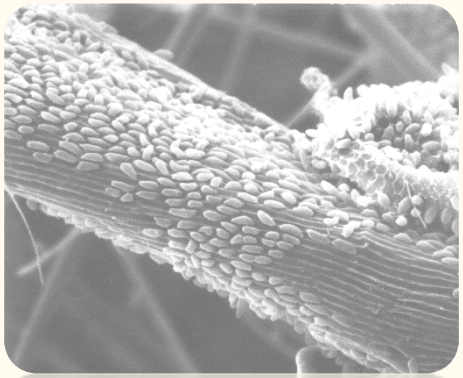
The Secret Life of Rumen Microbes



Paul Weimer, Ruminant Microbiologist
U.S. Dairy Forage Research Center, USDA-ARS

Introduction

The rumen of the dairy cow is one of the richest and most productive microbial habitats on earth.

But what exactly are these microbes?

How important are they?

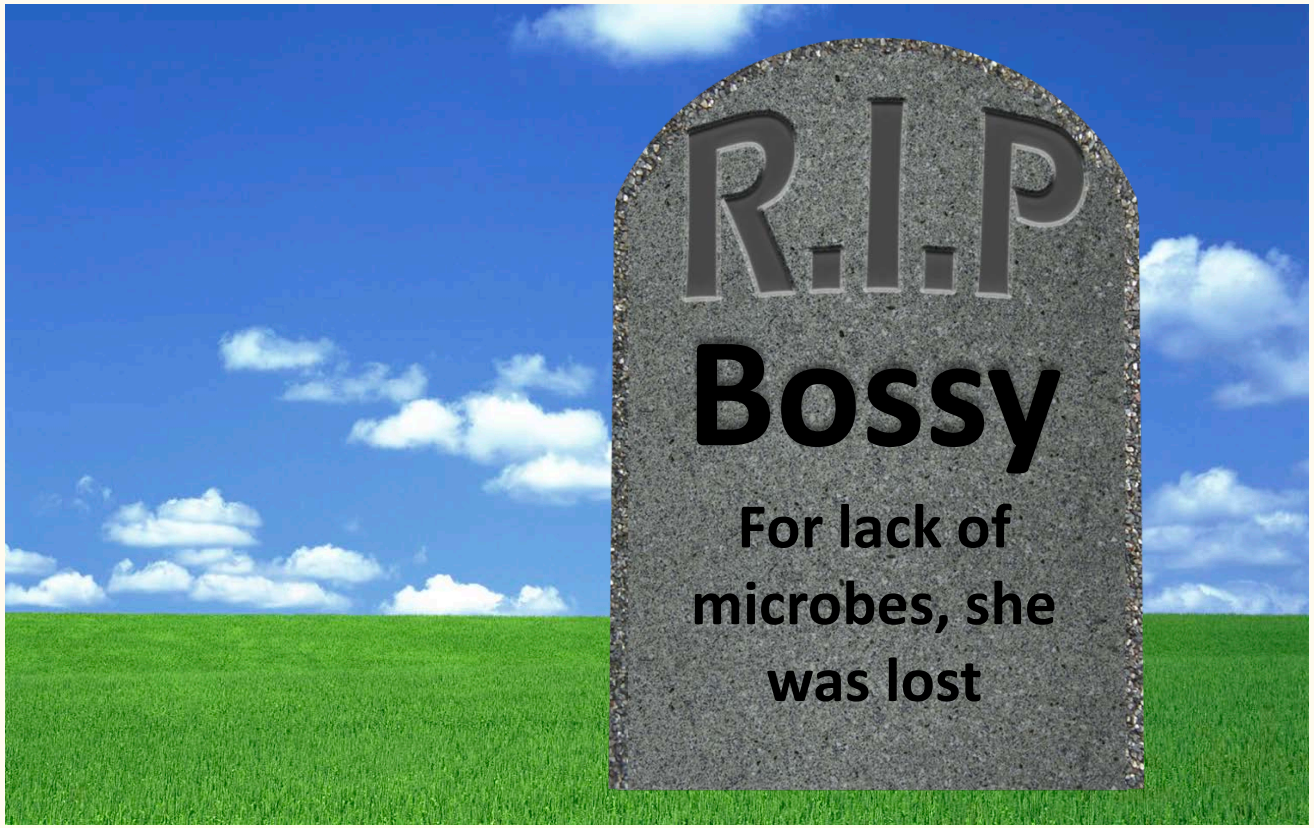
What do they do?

Can we do anything to make them do their jobs better?

QUESTION

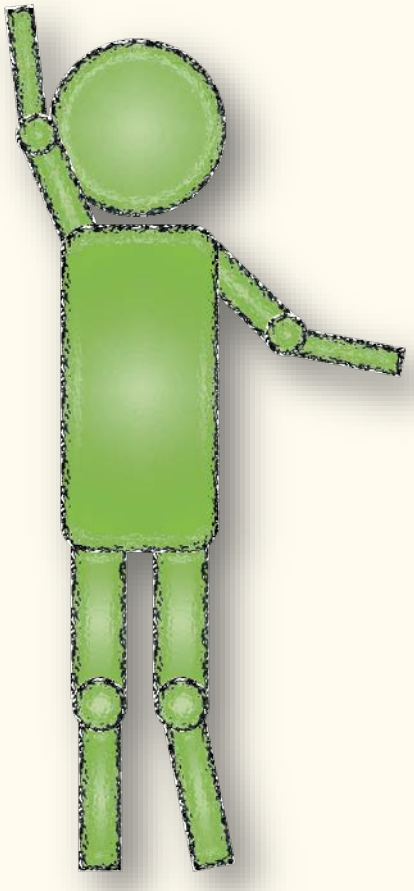
ANSWER

- **Rumen microbes are the foundation of ruminant animals: Without them the cow would die.**



QUESTION

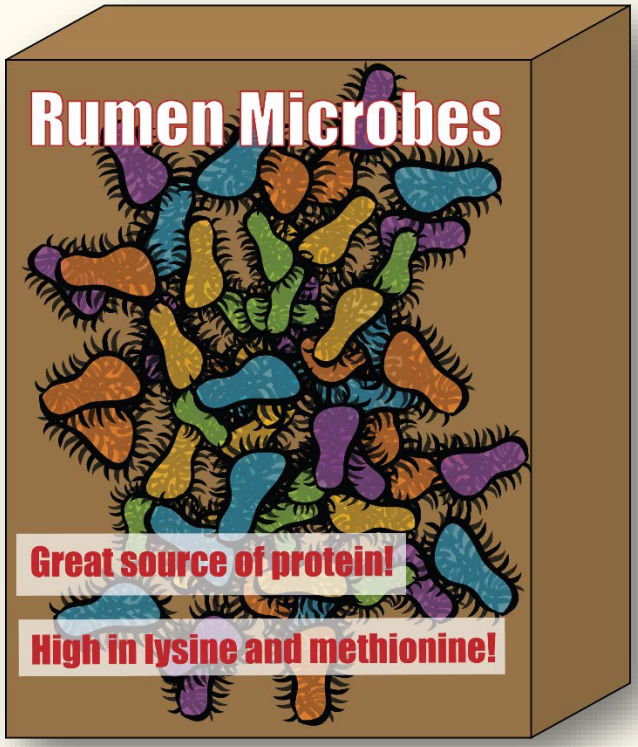
What do microbes do for the cow?



ANSWER

The microbes feed the cow! In other words, you are not feeding the cow, you are feeding the microbes. The microbes:

- **Convert carbohydrates to volatile fatty acids (VFA), the main energy source for cow and main source of fat for milk.**
- **Convert non-protein N to high-quality microbial protein, used by the cow.**
- **Metabolize some plant toxins.**



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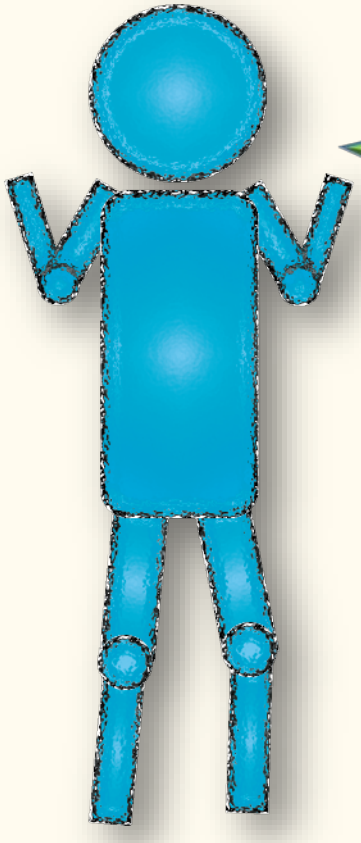
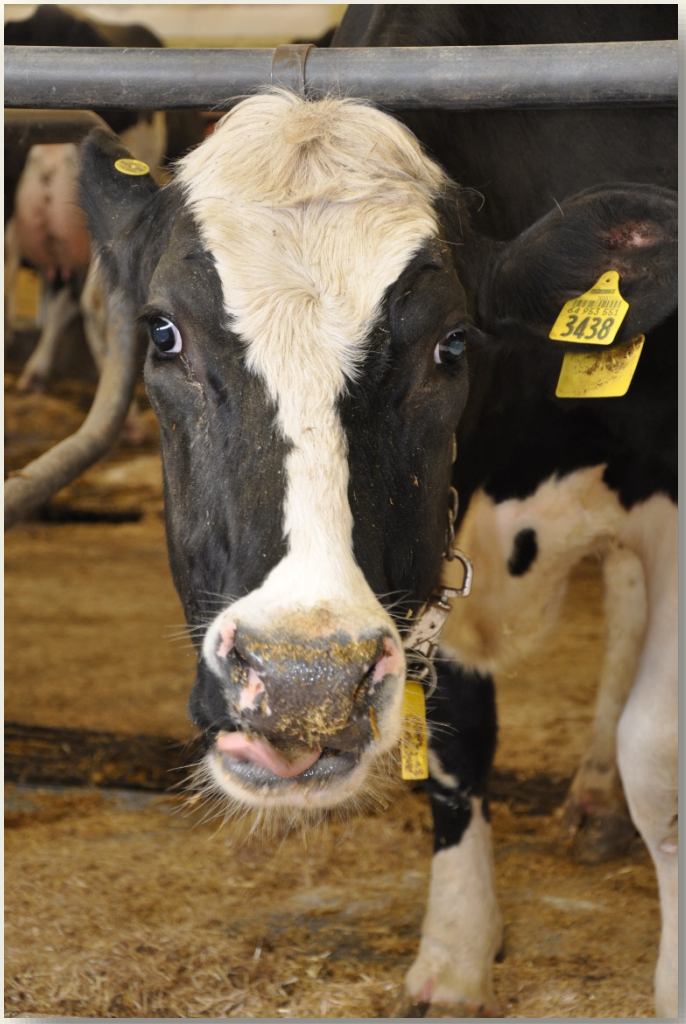


Does the cow do anything for the microbes?

ANSWER



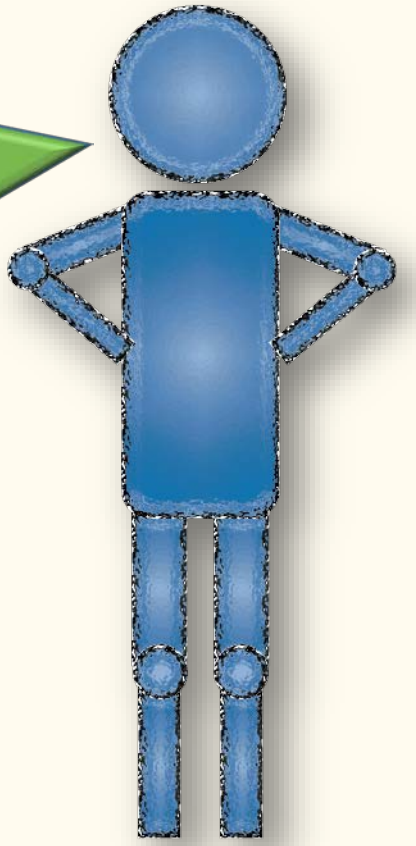
- **Ingests feeds for microbial fermentation**
- **Performs rumination to grind feed particles to small size**
- **Removes fermentation products to prevent inhibition of microbial growth**

ANSWER

- **Maintains a favorable environment for rumen microbes**
  - Anaerobic (no oxygen)
  - Temperature near microbial optimum of 102 ^{o}F
  - pH around 5.5 to 6.8

QUESTION

How were rumen microbes first discovered?



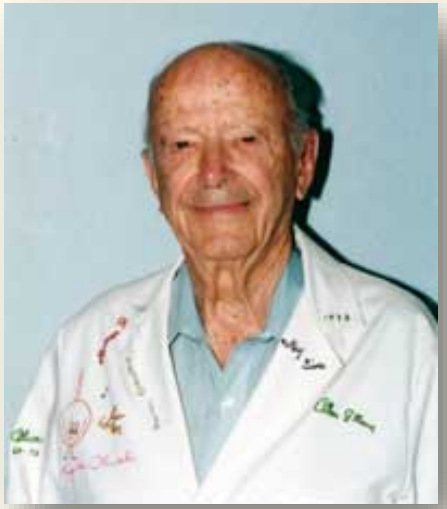
ANSWER

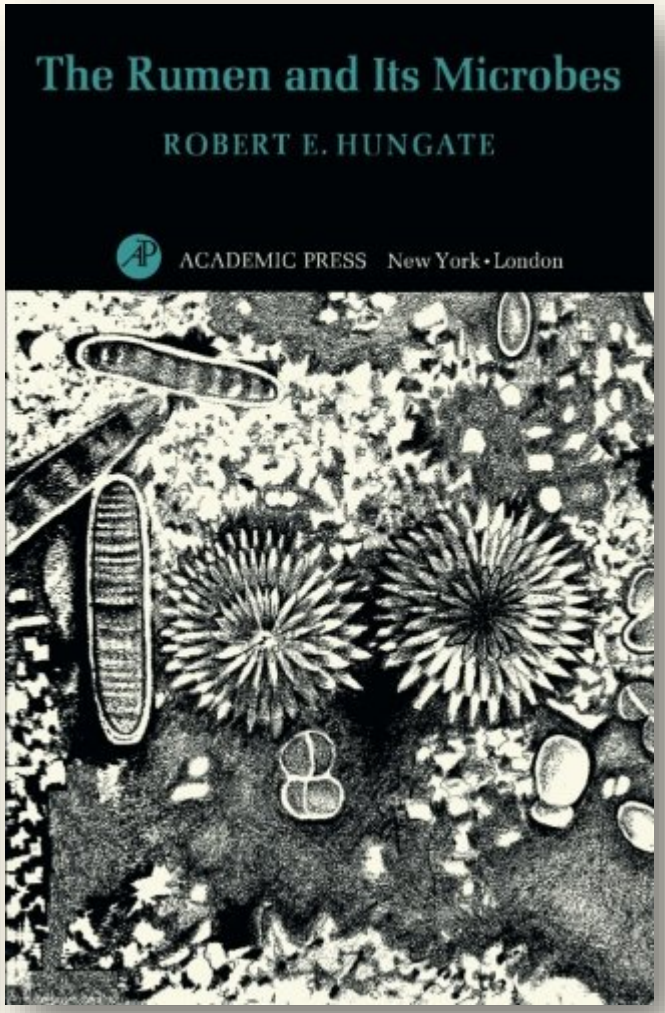
- Gmelin (1831) noted that plant fiber was converted in the rumen to acetic and butyric acids. 1831
- Gruby and Delafond (1843) – first to observe rumen microbes (protozoa). 1843
- Zuntz (1879) – determined that VFA and gas production in the rumen were due to microbial fermentation. 1879

ANSWER

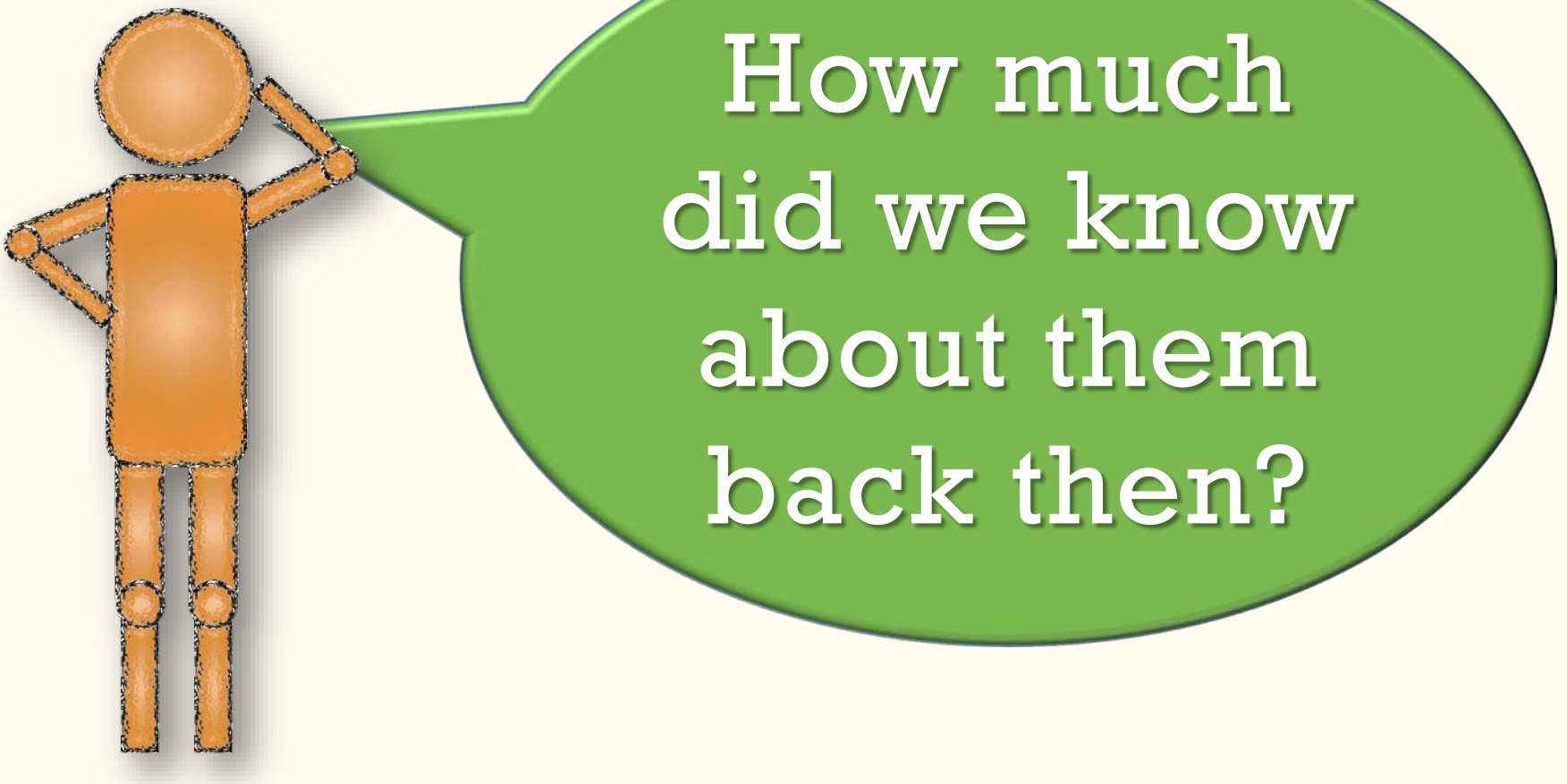
- **Hungate (1948) – developed methods for cultivating rumen microbes in the laboratory.**

1948





QUESTION

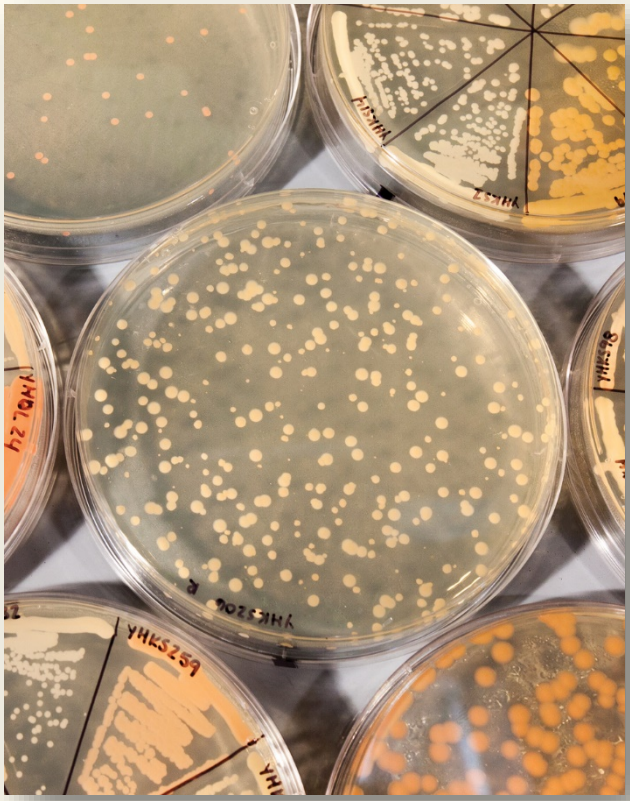


ANSWER

- **Digesta contents removed from the cow actively fermented plant material in culture vessels.**
- **Understanding microbial activities required the laborious isolation of pure cultures under anaerobic conditions.**

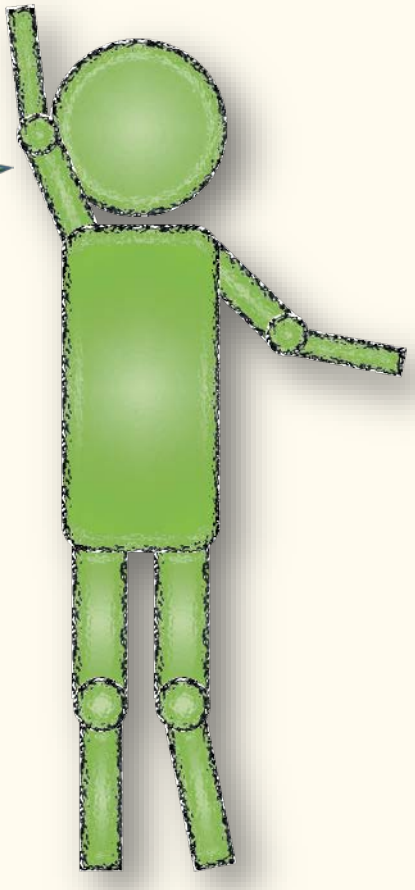
ANSWER

- **Only about 2 dozen species were isolated and their metabolic activities characterized.**
- **Rumen microbes participate in all of the important nutrient transformations in the rumen (carbohydrate and protein fermentation, methane and CO_2 production, protein synthesis).**



QUESTION

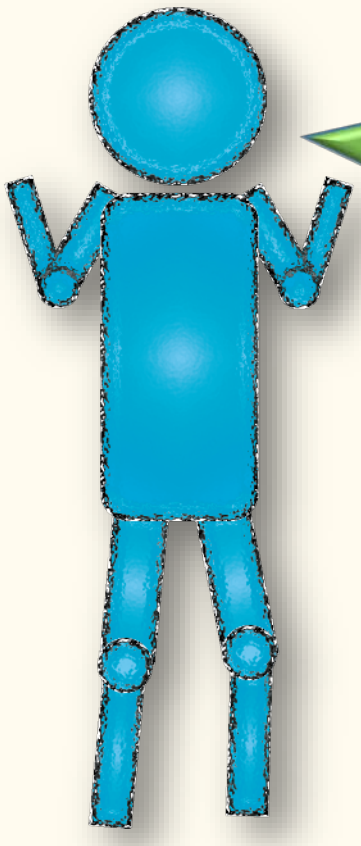
What kind of rumen microbes are there, and what do they do?



ANSWER

MICROBIAL GROUP	% of Cell Number	% of Microbial Weight	What they do
Bacteria	~ 98%	~ 60%	Ferment fiber, starch, sugars, protein, and more
Archaea	1%	< 1%	Produce methane gas
Protozoa	1%	~40%	Eat bacteria, ferment starch
Fungi	< 1%	1-3 %	Help break down fiber

QUESTION



Are there "good" and "bad" rumen microbes?

A N S W E R

Well, sort of…..

“Good bugs”

- Fiber digesters
- Most other carbohydrate fermenters
- Lactic acid degraders
- Detoxifiers

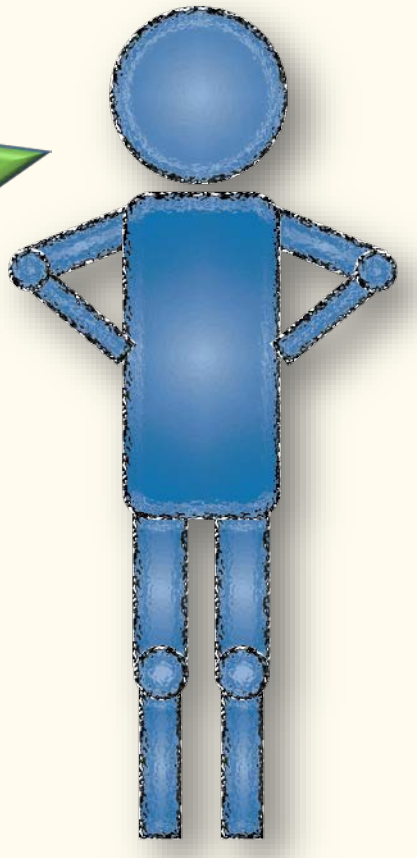
“Bad bugs”

- Methane producers
- Hyper ammonia-producers
- t10,c12-CLA producers
- Protozoa

IMPORTANT POINT: Because the microbes function as an interactive community, some seemingly “bad bugs” are still necessary for proper rumen function!

QUESTION

What changed our ability to learn more about the microbes?



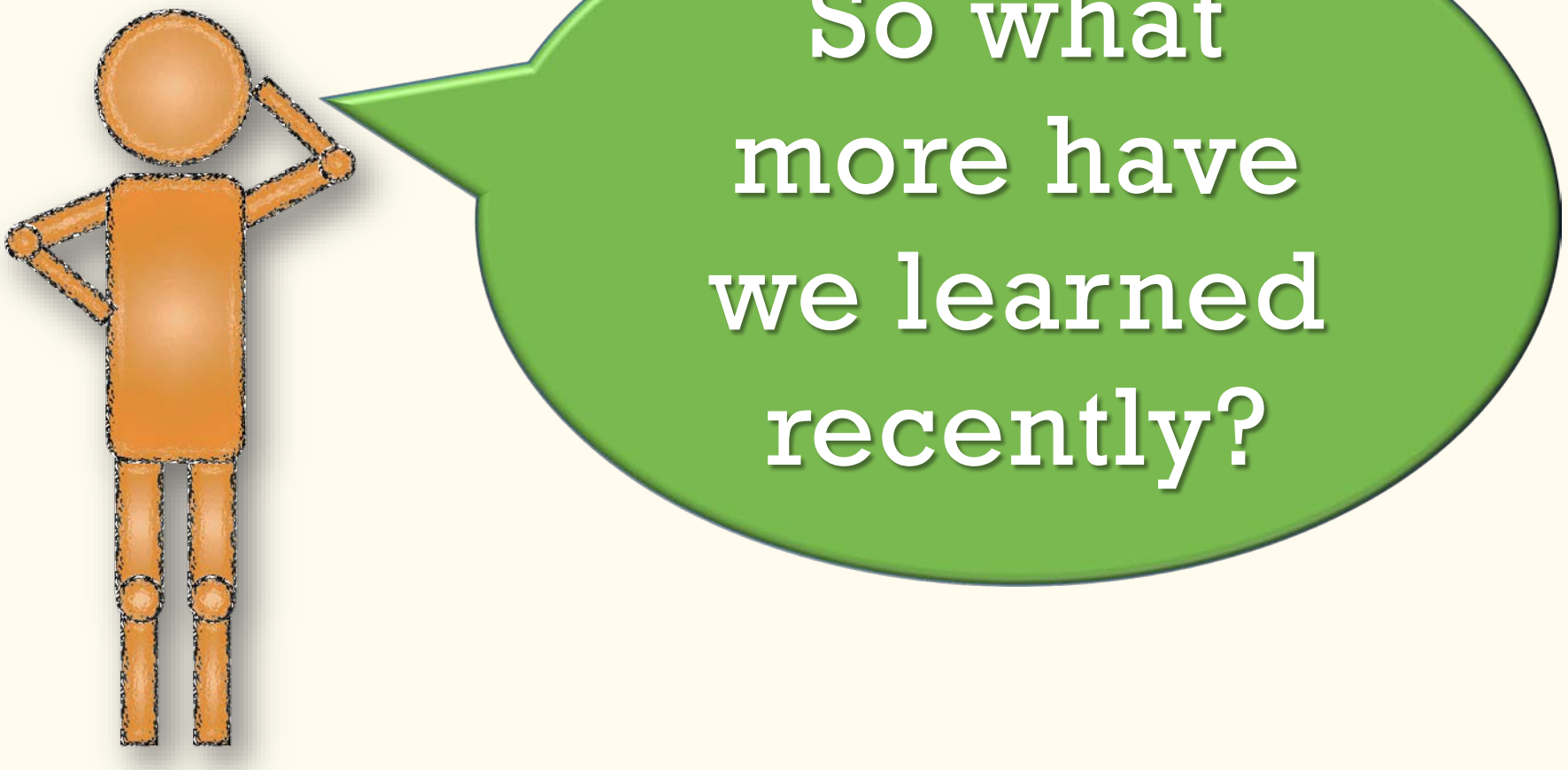
A N S W E R

The techniques of molecular biology

Whole-genome sequencing	→	Metabolic capabilities of individual species
Community fingerprinting methods Quantitative PCR Metagenomic sequencing	→	Species composition and abundance

Microbiologists now have the ability to track specific populations within the rumen and determine how these are impacted by feeding and management, and how they relate to animal performance.

QUESTION



ANSWER

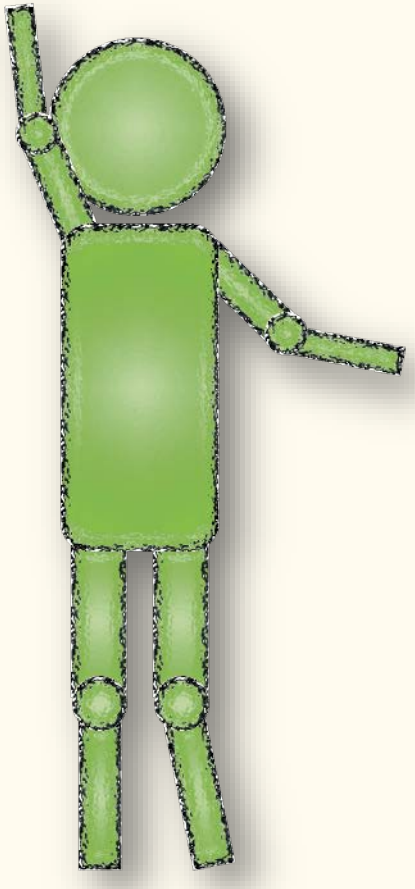
- **Only ~10% of the species in the rumen have been identified and cultured in the lab.**
- **Each cow contains a small set of microbial species (the "core microbiome") present in nearly every cow.**

But,

The overall microbial community is unique to each individual cow. ***A cow and her rumen microbes are well-matched partners.***

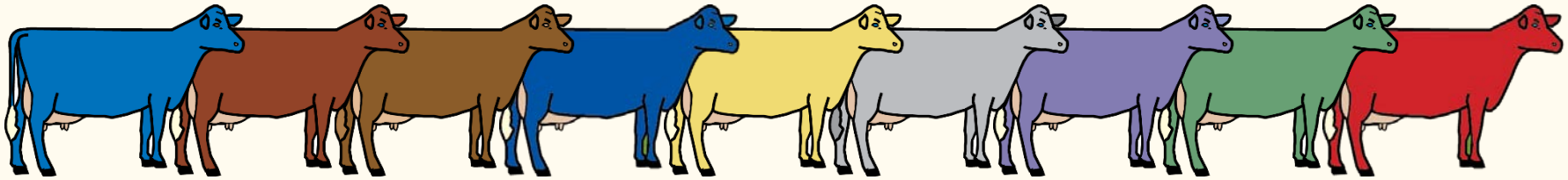
QUESTION

How stable is the microbial community in the rumen?



ANSWER

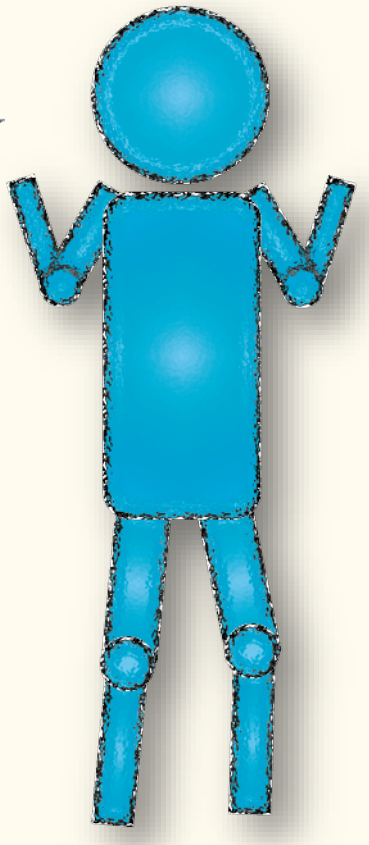
- **The community is very dynamic, with changes within and across daily feeding cycles, *but***
- **Overall, the community is relatively specific for each cow.**



- **The community displays “functional redundancy”.**
- **The community is surprisingly resilient when changes are introduced.**

QUESTION

What type of research is taking place right now?

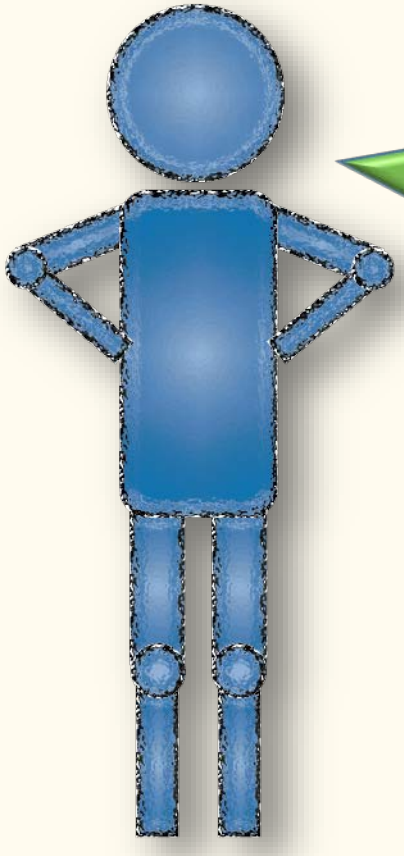


A N S W E R

- **Linking specific members of the rumen community to nutritional outcomes**
  - Feed efficiency
  - Milk fat production
  - Rumen acidosis
- **Search for new ways to control undesirable microbial activity**
  - Methane production

Evaluating the role of the rumen community in affecting health, immune response, etc.

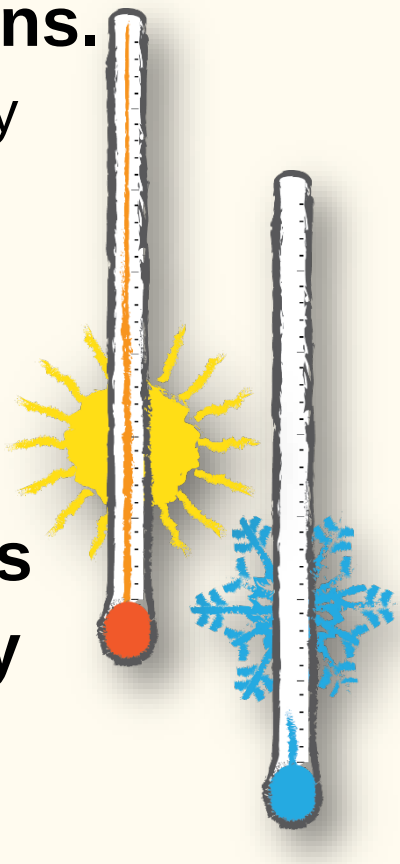
QUESTION



What can you do to help a cow's microbes work better?

ANSWER

- **Avoid sudden changes in rumen conditions.**
  - Introduce new feed sources and rations gradually over the course of several feedings.
  - Avoid pushing rumen temperatures outside the comfort zone of the microbes
    - Cold water, frozen silage
    - Heat stress
- **Recognize that the microbial communities of individual cows will respond differently to the same feeding and management.**



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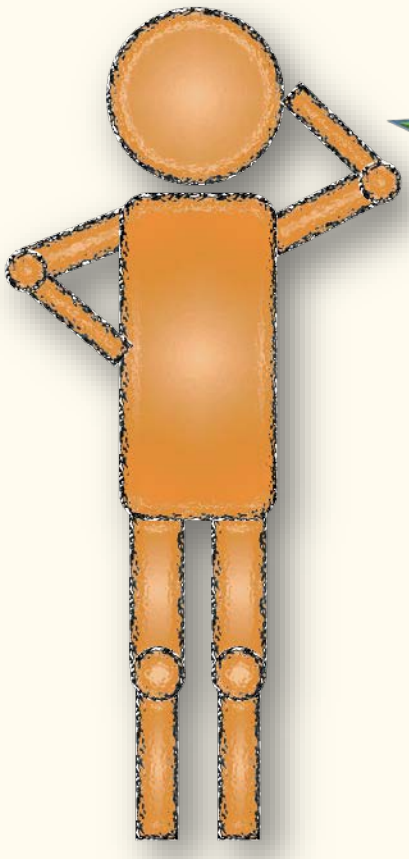

What do we still need to learn?

I have given years of study to the dairy cow and I believe I know a good deal about her, but more and more I am convinced that the darkest place in the world is the inside of a dairy cow. Chemists have their laboratory, mechanics may have their machines, but no man knows how the dairy cow transforms the hay and grain she eats into milk.

W.D. Hoard, Editor
Hoard's Dairyman, ca. 1885

We know much more today about the rumen than we did in 1885, but we still have much to learn.

A N S W E R

- **What exactly are those other 90% of the community doing?**
- **Can we dictate rumen community composition by how we feed and raise the calf or heifer?**
- **How can we get probiotic strains to persist in the rumen?**
- **Can rapid testing of the rumen community composition guide us to feeding cows more intelligently?**