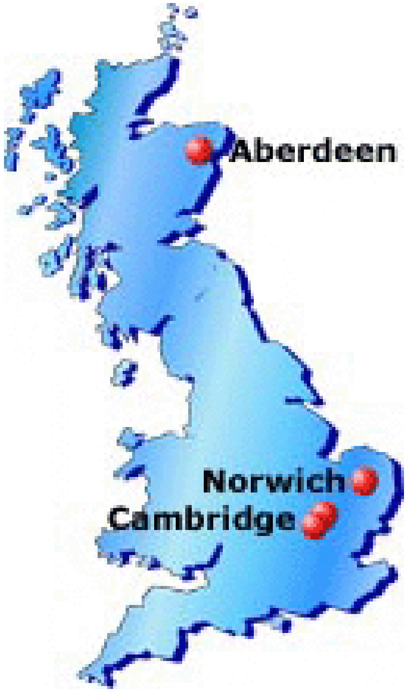
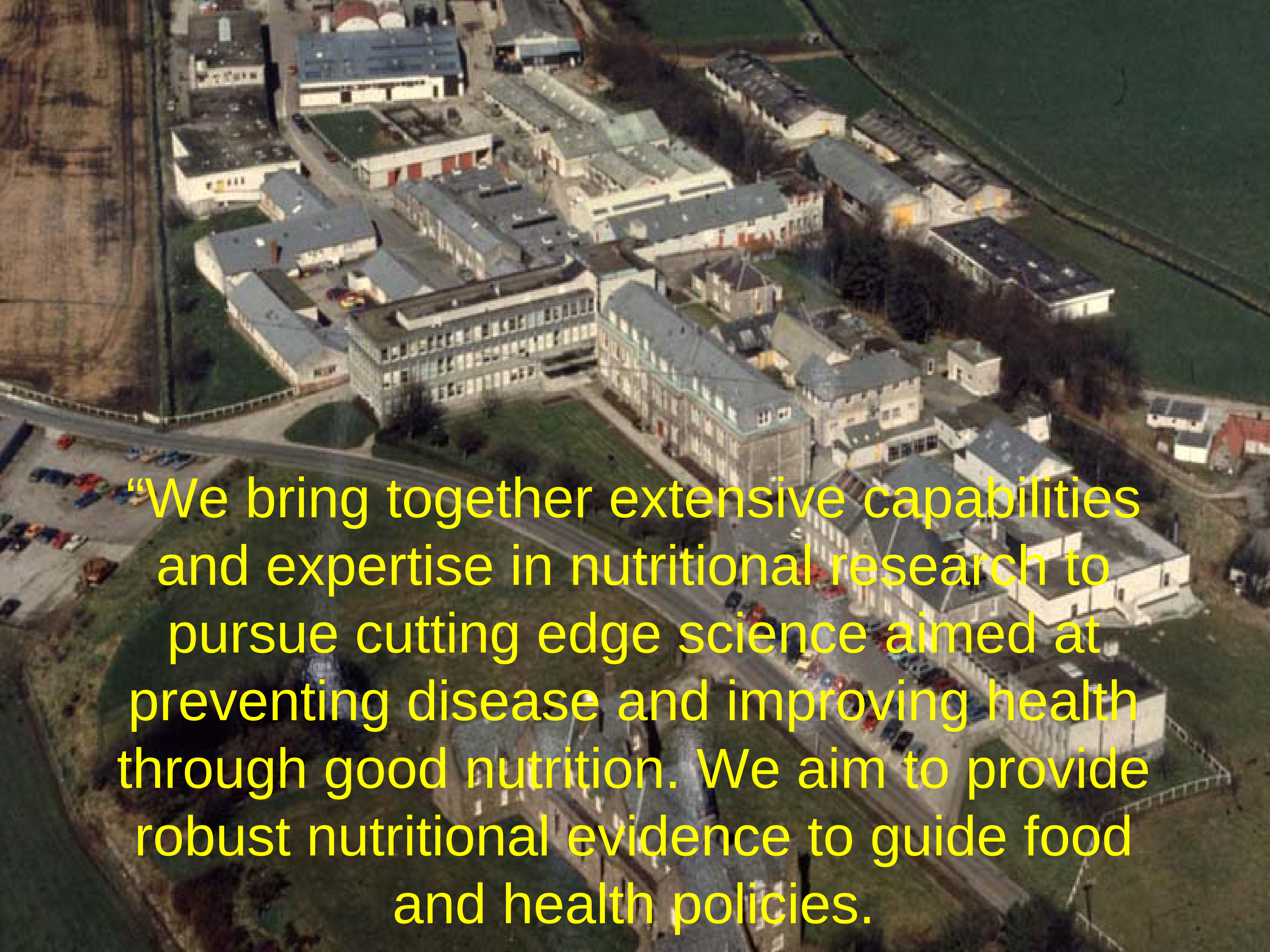
Microbial ecology of the rumen: impact on nutrition and the environment

John Wallace



Rowett Institute
of Nutrition and Health
University of Aberdeen


“We bring together extensive capabilities and expertise in nutritional research to pursue cutting edge science aimed at preventing disease and improving health through good nutrition. We aim to provide robust nutritional evidence to guide food and health policies.

Microbial ecology of the rumen: impact on nutrition and the environment

- Introduction to the rumen and its microorganisms
- Impact of the rumen on nutrition
- Ruminants and the environment
- Ruminant products and human health

The rumen

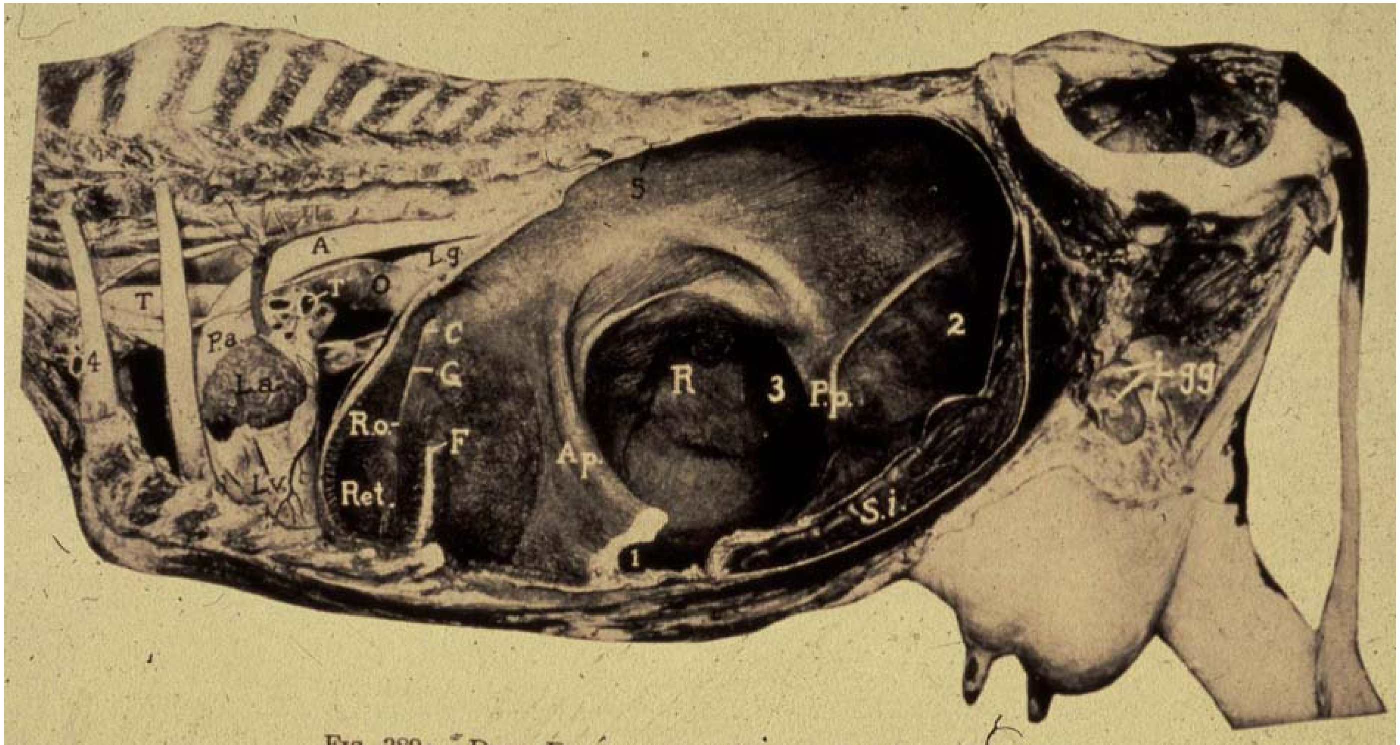
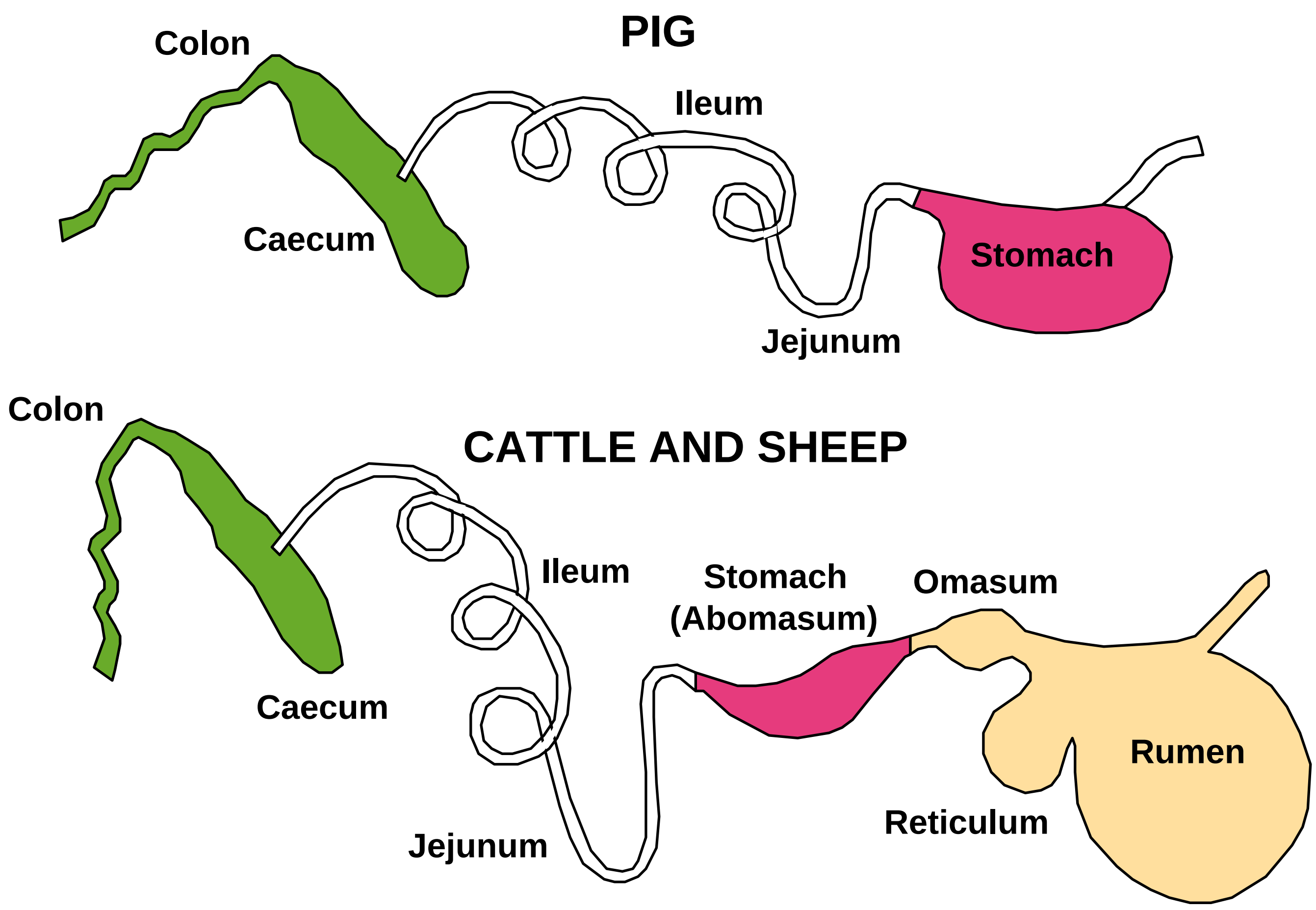


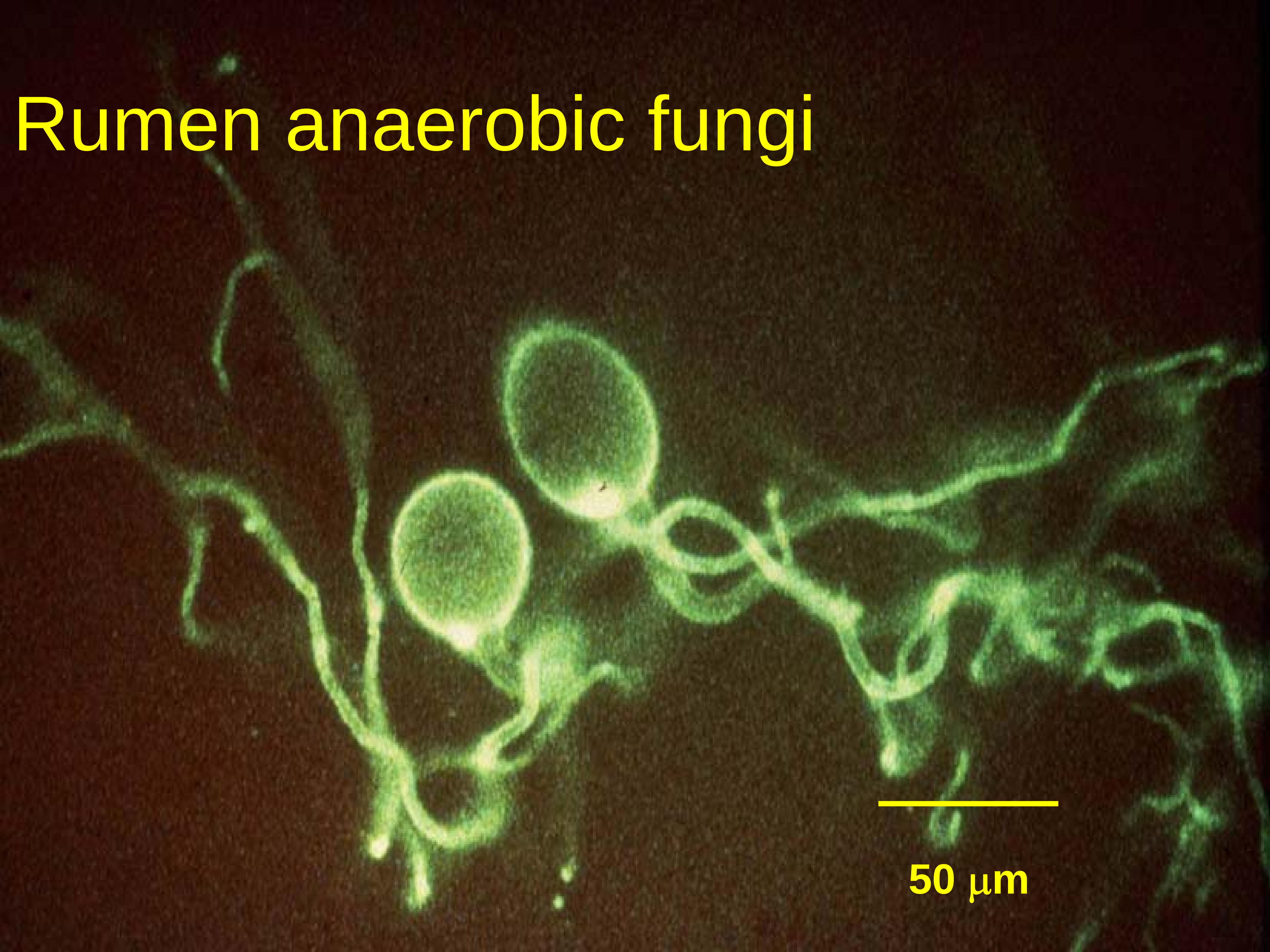
FIG. 389a.—DEEP DISSECTION OF HOLSTEIN COW: LEFT SIDE

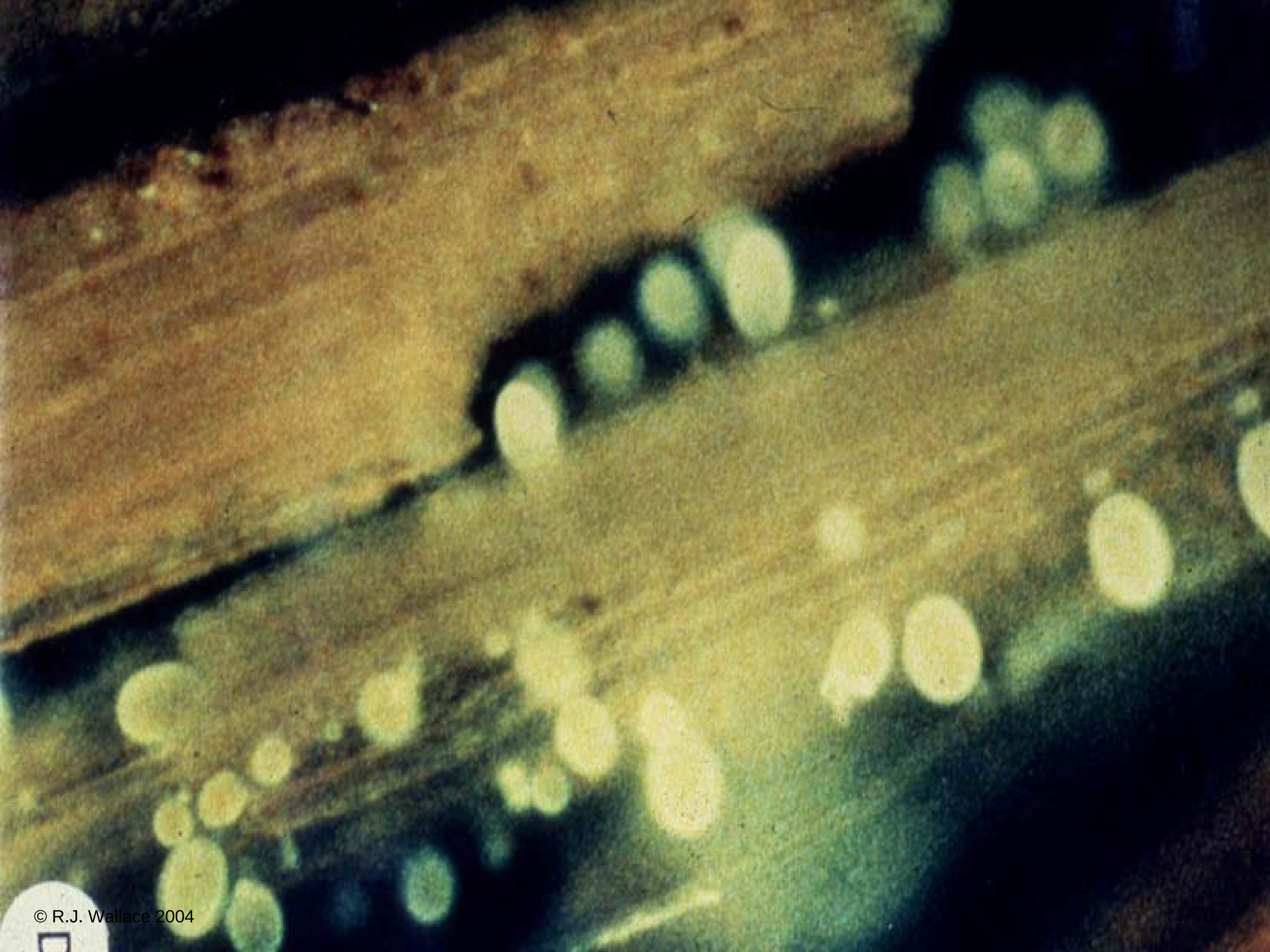
Gut anatomy



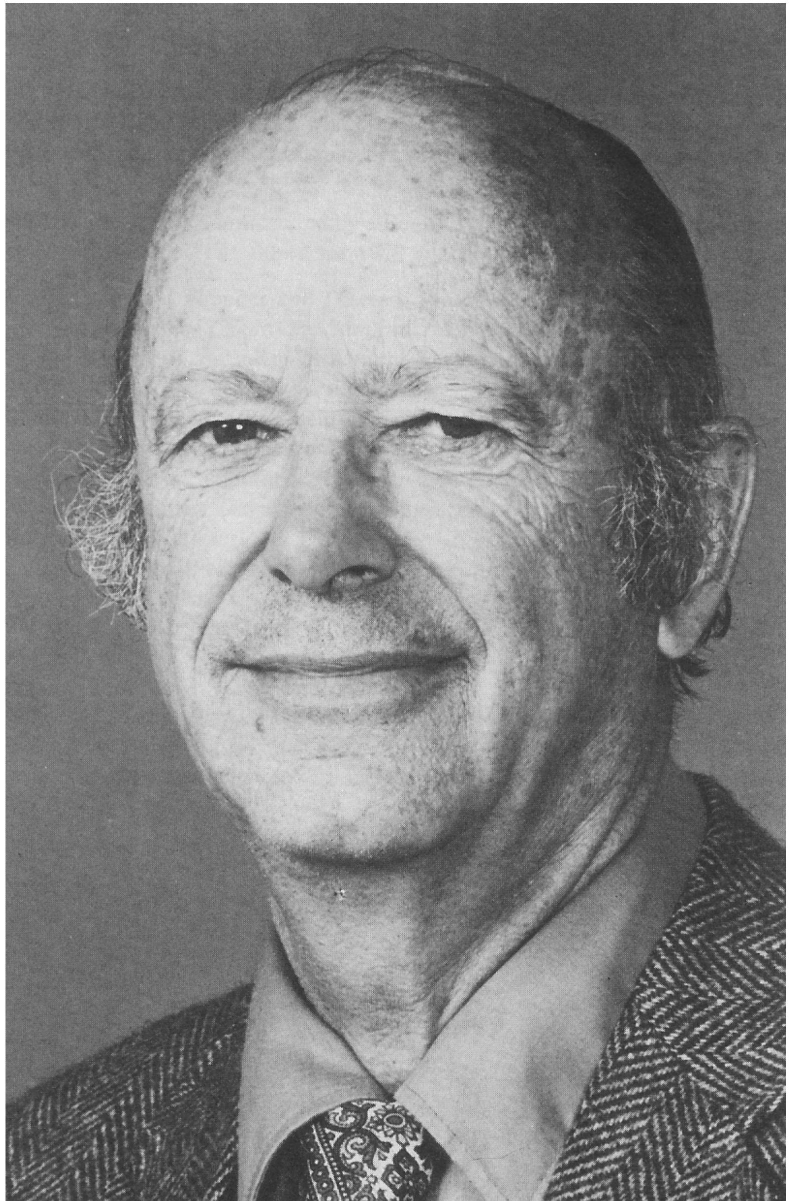
PIG
Colon
Ileum
Caecum
Stomach
Jejunum
Colon
CATTLE AND SHEEP
Ileum
Stomach
(Abomasum)
Omasum
Caecum
Rumen
Reticulum
Jejunum

Rumen ciliate protozoa


Rumen anaerobic fungi
50 μm

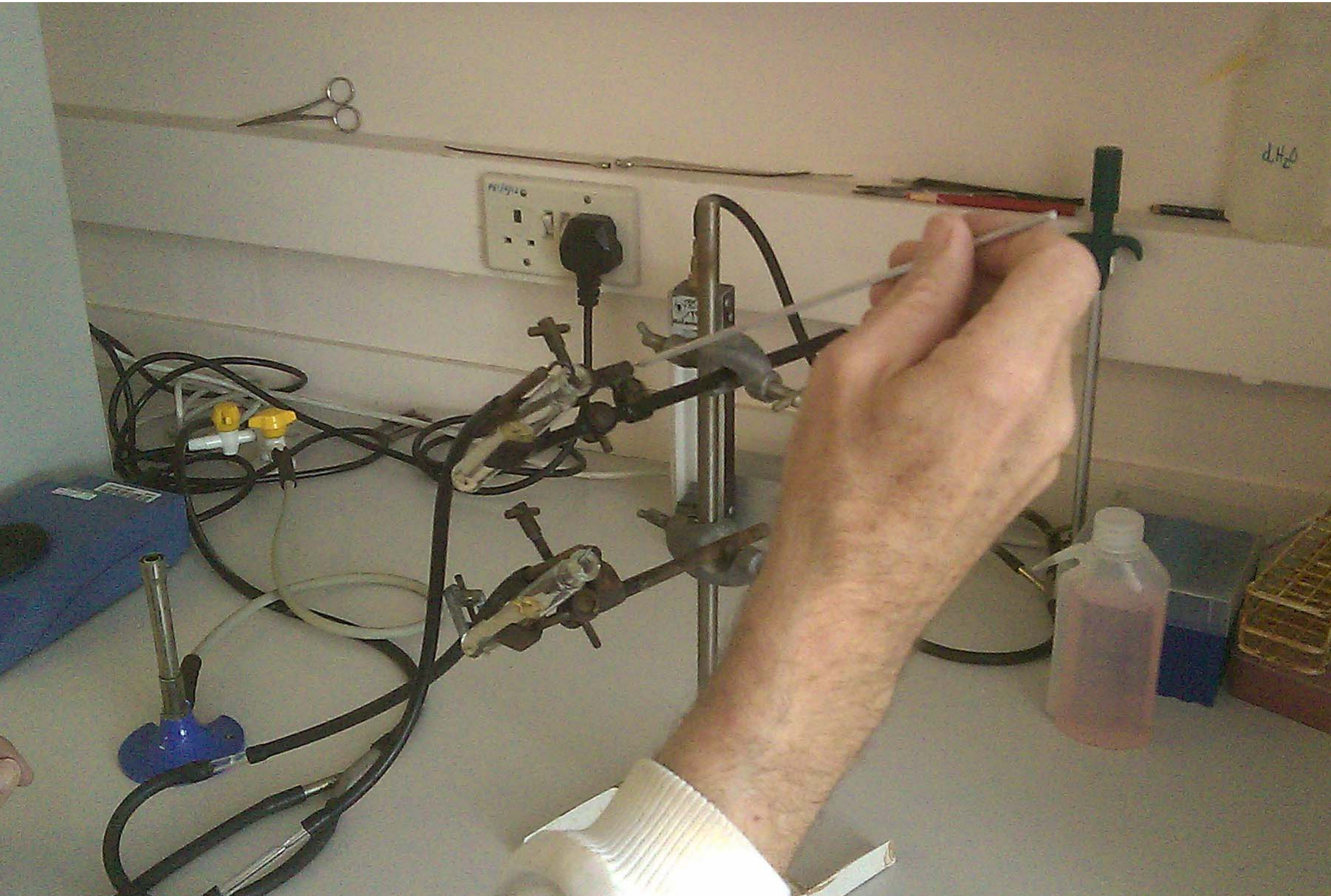



Rumen bacteria
1 μm



R E Hungate


1100
Rotameter
CARBON DIOXID


dH_2O


KIMTECH
PURPLE NITRILE

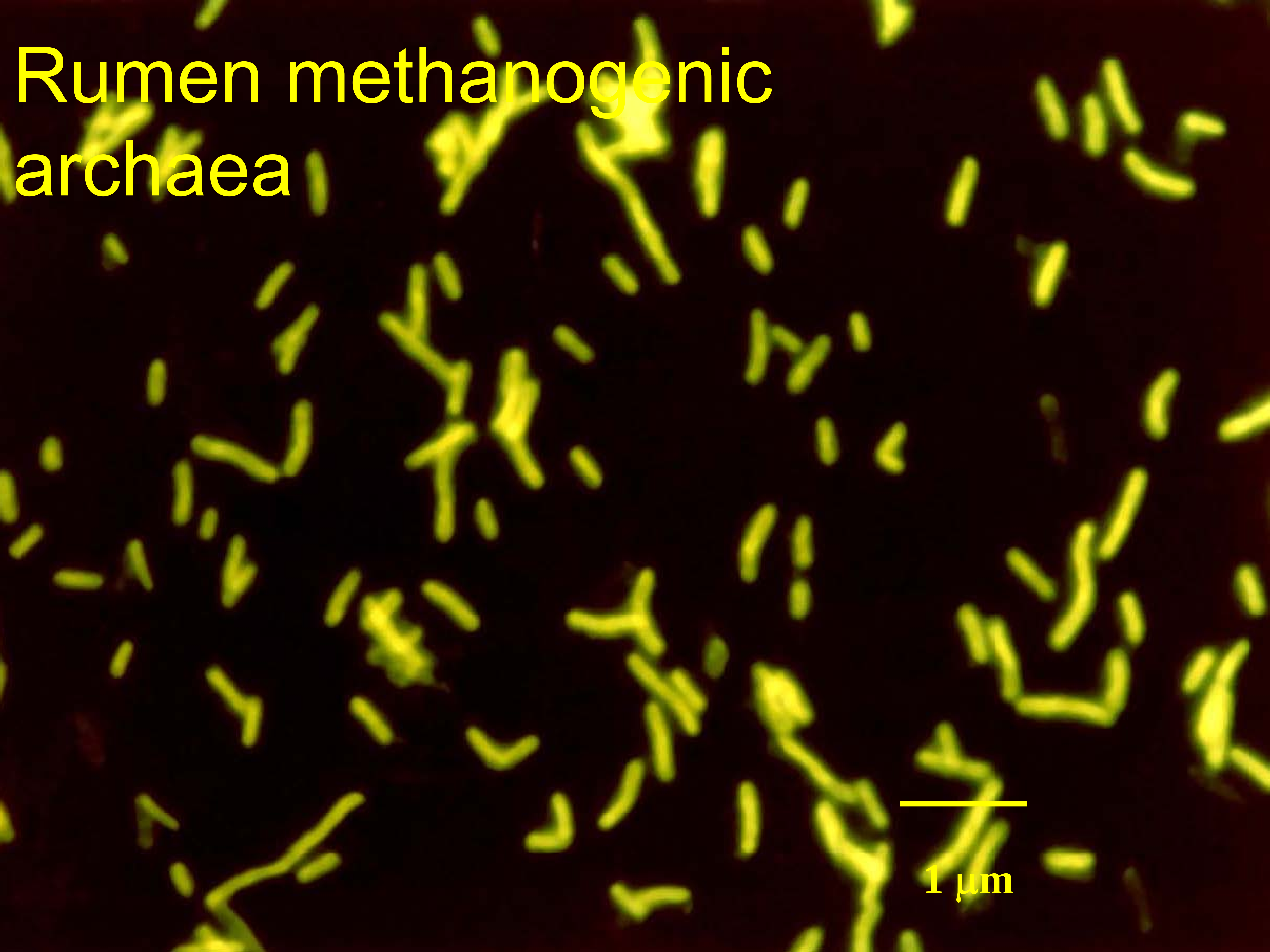
Proteobacteria

Cytophaga-Flexibacter-Bacteroides [CFB]

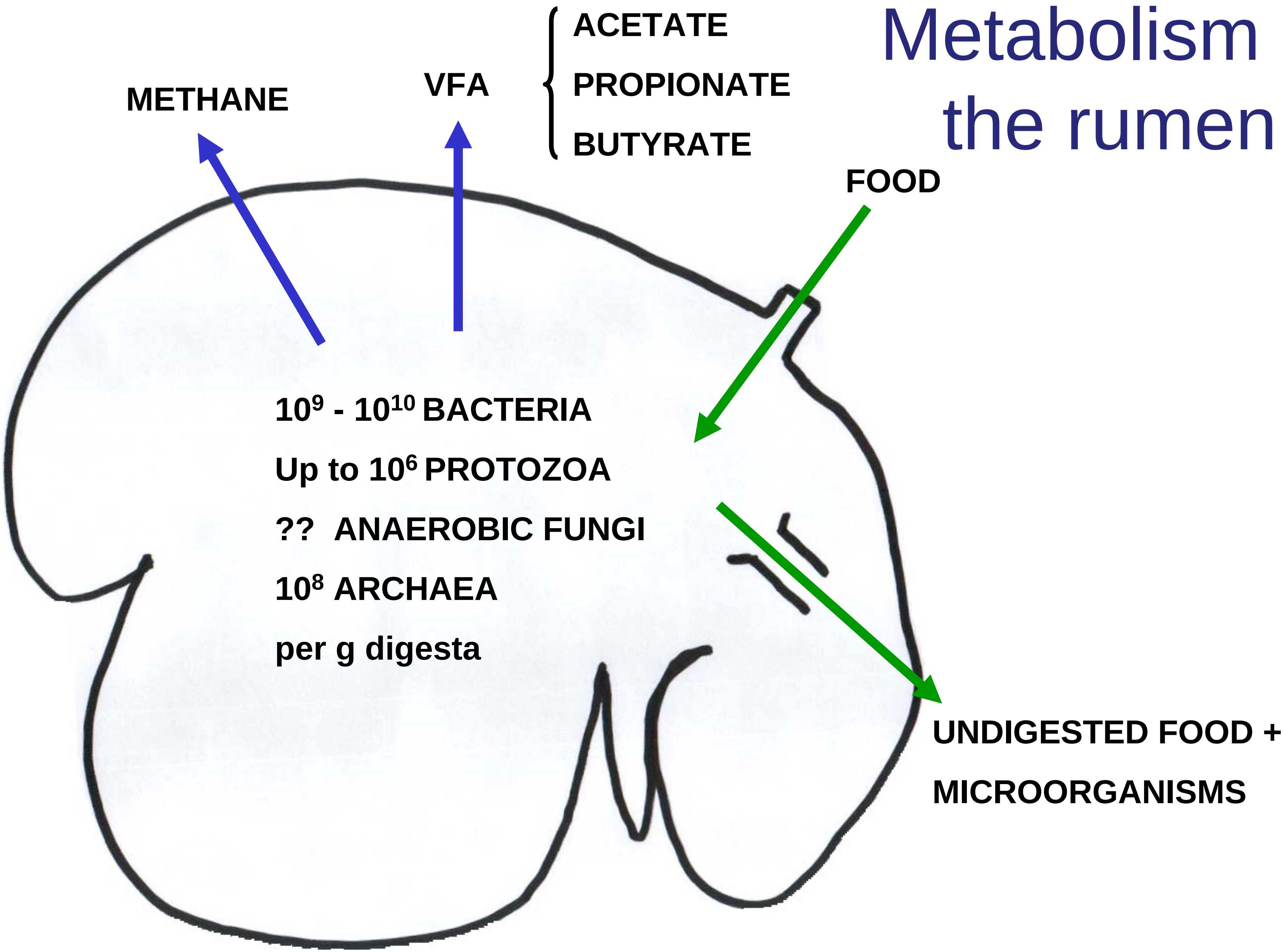
High bacterial diversity

Low G+C Gram positive

High G+C Gram positive, *Fibrobacter*, *Spirochaetes,* etc


Rumen methanogenic archaea
1 μm

Metabolism in the rumen



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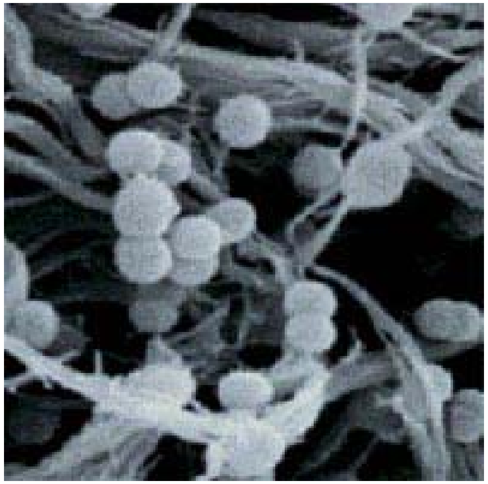
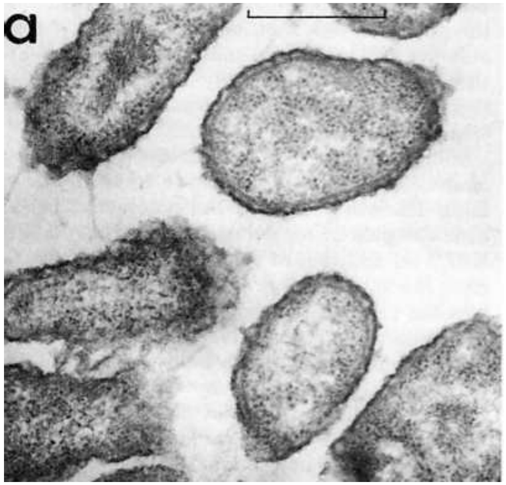
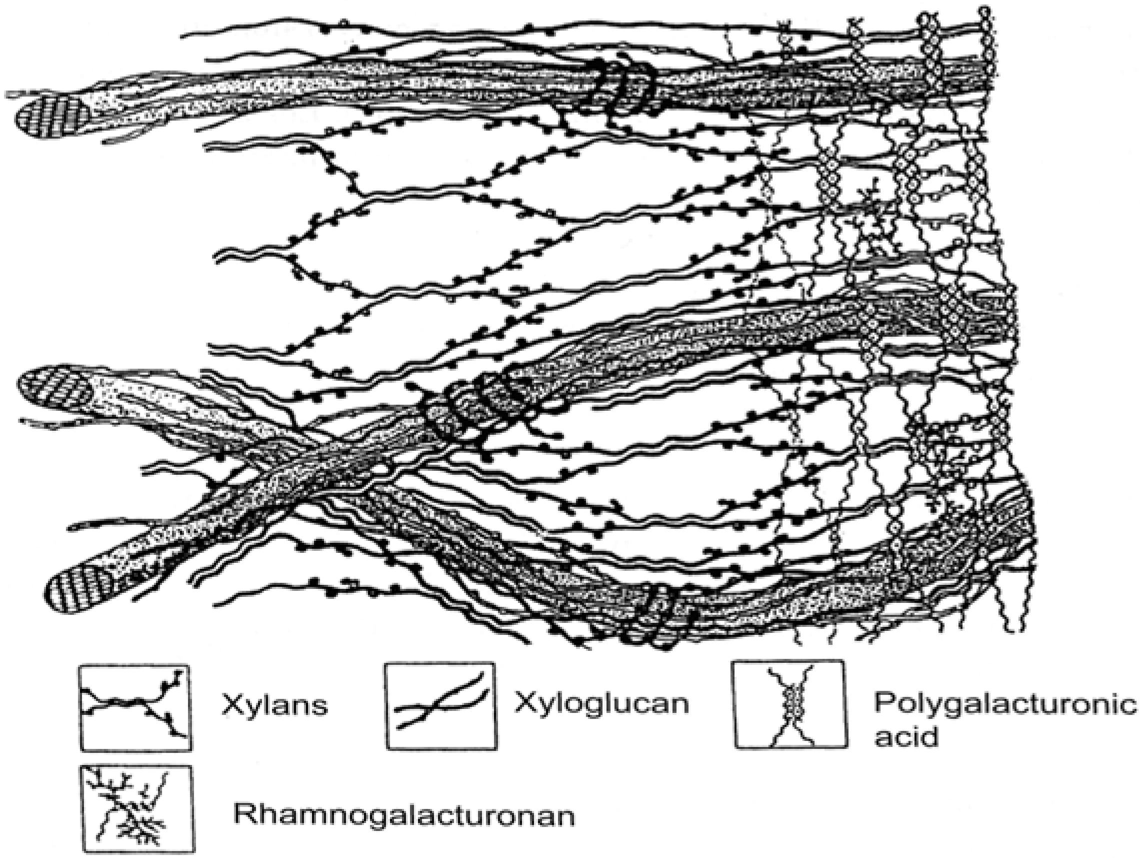
Fibre breakdown

Ruminococcus flavefaciens

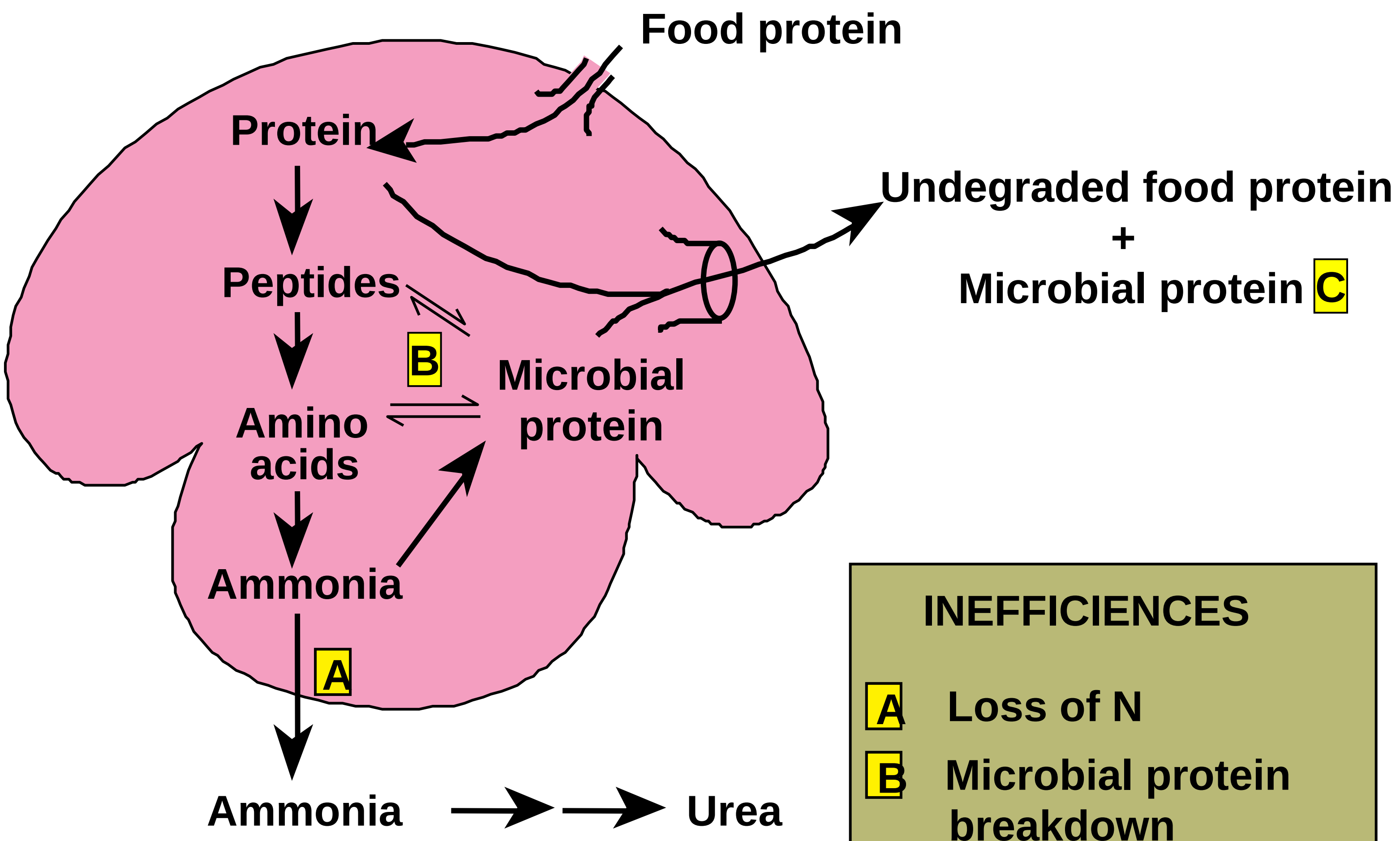


Fibrobacter succinogenes



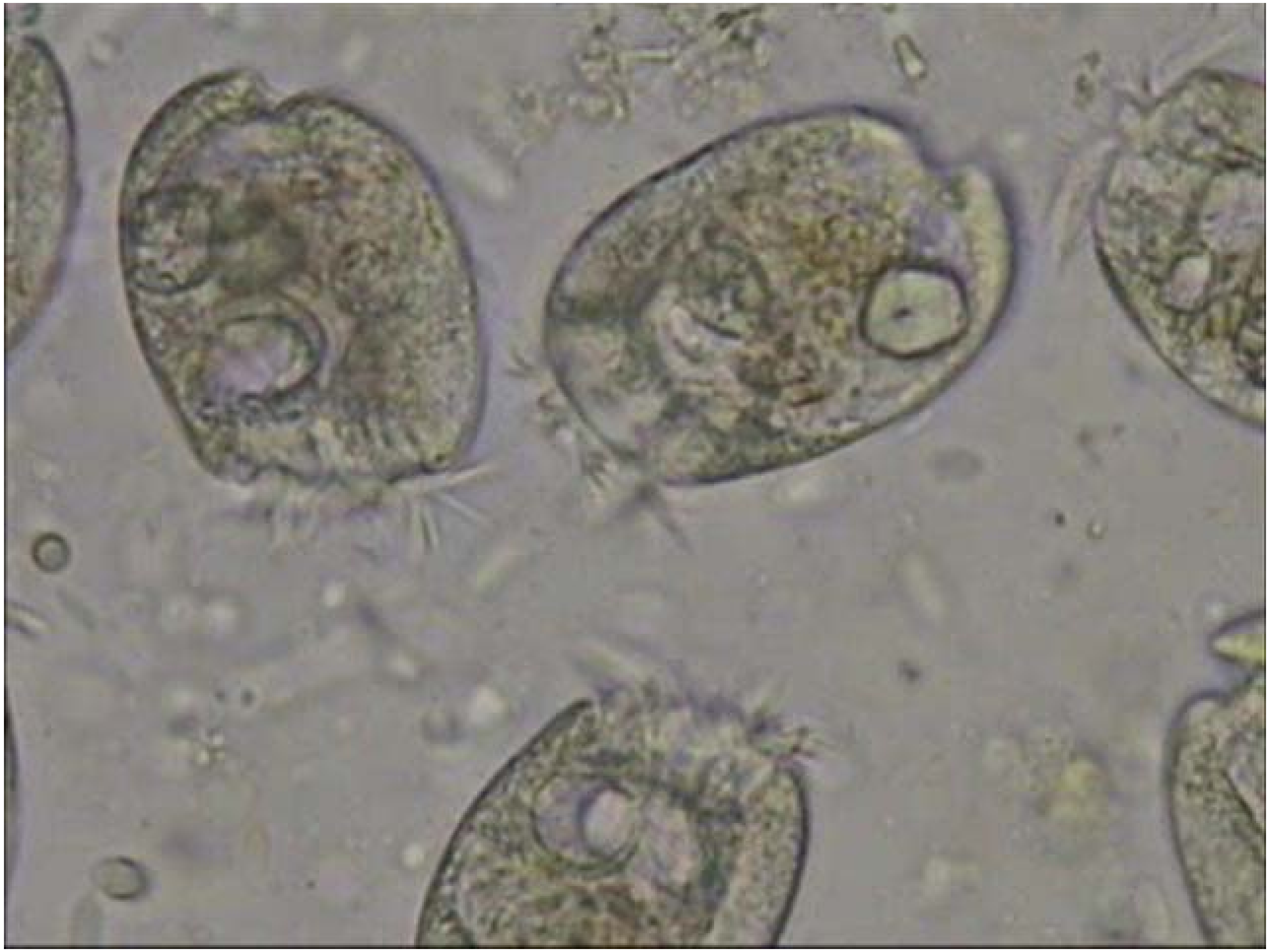


Protein metabolism

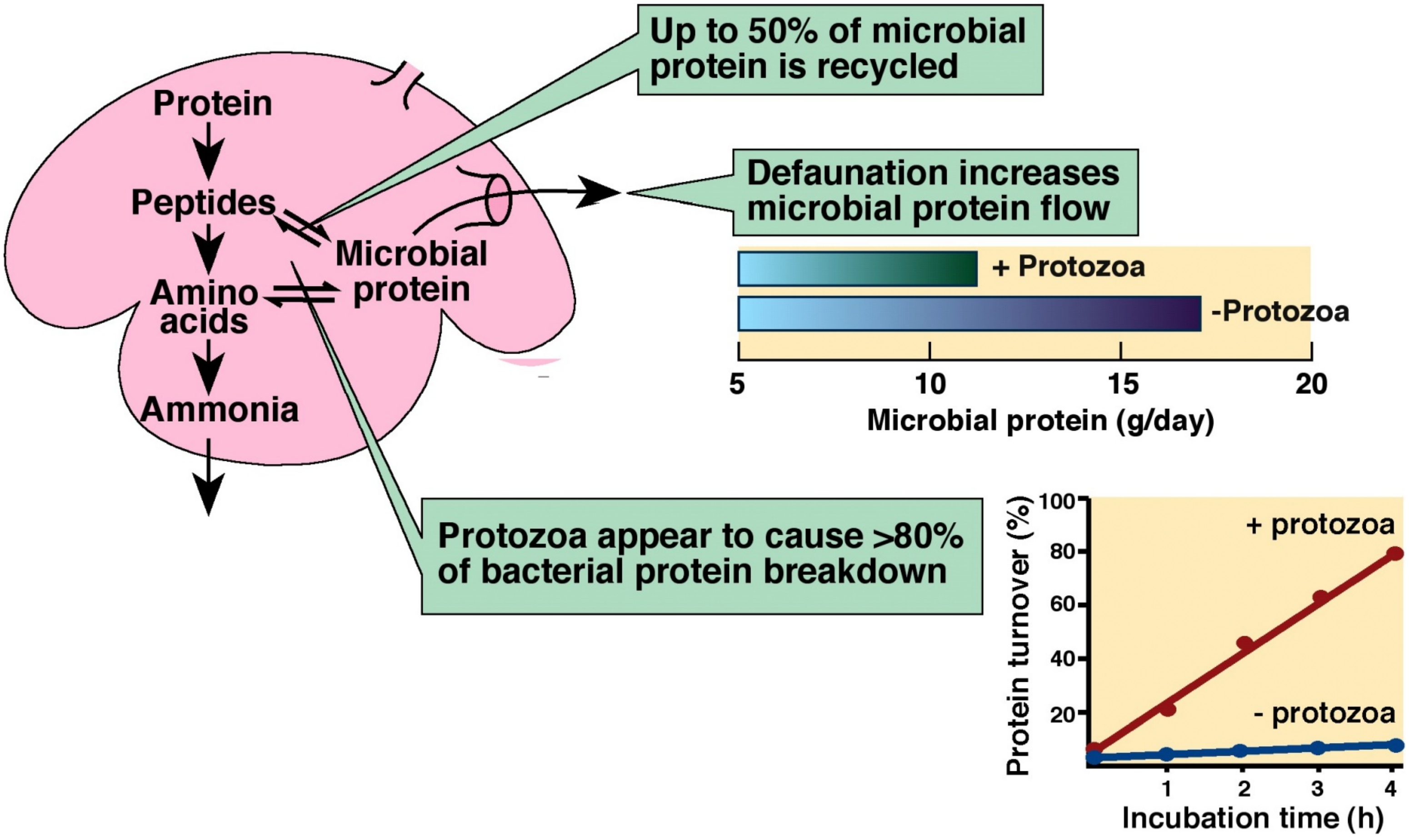


INEFFICIENCES

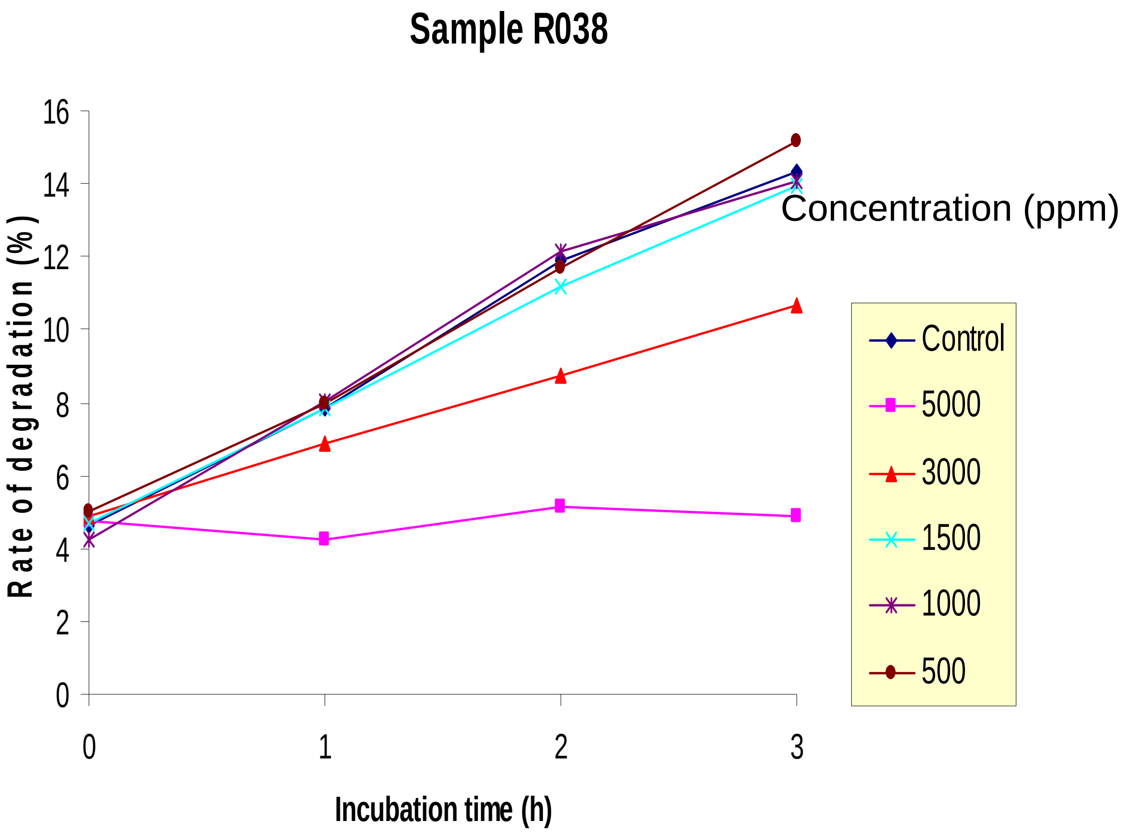
- A Loss of N
- B Microbial protein breakdown
- C Amino acid imbalance



Breakdown of microbial protein

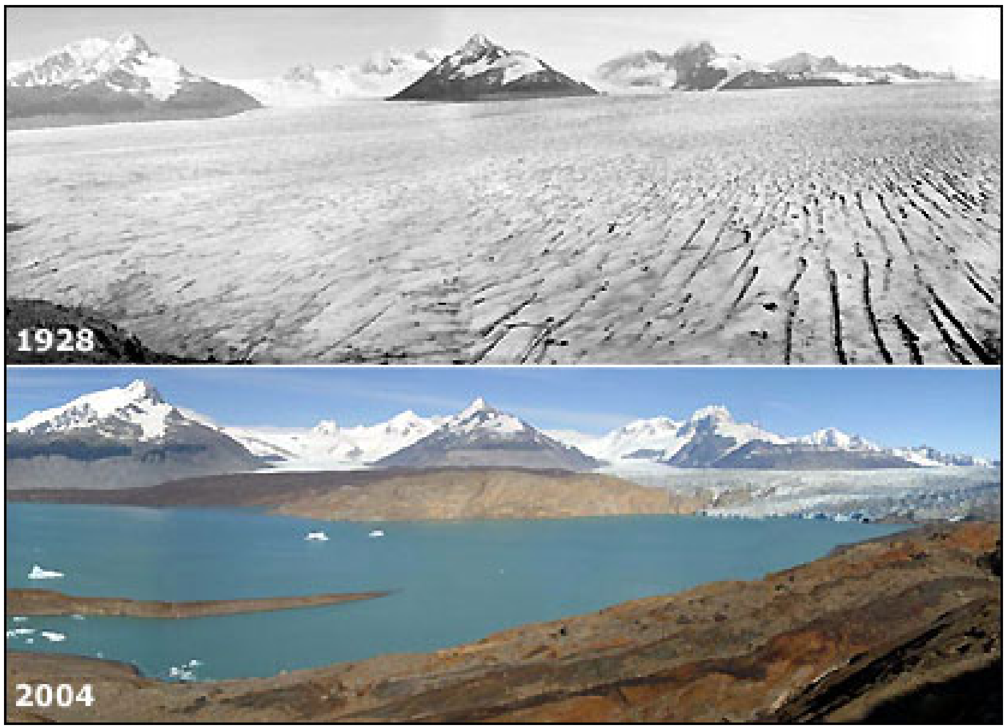


Rumen-up: influence on protozoal activity *in vitro*



Lonicera japonica **(Japanese honeysuckle)**

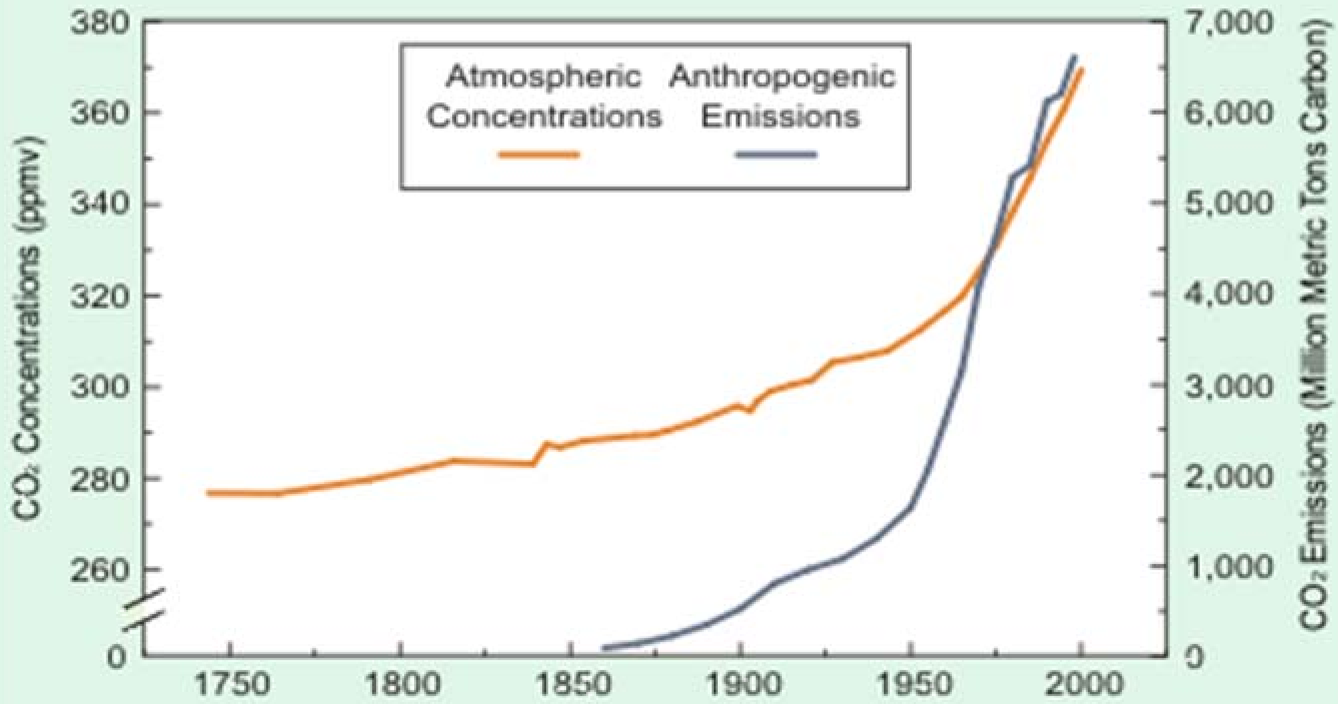
Methane, ruminants and the environment



Methane, ruminants and the environment

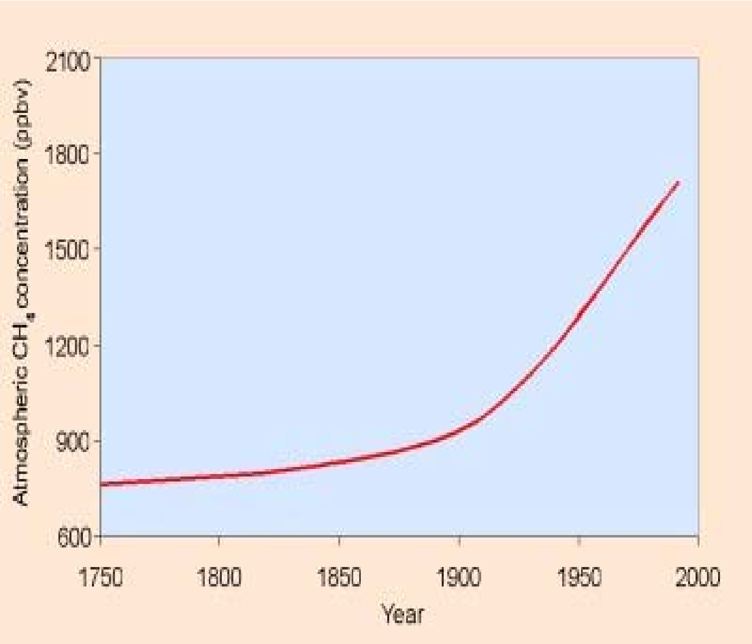
- How much is methane a problem as a greenhouse gas?
- Is methane from ruminants really a major part of the problem ?
- How does methane formation occur?
- How can we inhibit methane formation?
- Encapsulated fumaric acid, efficacy and commercial considerations

Greenhouse gases: CO_2



Source: Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center, http://cdiac.esd.oml.gov/.

Methane as a greenhouse gas



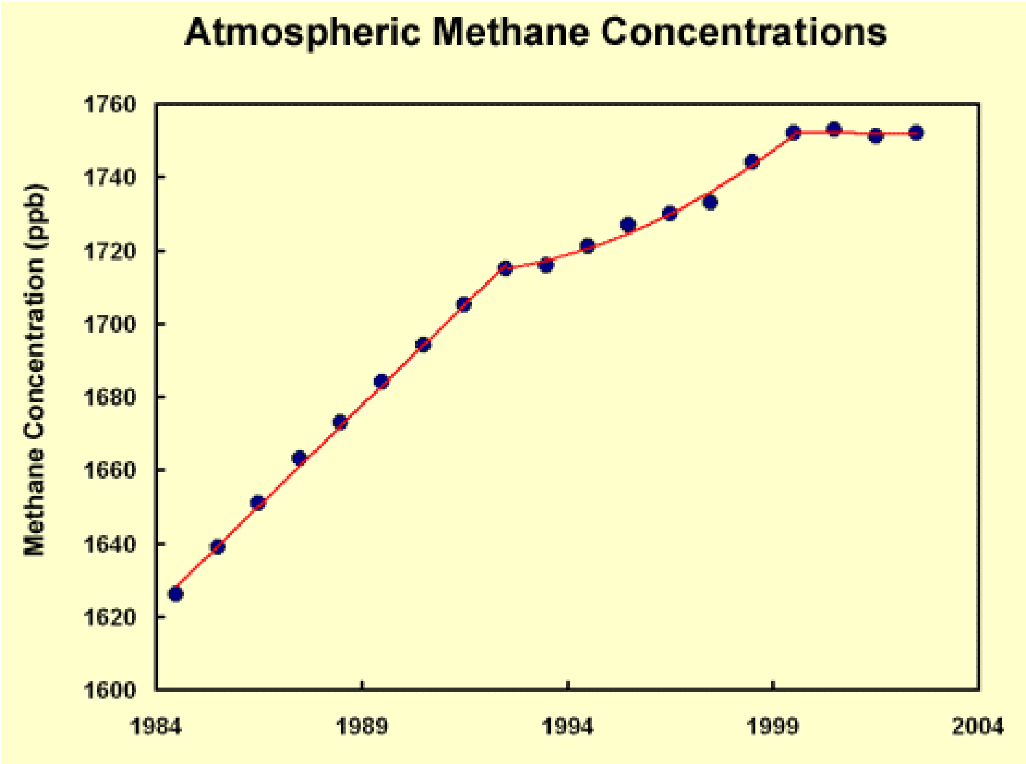
US Environmental Protection Agency, 2000

CH_4 has a global warming potential ("radiative forcing") 21 times that of CO_2

Methane contributes approximately 18% to the overall global warming effect

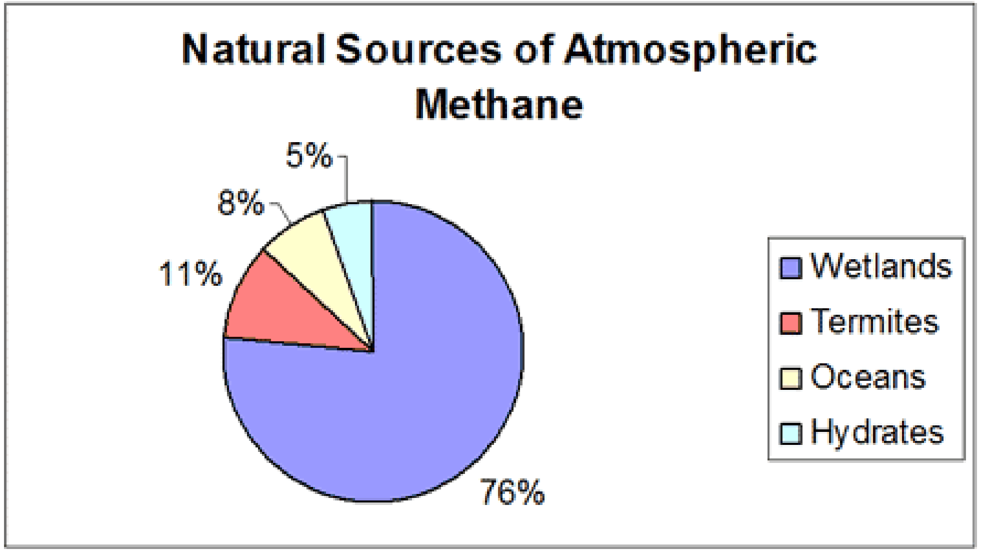
Methane as a greenhouse gas

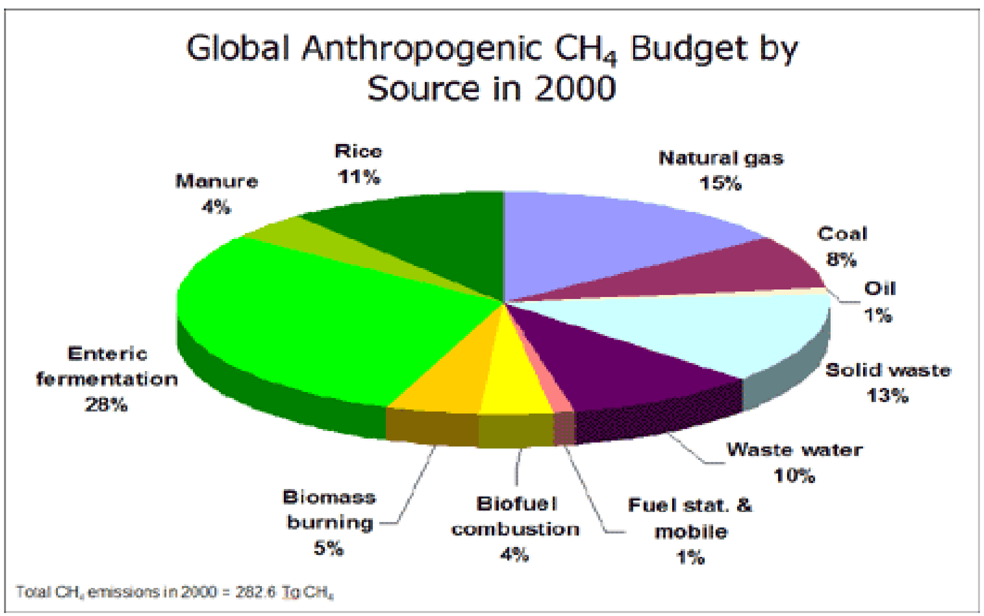
$t_{1/2}$ of CH_4 in atmosphere is 12 years



Dlugokencky *et al.*, 2003

Sources of atmospheric methane

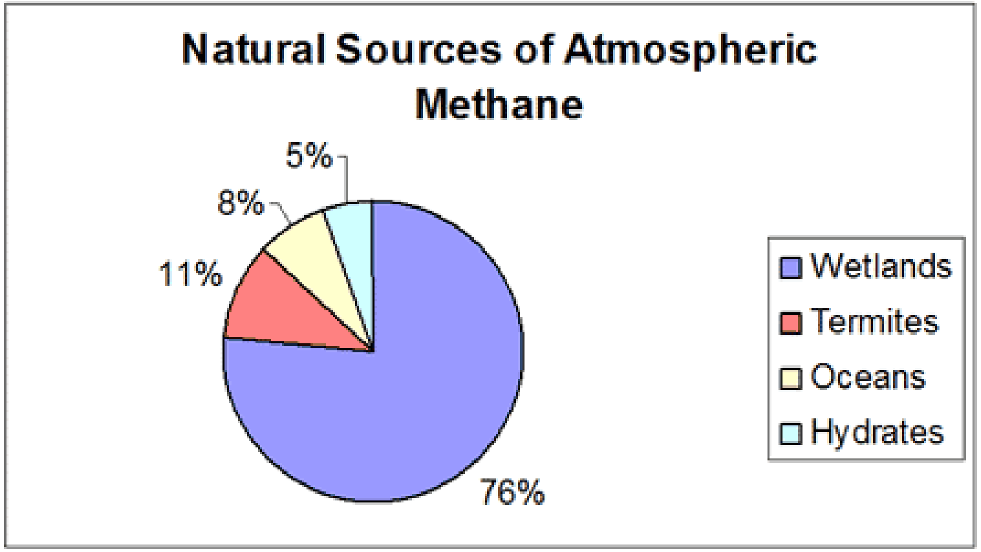


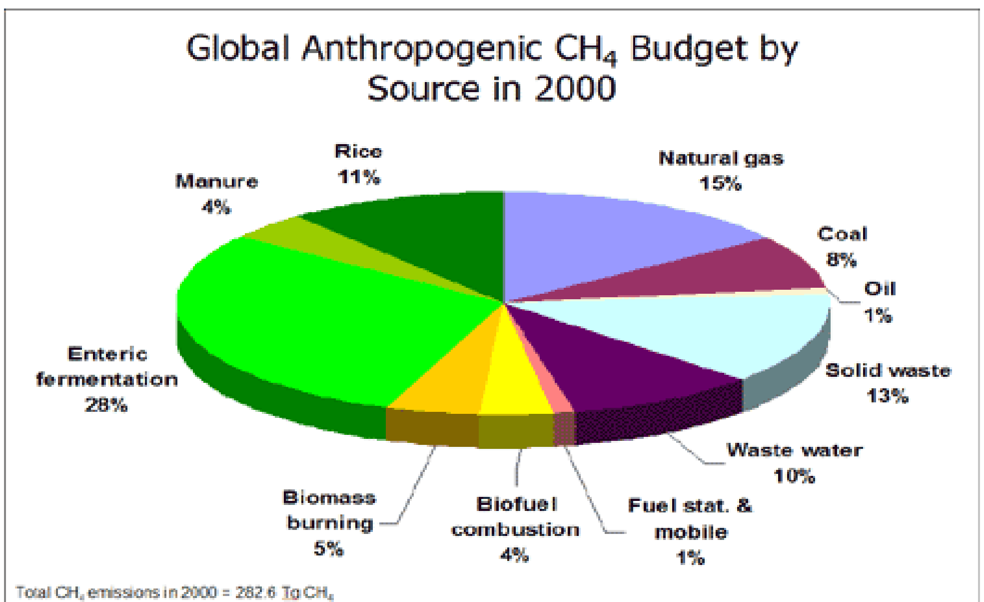


70% of global methane formation is due to man's activities

US Environmental Protection Agency, 2001

Sources of atmospheric methane

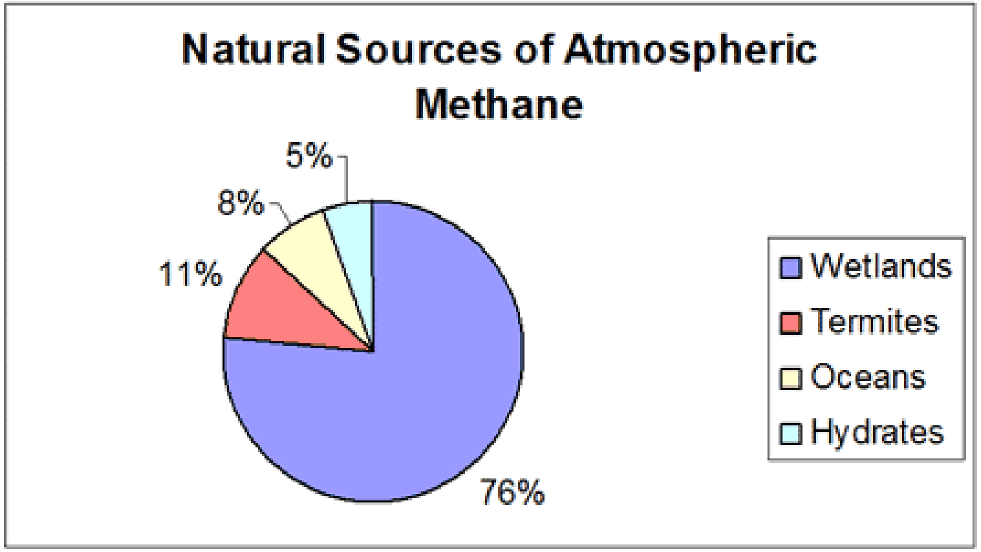


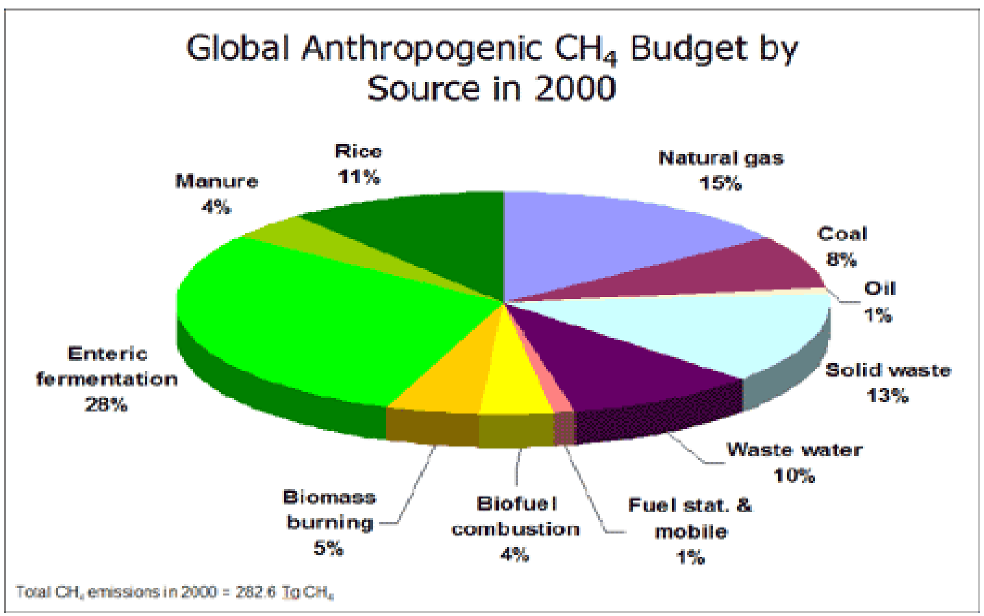


Therefore, 20% of global methane formation is due to ruminants

US Environmental Protection Agency, 2001

Sources of atmospheric methane





And so 20% of the 18% = 3.6% of the total radiative forcing is caused by ruminants

US Environmental Protection Agency, 2001

Ruminants, cars and methane

=

164 g CO_2/km at 19,000 km/year
= 164×19000 g CO_2/year
= 3×10^6 g CO_2/year

500 L CH_4/day
= 365×500 L/year
= 2×10^5 L/year
= $2 \times 16/22 \times 10^5$ g/year
= 1.5×10^5 g/year
$\cong 21 \times 1.5 \times 10^5$ g CO_2/year

$\cong 3 \times 10^6$ g CO_2/year

Ruminants, cars and methane

=

Ruminants, cars and methane

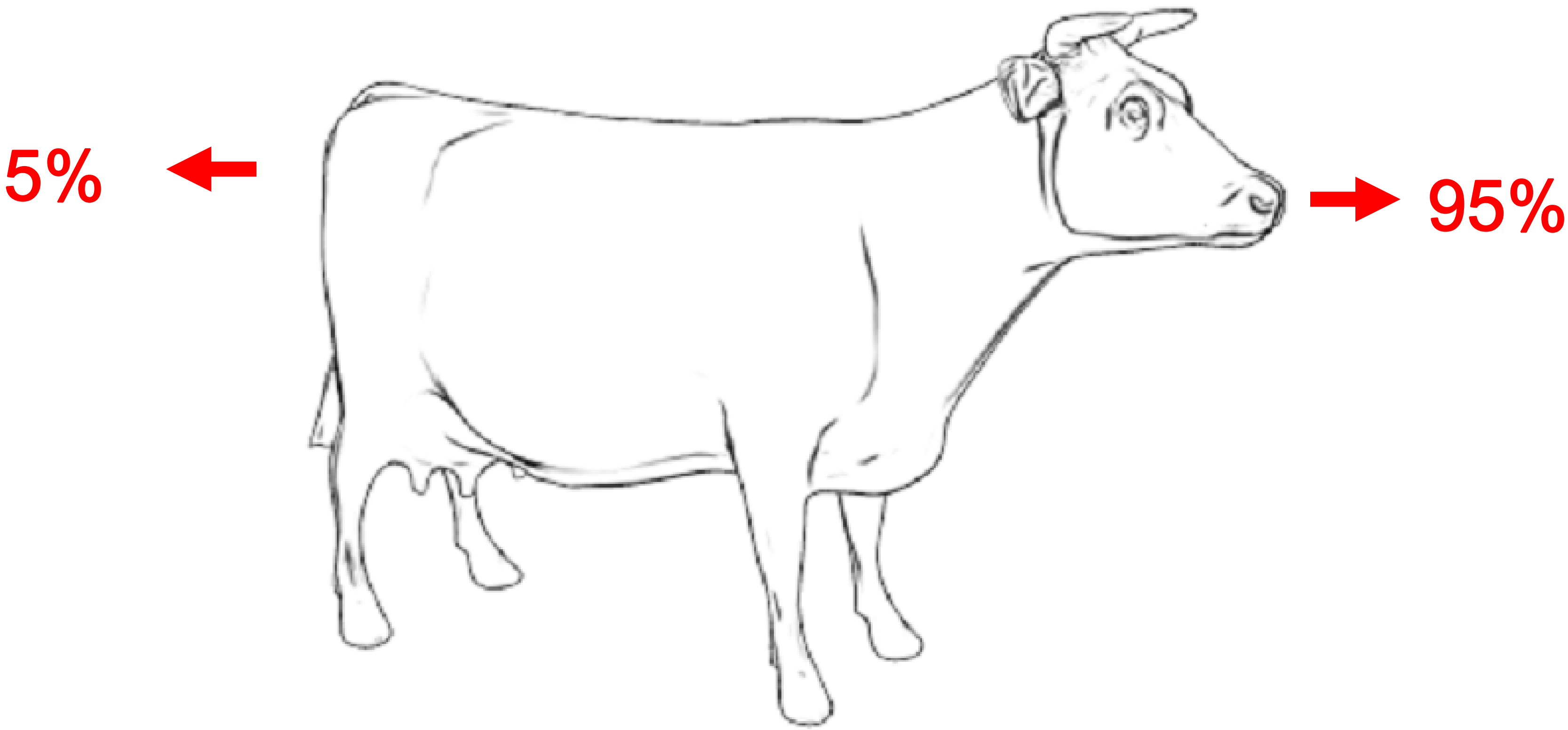
=

The New Zealand response

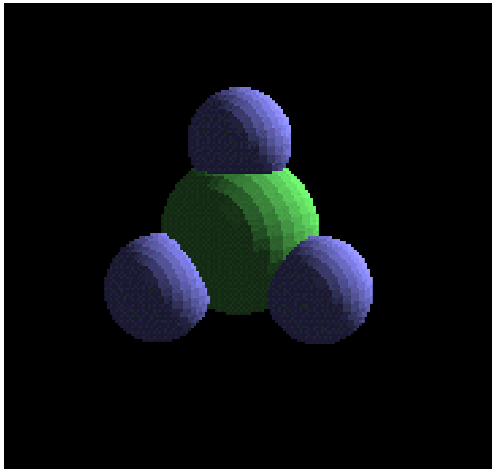
Carbon tax

As part of the Climate Change Policy Package, released in 2002, the government will be introducing a carbon tax in New Zealand from April 1, 2007. Hon. Pete Hodgson, Convener of the Ministerial Group on Climate Change, has announced that the carbon tax will be set at $15 per tonne of CO_2 and has released a consultation paper on the implementation of the tax.

Methane production in ruminants



Methane production in ruminants



Fermentation

↓ Protozoa, fungi, eubacteria

$H_2 + CO_2$

↓ Archaea

CH_4

Inhibition of methane formation

- Halogenated hydrocarbons
- Other chemicals
- Ionophores
- Acetogenesis
- Immunisation
- Defaunation
- Natural plant extracts
- Organic acids

Decreasing methane emission using "organic acids"

Fermentation

$\downarrow$

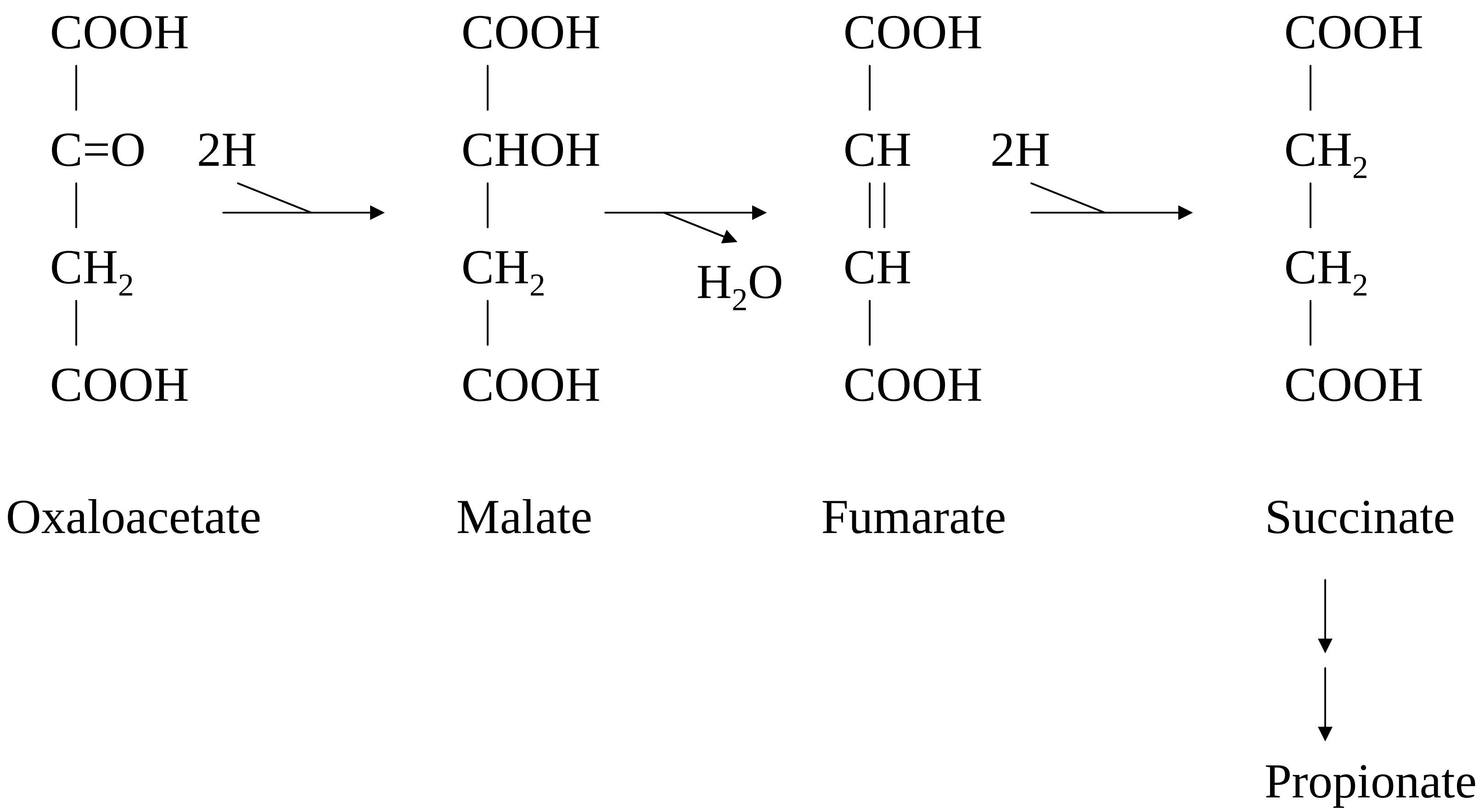
[Organic acid + H_2]+ CO_2

$\downarrow \quad\quad \downarrow$

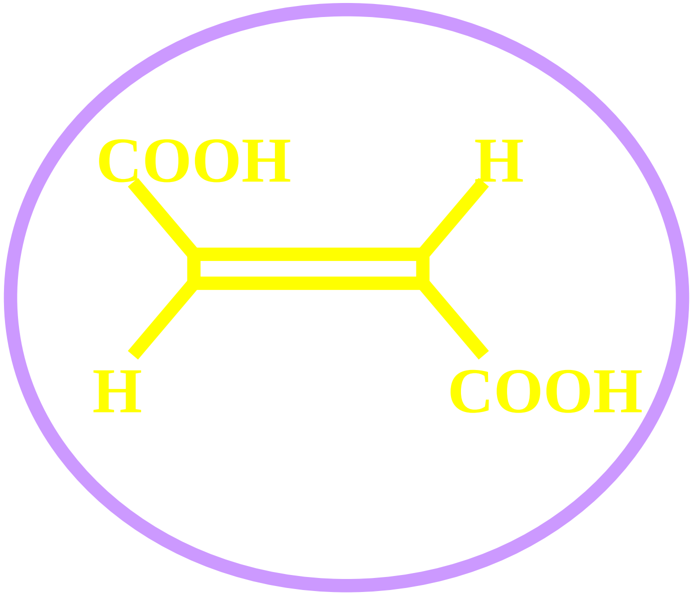
$\downarrow$

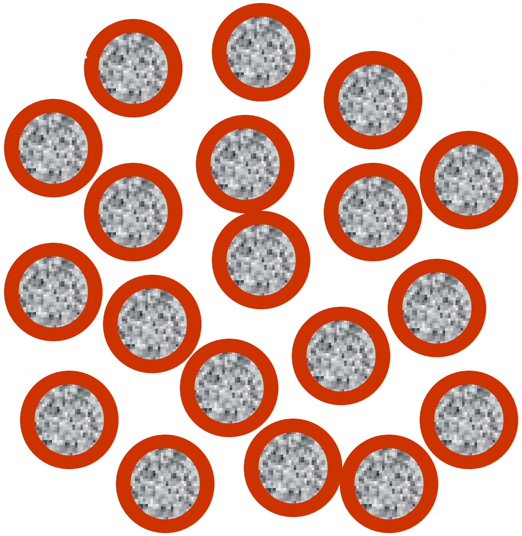
Propionic acid $\quad$ CH_4

Organic acids



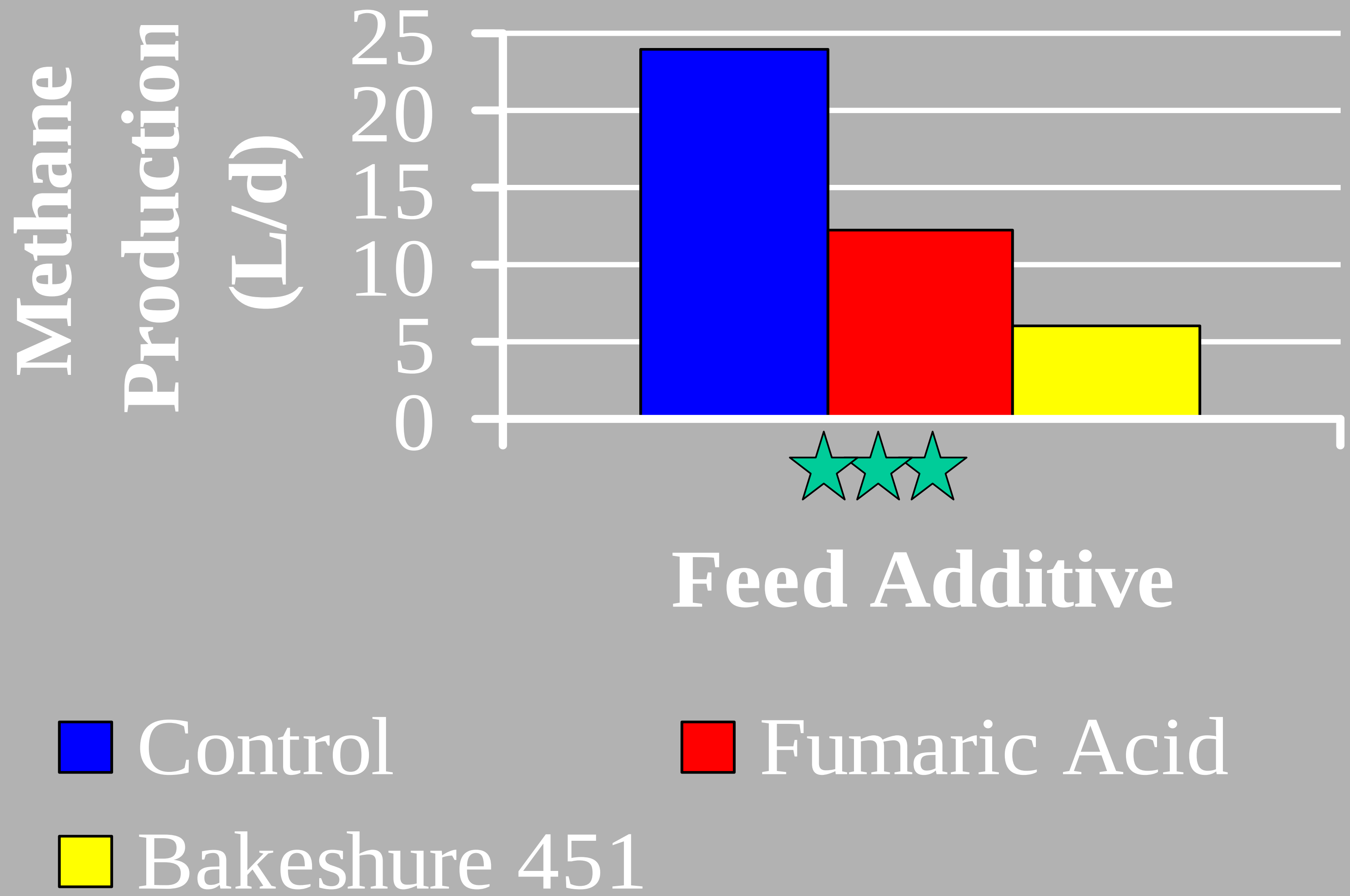
Bakeshure 451





Bakeshure 451 – Consists of 85% fumaric acid and 15% partially hydrogenated soybean oil

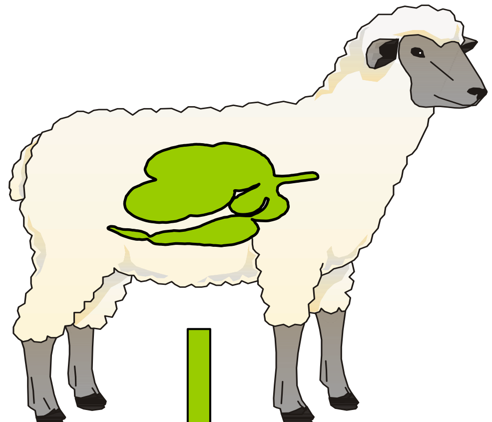
Large scale feeding trial in Aberystwyth

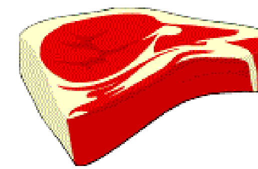


Health implications of biohydrogenation in the rumen

LNA C18:3 c9 c12 c15

LA C18:2 c9 c12





LNA

LA

Saturated fatty acids

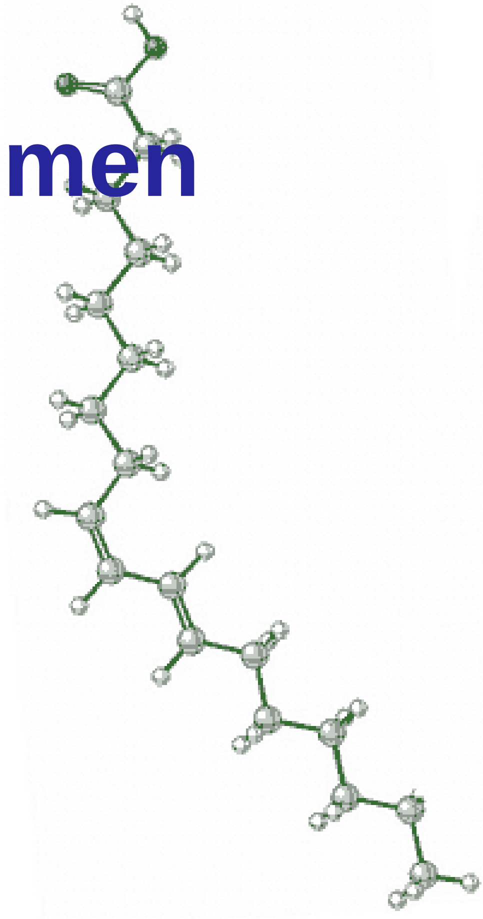
BIOHYDROGENATION

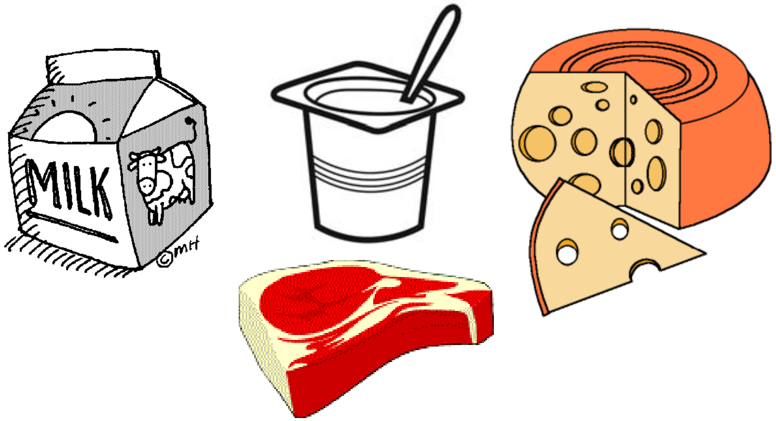
unsaturated saturated

LNA – linolenic acid

LA – linoleic acid

Health implications of biohydrogenation in the rumen





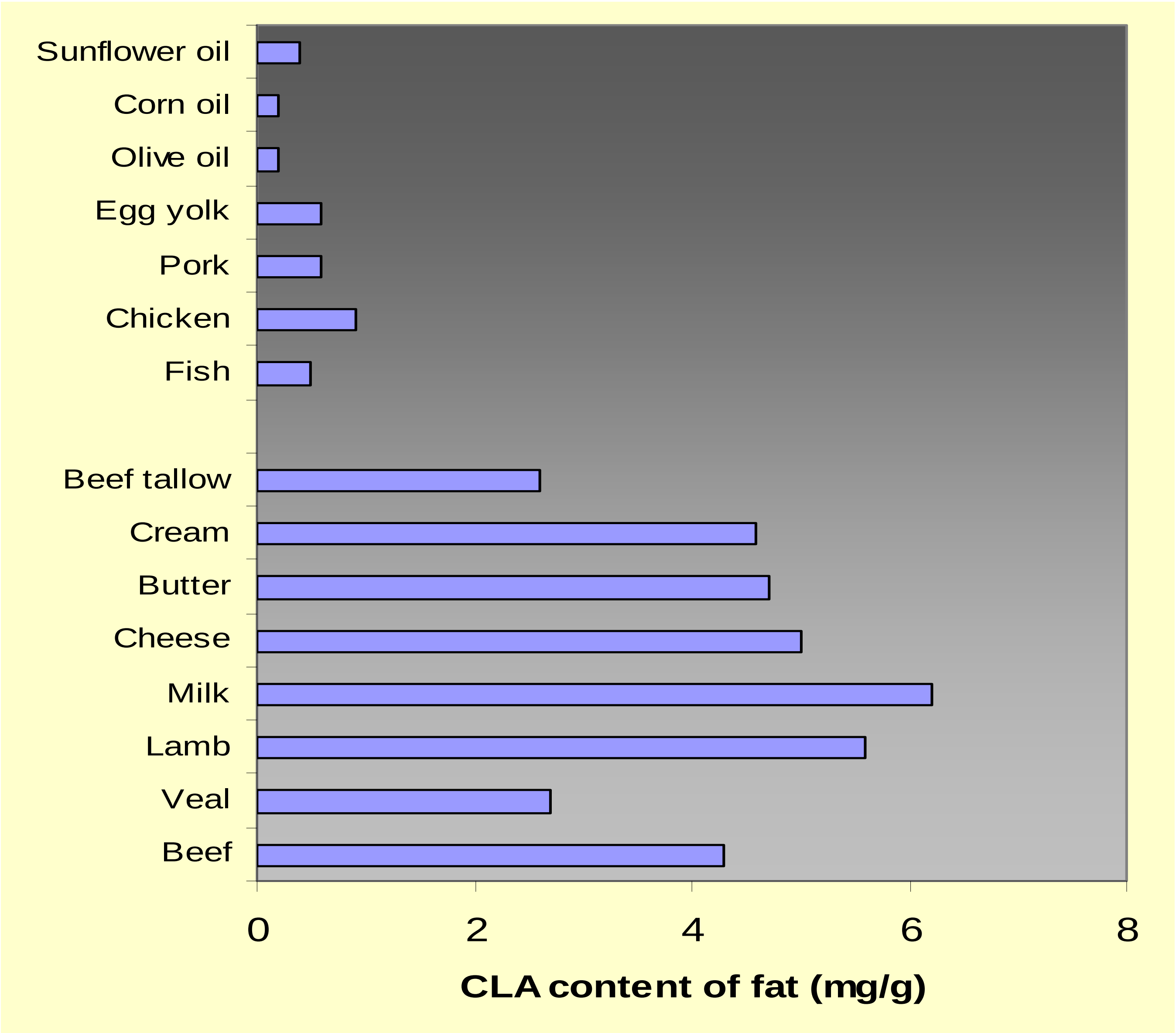
Helps Prevent Heart Disease

CLA

Stimulates Immune Response

Helps Prevent Cancer

CLA in foods

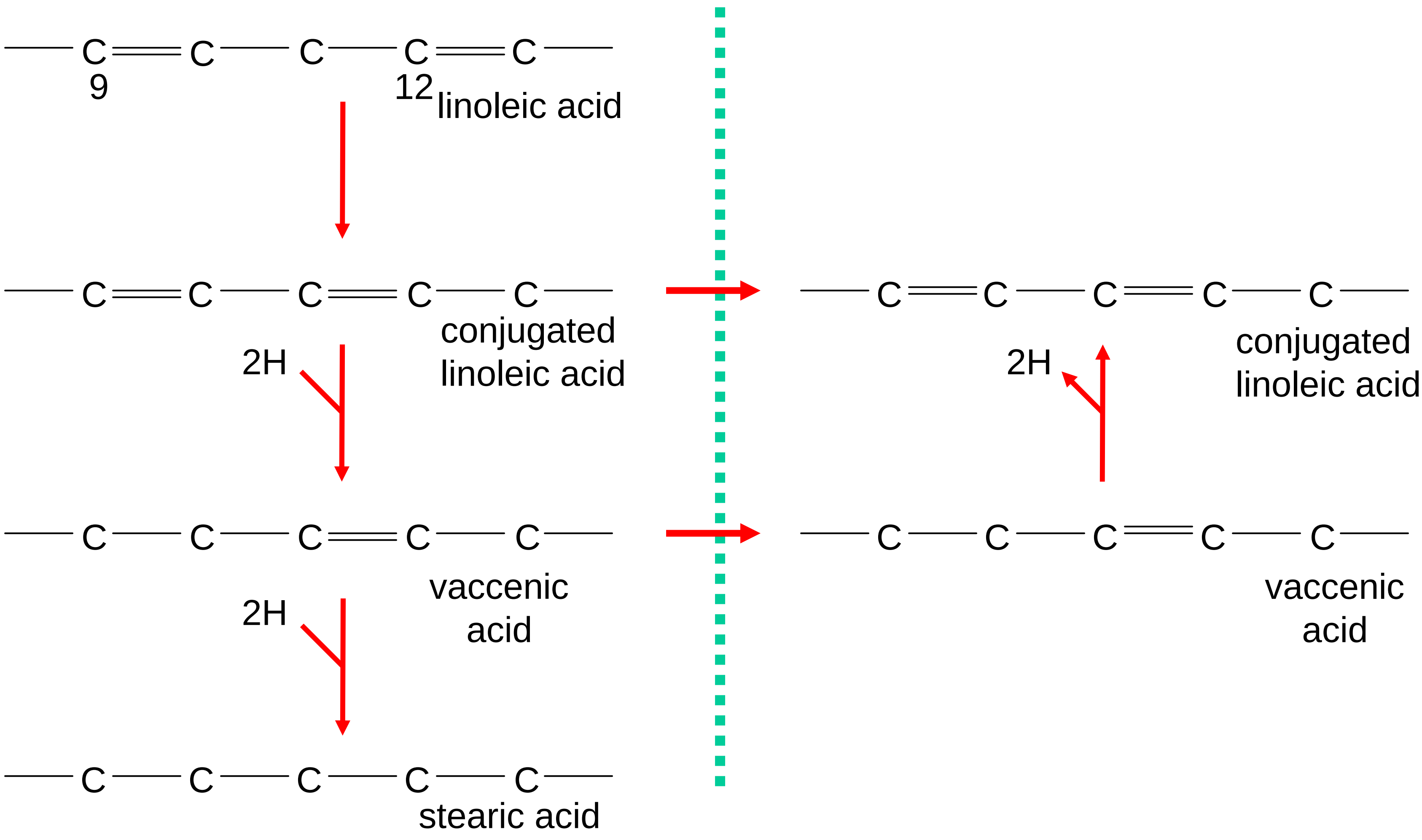

Sunflower oil
Corn oil
Olive oil
Egg yolk
Pork
Chicken
Fish
Beef tallow
Cream
Butter
Cheese
Milk
Lamb
Veal
Beef
0
2
4
6
8
CLA content of fat (mg/g)

CLA in foods

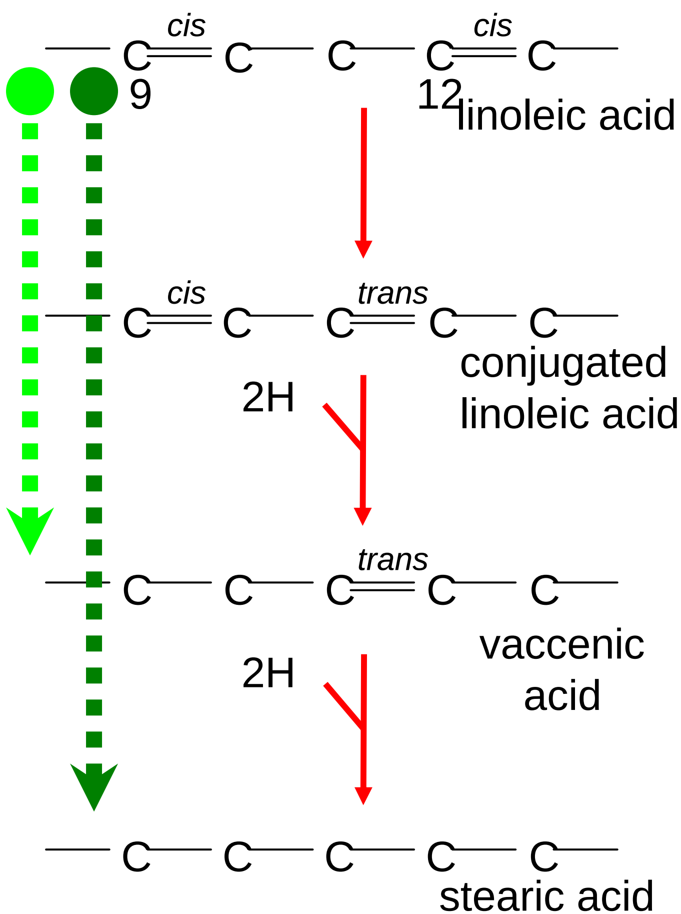
To provide 10 g of CLA/day requires 3.6 kg cheese

Rumen

Animal tissues



Effects on biohydrogenation of unsaturated fatty acids



Butyrivibrio fibrisolvens

Butyrivibrio proteoclasticus

19 samples with activity against *B. proteoclasticus* but not *B. fibrisolvens*

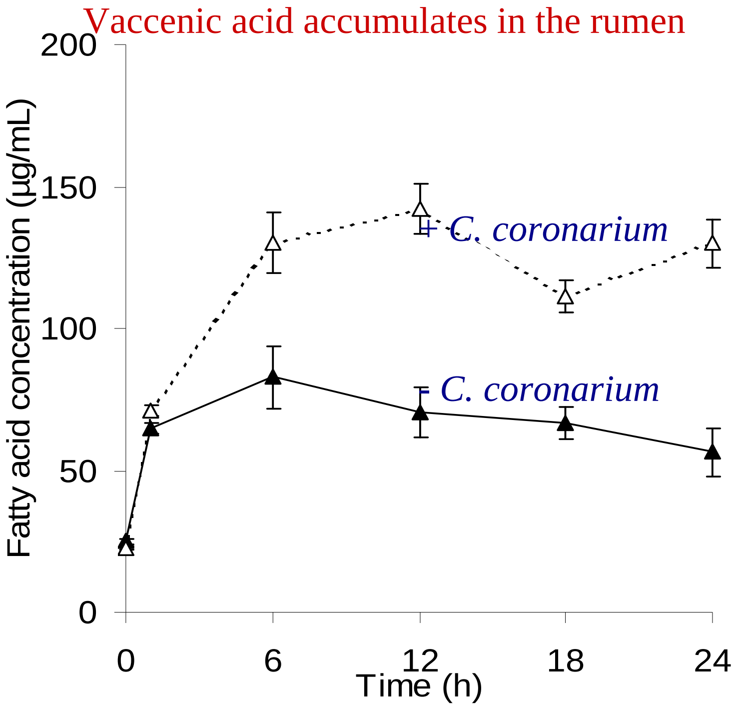
Replacing antibiotics in animal feed

EC FP6

Promotion of Safe, Healthy Food

Chrysanthemum coronarium

- *C. coronarium* inhibits last step in biohydrogenation process
- *C. coronarium* increases PUFA and CLA content of milk

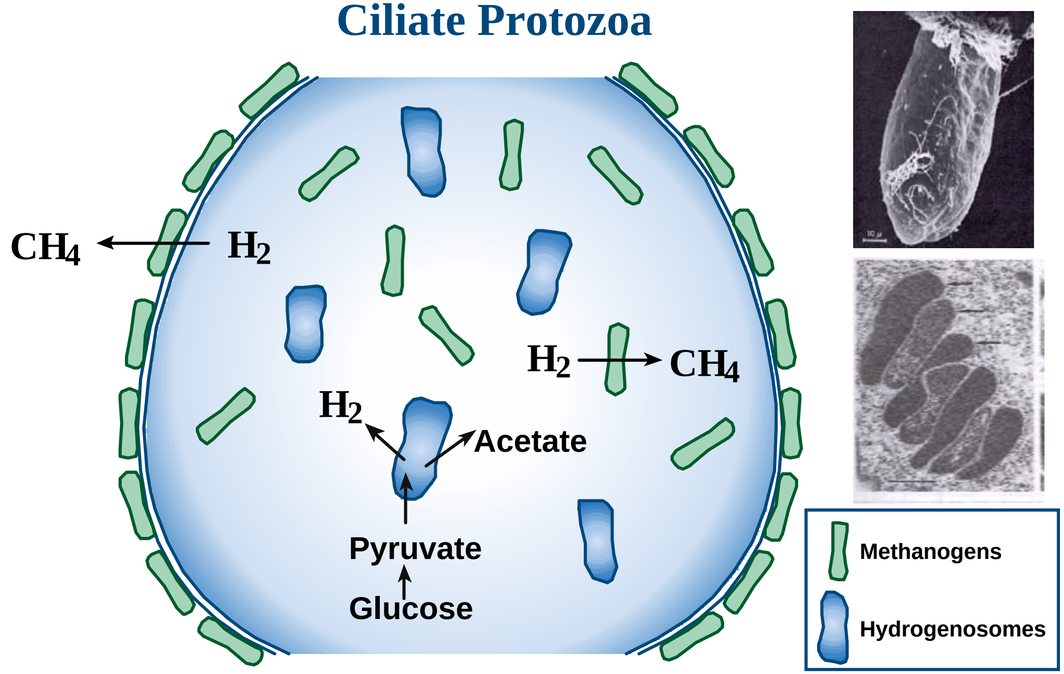


Tracy's Vision of the Future

Inhibition of methane formation

- Defaunation
  - Decreases methane formation by 20%

Intracellular Hydrogen Transfer in Ciliate Protozoa



Defaunation technically difficult
Adaptation will always be a problem