Introduction
Heterotrophic nutrition consume complex organic food material which originates from autotrophic organisms. There are several forms of heterotrophic nutrition:

1. **Holozoic nutrition** - involves

2. **Saprophytic nutrition** -

3. **Parasitic nutrition** -

4. Mutualism - organisms of two species in close relationship and gain some benefit from each other

5. Commensalism - organisms of two species in close relationship with one member gain benefit while the other neither benefits nor harmed

15.1 Holozoic Nutrition

**Holozoic organisms** obtain their _______ from the consumption of ____________ which is digested within their bodies. It involves:

1. Obtaining food  
2. Ingestion  
3. Physical (mechanical) digestion  
4. Chemical digestion  
5. Absorption  
6. Assimilation  
7. Elimination (egestion)

According to the type of food ingested, holozoic organisms are classified into:

__________ - those feed on plant material  
__________ - those feed on other animals  
__________ - those feed on both plants and animals  
__________ - those consume liquid materials  
__________ - those (majority) take in solid food  
__________ - phagotrophs taking in very small particles, e.g. by filter feeding mechanism  
__________ - phagotrophs taking in relatively large particles
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Name: _______________________________ (       )

15.2 Diet

In mammals carbohydrates and fats are needed in relatively large quantities as ________________________ and proteins for ____________________.

Vitamins and minerals are required in much smaller quantities for a variety of specific functions. Water is a ______________________ of the diet and roughage is necessary for ________________________.

15.2.1 Carbohydrates and fats (energy requirements)
The energy required by an organism varies with age, sex, size and activity. Ideally 2/3 from carbohydrates and 1/3 from fats. A high intake of fats, especially saturated fats, is a contributory factor in causing heart disease.

15.2.2 Proteins
- Main function: ________________________
- Plants are able to synthesize all their own amino acids but animals are more limited.
  Thus man requires essential amino acids in the diet.
- Although plant food contains proportionately fewer proteins, a properly balanced diet can nevertheless provide all the essential amino acids.

15.2.3 Vitamins - group of organic compounds with the following features:
1. no energy value
2. essential in very small quantities for maintenance of good health
3. not structural materials in body
4. work as cofactors in enzymatic reactions
Two groups of vitamins: __________________________

** too much vitamins, e.g. vitamin A, may be harmful to our body

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Sources</th>
<th>Deficiency Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>milk, carrot, vegetables</td>
<td></td>
</tr>
<tr>
<td>B₁</td>
<td>cereals, yeast, liver</td>
<td></td>
</tr>
<tr>
<td>B₂</td>
<td>milk, liver, vegetables</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>fruits, vegetables</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>egg-yolk, cod-liver oil</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>butter, peanuts, egg yolk</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>fish, liver, vegetables</td>
<td></td>
</tr>
</tbody>
</table>

** Vitamins B & C are water soluble; others fat soluble
** Vitamin C could be destroyed by prolonged heating; tested by decolorizing deep blue colour of DCPIP, relatively larger daily requirement than other vitamins
15.2.4 Minerals
- needed to regulate the metabolism of the body; essential for health
- needed in small amounts

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Sources</th>
<th>Deficiency diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium &amp; Phosphorus</td>
<td>cheese, milk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>vegetables</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>liver, egg, beef</td>
<td></td>
</tr>
<tr>
<td>Iodine</td>
<td>sea food</td>
<td></td>
</tr>
<tr>
<td>Sodium &amp; Potassium</td>
<td>table salts &amp; vegetables</td>
<td></td>
</tr>
<tr>
<td>Chlorine</td>
<td>table salts</td>
<td></td>
</tr>
</tbody>
</table>

15.2.5 Water
- makes up about 75% of body weight
- importance: as a solvent; for transport; as a reaction medium; as a reactant
- dilutes wastes & poisons; forms urine

15.2.6 Roughage/Dietary fibre
- consists of ________________
- indigestible because human body has no enzyme for its digestion
- stimulate peristalsis; absence will lead constipation

15.2.7 Milk
Milk is a balanced diet for growth and development of young mammals, but it cannot sustain healthy development indefinitely because:
1. ___________________________ - new born baby has Fe accumulated from mother, but store becomes deficient in later life
2. ___________________________ - constipation results with its long-term absence from diet
3. ___________________________ - ideal for young and actively growing organisms, but as energy demand decreases, more fat deposits around the body would increase risk of _____________ disease

**Food additives** - examples: colourings, preservative, antioxidants, texture enhancers, synthetic flavourings, flavour enhancers and sweeteners

**Feeding mechanisms**

**Small-particle feeders**
- microscopic food, e.g. bacteria, unicellular algae or small invertebrate larvae
- **Filter feeding mechanism**: microscopic foods are removed from the surrounding water by some form of filtration mechanism, e.g. mussel

**Large-particle feeders**
- involving ingestion of particles which are relatively large, e.g. most mammals
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Fluid and soft-tissue feeders
- a mechanism to pierce their "host" in some way and then use a specialized suction apparatus for drawing food into their bodies, e.g. mosquito

Teeth and dentition in man
The structure of the tooth
- enamel - non-living substance containing 97% calcium salt & 3% organic matter; cement forms the root of enamel; fibres attach to jawbone for anchorage forming periodontal membrane
- dentine - hard but softer than enamel; with channels of living cytoplasm from pulp cavity
- pulp cavity - contains living cells with blood vessels (supply food & O₂) and nerves (sensation)

Types of teeth
- incisors - at the front, chisel-like for biting & cutting
- canines - pointed, curved & long for tearing flesh; in carnivores, they are well developed for killing preys
- premolars - with one or two cusps for grinding & crushing food
- molars - have 4 cusps for grinding & crushing food

Wisdom teeth: last 4 molars, grow after the age of 20

Milk Teeth and Permanent Teeth
- man is diphyodont: ___ sets of teeth
- milk teeth - appear in babies; totally 20 in man
- permanent teeth - replace milk teeth in later years; cannot replaced if damaged; totally 32 in man
Dental decay (dental caries)

Cause of tooth decay
- results from a chemical reaction between bacteria & food debris in mouth;
  bacteria forms a sticky, invisible film (plaque) reacting with sugars to
  produce an acid which dissolves enamel, dentine & pulp cavity → toothache
- more serious → periodontal disease → teeth falling off
- calculus: hard deposits due to interaction of plaque & salts in saliva

15.3 Principles of Digestion

Mechanical breakdown of food has the effect of giving the food a large surface area which aids later digestion. The food must be made small enough to pass through cell membranes. Thus chemical digestion with the aid of enzymes occurs.

Amylase - breaks down starch into maltose
Peptidases -
Endopeptidases -
Exopeptidases -
Aminopeptidases -
Carboxypeptidases -
Lipase -

15.4 Digestion in Humans

The food vacuoles of protozoans represent the simplest form of digestive system:

Advantages:
This allows the organism to achieve an optimum concentration of enzymes in the small space within the vacuole

Disadvantages:
1. The organism is restricted to food small enough to be ingested by phagocytosis
2. All enzymes must operate together within a small space and so specialization of certain regions to permit more efficient breakdown is not possible
3. Acid and alkaline digestion must take place within the same vacuole. The two phases must therefore be separated in time

15.4.1 Digestion in the mouth

Mechanical digestion of food begins in the buccal cavity.
The tongue manipulates the food during chewing with saliva produced from 3 pairs of salivary glands.

Saliva contains:
1. Water
2. Salivary amylase
3. Mineral salts
4. Mucin

Taste buds allow food to be selected. The thoroughly chewed food (bolus) is passed to the back of the mouth for swallowing.
15.4.2 Swallowing and peristalsis
- pharynx leads to both trachea & oesophagus
- when swallowing food, epiglottis closes entrance to trachea to prevent food going into lungs
Peristalsis - longitudinal & circular muscles contract & relax alternately to drive food down oesophagus, small intestine, large intestine & out of the anus as faeces

15.4.3 Digestion in the stomach
The stomach is a muscular sac with a folded inner layer (gastric mucosa) with holes (gastric pits) lined with secretory cells which secrete gastric juice:
1. ____________________ - the bulk of the secretion
2. ____________________ - secreted by the oxyntic cells
Functions:
3. ____________________ - secreted by the zymogen (chief) cells in an inactive form to ____________________;
it is activated by ____________________
4. _____________ - secreted by zymogen cells; activated by HCl
5. _____________ - secreted by goblet cells to produced a protective layer to prevent _____________
of the gastric mucosa

The churning and mixing action of the muscular stomach wall changes the bolus of food into a creamy fluid (chyme). The chyme from any one meal takes 3-4 hours to be released little by little into the duodenum. This provides a continuous supply of food for absorption throughout the period between meals.
(a) **Entire stomach**

![Diagram of the entire stomach](image)

- Oesophagus
- Cardiac sphincter
- Cardiac region
- Pyloric sphincter
- Duodenum
- Pyloric region

(b) **Part of the stomach wall (VS)**

![Diagram of the stomach wall](image)

- Mucosa
- Muscularis mucosa
- Sub-mucosa
- Circular muscle
- Longitudinal muscle
- Gastric pit

(c) **Detail of gastric gland**

![Diagram of gastric gland](image)

- Gastric pit
- Mucus secreting cell
- Zymogen (chief) cells
- Oxymic cells

*Structure of the human stomach*
15.4.4 Digestion in the small intestine

*Duodenum:* for digestion

*Ileum:* chiefly for absorption

The walls of the small intestine are folded with *villi* which contain fibres of smooth muscle. These muscles regularly contract and relax to mix food and enzymes so as to facilitate absorption. The digestive juices of the small intestines are:

**Bile juice**
- a complex green fluid produced by the ______________, stored in the ______________
- contains no chemical enzymes but two important substances for digestion:
  1. ____________________________ - help to neutralize the acid chyme from the stomach and so create a more neutral pH for the enzymes of the small intestine
  2. ____________________________

**Pancreatic juice** - for digestion and hormone (insulin) secretion

1. Mineral salts (NaHCO₃)
2. Proteases

3. Pancreatic amylase
4. Lipase
5. Nuclease

**Intestinal juice**
- Brunner's glands secrete ____________________________
- enzymes are produced by the breakdown of cells at the tips of the villi
1. Mucus -
2. Mineral salts (NaHCO₃) -

3. Proteases ( erepsin ) -
4. Enterokinase -
5. Nucleotidase -
6. Carbohydrases -
15.4.5 Absorption and assimilation

- Absorption by ________________ and ________________
  
  Other factors: glucose & amino acids absorption seem to be linked to Na⁺ across the epithelium;
  
  Ca⁺⁺ absorption requires vitamin D
  
  - A large surface area is achieved by:
  
  - In addition, the epithelium is only ________________ which provides a very short distance for diffusion and active transport
  
  - glucose, amino acids, vitamins, minerals & water are small enough to enter the ________________
  
  - fatty acids, glycerol & small droplets of oil are too big and they enter the ________________

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  - fatty acids, glycerol & small droplets of oil are too big and they enter the ________________

Assimilation

- simple sugars & amino acids go to the liver via the hepatic portal vein
  
  - fatty acids & glycerol recombine to form very tiny oils before going into lacteal, then through lymphatic vessels, fats enter the blood vessels for transport throughout the body
  
  - On reaching the liver, excess glucose will be converted into ________________ and stored in liver & muscles; OR changed to fat & stored under the skin
  
  - amino acids: form proteins for growth & repair;
    
    excess cannot be stored but deaminated in the liver

Functions of the liver

1. Stores glycogen, converting back to glucose when necessary to maintain constant blood glucose level;
  
2. Deamination of excess amino acids
  
3. Secretes bile for emulsifying fats, provides an alkaline medium for enzymes in the small intestine
  
4. Stores fat soluble vitamins:
    
    stores Fe from break down of haemoglobin & form new red blood cells
Villi
Sub mucosa
Circular muscle
Longitudinal muscle

Section of small intestine (× 35 approx.)

Intestinal wall showing villi (LS)

Capillary
Lacteal
Crypt of Lieberkühn
Arteriole
Venule
Lymph vessel

Circular muscle
Longitudinal muscle

Brush border
Microwilli
Single epithelial cell
15.4.6 Water reabsorption in the large intestine
- most of the water drunk by man is absorbed by the ____________________
- water from the digestive secretions (about 10 litres) is absorbed mainly in the ileum while the large intestine is responsible for reabsorbing the remainder
- bacteria in the large intestine synthesize ____________ and is absorbed by the large intestine together with water & some minerals
- excess calcium and iron salts are actively transported from the blood into the large intestine for removal with the faeces

15.4.7 Elimination (Egestion)
- faeces consist of indigestible food, residual material from bile, bacteria, cells sloughed off the intestinal wall and some water
- mucus is secreted by the rectum for lubrication & binding faeces together
- defaecation through the anus is a reflex action in baby but voluntary as baby gets older
- faeces: mostly egested materials except cholesterol & bile pigments which are excretory products

Adaptations to particular diets
_Herbivorous adaptations of mammals_,
e. g. sheep

1. ____________________ - a gap to separate newly nibbled food from those chewing at the back

   Dental formula:

   ____________________________

3. Cheek teeth with ridged surfaces because of differential wearing of enamel and dentine
4. ____________________________ - for more efficient grinding by teeth
5. ____________________________ - teeth grow continuously throughout life to replace wearing by constant grinding activity
6. Stomach is divided into a number of chambers with micro-organisms to secreted ________________ for the digestion of cellulose;
   _Regurgitation_ of food from stomach to mouth before passing into the remaining stomach compartments
7. ____________________________
Digestion of cellulose by microorganisms
- micro-organisms must be kept separate from the gut so as to avoid the action of digestive enzymes, to provide long enough time for the break down of cellulose and a suitable pH for these micro-organisms

In ruminants, e.g. ____________________________
- four chambers: ____________________________

- food first enters the first two chambers (rumen & reticulum) to carry out extracellular digestion of cellulose by ____________________________
- products of digestion are either absorbed by walls of the rumen & reticulum or micro-organisms which are later digested
- a symbiotic relationship:
- after some hours, the ruminant regurgitates the food into the mouth and thoroughly chews it (chewing the cud)
- when re-swallowed, food enters the omasum & abomasum (true glandular stomach) where the usual process of protein digestion in acid condition takes place
- In rabbits and horse, the _____ & ________ are much enlarged and accommodate micro-organisms
- absorption of digested food takes place through the walls of the caecum; the yield is improved by re-swallowing of the faeces (coprophagy or reflection)

Carnivorous adaptations of mammals
Food is chiefly meat which is a more 'nutritional' than plant food.
Adaptations concern modifications to the jaw & its dentition:
1. Incisors are ____________________________
2. Canines are ____________________________
3. Carnassial teeth are particularly ____________________________
4. Teeth of upper jaw tend to ____________________________ for slicing meat like two blades of a pair of scissors
5. Jaw muscles are well developed & powerful to ____________________________
6. No lateral jaw movement which might lead to dislocation of the jaw
7. Vertical movement of the jaw is ____________________________
8. The alimentary canal is ____________________________
### Comparison of herbivorous and carnivorous adaptations in mammals

<table>
<thead>
<tr>
<th>Herbivores</th>
<th>Carnivores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incisors sharp, chisel-shaped for cutting or</td>
<td></td>
</tr>
<tr>
<td>gnawing</td>
<td></td>
</tr>
<tr>
<td>Upper incisors sometimes absent</td>
<td></td>
</tr>
<tr>
<td>Canines, if present, small &amp; incisor-like</td>
<td></td>
</tr>
<tr>
<td>Diastema present</td>
<td></td>
</tr>
<tr>
<td>Molars &amp; premolars flattened with ridges of</td>
<td></td>
</tr>
<tr>
<td>enamel for grinding food</td>
<td></td>
</tr>
<tr>
<td>Carnassial teeth absent</td>
<td></td>
</tr>
<tr>
<td>Open pulp cavity for continuous teeth growth</td>
<td></td>
</tr>
<tr>
<td>to compensate for wearing</td>
<td></td>
</tr>
<tr>
<td>Teeth of upper jaw meet those of lower jaw</td>
<td></td>
</tr>
<tr>
<td>end on to allow grinding of food</td>
<td></td>
</tr>
<tr>
<td>Lateral movement of lower jaw aids grinding</td>
<td></td>
</tr>
<tr>
<td>of food</td>
<td></td>
</tr>
<tr>
<td>Jaw muscles relatively small</td>
<td></td>
</tr>
<tr>
<td>Less well developed processes for muscle</td>
<td></td>
</tr>
<tr>
<td>attachment</td>
<td></td>
</tr>
<tr>
<td>Specialized stomach/caecum &amp; appendix to</td>
<td></td>
</tr>
<tr>
<td>accommodate symbiotic cellulose digesting</td>
<td></td>
</tr>
<tr>
<td>micro-organisms</td>
<td></td>
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<tr>
<td>Relatively long alimentary canal</td>
<td></td>
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</tbody>
</table>

### TABLE 15.5. SUMMARY OF DIGESTION
See P 307 of text book

15.5 Nervous and hormonal control of secretions - not required in syllabus

#### Carnivorous plants
All carnivorous plants are autotrophic but live in soils which are deficient in nitrogen, in cold places with slow decomposition of humus, or in places where leaching is common.

#### Parasites
**Endoparasites:**

**Ectoparasites:**
Parasites show some or all of the following features:
1. Structure of a tapeworm
- flat, long, ribbon like, with many (1000) segments
- head with hooks & sucker for attachment onto the __________ wall
- each segment contains both male & female reproductive organs (bisexual) for self-fertilization

2. Life cycle
   Primary host - man;  Secondary host - pig, for dispersal & infection

3. Adaptation of tapeworm to the parasitic mode of life in the ileum
- hooks & suckers for attaching itself onto the intestinal wall of host
- ______________ organs are well developed;
  bisexual for self-fertilization numerous eggs are produced to increase the chances of survival of the species
- no digestive system is needed;
  absorption of digested food by diffusion through the body surface which is long & flattened to increase the surface area for absorption of digested food
- can undergo anaerobic (no O₂) respiration in the intestine
- body is covered by a thick cuticle and secretes anti-enzymes to protect itself against the digestive juice of host

4. Effect on host
- host loses weight & becomes weak because tapeworm absorbs his digested food
- hooks & suckers damage the intestinal wall of host

5. Means to get rid of tapeworm
- take in drugs
- pork should be inspected by government before selling;
  pork should be thoroughly cooked before eating
- good sewage system so that pigs do not get in contact with human faeces

Saprophytes
- saprophytes obtain food from dead organic matter, e.g. ______________
- Mucor is a bread mould (fungus) which depends on bread for food;
  hyphae: filaments
  mycelium: colony of filaments

Nutrition -
hyphae go into bread;
produce digestive enzymes to break down complex organic substances in bread into simple soluble compounds for absorption

Extracellular digestion:

Importance of saprophytism: dead organisms are broken down to recycle materials
Symbionts

Examples of symbiosis:
1. **Lichen** - an association between ________________
   - Alga receives ________________________________
   - Fungus receives ________________________________

2. **Hydra-Chlorella symbiosis**

3. **Mycorrhizas** - an association between ________________________________
   - Fungus receives ________________________________
   - Higher plant receives ________________________________

Gut symbionts

Protozoans and bacteria living in the gut receive _________ and ___________.
They synthesize their own ________________, especially ________________,
and any excess is made available to the host animal.

In termites, protozoans producing cellulase which is essential for the digestion of wood. Many herbivorous
mammals have an enlarged caecum and appendix to hold large masses of plant tissue which is digested by
the cellulase secreted by these symbionts. In ruminants, the rumen houses a great variety of symbionts than
the caecum and they can achieve a more complete breakdown of cellulose. Further more, these symbionts
provide a source of protein when they die and pass into the gut.

Symbiosis and the nitrogen cycle

Nitrogen fixation by ________________ plants in their root nodules provides about 100 million tonnes
of nitrogen per year. This association provides bacteria with ________________ and plants
with ________________.

Root of pine tree

Hyphae of fungus