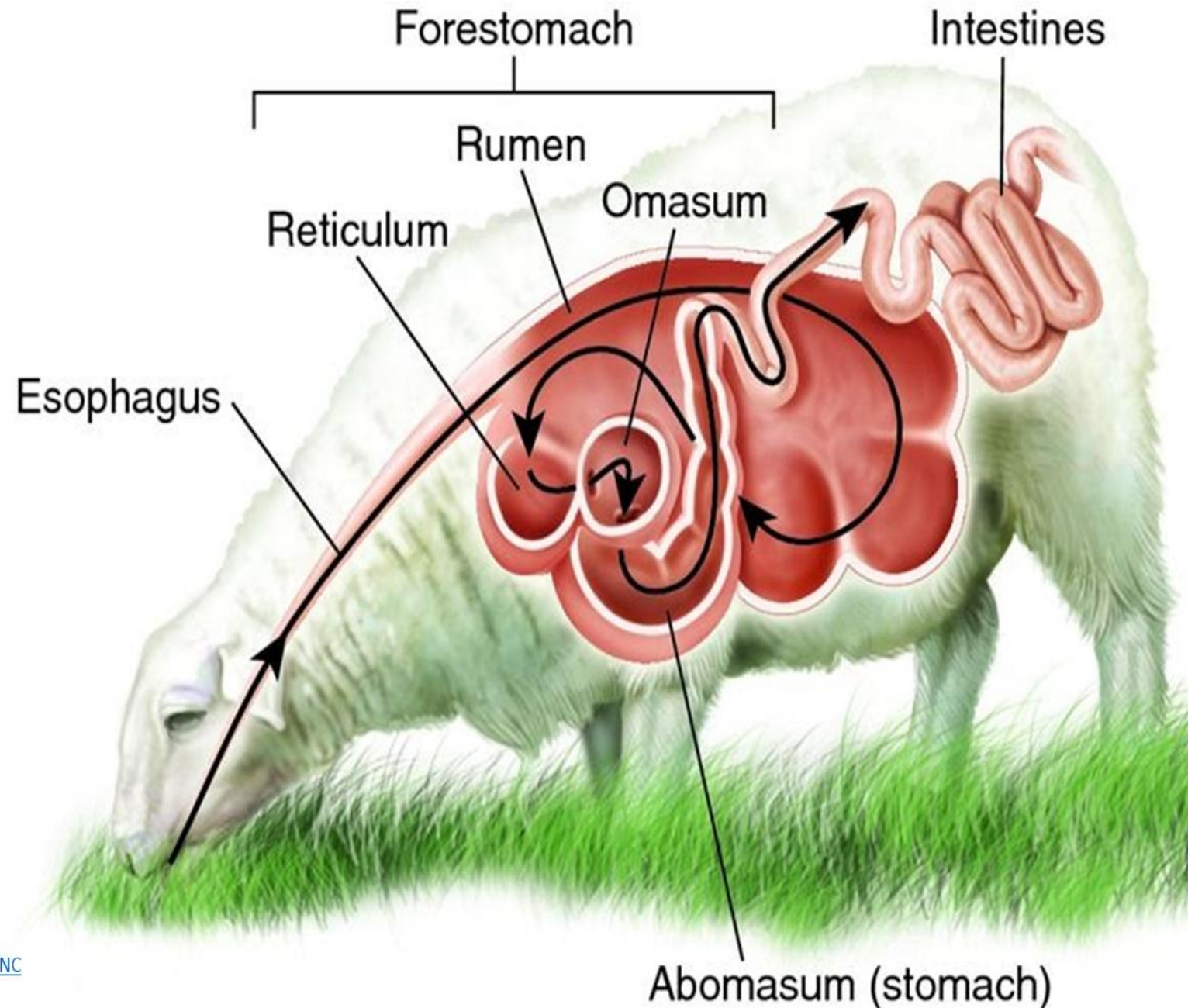


Digestion in ruminants

Digestion in the rumen – Reticulum, leaflet, abomasum and fermentation phenomena

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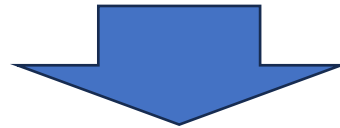
- 1. Digestion in the rumen - reticulum and fermentation phenomena.
- - The ruminal environment
- - The breakdown of carbohydrates and the formation of volatile fatty acids
- - Degradation of nitrogenous materials
- - Lipid breakdown
- - Balance of digestion in the rumen - – reticulum .
- 2. Digestion after the rumen – reticulum .
- - In the leaflet
- - In the abomasum and small intestine
- - In the large intestine.

DIAGRAM OF THE DIGESTIVE PROCESS IN RUMINANTS

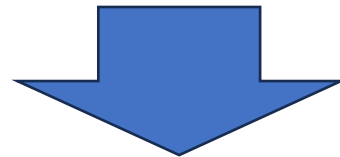
1. LA MOUTH; Ingestion, Chewing, kneading with saliva.

Organs: the tongue, the teeth and the salivary glands.

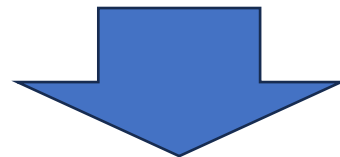
Descent through the esophagus.

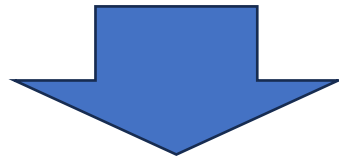


- 2. OESOPHAGUS / CARDIA: Transport of the feed to the rumen by a movement of peristalsis



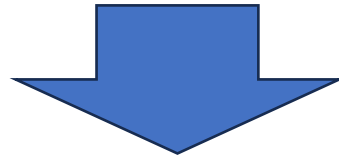
- 3. THE RUMEN (rumen) & THE reticulum (cap)
- This is where microbial fermentation occurs: Humidity 80%, (watering), Stagnation (24 to 48 hours), pH (6.2 to 6.8), Temperature (39.5°C). Anaerobic





- 4. FEUILLET (Omasum)

Action : Essorage du chyme.: Absorption : Les parois absorbent l'eau, les acides aminés, les vitamines et les sels minéraux.



- 5. CAILLETTE (Abomasum - Vrai estomac)

Action : Digestion enzymatique. Milieu : Très acide (Acide chlorhydrique + enzymes).



- 6. INTESTINS

- Action : Digestion finale et absorption des nutriments.

- * Apports externes : * Vésicule biliaire (Sels biliaires) + (enzymes pancréatiques)

7. DISPOSAL (Undigested waste through the anus)

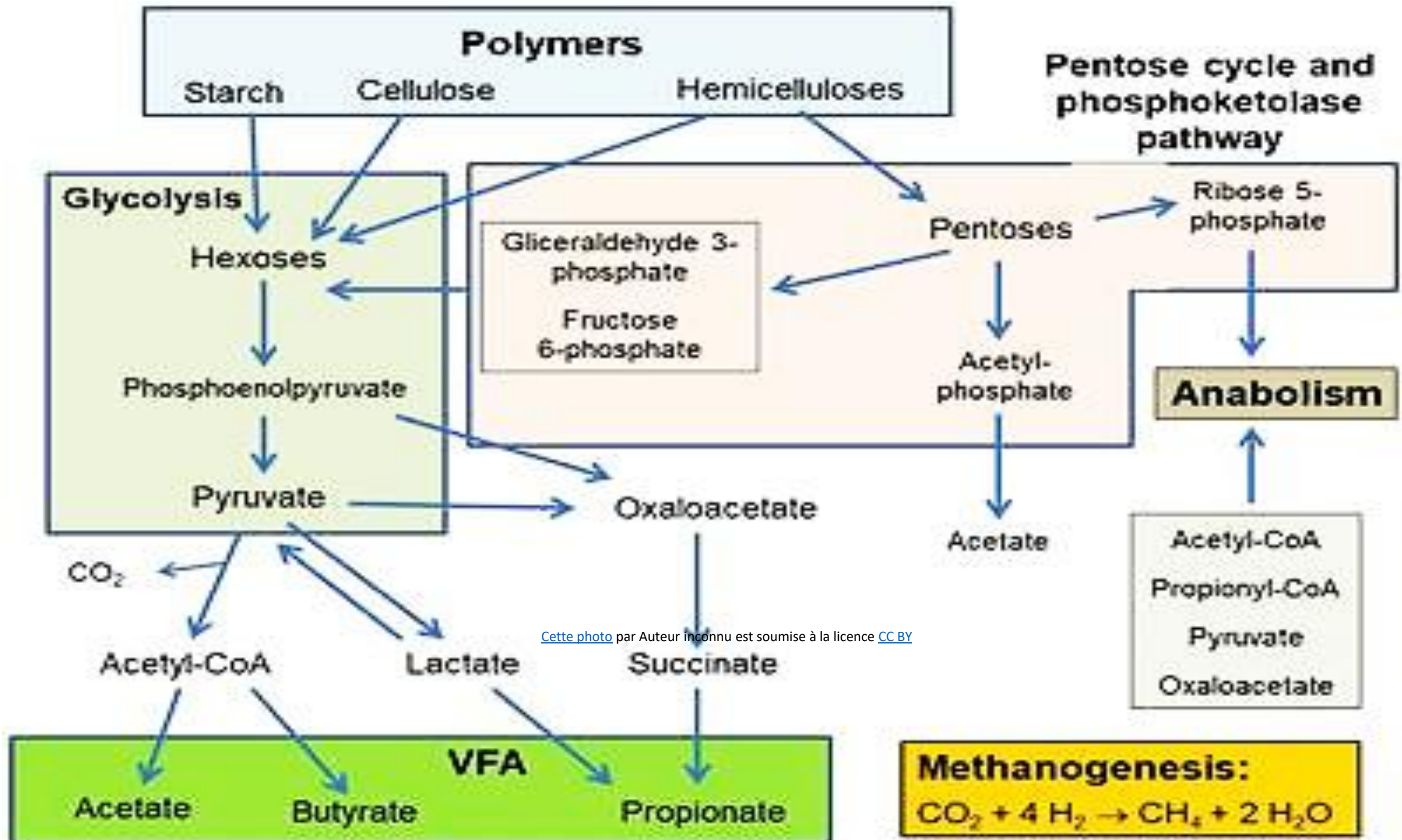
Summary of key steps:

Fermentation: In the Rumen/abomasum.

Water absorption: In the Leaflet by spinning.

Chemical digestion: In the abomasum (equivalent to the human stomach).

Final digestion: In the intestine thanks to the liver (bile) and pancreas.



1. Digestion in the rumen - abomasum and fermentation phenomena

- Digestion in ruminants is a unique process characterized by a stomach divided into four distinct compartments that allow for the efficient degradation of plant fibers (cellulose).

The digestion process is done in 4 steps:

1st stage in Rumen-

2nd step in the reticulum

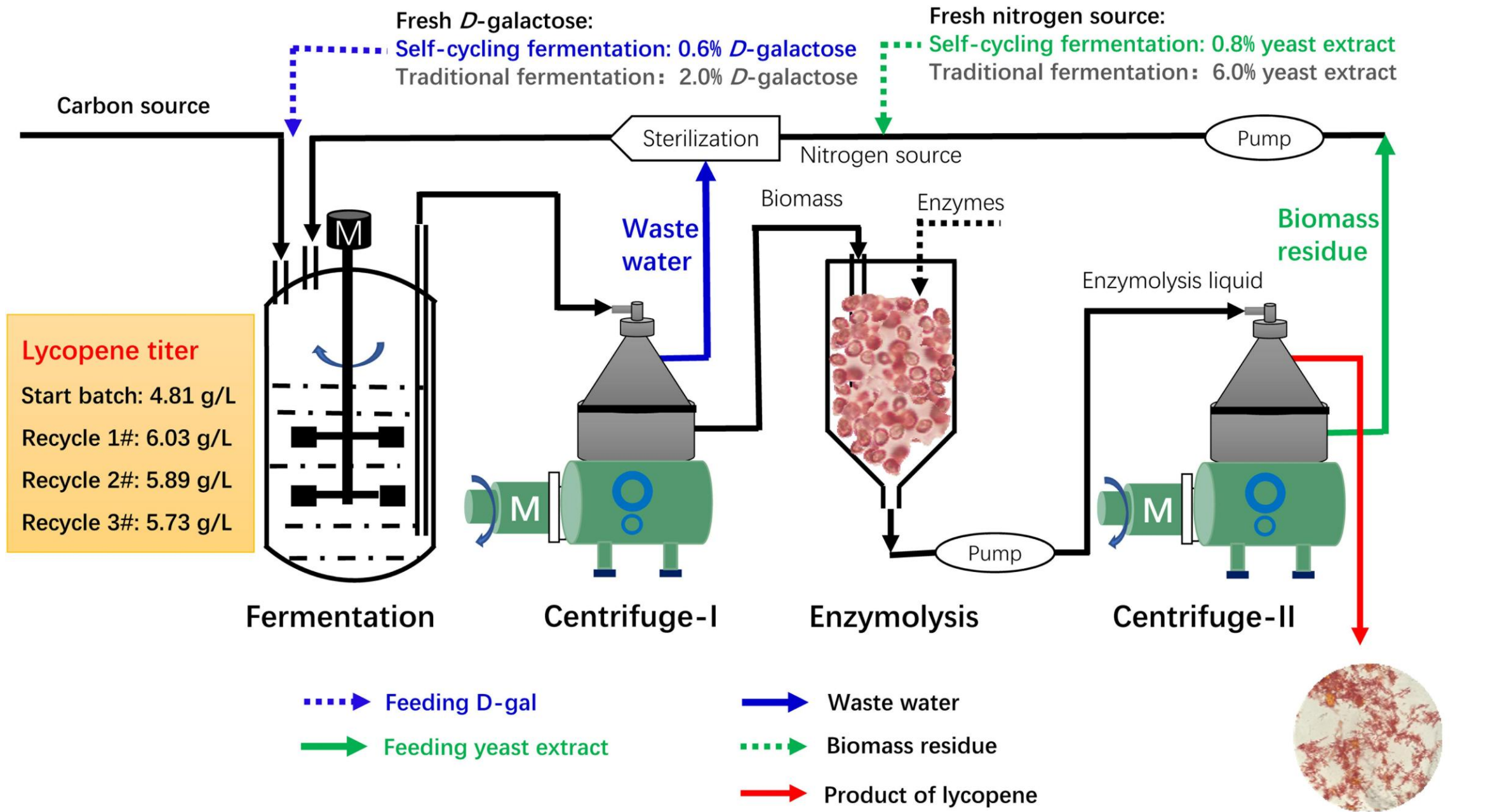
3step Leaflet-

4stage abomasum

The system works like a real fermentation and filtering plant:

The rumen (or rumen): This is the largest compartment.

The grass (hay, straw) swallowed undergoes anaerobic fermentation thanks to billions of bacteria, protozoa that transform carbohydrates into volatile fatty acids (VFAs), the animal's main source of energy.



Lycopene titer

Start batch: 4.81 g/L

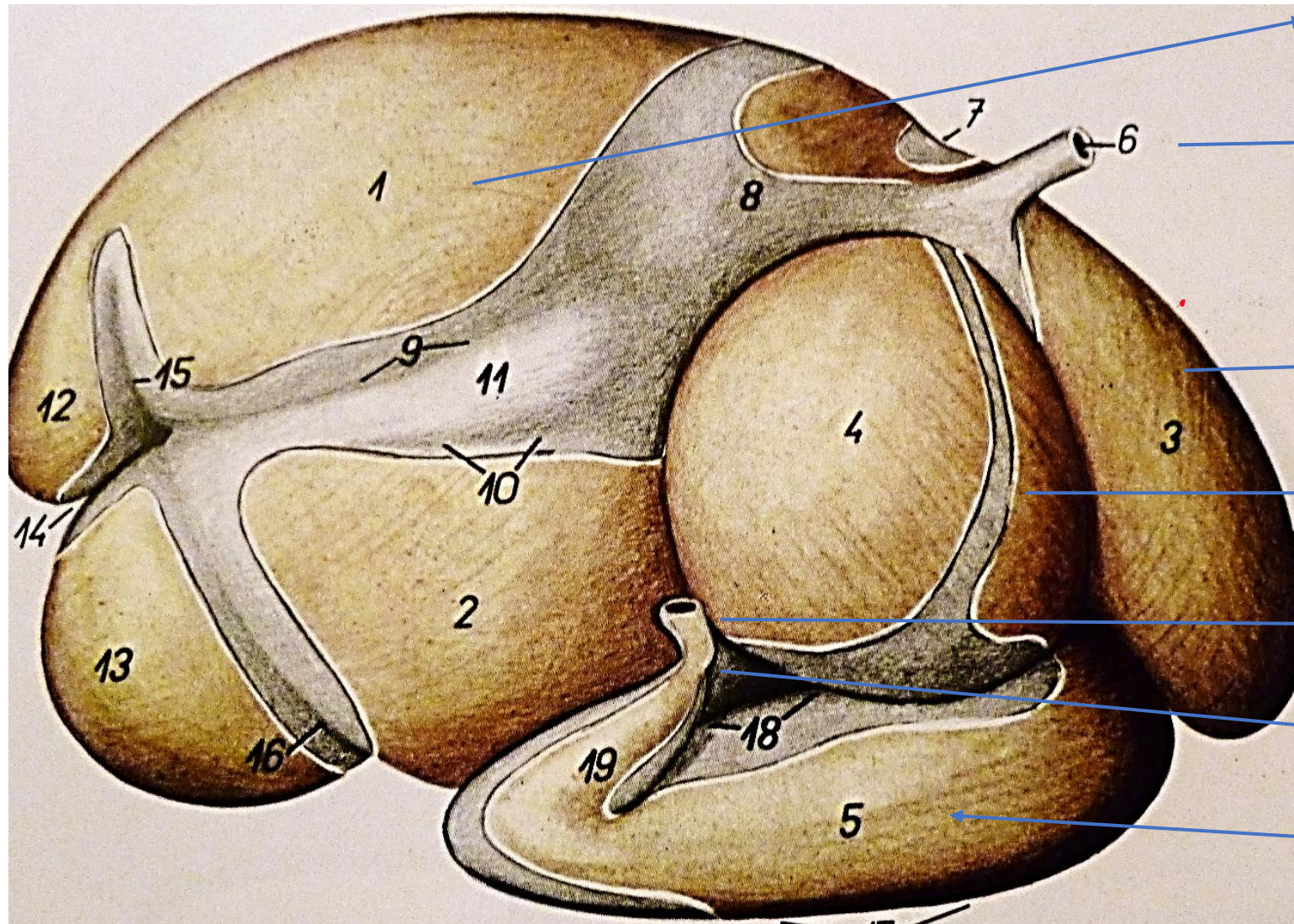
Recycle 1#: 6.03 g/L

Recycle 2#: 5.89 g/L

Recycle 3#: 5.73 g/L

Crystal of Lycopene
 Content > 70%

ANATOMY OF THE BOVINE RUMEN (right side view)



Dorsal lobe of the rumen

Esophagus (cardia)

Reticulum

Leaflet

pylorus

Sphincter pylori

Abomasum

- The Reticulum (or Bonnet): It acts as a filter or sieve. It separates fine particles from coarse particles. The latter are sent back to the mouth to be chewed again: this is rumination.
- The Omasum (or Leaflet): Once the food has been finely ground and back in the rumen, it passes into the leaflet which plays a wringing role by absorbing the water and minerals from the food porridge.

Key points of rumination

Rumination time: is 6 to 8 hours per day.

Salivation: Saliva production: (up to 180 liters per day in cows) is essential to maintain rumen pH.

Gas emissions: Fermentation produces gases, including methane, which the animal excretes by belching.

- The Abomasum (or Caillette):
- This is the "real" stomach, comparable to that of humans.

Acidic gastric juices (HCl) and enzymes digest proteins, including bacteria from the rumen, before nutrients pass into the small intestine.

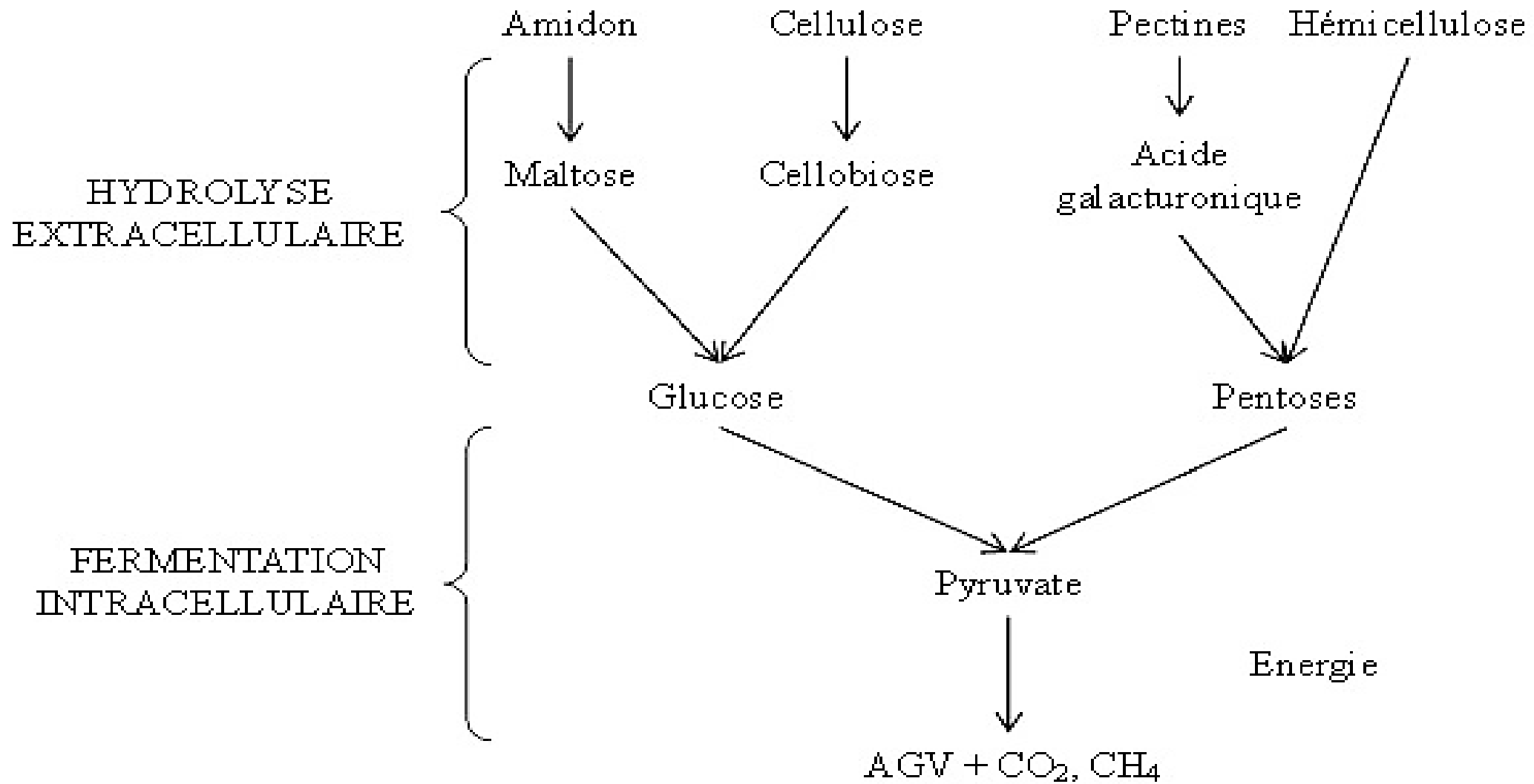
Ruminal environment

- Ruminant process
- Ruminant is the process of regurgitating and rechewing food to grind it finely, which is crucial for efficient digestion of plant fibers. Animals spend long hours ruminating and produce large amounts of saliva to maintain rumen pH.

- Ruminants do not produce enzymes capable of breaking down cellulose but they rely on a complex microbial ecosystem in their rumen:
- More numerous bacteria, play the main role in the degradation of cellulose. Key species include *Fibrobacter succinogenes* and *Ruminococcus* spp.
- Protozoa: These organisms also ingest starch, bacteria, and cellulose particles, helping to regulate the rate of fermentation.
- Mushrooms: Strictly anaerobic, they also help break down plant fibers.
- Methanogenic archaea: These microorganisms produce methane in the rumen.
- This ecosystem requires a warm, moist, and anaerobic environment, with a pH (6.2-6.7) ideal for fermentation.
- These microbes not only provide the main energy (volatile fatty acids) to the animal, but also synthesize proteins, B vitamins and vitamin K.

Fermentation process in the rumen

- The breakdown of carbohydrates and the formation of volatile fatty acids (VFAs) in the rumen takes place through a process of microbial fermentation in intense anaerobic conditions.
- Ingested carbohydrates (cellulose, starch, sugars) are broken down by the billions of microorganisms present in the rumen (bacteria, protozoa, fungi):
- Fermentation in the absence of oxygen, produces carbohydrates, releasing by-products: hydrogen (H_2), carbon dioxide (CO_2), and methane, (CH_4).
- Production of Volatile Fatty Acids (VFAs): This is the major final product of this fermentation. The main VFAs produced are:
 - (acetate, propionate and butyrate)
- These VFAs are absorbed through the rumen wall and enter the bloodstream.



La fermentation des glucides par les bactéries ruminales

Proportions d'Acides Gras Volatils (AGV)

- Les acides gras volatils (**acétate, propionate, butyrate**) sont les principaux produits terminaux de la fermentation des glucides dans le rumen.
- Leurs proportions varient en fonction du régime alimentaire de l'animal

In conclusion; Digestive flow details

PALATE

Chewing & Salivation: grinding and kneading food with saliva.

Action: Beginning of mechanical and somewhat enzymatic degradation.

ESOPHAGUS / CARDIA

Transport: Passage of chewed and kneaded food to the forestomachs.

RUMEN (*Rumen*) & Reticulum (*Bonnet*)

Brewing & Fermentation: Mixing with drinking water.

Optimal conditions:

Stagnation Duration: 24 to 48 hours.

pH: 6.2 to 6.8.

Temperature: 39.5 °C.

Humidity 80%

Strict anaerobic

LEAFLET (Omasum)

Spinning the chyme: The water is removed.

Absorption: Recovery of amino acids, vitamins and mineral salts through the walls.

CAILLETTE (Abomasum)

Enzymatic Digestion: Medium rich in Hydrochloric Acid.

Chemical digestion comparable to the human stomach.

INTESTINES

Receiving enzymes from the gallbladder (liver) and pancreas. Finalization of digestion

Result: Final absorption of the remaining nutrients and water in addition to the

Plan Type	acetate	Propionate	Butyrate
Diet rich in fibre (forages, grass)	High (60-70%)	Medium (15-20%)	Medium (10 -15)
Diet high in grains (starch)	Medium (approx. 40-50%)	High (approx. 30-40%)	Medium (approx. 10-15%)

Acetate and Butyrate: Their production tends to promote the production of methane in the rumen.

Acetate is the main source of carbon for the synthesis of body fat and milk in ruminants.

Propionate: Its formation constitutes an alternative route of hydrogen use, which indirectly reduces methane production. It is an important precursor of glucose

Role of ruminal pH

- Rumen pH is a critical factor that directly influences the efficiency of microbial digestion:
- The ideal pH: An optimal rumen pH is usually between 6.2 and 6.8 to promote bacteria that digest fiber efficiently (cellulose).

Ruminal acidosis

If the pH drops:

below 5.5 = subclinical acidosis,

below 5.0 = acute, usually fatal acidosis

In subclinical (chronic) acidosis, the bacteria that digest the fibers are inhibited, while other lactic acid-producing bacteria proliferate, creating a vicious cycle. This can be detrimental to the animal's health and milk production

Degradation of nitrogenous matter

- The degradation of nitrogenous materials, such as proteins, is done by proteolysis (enzymes) into amino acids, then
- by deamination releasing ammonia (NH_3),
- which is converted into ammonium (NH_4^+).
- In nature, micro-organisms (bacteria, fungi) mineralize this nitrogen into ammonia,
- then the nitrogen cycle continues by nitrification (ammonia \rightarrow nitrites \rightarrow nitrates) or denitrification (nitrates \rightarrow nitrogen gas),
- This process is essential for plants and the environment.

1. Protein degradation (in animals)

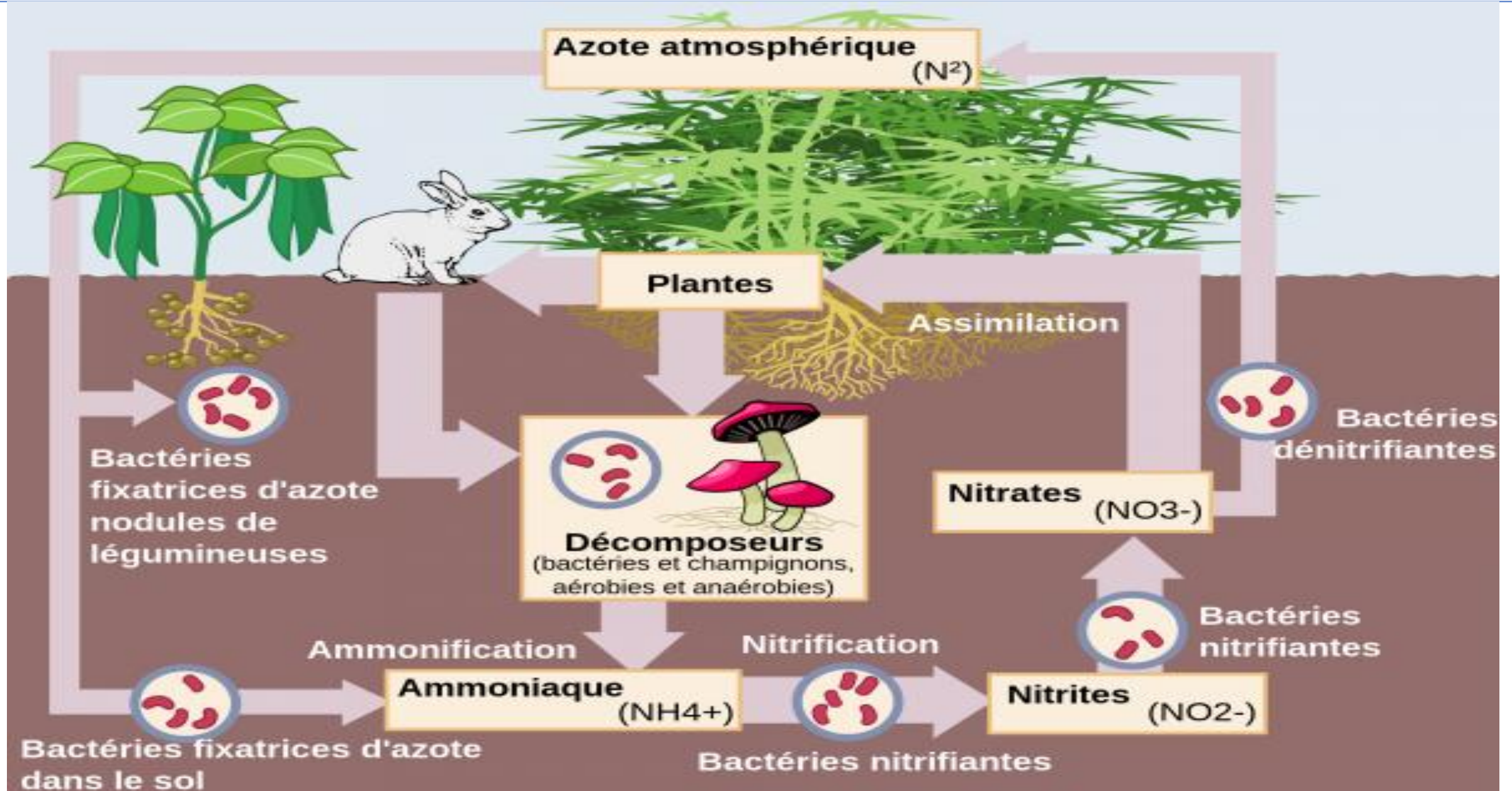
- Proteolysis: Proteins are cut by enzymes (proteases) into peptides and then into amino acids.
- Deamination: The amino group (NH_2) of amino acids is separated from the carbon backbone, forming ammonia (NH_3).
- Ammonia toxicity: In animals (mammals), ammonia, which is toxic, is converted to urea (urea cycle) to be excreted in urine via the kidneys.

2. Dégradation dans l'environnement (micro-organismes)

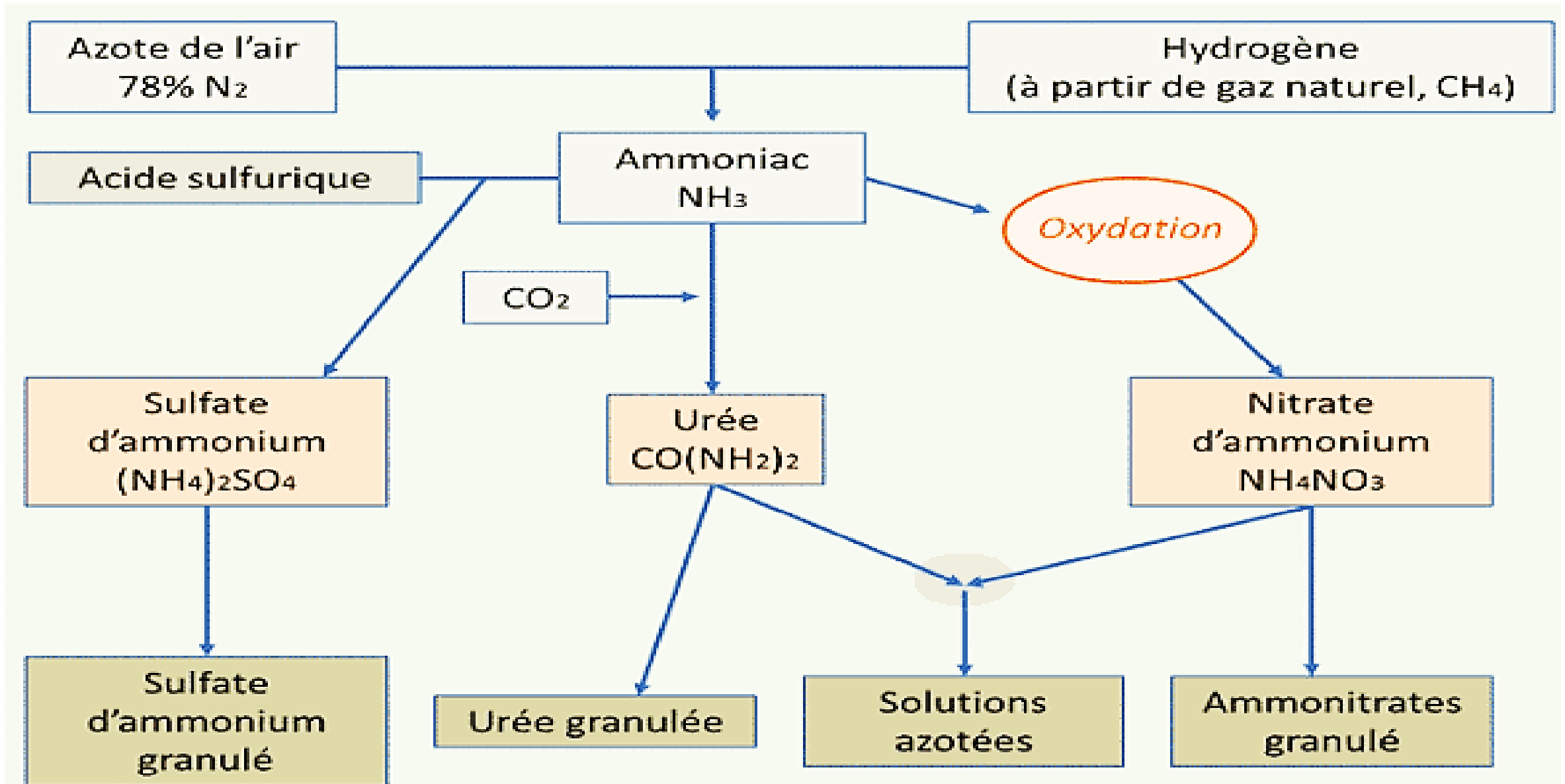
- Minéralisation : Micro-organismes décomposent la matière organique azotée, transformant l'azote organique en ammoniac ou ammonium.
- Nitrification : Des bactéries oxydent l'ammoniac en nitrites (NO_2^-), puis en nitrates (NO_3^-).
- Dénitrification : D'autres bactéries réduisent les nitrates en azote gazeux (N_2) libéré dans l'atmosphère, fermant le cycle.

3. Nitrogen degradation in soil and compost

- Composting degrades fresh nitrogenous materials, and soil microorganisms continue this process.
- Mineralized nitrogen (ammonia/nitrate) becomes available to plants.



La dégradation des matières azotées



Lipid breakdown

- Lipid breakdown, or lipolysis, is the metabolic process by which fats (mainly triglycerides) are broken down into fatty acids and glycerol for energy.

The steps of the lipolysis process

- 1. Lipolysis (Cytoplasm)
- Under the action of enzymes (lipases), the triglycerides stored in the adipose tissue are hydrolyzed.
- 1 molecule of glycerol and 3 molecules of fatty acids.
- Glycerol fate: It joins glycolysis to be transformed into energy or used for glucose synthesis.
- 1. Activation and Transport
- The released fatty acids enter the cells (mitochondria). To cross the mitochondrial membrane, they must be activated in Acyl-CoA and transported via the carnitine shuttle.

- **3. Beta-oxidation (Mitochondria)**

- This is the central stage of degradation. The fatty acid undergoes a series of cycles of four chemical reactions that "cut" the carbon chain two by two.
- Result: Each cycle produces Acetyl-CoA, FADH₂ and NADH.
- Acetyl-CoA then enters the Krebs cycle to generate a large amount of ATP (energy).
- 4. Ketogenesis (in case of fasting):
- If the body lacks glucose (prolonged fasting or a very low-carbohydrate diet), the excess Acetyl-CoA is converted by the liver into ketone bodies. These serve as an alternative fuel, especially for the brain. (beware of ketosis the cow)

- NADH (Nicotinamide Adenine Dinucleotide Reduced): This is the reduced form of coenzyme NAD⁺.
- It transfers its electrons to a specific complex in the respiratory chain, which allows the production of about three molecules of ATP (the cell's energy currency) per molecule of NADH. It is derived from vitamin B3 (niacin).
- FADH₂ (Flavin Adenine Dinucleotide Reduced): This is the reduced form of coenzyme FAD.
- It transfers its electrons to a slightly different point in the respiratory chain (at complex II), at a slightly lower energy level than NADH.
- It allows the production of about two molecules of ATP per molecule of FADH₂.
- It is derived from vitamin B2 (riboflavin).

Mechanical processes

- **Mixing and storage:** The rumen (rumen) serves as a reservoir (up to 200 litres in cows) where feed is mixed with saliva.
- **Rumination:** Coarse particles are returned to the mouth to be re-chewed, increasing the attack surface for microbes.
- **Selective sorting (Network):** The network (cap) acts as a filter, retaining large particles for a new rumination cycle and allowing the fine "slurry" to pass through to the sheet.

2. Nutrient fermentation (Microbial action)

- Carbohydrates (Energy): Cellulose, starch and sugars are broken down into Volatile Fatty Acids (VFAs): acetate, propionate and butyrate. These VFAs are absorbed through the rumen wall and provide up to 70-80% of the animal's energy.
- Proteins: Microbes break down dietary proteins into ammonia (NH_3) and amino acids to synthesize their own microbial proteins. These microbes are then digested in the abomasum, providing the animal with its main nitrogen inputs.
- Vitamins: Synthesis of vitamins B and K by the microbiota.

Gas balance and waste

- Methanogenesis: Archaea use the hydrogen (H_2) and CO_2 produced by fermentations to make methane (CH_4).
- Belching: Methane and carbon dioxide are expelled by regular belching to prevent bloating.

Summary of final products

- **Carbohydrates,**
- **Volatile fatty acids (VFAs),**
- **Gases: (CO₂ , CH₄, NH₃)**
- **Nitrogen, Microbial proteins, Ammonia ()**
- **Fats: Free fatty acids, Biohydrogenation**
- **Vitamins: Synthesis of Vitamins B and K**

Digestion in the abomasum and small intestine

- In ruminants), the abomasum ensures enzymatic digestion, while the small intestine finalizes the enzymatic digestion and absorbs nutrients (glucose, amino acids, fatty acids), continuing the work of the rumen where the fibers are fermented.
- The small intestine, which is very long (40-45m in cattle), receives pancreatic and biliary secretions to break down fats, carbohydrates and proteins, allowing maximum absorption.

1. Digestion in the abomasum

- The abomasum is the only compartment of the ruminant stomach with secretory glands.
- It secretes hydrochloric acid which lowers the pH (acidic environment), which also destroys bacteria from the rumen.
- It produces pepsin, an enzyme that breaks down proteins (food and microbial) into peptides and amino acids.
- In calves, abomasums secrete rennet (casein) which coagulates milk, facilitating its digestion.

2. digestion in the small intestine

- The acidic chyme coming out of the abomasum enters the small intestine, which is the main site of nutrient absorption.
- Neutralization and enzymes: The contents are mixed with secretions from the pancreas, the liver (bile) in the duodenum, and the intestine itself. These secretions raise the pH (between 7 and 8), allowing intestinal enzymes to function optimally.
- Final Breakdown: Fat, remaining carbohydrates, and protein are reduced to elemental nutrients.
- Absorption: The inner wall, covered with villi, provides an immense surface area for the passage of nutrients (amino acids, fatty acids, glucose, vitamins) to the blood and lymph.

Summary: Digestion after rumen –omasum.

- After passage through the network (reticulum) and the rumen, digestion in ruminants continues in:
- The omasum (leaflet): It acts as a filter pump. Its main function is to reabsorb the remaining water, magnesium and volatile fatty acids in order to concentrate the food content before it enters the "real" stomach [1, 2].
- The abomasum (abomasum): (equivalent to the stomach of monogastrics). It secretes gastric juices (hydrochloric acid and enzymes) that break down proteins, including microbial proteins (bacteria and protozoa in the rumen).
- The small intestine: This is the major site of enzymatic digestion and absorption of nutrients (amino acids, sugars and fats). Secretions from the pancreas and bile facilitate final decomposition [2, 4].
- The large intestine (cecum and colon): A secondary fermentation takes place here to break down the remaining fibre, followed by a final absorption of water and minerals

Digestion in monogastric patients

- Digestion in monogastric patients (humans, pigs, dogs, horses) is characterized by a stomach with a single pouch. The process transforms food into absorbable nutrients via four main steps:
 - 1. The Oral Phase
 - Digestion begins in the mouth with chewing (mechanical action) and salivation. The enzyme salivary amylase initiates the breakdown of starches.
 - 2. The stomach phase
 - Food becomes "chyme" under the action of:
 - Chemical: Hydrochloric acid and pepsin break down proteins.
 - Mechanics: Muscle contractions stir up the contents.

- 3. The intestinal phase (Small intestine)
- It is the main site of digestion and absorption:
- Digestion: The pancreas and liver release enzymes and bile to transform fats, carbohydrates and proteins into simple molecules (amino acids, fatty acids, glucose).
- Absorption: Nutrients pass through the intestinal wall to reach the bloodstream.
- 4. The terminal phase (Large intestine)
- The water is reabsorbed and the microflora ferments the undigested residues before the excretion of faecalis.
- Special case: Herbivorous monogastric (such as horses) have a highly developed cecum where microbes ferment plant fibers, unlike humans or pigs.
-

MOUTH

Food enters the alimentary canal through the mouth. It is chewed by teeth which break food down into smaller pieces. The food is mixed with saliva that contains enzymes.

LIVER

In the digestive system, the liver produces bile which helps with the digestion of fats and oils.

GALLBLADDER

The gallbladder is where bile is stored and concentrated.

PANCREAS

Biological catalysts called enzymes are produced in the pancreas. Digestive enzymes speed up the breaking down of large nutrient molecules.

SMALL INTESTINES

Food is mixed with digestive enzymes and bile in the small intestines. The enzymes speed up the digestion process. Nutrients are then absorbed into the bloodstream.

ESOPHAGUS

The fibromuscular tube connecting the mouth to the stomach is called the esophagus. Food is pushed down using a wave like muscular motion called peristalsis.

STOMACH

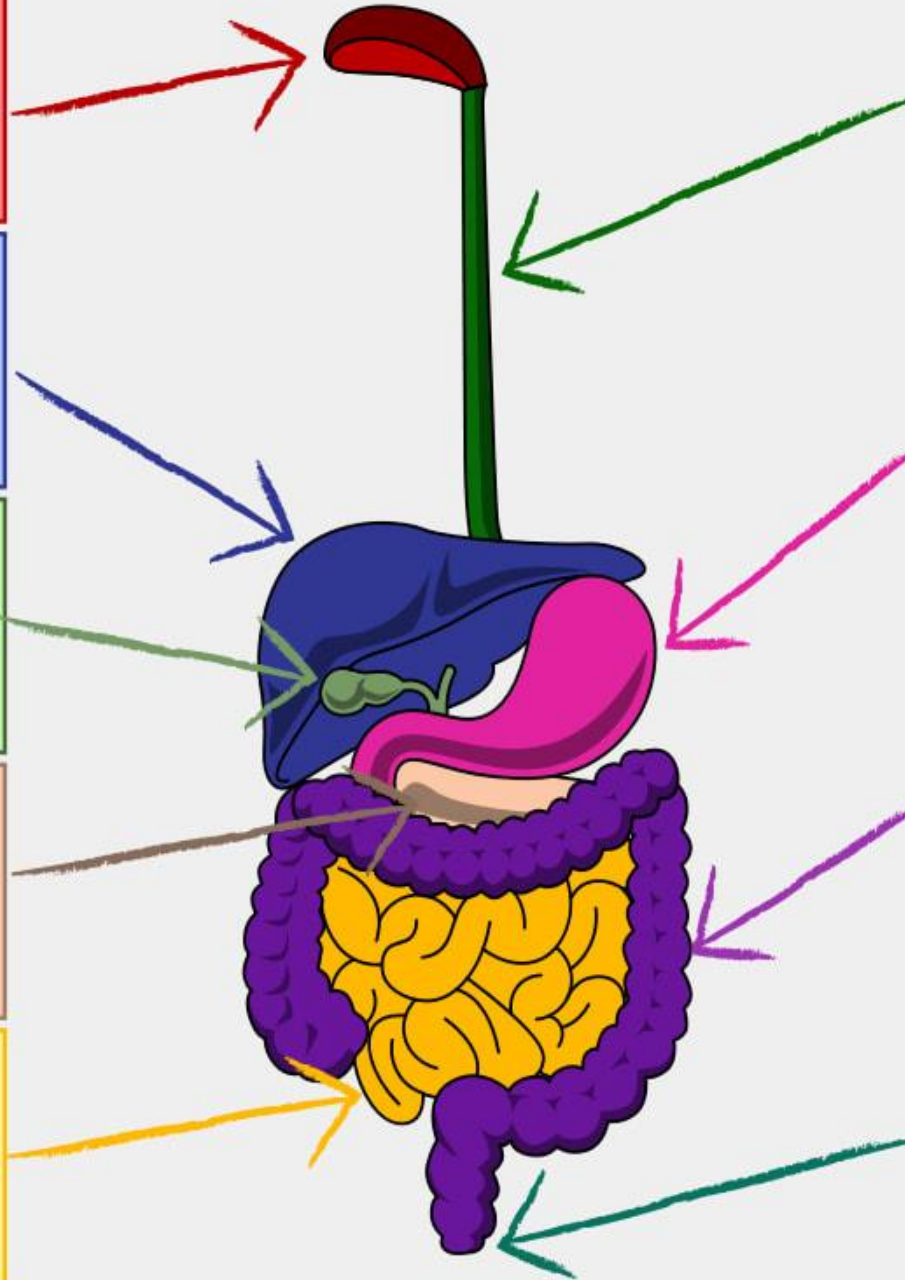
The stomach is the muscular organ where food is mixed with gastric juices. Gastric juice has a low pH, meaning it is acidic, and is used to help digest food and kill potentially harmful bacteria.

LARGE INTESTINES

The large intestines are made up of two parts: the colon and the rectum. In the colon, water is reabsorbed from the food. Feces are stored in the rectum until they are ready to be passed.

ANUS

Feces leave the alimentary canal through the anus.



Thank you