Enteric Fermentation / Enteric Methane

Tim Kurt, DVM, PhD
Foundation for Food and Agriculture Research (FFAR)

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Introduction/Background

Tim:

- Studied veterinary medicine and molecular biology, focusing on the determinants of susceptibility to cross-species infection and zoonotic diseases. Expertise with *in vivo* and *in vitro* models; small molecule inhibitors.

- Scientific Program Director for the Foundation for Food & Agriculture Research's (FFAR) Advanced Animal Systems Challenge Area and ROAR Programs since 2016.

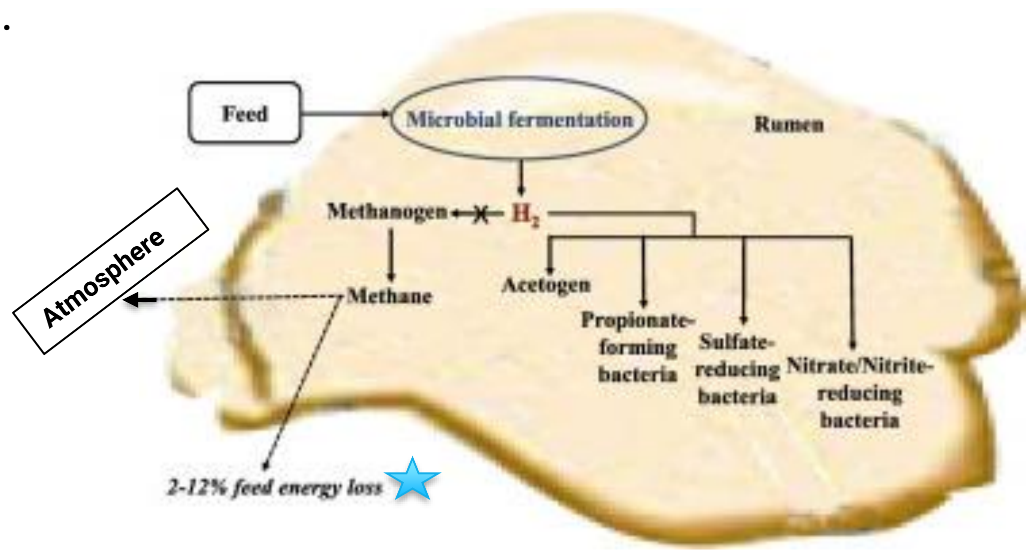
FFAR:

- FFAR is a Federally funded ($385M to date) nonprofit; supports research addressing food and agriculture challenges via 1:1 matching to non-Federal sources (e.g. State, sovereign, private).

- Relevant portfolio includes investigation of *Asparagopsis* farming and in vivo trials for enteric methane mitigation, other projects involving animal health / productivity and environmental impact.

Enteric Fermentation – Background

- Approximately 26.7% of methane (CH4) emissions in the **U.S.** are attributed to enteric fermentation in ruminants, corresponding to approximately **2.7% of total GHG emissions** in the US (EPA, 2019).
- Total emissions from **global** livestock: 7.1 Gigatonnes of Co2-equiv per year, representing 14.5 percent of all anthropogenic GHG emissions (Gerber, 2013). 39% is attributed to enteric methane= **2.77 Gt Co2-equiv**; **5.66% total anthropogenic GHG emissions**.



- Rumen volume: 200L
- Gas, fibrous mat and fluid compartments
- Hardware (magnets, rumen bolus) is commonly placed within rumen for life of animal

★ Can 12% energy loss attributed to methane be recovered?

Enteric Methane – Chemistry

Plants → Carbohydrates / Oligosaccharides

↓

Pyruvate

↓

- Acetate + 2H.
- Butyrate + 2H.
- Propionate (net incorporation of 2H).

- ➢ H inhibits carbohydrate fermentation.
- ➢ CH_4 is the main sink of H in the rumen.
- ➢ CO_2 + 8H → CH_4 + 2H2O
- ➢ 30-50L gas eructation per hr
- ➢ Concentration of dissolved H_2 is near 1 μM (partial pressure of near 140 Pa)

Possible Strategies & Considerations

- Enzyme inhibitor targets
  - methyl-CoM reductases, e.g. 3NOP
  - methyl transferases, e.g. bromoform (→ ozone depletion, toxicity)
- Vaccination
  - Difficult to achieve sufficient antibody levels in rumen (CSIRO)
- Genetics/rumen microbiome
  - Genetic improvement: reductions per unit volume of meat/milk
  - Rumen microbiome poorly heritable; thus can be targeted separately
  - Ruminal methanogenic archaea are highly conserved globally
- Diet
  - High grain, low forage.
  - Nitrates. Reduced to nitrite → toxicity
  - Producers of propionate (*Quinella ovalis*), lactate, and succinate (*Fibrobacter, Succinivibrionaceae* spp.)
- Others options
  - Bacteriophages (unlikely due to volume of distribution)
  - Hardware-based hydrogen/methane scavengers
  - Cofactor competitors (e.g. coenzyme M analogs)

Enteric Methane - Resources

Rumen Microbial Genomics Network:
    http://www.rmgnetwork.org/

Methanotroph Consortium:
    http://www.methanotroph.org/wiki/introduction/

State of the Art Methane Inhibitors

Example 1: 3-Nitrooxypropanol (3NOP)

Established efficacy and safety. ~30% reduction in methane.
Registered in Europe; Not FDA-approved for use in U.S.
No growth promotion/productivity gain; little incentive for adoption without State/Federal mandates or carbon credits.

Example 2: Garlic oil

Generally recognized as safe (GRAS). May alter rumen microbial populations.
Questionable efficacy; needs controlled trials.
Not registered in EU or U.S.; labeled as a feed "flavoring" and used off-label for methane reduction.

Example 3: *Asparagopsis* seaweeds

80-90% methane reduction at low inclusion in diet. MOA unclear.
Possibly has <u>substantial productivity gains</u>; needs to verified.
Regulatory pathway unclear (Drug or Feed Additive? Both FDA).
Safety concerns – bromoform, iodine.
No commercial source and difficult to cultivate.
Rapidly expanding field of startups competing for first in market.

Enteric Methane - Strategies

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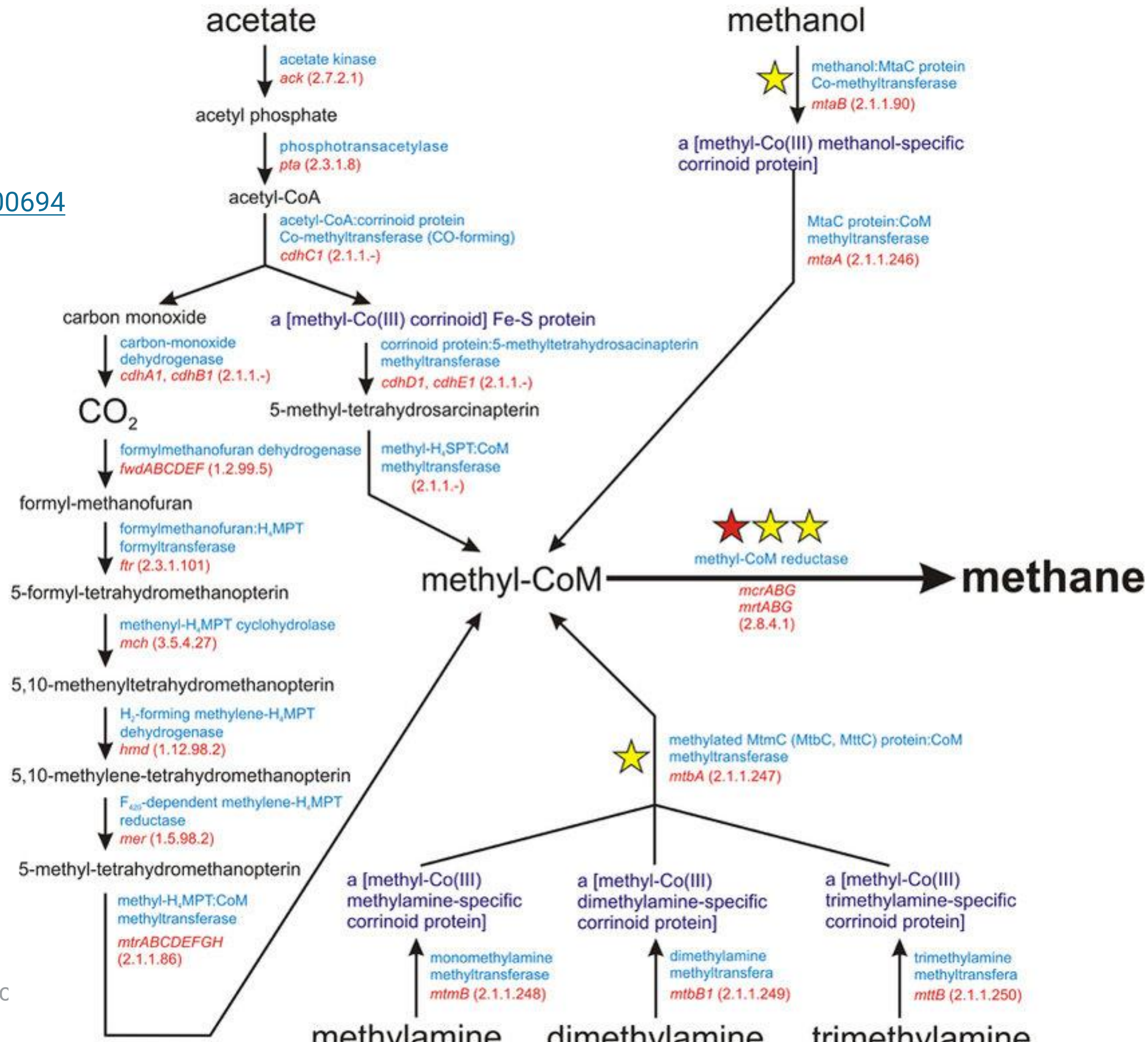

CHANGING WHAT'S POSSIBLE

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Extra Slide – Rumen Chemistry

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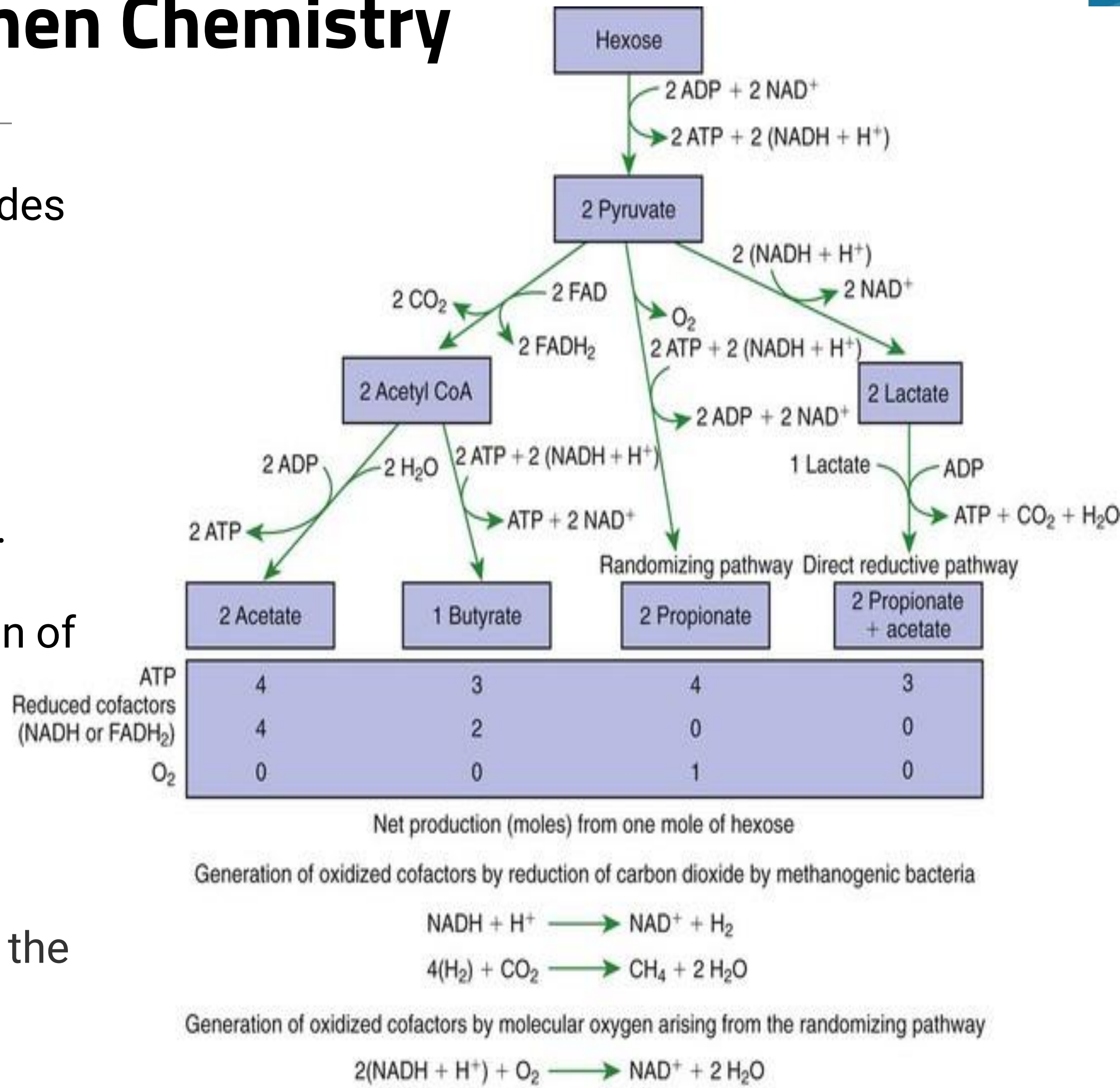
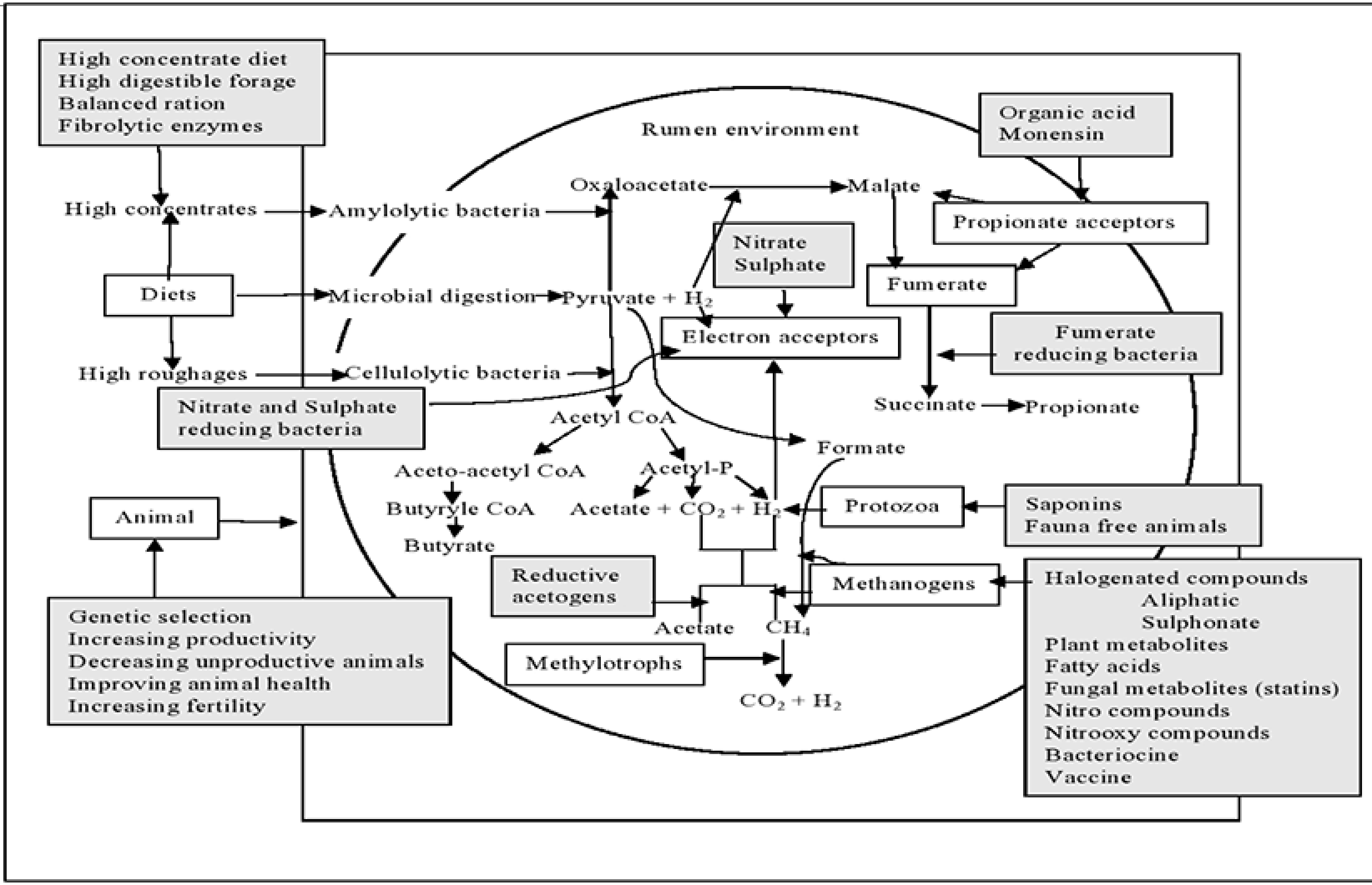


https://veteriankey.com/digestion-the-fermentative-processes/

Extra Slide – Enteric Methane Inhibitors



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