Digestive System of Animals

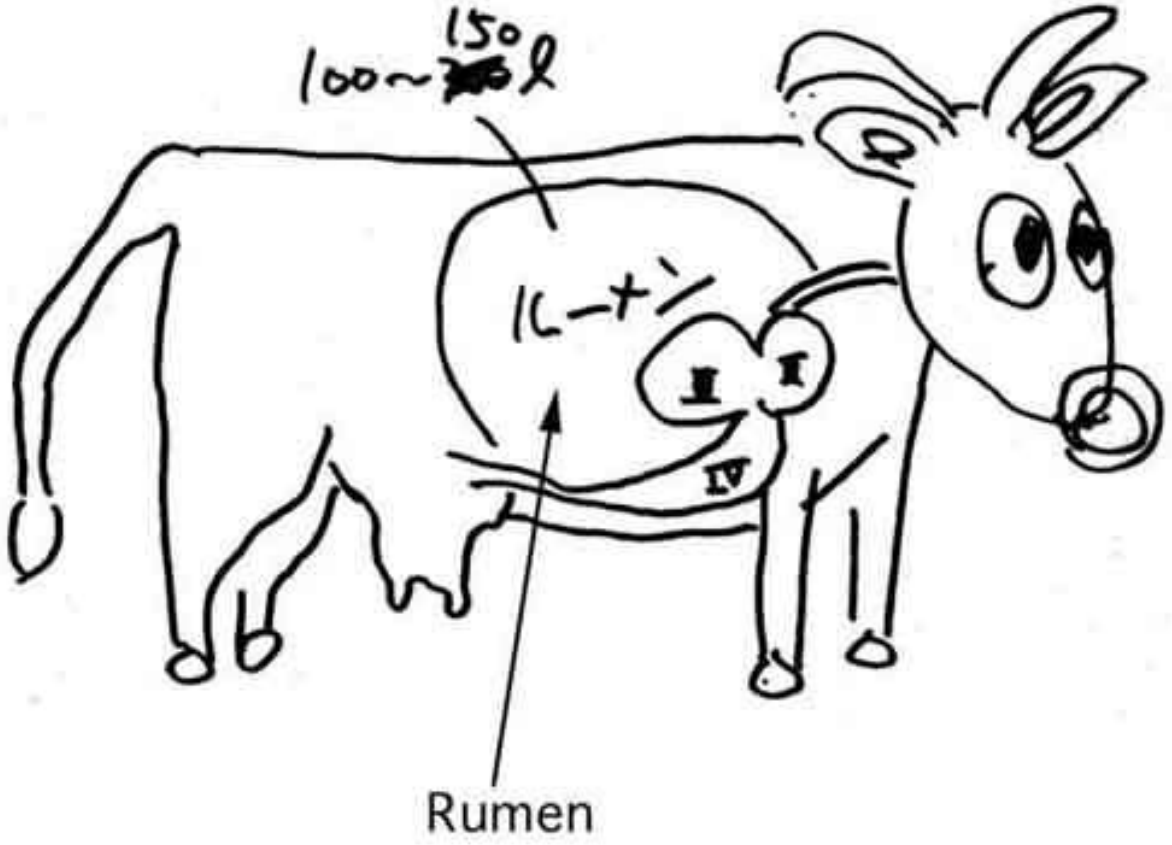
- Video (nutrients and digestive system)
- Digestive system of humans (Dummy and handout)
- Complete pages114-116
- Homework – different diets p 106-108

Different diets

- Omnivores
- Carnivores
- Herbivores
- Foregut fermenters and Hind gut fermenters (cont…)

Ruminants are big fermentation vats

- Rumen is an anaerobic environment
- Colonized by a great diversity of organisms
  - Cellulytic organisms are only ~ 10%!
- Animal provides cellulose, microorganisms provide VFAs and protein

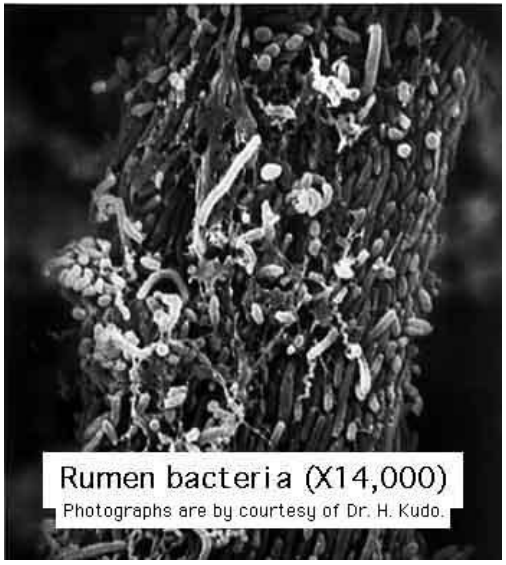


Bacteria isolated from rumen.

genus	strain
Acetitomaculum	Acetomaculum ruminis
Amycolatopsis	Amycolatopsis rugosa
Anaeroplasma	Anaeroplasma abactoclasticum
	Anaeroplasma bactoclasticum
Anaerovibrio	Anaerovibrio lipolytica
Bacillus	Bacillus cereus
Bifidobacterium	Bifidobacterium boum
	Bifidobacterium merycicum
	Bifidobacterium pseudolongum (Bifidobacterium globosum)
	Bifidobacterium ruminantium
	Bifidobacterium sp.(ATCC27918)
	Bifidobacterium thermophilum
Borrelia	Borrelia sp.(?)
Butyrivibrio	Butyrivibrio fibrisolvens
	Butyrivibrio sp.(ATCC29550)
Cellulomonas	Cellulomonas flavigena
Clostridium	Clostridium aerotolerans
	Clostridium aminophilum
	Clostridium cellobioparum
	Clostridium clostridiiforme
	Clostridium longisporum
	Clostridium polysaccharolyticum
	Clostridium proteoclasticum
	Clostridium sticklandii
Coprococcus	Coprococcus sp.(ATCC29549)
Desulfotomaculum	Desulfotomaculum ruminis
Desulfovibrio	Desulfovibrio sp.(ATCC27882)
	Desulfovibrio desulfuricans
Eubacterium	Eubacterium cellulosolvens
	Eubacterium limosum (Bacteroides limosus)
	Eubacterium ruminantium
	Eubacterium uniforme
	Eubacterium xylanophilum
Fibrobacter	Fibrobacter succinogenes (Bacteroides succinogenes)
Lachnospira (Lachnopira?)	Lachnospira multipara (Lachnopira multiparus?)
Lactobacillus	Lactobacillus ruminis
	Lactobacillus vitulinus
Lampropedia	Lampropedia hyalina
Megasphaera	Megasphaera elsdenii
Mycoplasma	Mycoplasma agalactiae
	Mycoplasma alkalescens
	Mycoplasma alvi
	Mycoplasma bovirhinis
	Mycoplasma bovis
	Mycoplasma bovoculi
	Mycoplasma canadense
	Mycoplasma conjunctivae
	Mycoplasma ovipneumoniae
Micromonospora	Micromonospora ruminantium
Oxalobacter	Oxalobacter formigenes
Peptostreptococcus	Peptostreptococcus asaccharolyticus (Peptococcus asaccharolyticus)
	Peptostreptococcus heliotrinreducens (Peptococcus heliotrinreducens)
Prevotella	Prevotella ruminicola (Bacteroides ruminicola)
	Prevotella bryantii
	Prevotella brevis
	Prevotella albensis
Porphyromonas	Porphyromonas levii (Bacteroides melaninogenicus, Bacteroides levii)
Propionibacterium	Propionibacterium acnes
Pseudobutyrivibrio	Pseudobutyrivibrio ruminis
Ruminobacter	Ruminobacter amylophilus (Bacteroides amylophilus)
Ruminococcus	Ruminococcus albus
	Ruminococcus flavefaciens
Schwartzia	Schwartzia succinivorans
Selenomonas	Selenomonas ruminantium
Streptococcus	Streptococcus bovis
Succiniclasticum	Succiniclasticum ruminis
Succinimonas	Succinimonas amylolytica
Succinivibrio	Succinivibrio dextrinosolvens
Synergistes	Synergistes jonesii
Treponema	Treponema bryantii
	Treponema saccharophilum
Veillonella	Veillonella alcalescens
Wolinella	Wolinella succinogenes
	Wolinella sp.(ATCC33567)

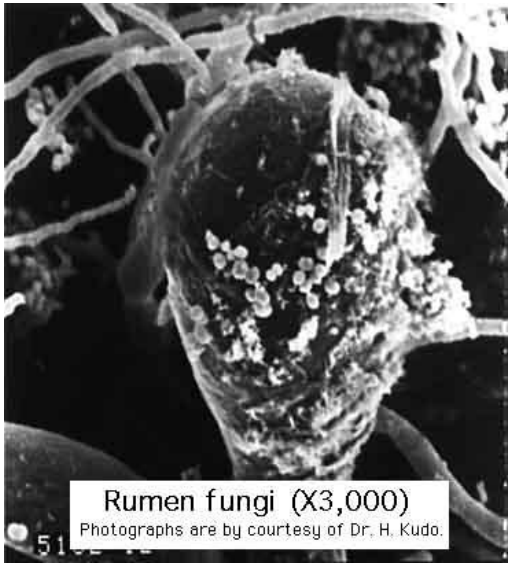
Rumen is a large and diverse community of bacteria, archaea, fungi, and protists –

A cow is an ecosystem!



Rumen bacteria (X14,000)

Photographs are by courtesy of Dr. H. Kudo.



Rumen fungi (X3,000)

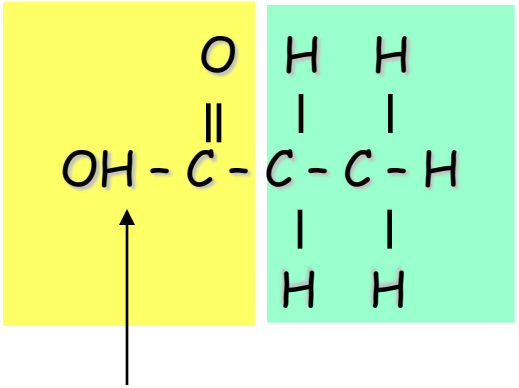
Photographs are by courtesy of Dr. H. Kudo.

Stoichiometry of rumen fermentation

$$\text{Cellulose } (CH_2O)_n + \text{micro-organisms} + NH_3 =$$

$$\text{more micro-organisms} + \text{VFAs} + CO_2 + CH_4$$

Volatile fatty acids =
Short fatty acids with 1 - 4 carbons

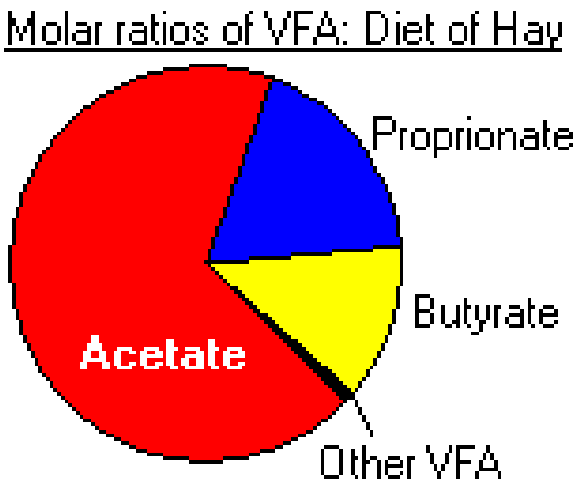


e.g.
Acetate (2C)

Propionate (3C)

Butyrate (4C)

This H+ dissociates, making solution acidic



Proprionate is the only fatty acid that can be used to synthesize glucose!

Stoichiometry of rumen fermentation

$Cellulose\ (CH_2O)_n$ + micro-organisms + NH_3 =

more micro-organisms + VFAs + CO_2 + CH_4

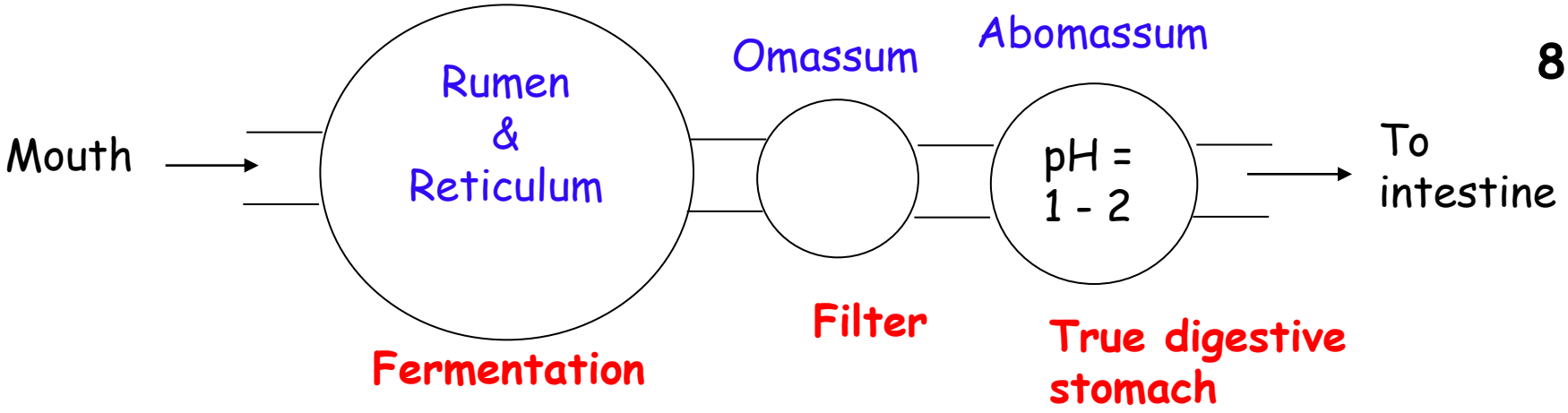
Q: where does the NH3 come from?

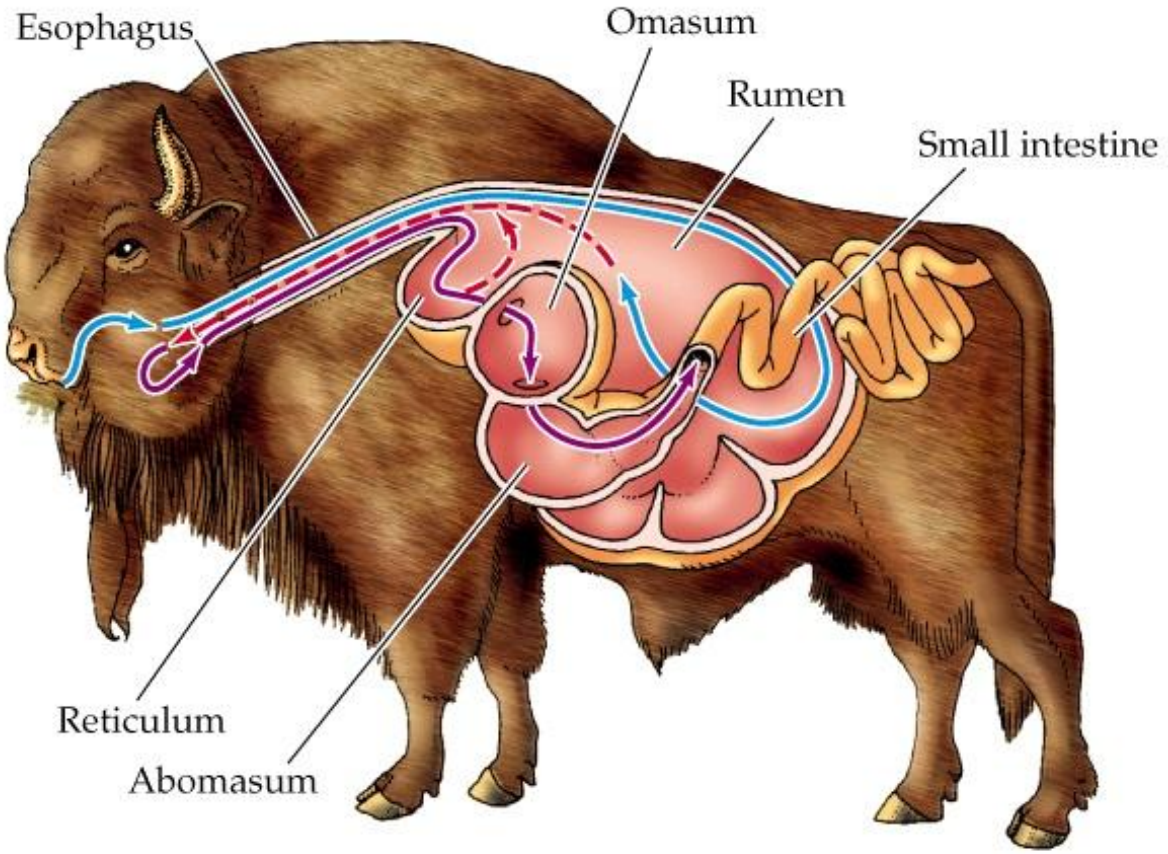
1 cow produces ~100,000 liters of methane annually

Total methane production per year by cattle = ~ 94 million tons

A: SALIVA!

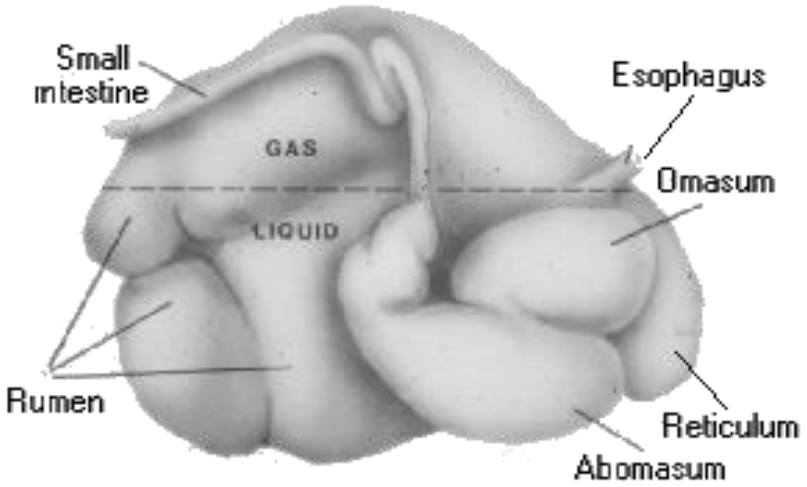
- Ruminants produce and swallow ENORMOUS quantities of saliva!
  - Provides fluid environment for microorganisms
  - Urea is actively secreted into saliva "urea recycling"
    - This is the source of N for microorganism protein synthesis and growth!
  - Bicarbonate is also actively secreted into saliva
    - Volatile fatty acid production makes rumen acidic
    - Salivary bicarbonate buffers the acid back to normality
- Estimated at ~ 100-150 liters/day!





Four chambered foreguts

- Reticulum and Rumen
  - Fermentation,
  - pH 5.5 - 7.5
  - Houses the microorganisms
  - Volatile fatty acids absorbed through rumen walls



Omasum

Acts like a filter: accepts only smallest particles

Abomassum

True stomach
pH 1-2
Pepsin secreting

4) True Stomach is used to digest excess microorganisms

This is how ruminants get their protein!

Not easy to do: requires Lysozyme

Most mammals secrete in saliva

4 aa substitutions allow enzyme to be acid - tolerant in cows

Same 4 substitutions in the langur

Independent evolution!

Rumination or foregut fermentation: A highly efficient way to use cellulose

1) Fermentation vat (rumen) comes before the "stomach"

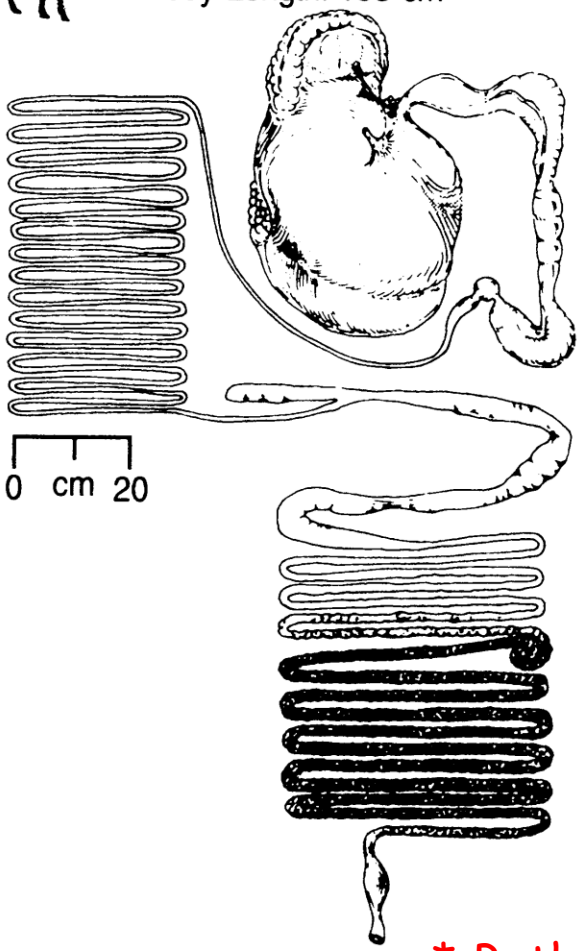
2) Food is entirely processed by microorganisms

3) VFA's are absorbed straight through rumen walls
This is how ruminants get their energy!

4) True stomach is used to digest excess microorganisms
This is how ruminants get their protein!

Foregut fermenters:

Llama
(Lama glama)
Body Length: 193 cm



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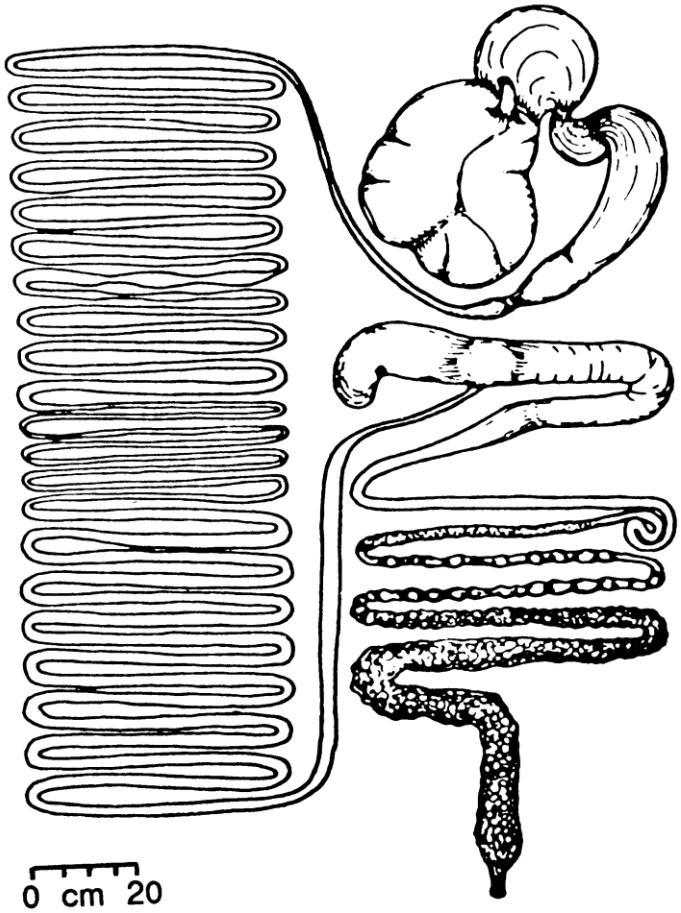
Sheep (Ovis aries)
Body length: 110 cm



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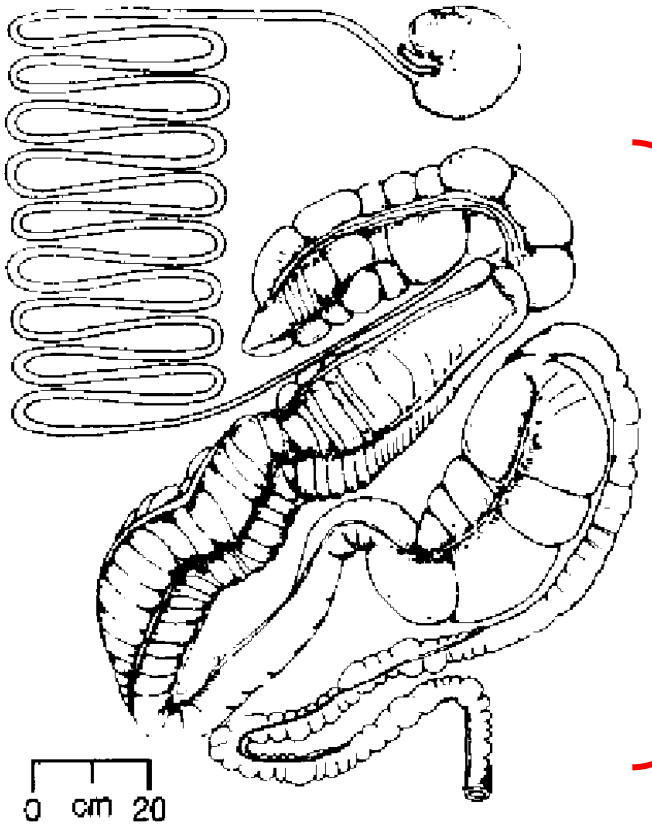
* Both have enlarged, multi-chambered foreguts

Hindgut fermenters

Pony
(Equus caballus)
Body Length: 164 cm



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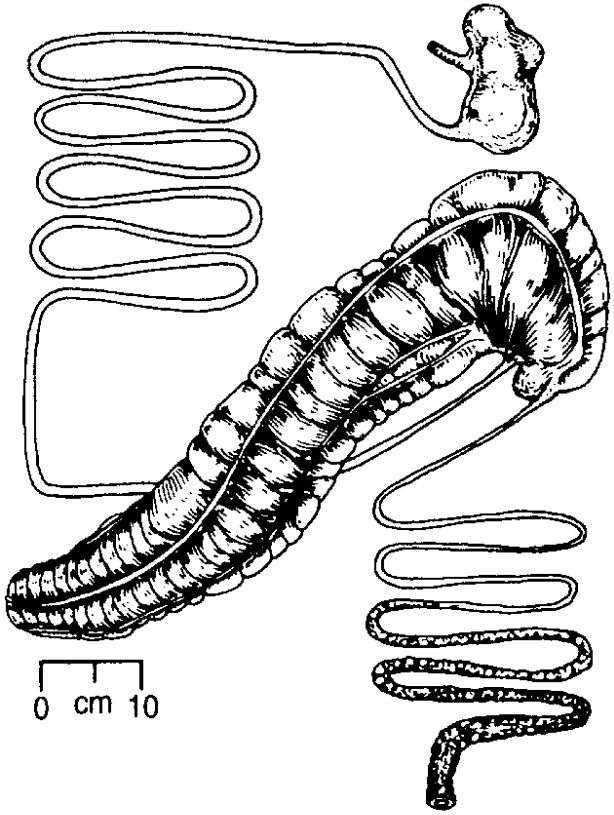
Capybara
(Hydrochoerus hydrochaeris)
Body Length: 140 cm

(a big S. American rodent)



cecum

* Enlarged hindgut

Hindgut fermentation:
A way to use cellulose without losing the rest of your dietary nutrients

1) Fermentation chamber(s) comes after the "stomach" and the small intestine

Enlarged hindgut or pouches called "cecae"

2) Microorganisms get what the animal doesn't use

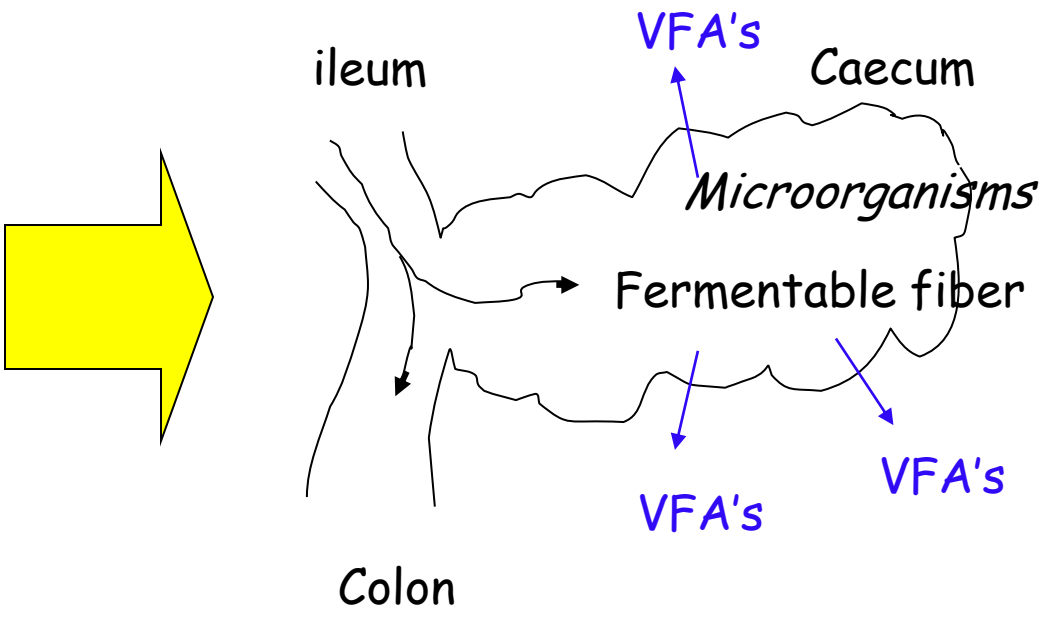
Better if your diet is of higher quality

3) VFA's are absorbed straight through hindgut walls

4) Excess microorganisms are defecated

Hindgut fermenters miss out on microbial protein!

Coprophagy in rabbits



- Produces two kinds of feces
  - One has lots of undigested fiber
  - The other is a clearance of caecal contents (soft, high in microbial content)
    - Rabbits eat this to gain microbial nutrition!

Comparing fermentation strategies

Characteristics	Foregut (Ruminants)	Hindgut
Where are the microbes?	Before stomach	After stomach
Are microbes digested?	YES	NO
Source of energy	VFA's	Food, VFA's
Source of protein	Microbes	Diet
Dietary flexibility?	LOW	HIGHER
Throughput rate?	SLOW (40-50 hrs retention time)	FASTER, (3 - 5 X)
Efficiency of cellulose assimilation?	HIGH (70-100%)	LOWER (20-65%)

Who are they?

Foregut fermenters:

Bovids
Camelids
Sloths
Colobus monkeys
Kangaroos
Hoatzins!

Hindgut fermenters:

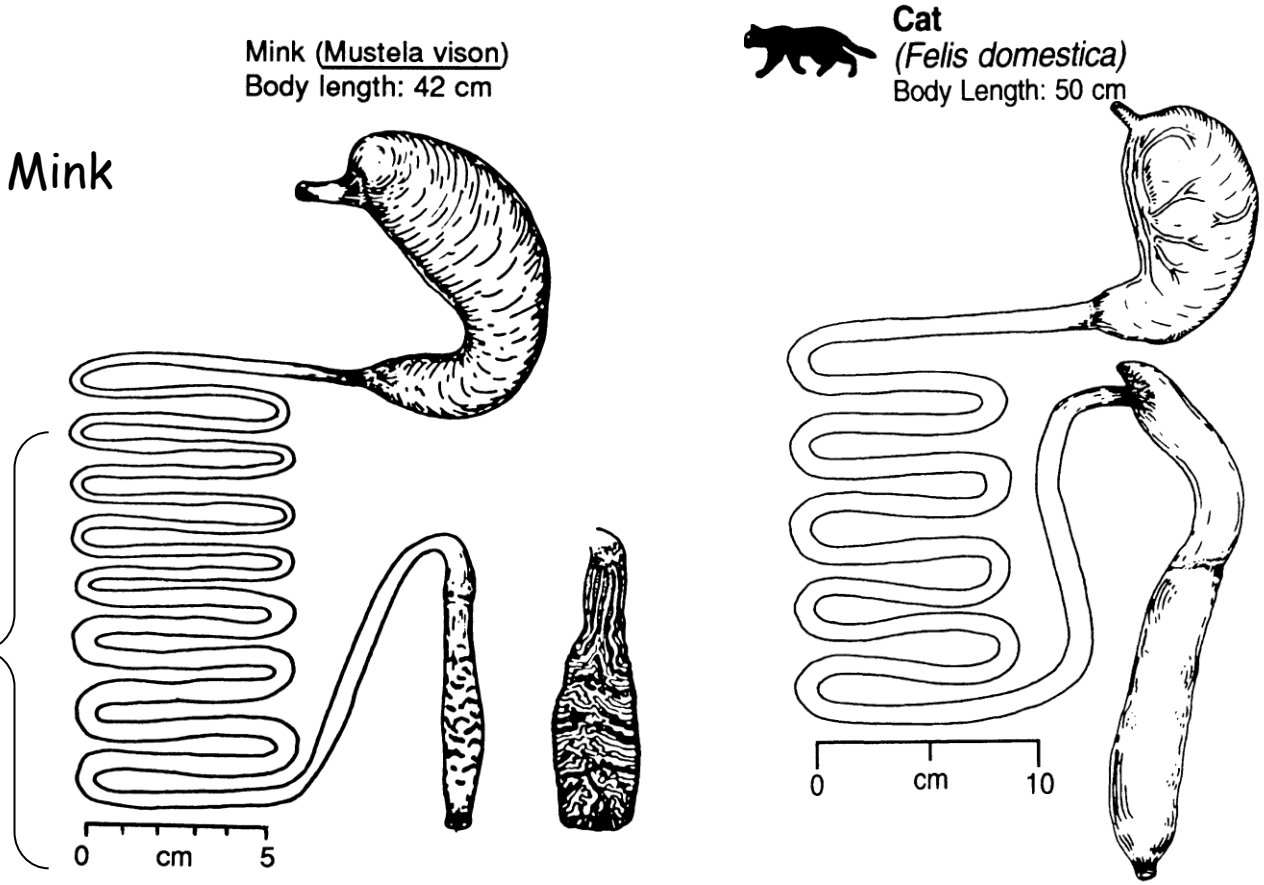
Elephants
Horses
Rabbits
Rodents
Grouse
Iguanas
Some turtles

And to some extent, many omnivores!

Carnivores in contrast

1) Simple, single chambered, muscular stomach
2) Straight, simple hindgut
3) Primary nutrient is protein

Difference between
Midgut and hindgut
Is not obvious!



- Handout on ringtail possum