreted by chief cells, is present in gastric secretion stimulated by **Gastrin**.
- It hydrolyzes short and medium chain (few to 12) fatty acids from dietary triacylglycerols.
- Up to 30 % digestion of triglycerides occurs in stomach.
Significance of Lingual and Gastric Lipases

- Play important role in lipid digestion in neonates since milk is the main source of energy.
- Important digestive enzymes in pancreatic insufficiency and pancreatic disorders.
- Lingual and gastric lipases can degrade triglycerides with short and medium chain fatty acids in patients with pancreatic disorders despite a near or complete absence of pancreatic lipase.
Digestion in small intestine

Emulsification of dietary lipid:

- Emulsification is a pre-requisite for digestion of lipids which is achieved by the help of bile (bile salts).
- The lipids are dispersed into smaller droplets which increases the surface area.
Digestion in small intestine

Degradation of dietary lipids:

- By pancreatic enzymes.
- Pancreatic enzymes are primarily responsible for the degradation of dietary triacylglycerols, phospholipids, and cholesterylesters.

- Secretion of pancreatic juice is stimulated by the acidic chyme which stimulates enteric hormones called secretin and cholecystokinin which causes release of bile and enzyme is pancreatic lipase.
Fat Digestion and Absorption (1)

Emulsification
In lumen of duodenum

Lecithin

Hydrophobic region

Bile salt

Hydrophilic region

Emulsification droplets

Fat globule is broken up by lecithin and bile salts
Digestion in small intestine

- Pancreatic colipase is released to help facilitate lipase enzyme action.
- There are mainly three digestive enzymes (lipolytic enzymes) are present in pancreatic juice.
- They are: Pancreatic lipase, cholesterol esterase, and Phospholipase A2 (Lecithinase).
- Some other important lipases are:
  - Lingual lipase
  - Pancreatic lipase
  - Phospholipase A2
  - Hormone sensitive lipase
  - Gastric lipase
  - Intestinal lipase
  - Lipoprotein lipase
Gastro Intestinal hormones

- **Secretin**: Increases the secretion of electrolytes and fluid components of pancreatic juice.
- **Pancreozymin** of CCK-PZ stimulates the secretion of the pancreatic enzymes.
- **Cholecystokinin** of CCK-PZ causes the contraction of the gall bladder and discharges the bile into the duodenum.
Bile Salts

- Bile salts are required for the proper functioning of the pancreatic lipase enzyme.
- Bile salts help in combination of lipase with two molecules of a small protein called as Colipase. This combination enhances the lipase activity.
- Bile salts also help in the emulsification of fats.
<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Substrate</th>
<th>Action</th>
<th>Final Product</th>
</tr>
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<tbody>
<tr>
<td>Cholesterol esterase</td>
<td>Cholesteryl ester</td>
<td>Hydrolysis to cholesterol and fatty acids</td>
<td>Free cholesterol + Free fatty acids</td>
</tr>
<tr>
<td>Phospholipase A2</td>
<td>Dietary Phospholipids</td>
<td>Hydrolysis of lysophospholipids</td>
<td>Free fatty acids + Lysolecithin</td>
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<tr>
<td>Lipase</td>
<td>Emulsified triacylglycerols</td>
<td>Hydrolysis to monoglycerides</td>
<td>Free fatty acids + 2-monoacylglycerol</td>
</tr>
</tbody>
</table>
Absorption in small intestines

- **Absorption** is the process of moving molecules across a cell membrane and into various cell.

  - Folds, villi, microvilli expand absorptive surface
  - Most nutrients absorbed here
Lipid Absorption

- Small lipid fragments such as glycerol and short chain fatty acids do not need re-esterification.
- Small lipid fragments do not form micelles and it is absorbed directly into the bloodstream.
- From blood to portal vein and finally to liver where they are immediately utilized for energy.
- The absorption is rapid process.
Lipid absorption

- Large lipid fragments such as monoglycerides and long chain fatty acids need re-esterification.
- Bile salts coat these and other lipids and form droplets called micelles.
- The lipid digestive products are phospholipids, cholesterol, monoacylglycerols, and fatty acids. These with bile salts forms mixed micelles.
Lipid absorption

- Micelles release their lipids, which diffuse freely across the plasma membrane.
- Resynthesis of triglycerides. Coating with protein and forming packages called chylomicrons.
Lipid absorption

- Chylomicrons are too large to enter blood capillaries and must be first transported in the lymphatic lacteal.
Fat globule → Bile salts → emulsification droplets → micelles → chylomicrons → Intestinal epithelial cells → lacteal → blood
Fat absorption

- Mixed Micelles diffuse across the brush border of intestinal epithelial cells
- Micelles merge there (diffusion)
- Monoglycerides built into triglycerides & covered with protein coat
- Packaged into chylomicron
- The chylomicrons are emptied into lymphatic capillaries, the lacteal → lymph circulation → thoracic duct → blood → cells and liver
Fat Absorption

Diagram showing the process of fat absorption in the intestinal lumen. Bile salts help emulsify fats, allowing fats to be broken down into smaller molecules by pancreatic lipase. These smaller molecules, including fatty acids and monoglycerides, are then absorbed by epithelial cells and enter the bloodstream as chylomicrons.
Impaired fat absorption

Steatorrhoea

- 6% of dietary fat in the feces
- > 7 gm of fat/24 hours in feces
- The stool is greasy, foul smelling and hard to flush.
- There is deficiency of fat soluble vitamins too.
Chyluria:
• It is an abnormality in which the patient excretes **milky urine** because of the presence of abnormal connection between urinary tract and lymphatic drainage system of the intestine, forming a so-called **chylous fistula**.

Chylothorax
• A similar abnormality, an abnormal connection between pleural space and the lymphatic drainage of small intestine results in accumulation of lymph in pleural cavity giving **milky pleural effusion**.
SUMMARY

- **Minor digestion** of triacylglycerols in mouth and stomach by lingual lipase.

- **Major digestion** of all lipids in the lumen of the duodenum/jejunum by pancreatic lipolytic enzymes.

- **Bile acid** facilitated formation of mixed micelles that present the lipolytic products to the mucosal surface.

- **Passive absorption** of the lipolytic products from the mixed micelle into the intestinal epithelial cell.

- **Reesterification** of 2-monoacylglycerol, lysolecithin, and cholesterol with free fatty acids inside the intestinal enterocyte.

- **Assembly and export** from intestinal cells to the lymphatics of chylomicrons coated with Apo B48 and containing triacylglycerols, cholesterol esters and phospholipids.
The end