# Ruminant digestion
for BVSc & AH 1st year

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# Ruminants: 4 stomach

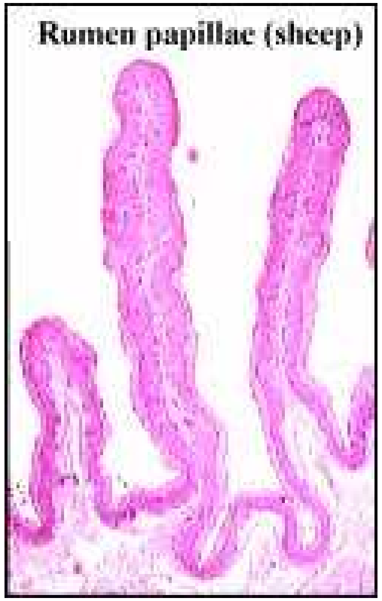
**Rumen:**

- rgest (80%)
- on-glandular
- overed with papillae
- ontent: coarse ingesta and fluid
- **unctions:** 1) Reservoir

  2) site for cellulose digestion

  3) synthesis of vit B complex

  4) production of gases: $CO_2$, $CH_4$, $H_2S$



## Reticulum:

nallest

ithelium: **honey comb** like structure : contents are liquid

 digestive glands

**nctions:** 1) Reservoir: of swallowed saliva and liquid

2) Regulate passage of food particles from rumen to omasum
ter rumination (act as a strainer: pushes solid ingesta back to the rumen,
uid ingesta to omasum)

men communicate with reticulum by **rumeno-reticular fold**

Omasum:

.Mem : numerous **folds/laminae.**

received the food directly from esophagus after rumination

unctions: grind the food particles

absorb water, Na, K & VFA

Abomesum: chemical & enzymatic digestion

Blood supply is very rich

Vagal & Splanchnic nerve : innervate the stomach

**Advantage/benefits of ruminant digestion:**

**Synthesis of high quality protein in the form of microbial protein :** rich in essential aa, from law biological value plant protein & from dietary NPN & from recycled nitrogenous metabolic end product (urea through saliva).

**Synthesis of B vitamins:** Cu should be available for Vit $B_{12}$.

**Allow utilization of too fibrous food**

**Can utilize cellulose, most abundant plant material**

isadvantages:

Adequate feed needed

Ruminants need complicated mechanism to keep fermentation vat working efficiently

: 1) addition of large quantity of saliva

2) powerful mixing movement of the stomach

3) mech. Involved in eructation (elimination of gases), rumination egurgitation of cud), absorption of end products and for onward passage of od to omasum.

4) Food particles leave the rumen- to -reticulum, when size decrease to m, most commonly , < 2 mm in length

5) Only p. a. (VFA) is converted to glucose, so high reqmt of feed durin ctation and pregnancy (last stages: fetal growth).

## minal Microbes:

cteria, protozoa and the fungi.

cteria are single cell plants (rumen flora).

otozoa are single cell animals (rumen fauna) and

ngi are the vegetative forms.

**Protozoa feed on the bacteria and ingested feed.**

locations in the rumen: Some microbes adhere **tightly to the wall of the rumen,** most microbes are **associated with feed particles** in the rumen or **float freely** in ruminal liquid.

- Most of the rumen microorganisms are strictly **anaerobic**, i.e, they live and grow without oxygen.
- Many of the isolated species of rumen microorganisms are sensitive to even small amounts of oxygen.
- But a small proportion of bacteria (facultative anaerobic bacteria) can tolerate small amounts of oxygen and can also use it in their metabolism.

## 1.Rumen bacteria

X$10^{10-11}$ / gram of rumen material.

200 species of bacteria with different digestive capabilities have been entified.

umen bacteria vary in size and shape:

anaeorobic, gm +ve or gm –ve,

boreforms, non-sporforms, motile, non-motile,

Shape: rod, cocci, spirochetes

**classified into:**

**1) Primary bacteria** are those that degrade the actual constituents of the diet and depending on their preference for cellulose or starch are termed **cellulolytic or amylolytic.**

2) **Secondary bacteria** are the end products of primary bacteria degradations as their substrates. This group includes – **1) lactate utilizing proportionate bacteria** which produces some of the propionate and **2) hydrogen utilizing methanogenic bacteria**.

Although there is some specialization, many bacteria utilize multiple substrates.

Secondary bacteria prevent accumulation of lactic acid by converting it to propionate.

## ome of the major groups:

Cellulolytic (digest cellulose)

Hemicellulolytic (digest hemi cellulose)

Amylolytic (digest starch)

Proteolytic (digest proteins)

Sugar utilizing (utilize monosaccharides and diasaccharides)

Acid utilizing (utilize such substrates as lactic, succinic and malic acids)

Ammonia producers

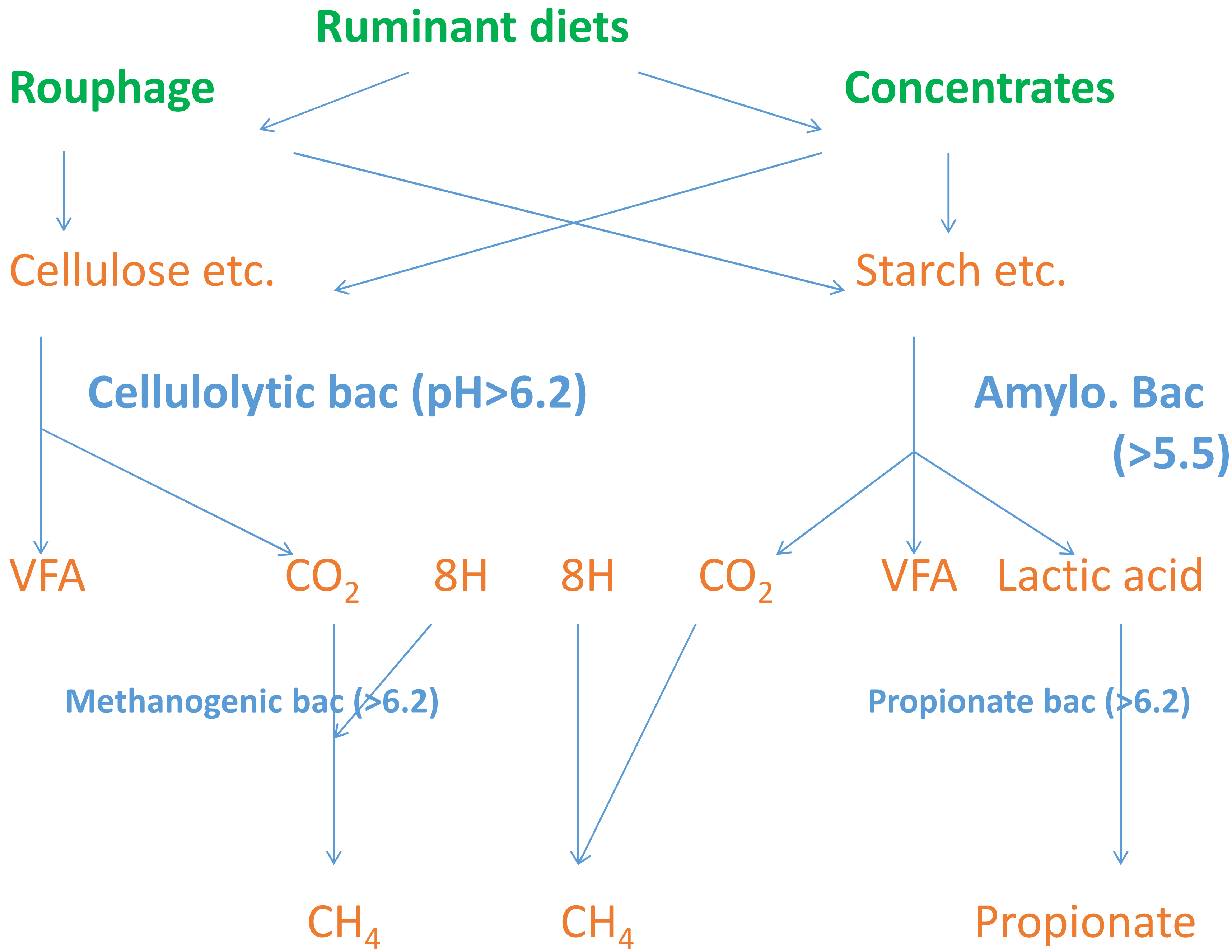
Vitamin synthesizers

Methane producers

- **Different types of bacteria are:**

**(according to their fermentative property)**

1. Cellulolytic bacteria
2. Hemicellulose digesting bacteria
3. Amylolytic bacteria
4. Bacteria utilizing sugars
5. Acid utilizing bacteria
6. Bacteria utilizing protein
7. ,, ,, aa
8. ,, ,, methan
9. Lypolytic bacteria



Ruminant diets
Rouphage
Concentrates
Cellulose etc.
Starch etc.
Cellulolytic bac (pH>6.2)
Amylo. Bac (>5.5)
VFA
$CO_2$
8H
8H
$CO_2$
VFA
Lactic acid
Methanogenic bac (>6.2)
Propionate bac (>6.2)
$CH_4$
$CH_4$
Propionate

- Fungi:

Little important in fermentation.

# Protozoa

- Anerobic
- Feed ruminal bacteria, plant, starch granules & PUFA, linoleic and linolenic acid
- Very sensible, presence: indicator of normality

# Difference between Holotrichs & Entodiniomorphs

| **Holotrichs** | **Entodiniomorphs** |
|---|---|
| 1. Entire body is covered with cilia | 1. Cilia aggregated in a tuft or syncilia that donot cover much of the body surface |
| 2. Depends on non-structural polysaccharides (starches, soluble sugar) | 2.Engulf materials that are attacked by enzyme (enzyme attack cellulose and hemicellulose) |
| 3. First established | 3. Later established |
| 4. Large size | 4. Smaller |
| 5. Survive for longer period | 5. Shorter period |

## Role of micro-organism

1.It provide digestion of soluble and insoluble CHO into organic acid, which are readily absorbed----source of energy.

**2. Both quality & quantity of dietary protein can be upgraded.**

3. Microflora protect the gut from disease both

by stimulation of immune system & direct competition with pathogenic micro-organism

**4. Toxic substances in the diet may be attacked by the microbes before they are presented for absorption in the SI.**

5. Capable of Vit. B complex synthesis

**6. They can digest mucus, bilirubin, GI enzymes, urea, protein and other nitrogenous compound & wide varieties of drugs.**

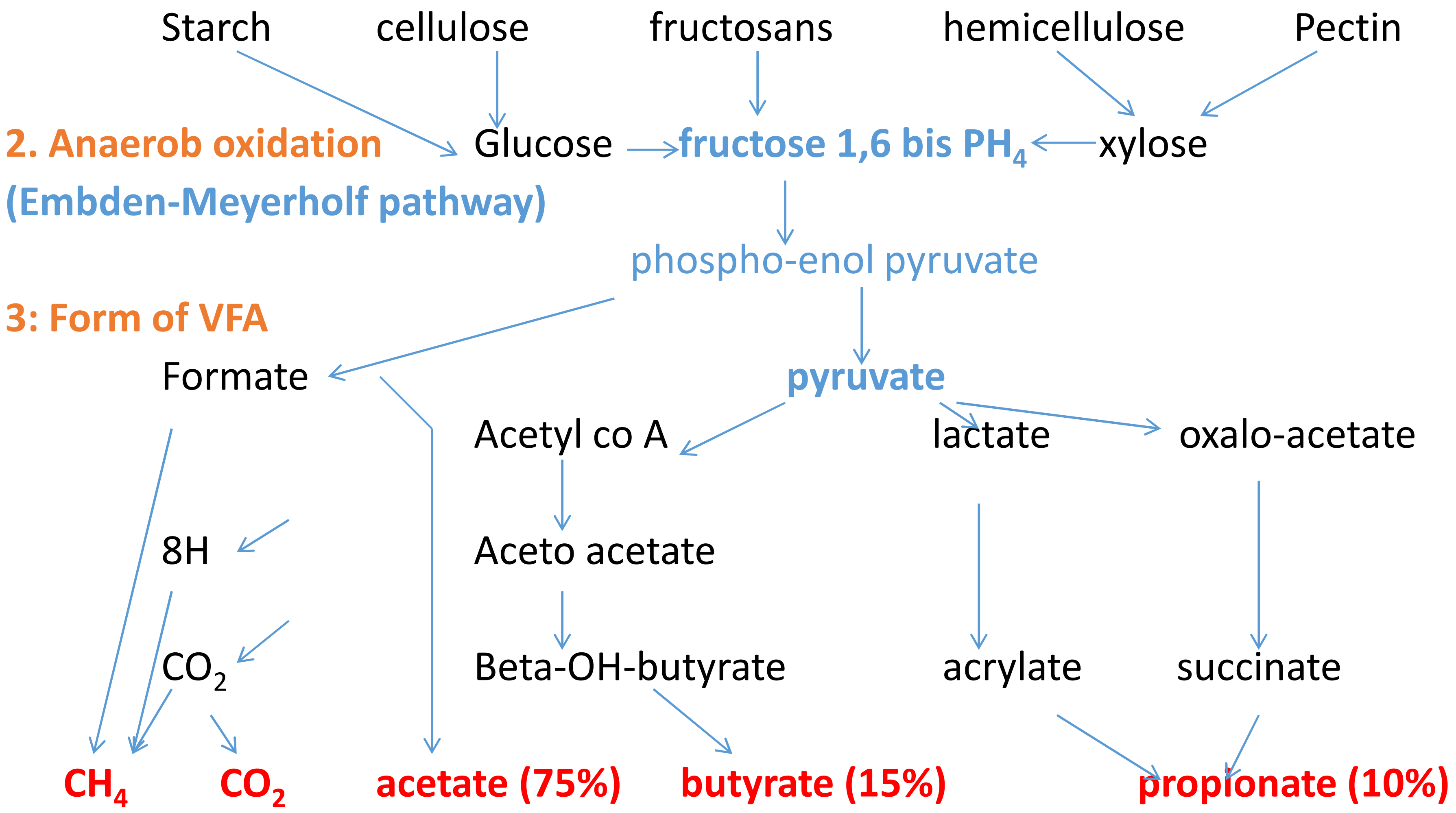
7. They can produce organic acid, $CO_2$, $H_2$, $NH_3$ as well as toxic amines and phenols

- Rumen pH: 5.5 -7
- Diet affects pH: lower pH with concentrate diet
- 25% microbial protein is protozoal in origin.
- Protozoa accounts for ¼ to 1/3 of ruminal fiber digestion
- **Defaunated animals (protozoa free) :** less digestion of organic matter , degradation of dietary protein is less. Less rumen $NH_4$.
- Using CuSO4,
- Isolation of young ruminants from faunated animals

- Increased Protozoa conc. --- important : if diet contain excess starch and sugar: protozoa incorporate these into **i/cellular reserve polysaccharide**. So, less lactic acid produced.

- Pathway of fermentation of dietary CHO: (page: 445, duke's)

**1. Hydrolysis of polysaccharides:**




**Stage 4:** microbial digestion : syn. Of new protein

- High starch rich concentrate diet (cereal grains, legume seeds): **70:25:5** (more VFA production with increased conc. of propionate)---low methane prod.

**Absorption:**

- Most VFAs are absorbed in the rumen (passive/facilitated diffusion)
- absorp higher when ruminal pH reduced &
- Increased chain length. Eg: b.a> p.a> a.a

- B.a:-ketone bodies; beta-OH-Bu acid
- P.a:- lactic acid (rumen) & oxalo-acetic acid (liver)---glucose
- A.a:- acetyl co-A (liver) & $CO_2$ (rumen); acetyl Co-A reacts with oxalo-acetate and form citrate to use in Kreb's cycle

- Lactic acid: converted to propionate

- Higher starch rich diet : pH falls : propionate bacteria inactivate;
- Lactic acid accumulates: L.A is stronger acid than other VFA
- Metabolized in the liver to pyruvate, then to glucose and glycogen
- Metabolized acid turn to **metabolic acidosis**

# Gases:

- $CO_2$ (60%)
- $CH_4$ (30-40%)
- $N_2$. $H_2S$, $H_2$ & $O_2$ (eliminated through eructation)

- Ammonia: deamination of protein (dietary Protein, urea or NPN subs)

**Other end products:**

aa: high biological value proteins

small amts of lipids (PUFA)

and some vitamins

- Proteolytic bacteria: 12-38%

**Dietary proteins are classified into:**

**1.RDPs :** rumen degradable protein

**2.RUPs**: rumen un degradable protein (protected protein): present in plant (maize) poorly fermented in fore-stomach but are radily digested in the abomesum and intestine

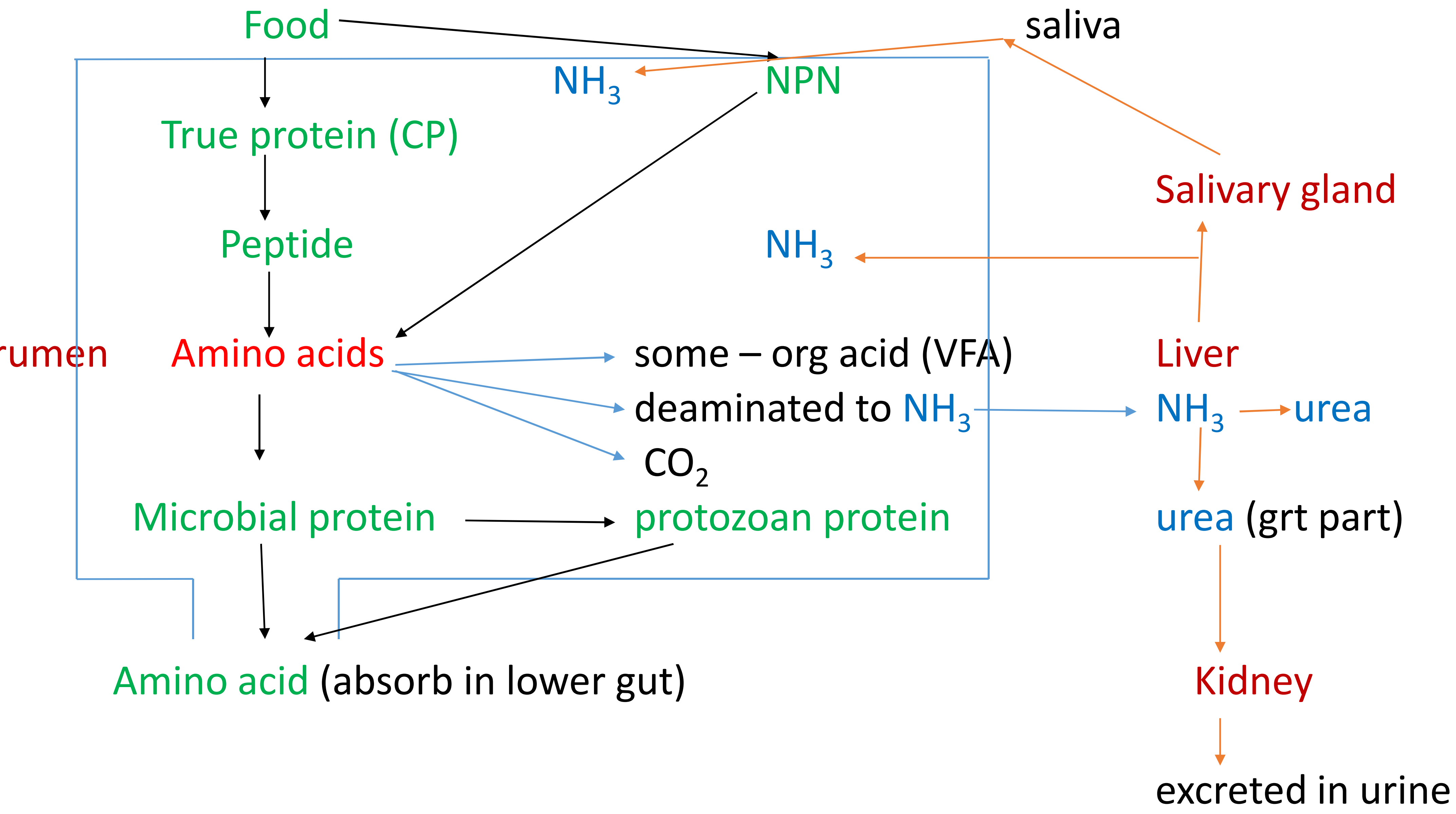
Half of dietary protein: degraded in the rumen

RDPs ⟶ RUPs

**heat/ formaline** (prevent microbial dig of high quality protein, so that it is available in the intestine) : called **protected protein**

**Formalized protein has been used to coat & protect fats from microbial attack to enhance the milk yield & increase amt of unsaturated fatty acid in milk / animal fat.**

## Fermentation of dietary protein:



# How microbial proteins are produced?

**Protein**

↓ entry into the rumen

**Attached by microbial proteases (majority are endopeptidases)**

↓ digest

**Short chain peptides**

↓ immediately absorb in the microbial cells &

**Degraded to aa**

↓ esterified for the formation of

**Microbial protein**

- **Remember it:**

**Feeding excess protein** ----------- wasteful input-------leads to overproduction of $NH_3$, which takes energy to convert to urea (liver)---------- leads to ammonia toxicity.

Protozoa mostly engulf bacteria for nitrogen source.  Convert bacterial protein to protozoan protein

Each protozoa can engulf about **60-700 bacteria / hour**

- LIPID DIGESTION:

- **Source:** **1) leaves of forage plants** (cell membranes) that contain lipid: phospholipid, f.a., palmitic, linoleic, linolenic acids.

  **2) oil seeds :** free fatty acids, palmitic, linoleic, linolenic acids

Dietary lipid

↓ hydrolysed by rumen microbes

Stearic acid

VFA ⟶ microbial lipids

microbes

- Protozoa plays an important role in lipid metabolism

**Absorb PUFA (Polyunsaturated Fatty acid), protect them from hydrogenation,**

↓

**Then flow out from rumen to the intestine**

↓

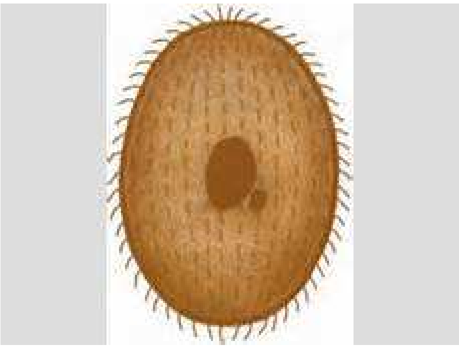
**Release their content**

# Concentrations

- Bacteria: $10^9$ – $10^{10}$/ml rumen liquor
- Protozoa: $10^5$ – $10^6$/ml rumen liquor
- Fungi: $2X10^3$ – $3X10^4$/ml rumen liquor

# Holotrichs

# Entodiniomorphs



**Reticulo ruminal motility:**

an orderly pattern of ruminal motility

contractions occurs **1 to 3 times per minute**.

highest frequency ---- during feeding

lowest --- animal is resting.

Motility centers in the brainstem: **dorsal vagal nucleus of the brainstem**

control both the **rate and strength of contraction** via vagal efferents.

Two types of contractions are identified:

**Primary contractions:**

Originate in the reticulum and pass caudally around the rumen

mixing of the ingesta (mixing contractions).

This process involves a wave of contraction followed by a wave of relaxation

**Secondary contractions:**

Occur in only parts of the rumen

usually associated with eructation (Eructation contractions)

**Rumination: (chewing the cud)**

- regurgitation of the ingesta (cud) from the reticulum followed by remastication, reinsalvation and redeglutition.

- It provides for effective mechanical breakdown of roughage and thereby increases subtrate surface area to fermentative microbes.

- Rumination is a unique characteristic of the true ruminants and pseudoruminants.

# Vomition: (Emesis)

- It can be defined as the **forceful expulsion of contents of the stomach and often small intestine out of the mouth.**

## Causes:

- Presence of irritating contents of GIT-stimulate nerve fibre.
- Mechanical stimulation of pharynx.
- Inflammation of intestine.
- Nauseating sight, odor or taste.
- Unusual stimulation of labyrynthine apparatus (vestibular apparatus) as in the case of sea sickness, air sickness, car sickness or swinging.
- Direct stimulation of **medulla** etc.

- **MOVEMENTS OF GI TRACT**

"Cutting of food particles or substances into a smaller particles and grinding them into a soft bolus" is known as mastication.

**MOVEMENTS OF STOMACH**

The movement of empty stomach is related to the sensation of hunger, so called hunger contraction.

## MOVEMENT OF SI

Movement of SI is essential for mixing the chyme with a juices, propulsion of food and absorption.

### 1. Mixing movement:

- **Segmental contraction:**

Common type in a rhythmic fashion. The contractions occur at regularly spaced intervals along a section of intestine. The segments of intestine in between the contracted segments are relaxed.

All the segments (both contracted and relaxed) give a ring like appearance resembling the chain of sausage.

- **Pendular movement:**

Intestinal loop move like the pendulum of the clock.

## 2. Propulsive movement:

- **Peristaltic movement:**

Peristalsis means the **wave of contraction followed by wave of relaxation**/ sequently timed contraction  of longitudinal and circular muscle.

- **Peristaltic rush:**
- Sometimes, the **SI shows a powerful peristaltic contractions**.
- caused by **excessive irritation** of intestinal mucus membrane or extreme distension of the intestine.
- **begins in duodenum and passes through the entire  length of SI** and finally reaches the ilocecal valve within few minutes.
- This sweeps the content of intestine into colon. Thus, it **relieves the SI** off either **irritant or excessive distension.**

- **MOVEMENT OF LI**

1. Mixing Movement – segmented contraction

2. Propulsive movement- Mass particles.

  - Segmented contraction: Large circular constriction, appears in the colon, are called mixing segmentation.
  - Mass peristalsis: or mass movement propels the faces from colon towards anus. Usually, this movement is developed only a few times everyday.