VE Vet eBooks
VET-EBOOKS.COM

FREE · NO SIGN-UP

BASIC SCIENCES · PHYSIOLOGY

— STUDY NOTES

How the Rumen Works

Rumen physiology in cattle, sheep and goats is the story of a giant **fermentation vat** that turns grass — the cellulose no mammal can digest alone — into energy, milk and meat. The **four-compartment stomach** (reticulum, rumen, omasum, abomasum) hands feed to a dense **rumen microbiome** of bacteria, protozoa and fungi that own the enzymes the animal lacks. They ferment carbohydrate into **volatile fatty acids (VFAs)** — **acetate**, **propionate** and **butyrate** — plus CO_2, methane and heat. **Rumination** (chewing the cud) and 100–190 L/day of buffered saliva keep the vat mixed and its pH near 6.0–6.8. Understand this and you understand **ruminant digestion**, why **propionate** makes a dairy cow's glucose, and how the system fails in **subacute ruminal acidosis (SARA)**, **rumen bloat** and milk-fat depression.

INSIDE THESE NOTES

- Why the rumen matters
- Rumination (chewing the cud)
- Fermentation: cellulose → VFAs + gas
- VFA absorption + rumen pH
- Rumen development (calf → ruminant)
- The four-compartment stomach
- The rumen microbiome
- The three VFAs — propionate is king
- Protein from non-protein nitrogen (urea)
- When the rumen fails

LEVEL
Vets & veterinary students

EDITION
2026-07-06

READ ONLINE
vet-ebooks.com/articles/veterinary-rumen-physiology

How the Rumen Works

STUDY NOTES · BASIC SCIENCES · PHYSIOLOGY · UPDATED 2026-07-06

CONTENTS

1. Why the rumen matters
2. The four-compartment stomach
3. Rumination (chewing the cud)
4. The rumen microbiome
5. Fermentation: cellulose → VFAs + gas
6. The three VFAs — propionate is king
7. VFA absorption + rumen pH
8. Protein from non-protein nitrogen (urea)
9. Rumen development (calf → ruminant)
10. When the rumen fails

LEARNING OBJECTIVES

After working through these notes you will be able to:

- ✓ Name the four compartments of the ruminant stomach in order and state the function of each, and which is the true acid stomach.
- ✓ Explain how rumination (chewing the cud) and buffered saliva keep the reticulorumen mixed and its pH stable.
- ✓ Describe the rumen microbiome (bacteria, protozoa, fungi) and why it lets cattle, sheep and goats digest cellulose the host cannot.
- ✓ Walk the fermentation of carbohydrate to VFAs, CO_2, methane, microbial protein and heat, and give rough quantities.
- ✓ List the three major VFAs, their ~70:20:10 fibre-diet ratio and their metabolic fates, and explain why propionate is the key VFA for a dairy cow.
- ✓ Explain how VFAs are absorbed across the rumen papillae and how saliva bicarbonate and absorption hold rumen pH near 6.0–6.8.
- ✓ Explain how microbes make microbial protein from ammonia and non-protein nitrogen (urea), and the risk of ammonia toxicity.
- ✓ Describe rumen development from the milk-fed neonate (oesophageal groove) to the weaned functional ruminant.
- ✓ Relate SARA, bloat, LDA and milk-fat depression to the underlying rumen physiology, with the defining rumen pH for SARA.

TL;DR

Rumen physiology in cattle, sheep and goats is the story of a giant **fermentation vat** that turns grass — the cellulose no mammal can digest alone — into energy, milk and meat. The **four-compartment stomach** (reticulum, rumen, omasum, abomasum) hands feed to a dense **rumen microbiome** of bacteria, protozoa and fungi that own the enzymes the animal lacks. They ferment carbohydrate into **volatile fatty acids (VFAs)** — **acetate**, **propionate** and **butyrate** — plus CO_2, methane and heat. **Rumination** (chewing the cud) and 100–190 L/day of buffered saliva keep the vat mixed and its pH near 6.0–6.8. Understand this and you understand **ruminant digestion**, why **propionate** makes a dairy cow's glucose, and how the system fails in **subacute ruminal acidosis (SARA)**, **rumen bloat** and milk-fat depression.

AT A GLANCE

WHAT THE RUMEN IS	A microbial **fermentation vat** — ~75% of the abdomen in adult cattle — that digests fibre the host cannot
THE FOUR COMPARTMENTS	**Reticulum** → **rumen** → **omasum** → **abomasum**. The first three (forestomach) make no acid; the abomasum is the true stomach
RUMINATION (CUD)	Swallow → mix → regurgitate → re-chew → re-swallow; saliva 100–190 L/day (cow) buffers with bicarbonate
THE MICROBIOME	Anaerobic **bacteria, protozoa and fungi** (~10^{10}–10^{11}/mL) — they carry the cellulase the animal lacks
FERMENTATION OUTPUT	Carbohydrate → **VFAs** + CO_2 + methane (CH_4) + microbial protein + heat; 30–50 L gas/hour
THE THREE VFAS	**Acetate** → fat/milk-fat · **propionate** → glucose (the only glucogenic one) · **butyrate** → ketones + epithelium
VFA ABSORPTION + PH	Absorbed directly across rumen **papillae**; saliva HCO_3^- + absorption hold pH ~6.0–6.8
PROTEIN FROM NPN	Microbes build **microbial protein** from ammonia — from dietary protein and from urea (non-protein nitrogen)
WHEN IT FAILS	**SARA** (grain overload, pH < 5.5) · **bloat** (eructation failure) · **LDA** · milk-fat depression

01 Why the rumen matters

- **Rumen physiology in cattle**, sheep and goats is the physiology of a giant **fermentation vat**: microbes digest **cellulose** (grass fibre) that no mammal can, turning it into energy, milk and meat.
- **The animal supplies** the vat, warmth, anaerobic conditions, mixing and buffering saliva. **The microbes supply** the enzymes. A symbiosis.
- **Products** = volatile fatty acids (VFAs, the energy) + microbial protein + gas (belched) + heat.

02 The four-compartment stomach

- **Reticulum** — honeycomb lining; traps heavy/sharp objects (hardware); works with the rumen as one unit (the **reticulorumen**).
- **Rumen** — the fermentation vat, ~**75% of the abdomen**; most VFA absorption via papillae.
- **Omasum** — many leaves ("plies"); absorbs water + residual VFAs; squeezes digesta.
- **Abomasum** — the **TRUE (acid) stomach**: HCl + pepsin, like a dog/cat; digests the feed AND the microbes.
- **Forestomach = the first three** (no acid, no host enzymes). Order: reticulum → rumen → omasum → abomasum.

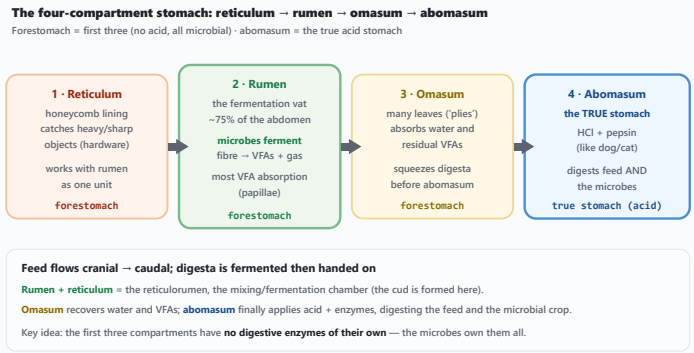

Fig 1 — The four-compartment stomach: reticulum → rumen → omasum → abomasum (the true acid stomach).

03 Rumination (chewing the cud)

- **The cycle:** swallow coarse feed → reticulorumen mixing contractions → regurgitate a bolus (the **cud**) → re-chew (grinds fibre finer, adds saliva) → re-swallow. Repeated ~8 h/day.
- **Saliva** = **100–190 L/day** in a cow; its **bicarbonate (HCO_3^-)** buffers the fermentation acid.
- **Eructation** = belching the fermentation gas (**CO_2 + methane**). Failure to eructate = bloat.

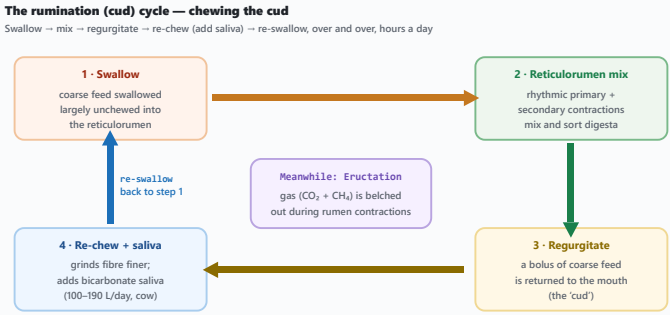

Fig 2 — The rumination (cud) cycle: swallow → mix → regurgitate → re-chew → re-swallow; eructation belches the gas.

04 The rumen microbiome

- **Anaerobic** community: **bacteria** (the bulk), **protozoa** (ciliates), **fungi** — ~**10^{10}–10^{11}/mL**.
- They carry **cellulase** and other fibre-digesting enzymes the cow itself lacks — no mammal makes an enzyme for the β-1,4 bonds of cellulose.
- The cow farms them: feeds fibre in, digests the microbes downstream for protein.

05 Fermentation: cellulose → VFAs + gas

- **Inputs:** feed carbohydrate (cellulose, starch, sugars) + the microbes.
- **Outputs: VFAs** (energy) + **CO_2 + methane** (30–50 L gas/hour, belched) + **microbial protein** + **heat**.
- **Methane** is the H_2 sink of fermentation — an energy loss to the cow and a greenhouse gas.

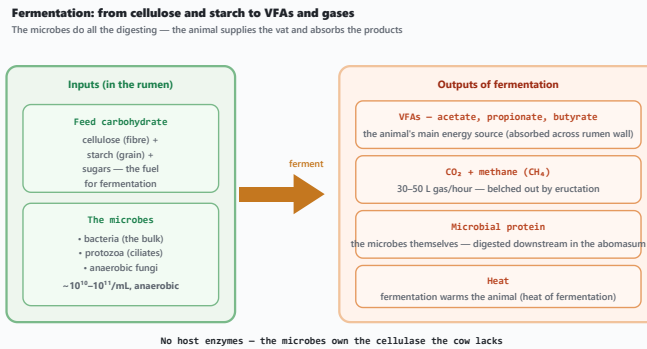

Fig 3 — Fermentation: feed carbohydrate + microbes → VFAs + CO_2 + methane + microbial protein + heat.

06 The three VFAs — propionate is king

- **Ratio on fibre ~ 70 : 20 : 10** (acetate : propionate : butyrate); grain shifts it toward propionate (~60:30:10).
- **Acetate** (~70%) → energy + **body fat** + the main precursor of **milk fat** (low acetate = milk-fat depression).
- **Propionate** (~20%) → the **ONLY glucogenic VFA** → hepatic **gluconeogenesis** → glucose → milk lactose. Supplies **65–80%** of a dairy cow's glucose (a ruminant absorbs almost no dietary glucose).
- **Butyrate** (~10%) → ketone bodies (β-hydroxybutyrate) + fuels the **rumen epithelium** (drives papillary growth).

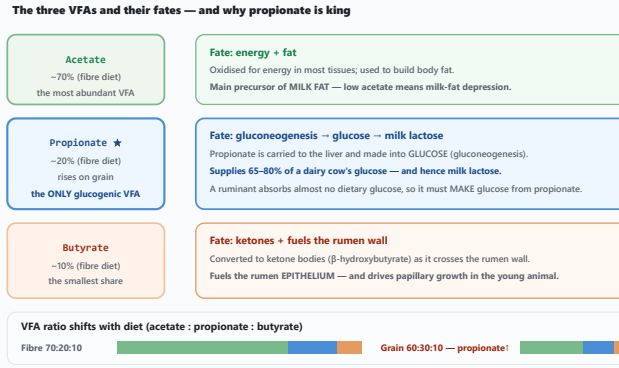

Fig 4 — The 3 VFAs and fates: acetate→milk fat, propionate→glucose (the only glucogenic one), butyrate→ketones + epithelium.

07 VFA absorption + rumen pH

- VFAs are absorbed **directly across the rumen wall** as protonated (undissociated) acid; **papillae** multiply the surface area.
- **pH is held ~6.0–6.8** by saliva bicarbonate + the removal of acid by absorption.
- **pH < 5.5** = SARA territory (grain overload → lactate accumulates).

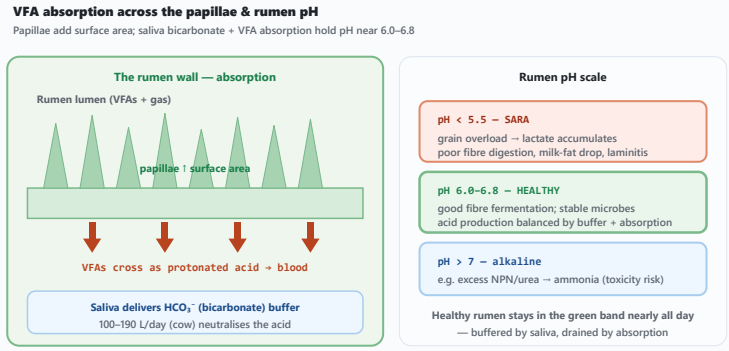

Fig 5 — VFA absorption across the papillae + saliva bicarbonate buffering; healthy rumen pH 6.0–6.8.

08 Protein from non-protein nitrogen (urea)

- Microbes build **microbial protein** from **ammonia** — from dietary protein AND from **non-protein nitrogen (NPN)** such as **urea**.
- This is why cattle can be fed urea: the microbes turn it into protein, then the cow digests the microbes.
- **Nitrogen is recycled** (urea in saliva → rumen). **Vet caution:** too much urea → ammonia absorbed faster than the liver clears it → **ammonia toxicity**.

09 Rumen development (calf → ruminant)

- A calf/lamb is born a **functional monogastric** — the rumen is undeveloped.
- The **oesophageal (reticular) groove** reflex closes on suckling and shunts **milk straight to the abomasum**, bypassing the rumen.
- As the young eat solids, **butyrate** (and propionate) drive **papillary growth**; the rumen matures. **Vet:** ruminal drinkers = milk spilling into an undeveloped rumen → rots & bloats.

10 When the rumen fails

- **SARA (subacute ruminal acidosis):** grain overload → pH < 5.5 for hours → poor fibre digestion, milk-fat drop, laminitis. *Feedlot steer pushed onto grain too fast.*
- **Bloat (ruminal tympany):** eructation fails → frothy (legume) or free gas → distended LEFT flank → the gas compresses the lungs → dyspnoea. *Bullock on lush clover.*
- **LDA (left displaced abomasum):** gas + atony after calving → abomasum slips under the left ribs → metallic "PING" on percussion; off-feed fresh cow.
- **Milk-fat depression:** low effective fibre / high grain shifts VFAs away from acetate → milk fat falls (often < 3%).

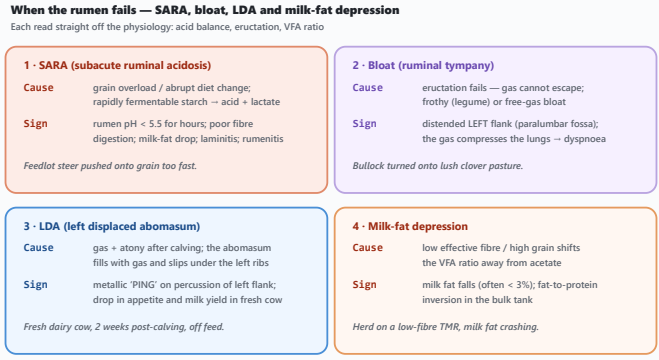

Fig 6 — When the rumen fails: SARA, bloat, LDA and milk-fat depression — each reads straight off the physiology.

RED FLAG

Acute, severe left-flank distension with open-mouth breathing in a cow on lush pasture or grain — life-threatening bloat. Pass a stomach tube (free gas) or trocarise; anti-foaming agent for frothy bloat; treat as an emergency.

> *The rumen is the one organ with no enzymes of its own — a cow is really a walking fermentation vat, farming microbes to eat the grass she cannot.*
>
> — after Cunningham 6e Ch31 & PDA 3e Ch15.

KEY TERMS — QUICK GLOSSARY

Reticulum	The most cranial forestomach compartment; honeycomb lining; traps heavy/sharp objects (hardware) and works with the rumen as one functional unit.

Rumen	The huge fermentation vat — ~75% of the abdomen in adult cattle; houses the microbes; site of fermentation and most VFA absorption.
Omasum	The many-leaved ('book'/'many-plies') compartment; absorbs water and residual VFAs and squeezes digesta before the abomasum.
Abomasum	The 'true' stomach; secretes hydrochloric acid and pepsin; digests feed and the microbes flowing out of the forestomach.
Forestomach	Collective name for the reticulum, rumen and omasum — no acid or host enzymes; all microbial fermentation.
Reticulorumen	The reticulum and rumen treated as one mixing chamber; where the cud is formed and fermentation happens.
Rumination (cud)	Regurgitation, re-chewing and re-swallowing of coarse feed; grinds fibre finer and adds buffering saliva; hours per day.
Eructation	Belching of fermentation gas (mostly CO_2 and methane); failure of eructation causes bloat.
Rumen microbiome	The anaerobic community of bacteria, protozoa and fungi (~10^{10}–10^{11}/mL) that ferments feed.
Volatile fatty acid (VFA)	Short-chain fatty acid (acetate, propionate, butyrate) made by fermentation; the ruminant's main energy source.
Acetate	The most abundant VFA on fibre diets; used for energy and is the main precursor of milk fat.
Propionate	The only glucogenic VFA; feeds hepatic gluconeogenesis to make glucose (and milk lactose); rises on grain diets.
Butyrate	Converted to ketones (β-hydroxybutyrate) and fuels the rumen epithelium; drives papillary development in the young.
Gluconeogenesis	Hepatic synthesis of glucose from propionate (and other precursors); the ruminant's main route to glucose.
Microbial protein	High-quality protein in the microbial cells, built from ammonia; digested in the abomasum and small intestine.
Non-protein nitrogen (NPN)	Nitrogen sources such as urea that microbes convert to ammonia and then to microbial protein.
Oesophageal groove	Reflex fold (reticular groove) that shunts suckled milk past the forestomach straight to the abomasum in the neonate.
Papillae	Finger-like projections of the rumen wall that greatly increase surface area for VFA absorption.

SARA	Subacute ruminal acidosis — grain overload drives rumen pH below ~5.5 with lactate accumulation.
Bloat (ruminal tympany)	Distension of the reticulorumen by gas that cannot be eructated; frothy (legume) or free-gas.
LDA	Left displaced abomasum — gas-filled abomasum trapped under the left rib cage, classically in the fresh dairy cow.

QUICK REVISION — REMEMBER THESE

1. **Rumen physiology in cattle**, sheep and goats explains the single biggest trick in veterinary nutrition: how a herbivore lives on grass. Mammals make no enzyme that can break the β-1,4 bonds of **cellulose**. The ruminant solves this by outsourcing digestion to a vast microbial culture housed in a fermentation vat — the reticulorumen — and then digesting the microbes. This is **ruminant digestion**: fibre in, volatile fatty acids, microbial protein, milk and meat out.
2. The ruminant has a **four-compartment stomach**: **reticulum, rumen, omasum and abomasum**. The first three form the *forestomach* and make no acid or enzymes of their own; only the **abomasum** is the 'true' stomach, secreting hydrochloric acid and pepsin like a dog's or a cat's. The rumen alone fills roughly 75% of the abdominal cavity in an adult cow.
3. Feed is handled by **rumination** — chewing the cud. The animal swallows coarse feed, the reticulorumen mixes it with rhythmic contractions, a bolus is regurgitated, re-chewed to grind the fibre finer and soak it in saliva, then re-swallowed. A dairy cow secretes **100–190 litres of saliva a day**, rich in bicarbonate and phosphate, which buffers the acids the microbes make. Fermentation gas is expelled by **eructation** (belching).
4. The **rumen microbiome** is the workforce. Densities reach **~10^{10}–10^{11} organisms per millilitre** of rumen fluid: anaerobic **bacteria** (the bulk of the fermentation), **protozoa** (ciliates that graze bacteria and store starch) and anaerobic **fungi** (which attack tough plant fibre). Between them they carry the **cellulase** and other enzymes the host genome does not encode. The relationship is a true symbiosis.
5. Fermentation converts plant carbohydrate into **volatile fatty acids (VFAs)** plus gases and microbial cells. For every mouthful of fermentable carbohydrate the microbes release **VFAs** (the animal's main energy currency), **carbon dioxide** and **methane (CH_4)**, **heat**, and new microbial biomass. A cow produces **30–50 litres of fermentation gas an hour**, most of it belched away.
6. The three major VFAs are **acetate, propionate and butyrate**, produced on a fibre diet in a ratio of roughly **70 : 20 : 10**. **Acetate** is used for energy and is the main precursor of **milk fat**. **Propionate** is the *only glucogenic VFA*: it feeds **gluconeogenesis** in the liver to make glucose, which supplies 65–80% of a dairy cow's glucose and thus milk lactose. **Butyrate** is converted to ketones and fuels the rumen epithelium itself.

7. VFAs are **absorbed directly across the rumen wall**, not passed downstream first. The wall is carpeted with finger-like **papillae** that hugely increase surface area; VFAs cross mostly in their protonated (uncharged) acid form. Together with the bicarbonate delivered in saliva, this absorption keeps the healthy **rumen pH near 6.0–6.8**. When acid production outruns buffering and absorption, pH falls and disease follows.

8. Ruminants make high-quality protein from cheap nitrogen. Microbes build **microbial protein** from ammonia, and that ammonia can come from dietary protein *or* from **non-protein nitrogen (NPN)** such as **urea**. The cow then digests the microbes downstream in the abomasum. This is why urea can be fed to cattle — but overfeeding NPN releases ammonia faster than the microbes can use it, and ammonia toxicity can kill.

9. The rumen is **made, not inherited**. A newborn calf, lamb or kid is a functional *monogastric*: milk must bypass the undeveloped rumen. The **oesophageal (reticular) groove** closes reflexly during suckling and channels milk straight to the abomasum. As the young animal starts eating solids, **butyrate** drives growth of the rumen papillae and the microbial population establishes, so that by weaning the animal is a fully functional ruminant.

10. When the system fails, the failures are classic and examinable. **Subacute ruminal acidosis (SARA)** follows grain overload (rumen pH < 5.5, lactate accumulation). **Rumen bloat** is failure of eructation — frothy (legume) or free-gas — distending the left flank and compressing the lungs. **Left displaced abomasum (LDA)** follows gas and atony in the fresh cow. **Milk-fat depression** follows a low-fibre ration that shifts the VFA ratio away from acetate. Every one of these is read straight off the physiology above.

MEMORY AIDS

Cows Really Ought (to) Absorb — the four compartments in order — **C** **R**eticulum → **R**umen → **O**masum → **A**bomasum (the true acid stomach). Cranial-to-caudal, the flow is **R**–**R**–**O**–**A**.

APB fates — the three VFAs — **A**cetate → fat (and milk fat) · **P**ropionate → glucose (the ONLY glucogenic one) · **B**utyrate → ketones + rumen epithelium.

SARA = Sugar/grain Acid Rumen Attack — Too much rapidly fermentable sugar/grain → acid outruns the saliva buffer → rumen pH < 5.5. Read bloat, LDA and milk-fat depression off the same physiology.

TEST YOURSELF — ACTIVE RECALL

Cover the answers and try to retrieve each one from memory first — self-testing beats re-reading.

1. **Name the four compartments of the ruminant stomach in order, and state which is the true acid stomach.**
2. **How do rumen microbes let cattle digest cellulose that the cow itself cannot?**
3. **What are the three major VFAs and their approximate ratio on a fibre diet?**
4. **Why is propionate the most important VFA for a dairy cow?**
5. **What is the oesophageal groove and why does it matter in calves?**
6. **What causes SARA and what rumen pH defines it?**
7. **How can cattle make protein from urea?**

8. **Why does grain overload lower rumen pH, and give one clinical consequence.**

ANSWERS

1. In order of digesta flow: **reticulum** → **rumen** → **omasum** → **abomasum**. The first three are the *forestomach* and make no acid or host enzymes — all their digestion is microbial. The **abomasum** is the true stomach: it secretes hydrochloric acid and pepsin, exactly like the single stomach of a dog or cat, and it digests both the feed and the microbes flowing out of the forestomach.
2. No mammal makes an enzyme that breaks the β-1,4 bonds of **cellulose**. The rumen houses an anaerobic microbial community (bacteria, protozoa, fungi at ~10^{10}–10^{11}/mL) that *does* carry **cellulase** and related fibre-digesting enzymes. The microbes ferment the fibre into VFAs the cow can absorb, and the cow then digests the microbes themselves for protein. The cow supplies the vat, the anaerobic conditions, the buffering saliva and the mixing; the microbes supply the enzymes. It is a symbiosis.
3. The three major volatile fatty acids are **acetate**, **propionate** and **butyrate**. On a fibre (forage) diet they are produced in a ratio of roughly **70 : 20 : 10** — acetate dominant. On a high-grain ration the pattern shifts toward **propionate** (and total acid rises, so rumen pH falls). Acetate is the main precursor of milk fat, so the grain-driven shift away from acetate is why low-fibre rations cause milk-fat depression.
4. Because **propionate is the only glucogenic VFA**. Acetate and butyrate cannot be made into glucose, but propionate feeds hepatic **gluconeogenesis** to produce glucose. A ruminant absorbs almost no glucose from the gut (the microbes ferment dietary sugars before they can be absorbed), so it must *make* its glucose — and propionate supplies 65–80% of a dairy cow's glucose, which in turn becomes the lactose of milk. A high-yielding cow's milk output is therefore propionate-limited, not grass-sugar-limited.
5. The **oesophageal (reticular) groove** is a muscular fold that, during suckling, closes to form a channel carrying milk directly from the oesophagus to the abomasum, *bypassing* the undeveloped rumen. This matters because a newborn calf, lamb or kid is a functional *monogastric*: its rumen is empty of microbes and cannot ferment milk, and milk left in the rumen would ferment abnormally. Groove-closure failure causes 'ruminal drinkers' — milk spilling into the rumen — with poor growth and ruminal acidosis.
6. **Subacute ruminal acidosis (SARA)** is caused by feeding too much rapidly fermentable carbohydrate (grain/concentrate) relative to effective fibre — grain overload, or an abrupt dietary change. The microbes ferment the starch fast, VFAs (and, in acute cases, lactic acid) accumulate faster than saliva bicarbonate and absorption can buffer them, and rumen pH falls. SARA is defined by a rumen pH depressed below about **5.5** for several hours a day. Consequences include reduced fibre digestion, milk-fat depression, laminitis and rumenitis.
7. Rumen microbes build their own **microbial protein** from **ammonia**. That ammonia can be released from dietary protein *or* from **non-protein nitrogen (NPN)** such as **urea**, which microbial urease splits to ammonia. The microbes combine the ammonia with a carbon skeleton (from fermenting carbohydrate) to make amino acids and protein; the cow then digests the microbes in the abomasum. This is why urea is a cheap protein supplement — but if urea is fed faster than the microbes can capture the ammonia, blood ammonia rises and the animal can die of ammonia (urea) toxicity.
8. Grain is rapidly fermentable starch. The microbes ferment it quickly to VFAs, and in overload conditions certain bacteria produce **lactic acid**, a stronger acid than the VFAs. Acid is generated faster than the animal's buffers (saliva bicarbonate) and VFA absorption can neutralise it, so **rumen pH falls** (below ~5.5 in SARA, lower still in acute lactic acidosis). One clinical consequence: **milk-fat depression** (from the altered VFA pattern), or laminitis, rumenitis and, in severe acute cases, systemic acidosis and death.

WHEN TO REFER OR ESCALATE

- A cow or steer with acute grain overload (raided the feed store) — rumen pH crashing, staggering, profuse diarrhoea; a lactic-acidosis emergency needing urgent rumen decompression, fluids and alkalinising therapy — refer or treat aggressively.
- A bloated animal with a rapidly distending left flank and dyspnoea — frothy or free-gas bloat is an emergency; pass a stomach tube and, if severe and life-threatening, be prepared for emergency trocarisation of the left paralumbar fossa.
- A fresh dairy cow (within ~1 month of calving) off feed with a drop in yield and a metallic **ping** on left-flank percussion — suspect **left displaced abomasum (LDA)**; refer for surgical or toggle correction.
- A herd with falling bulk-tank milk fat (often < 3%) — investigate the ration for inadequate effective fibre / excess grain driving milk-fat depression and possible subclinical SARA; a whole-group nutrition review, not an individual-cow problem.
- Any animal after urea/NPN feeding showing muscle tremors, bloat, salivation and convulsions — suspect **ammonia (urea) toxicity**; a rapidly fatal poisoning — treat as an emergency (cold water and vinegar into the rumen buys time) and review how the urea was fed.

SOURCES

1. Klein BG (ed). *Cunningham's Textbook of Veterinary Physiology*. 6th ed. St Louis: Elsevier; 2020. **Ch 31 'Digestion: The Fermentative Process' (pp 339–360)** — primary source for the four-compartment anatomy, rumination and eructation, the rumen microbiome, VFA production/absorption, microbial protein synthesis and rumen development.
2. Sjaastad ØV, Sand O, Hove K. *Physiology of Domestic Animals*. 3rd ed. Oslo: Scandinavian Veterinary Press; 2016. **Ch 15 'The Digestive System'** (ruminant/forestomach sections) — secondary source for the species comparison, saliva buffering and fermentation.
3. Constable PD, Hinchcliff KW, Done SH, Grünberg W. *Veterinary Medicine (Radostits)*. 11th ed. Elsevier; 2017. Chapters on ruminal acidosis (SARA), bloat, left displaced abomasum and urea toxicity — clinical anchor for thresholds and management.
4. Merck Veterinary Manual (online). Sections on the digestive system of ruminants, ruminal acidosis, ruminal tympany (bloat), displaced abomasum and non-protein nitrogen (urea) poisoning — clinical reference for signs and treatment.

Vet eBooks
VET-EBOOKS.COM

MORE FREE STUDY NOTES & RESOURCES

More free vet study notes

This is one of a growing library of free veterinary study notes on vet-ebooks.com — built for practising vets and students, sourced from leading veterinary texts, every set free with a downloadable PDF.

3,400+
VETERINARY BOOKS

400+
DRUG PROFILES (PAPICH)

Study notes
+ FREE PDF EACH

All free
NO SIGNUP NEEDED

RELATED ON VET-EBOOKS.COM

Cellular Homeostasis
Where the energy carried by the VFAs is finally spent — at the level of the cell.

Oedema & the Starling Forces
The 'bottle jaw' of the parasitised ruminant — hypoproteinaemia and fluid shift.

The Cardiac Cycle
The pump that delivers absorbed VFAs and nutrients to every tissue in the body.

www.vet-ebooks.com