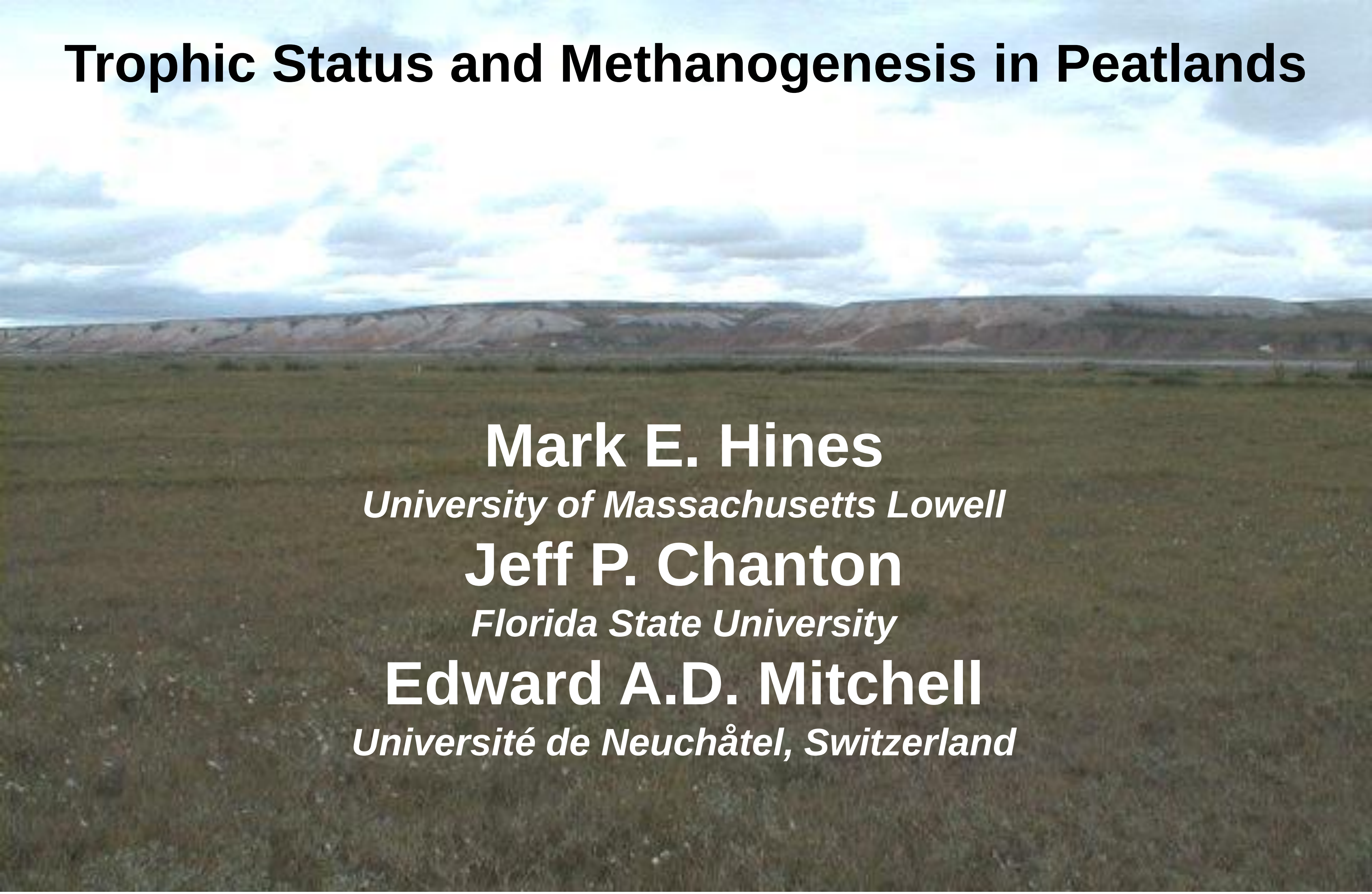
Trophic Status and Methanogenesis in Peatlands



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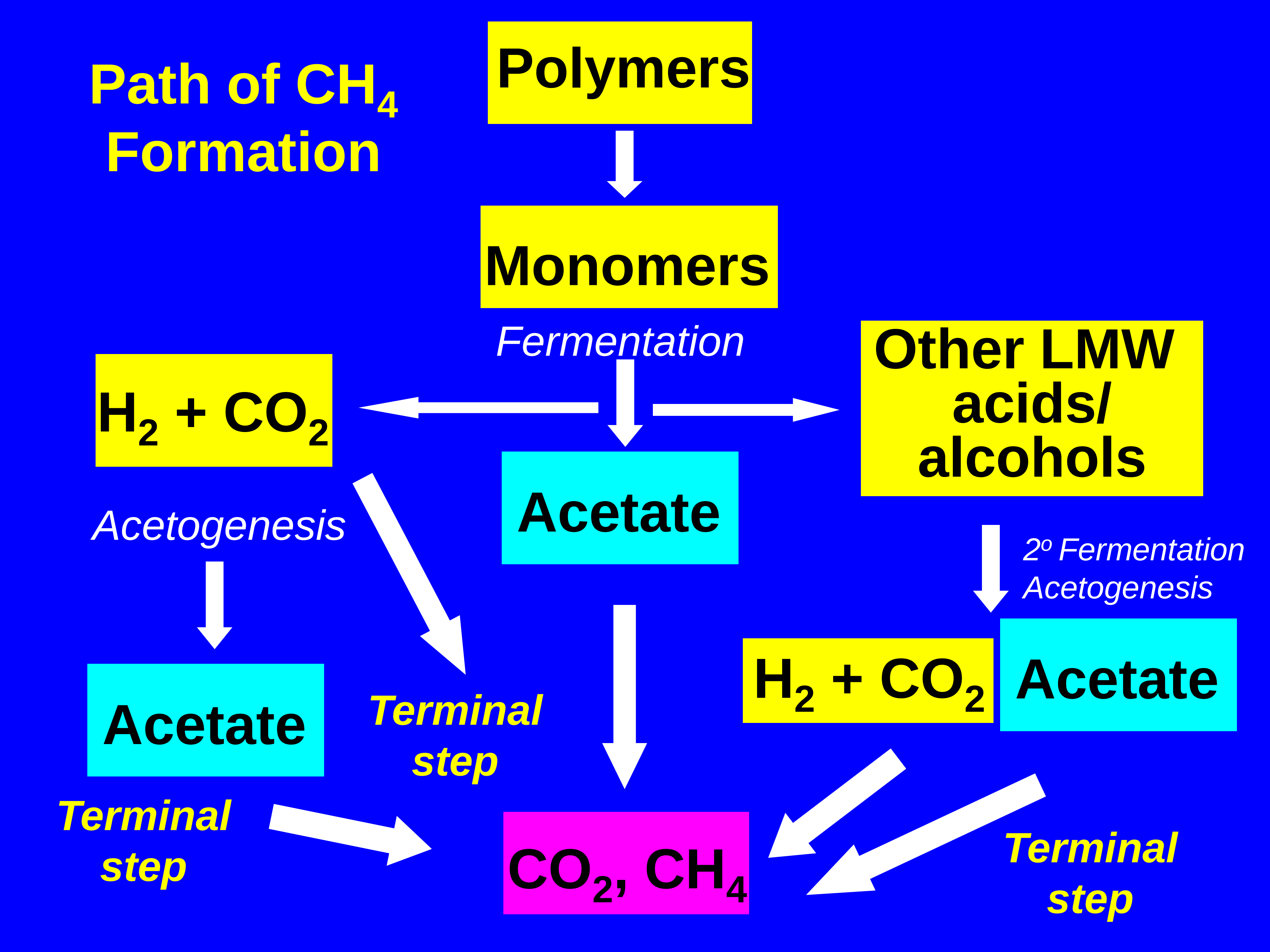

Path of CH_4 Formation
Polymers
Monomers
Fermentation
$H_2 + CO_2$
Other LMW acids/ alcohols
Acetate
Acetogenesis
2º Fermentation
Acetogenesis
$H_2 + CO_2$
Acetate
Acetate
Terminal step
Terminal step
Terminal step
CO_2, CH_4

Which Pathway Matters?

In typical anaerobic systems

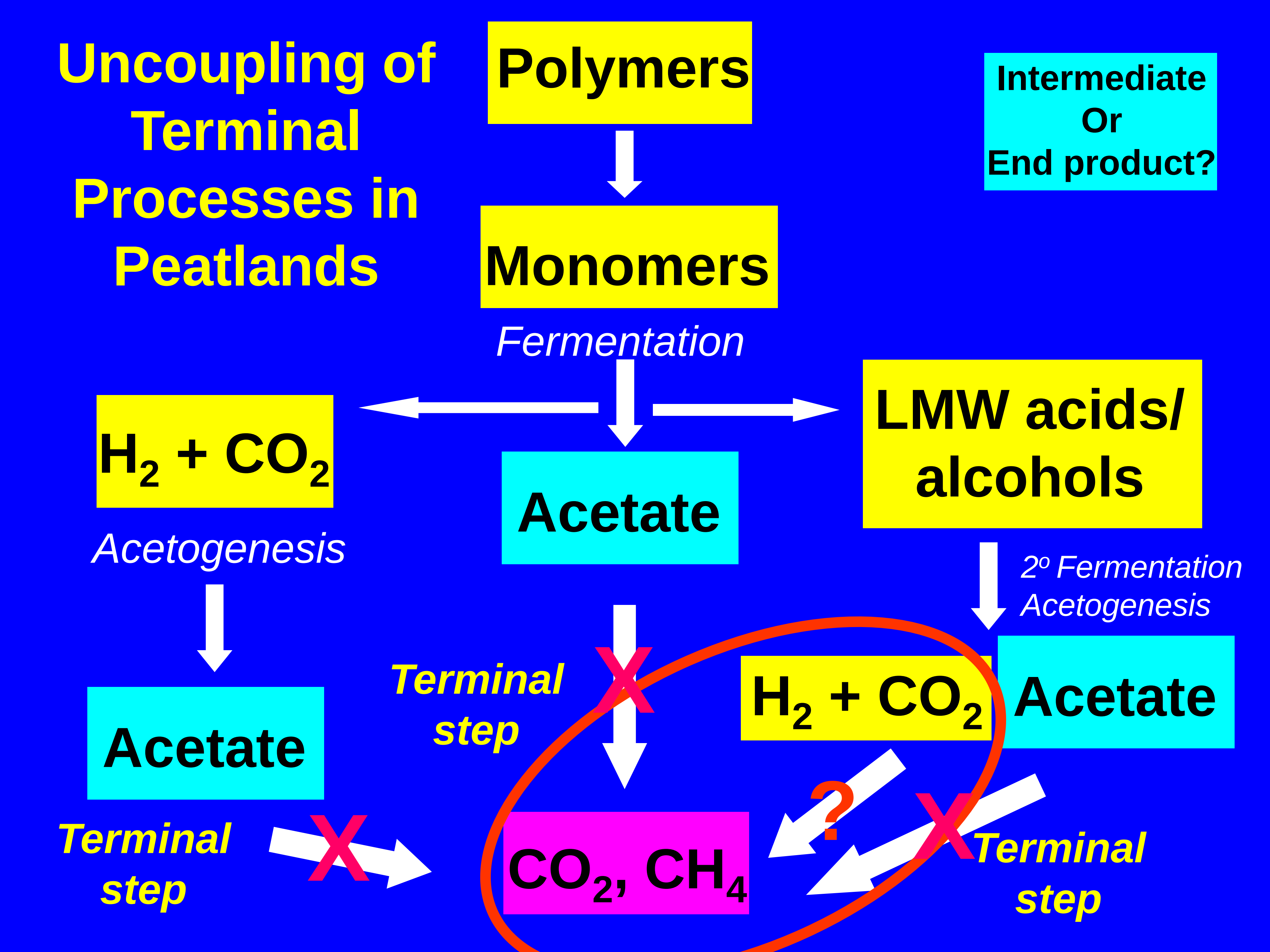
e.g., freshwater and marine muds, sewage sludge, intestinal tracts

2/3 of CH_4 is derived from acetate

1/3 from H_2/CO_2

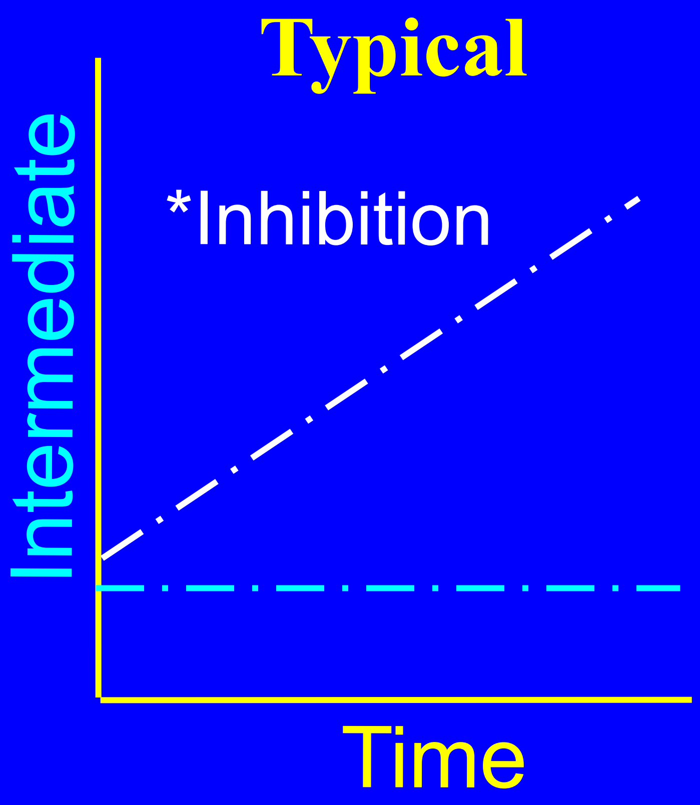
Ideal conditions: Ratio of $CO_2:CH_4 = \sim 1$

In some marine systems, C-one compounds can be quite important


Uncoupling of Terminal Processes in Peatlands
Polymers
Intermediate Or End product?
Monomers
Fermentation
$H_2 + CO_2$
Acetate
LMW acids/ alcohols
Acetogenesis
2º Fermentation Acetogenesis
Terminal step
X
$H_2 + CO_2$
Acetate
Acetate
?
X
Terminal step
X
CO_2, CH_4
Terminal step

Turnover of *in situ* Intermediates

Monomer → acetate → X CO_2 + CH_4



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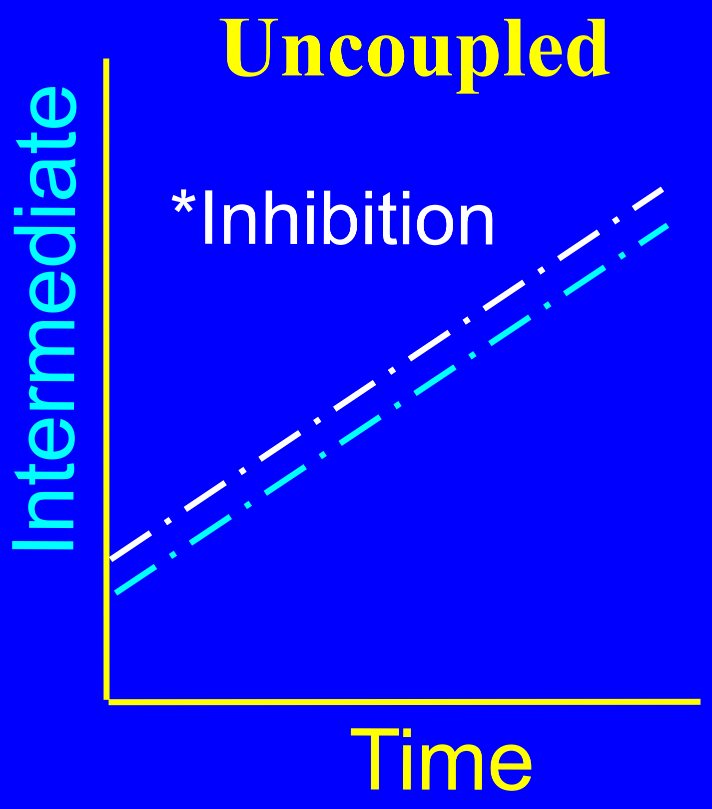
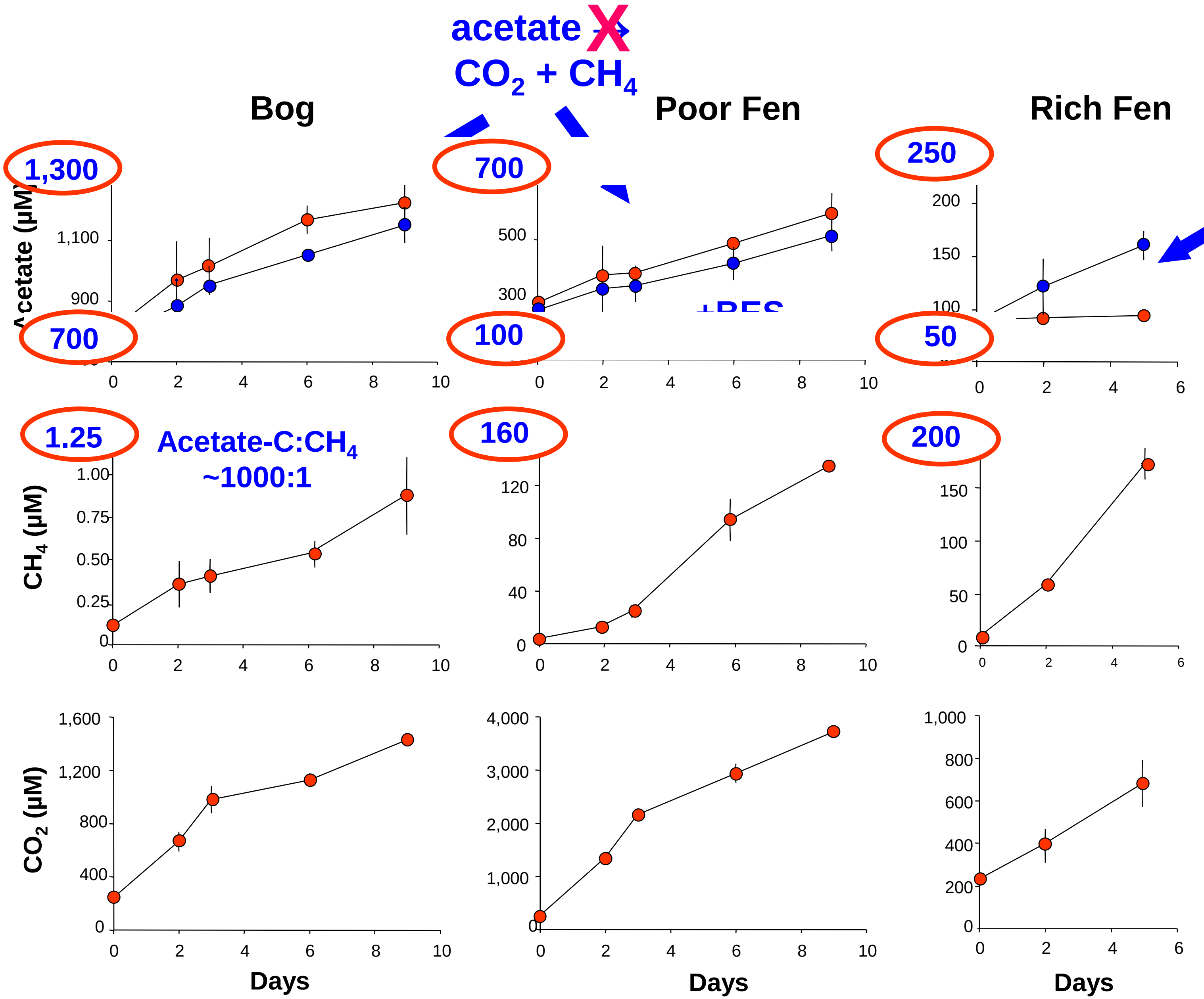
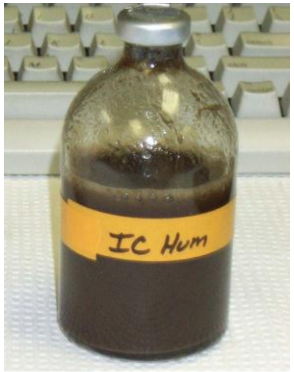


Trophic Status Affects Pathway



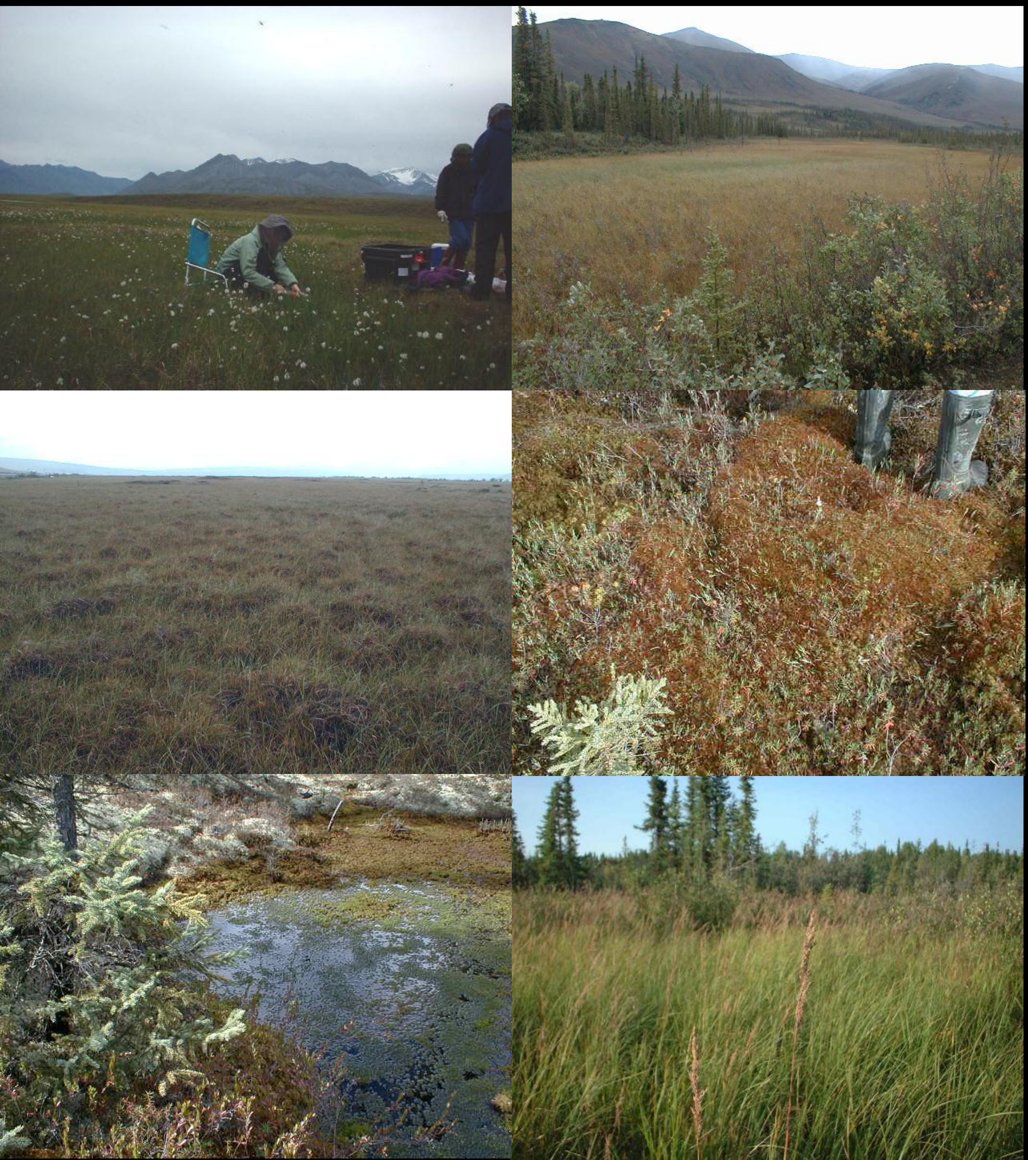


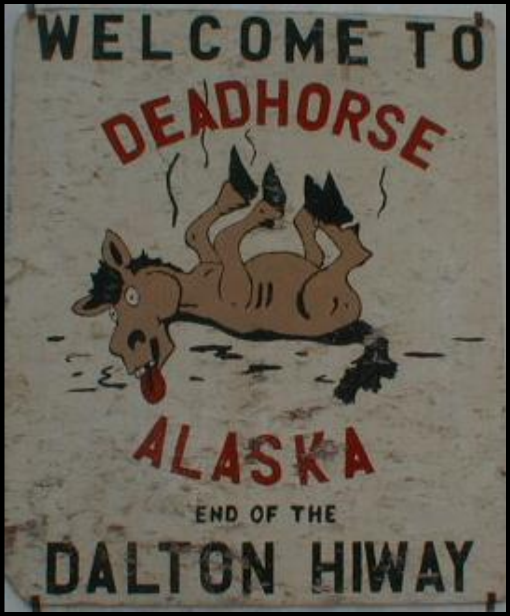
Questions

- **How ubiquitous?**
- **Are acetotrophs not present, or not active?**
- **Does it vary seasonally?**
- **What happens with alternate electron acceptors?**
- **What about other organic acids (or alcohols)?**
- **How might climate change affect decomposition path?**
- **Is elevation a surrogate for latitude?**
- **Do other compounds behave like acetate?**

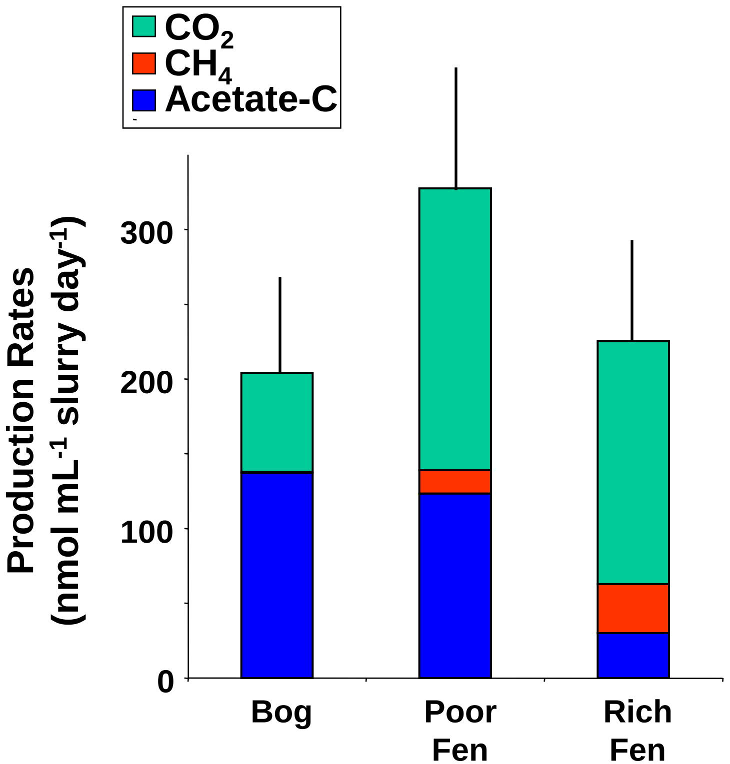
Alaskan Study Sites

Grouped sites by trophic status (vegetation cover)



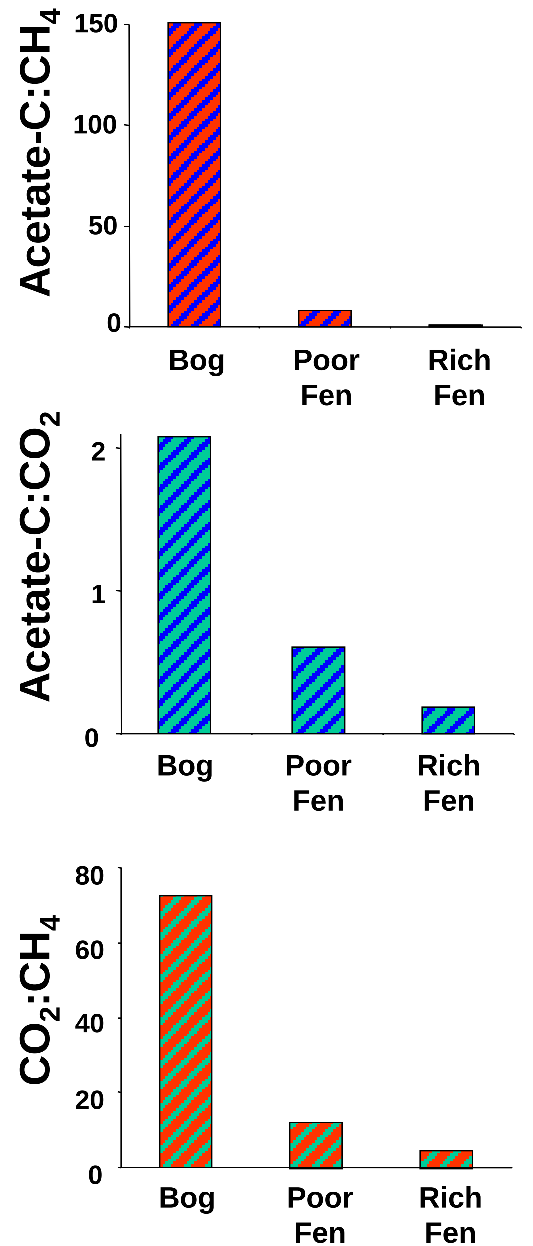


Path of Anaerobic C Flow Varies with Vegetation Cover



CH_4 production increases with trophic status, but total C flow does not vary greatly (acetate remains important)

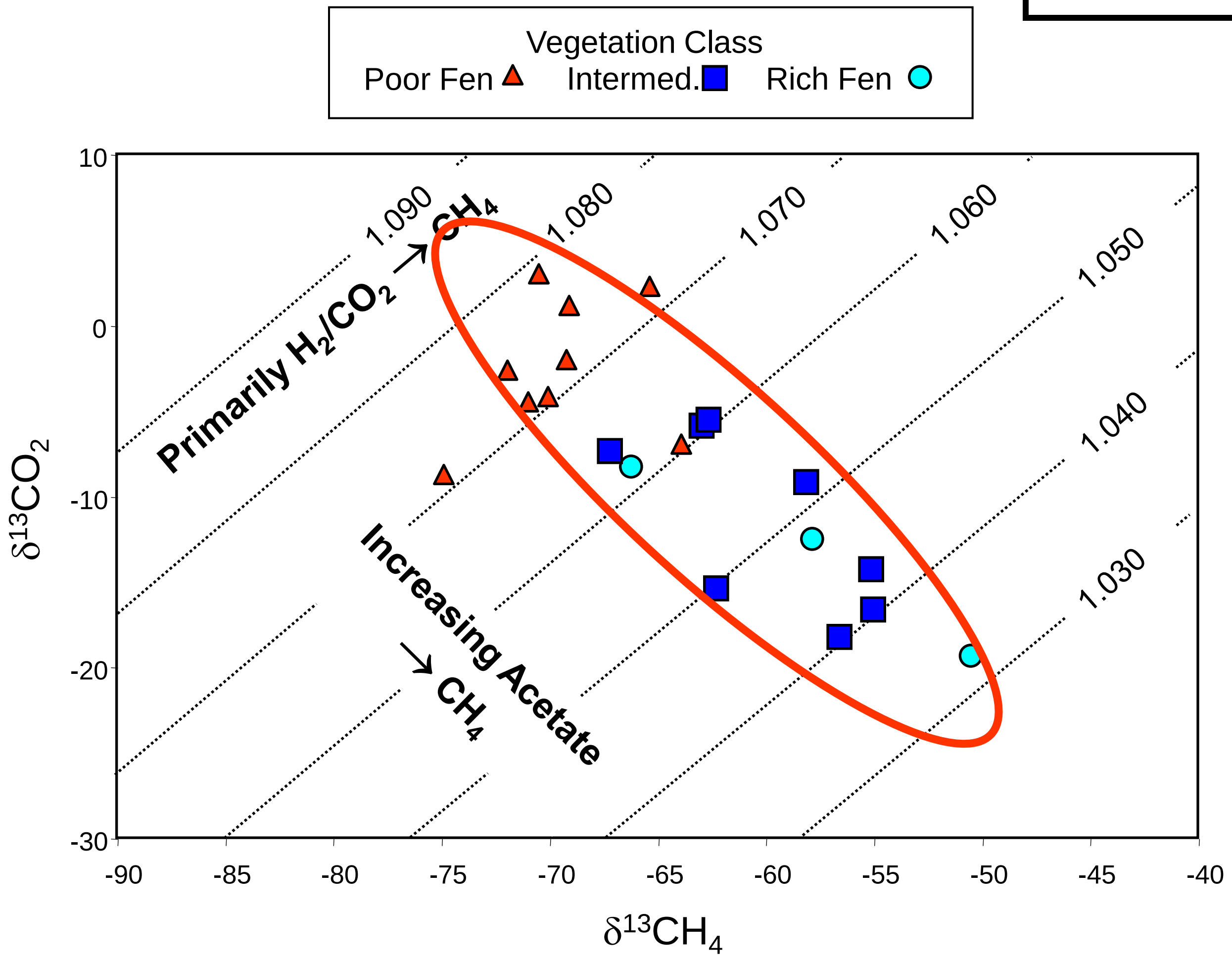
Ratios



Stable C Isotopes and CH_4 Production Path

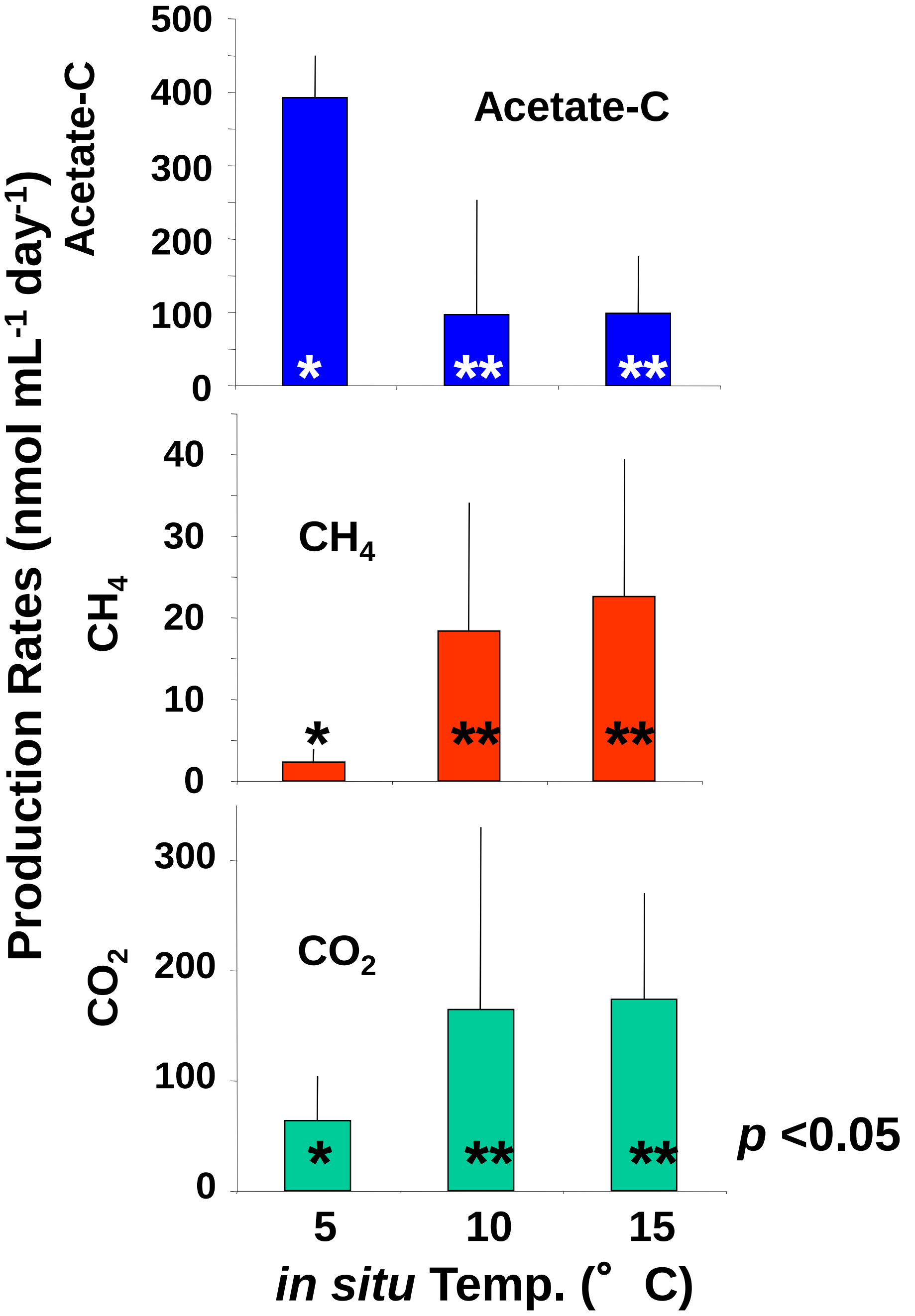
$$\alpha = \frac{\delta^{13}CO_2 + 1000}{\delta^{13}CH_4 + 1000}$$

Sphagnum* → *Carex



Temperature Affects Pathway

Temperature increases CH_4 and CO_2, but acetate production is highest at low temperature



Incubation temperature similar to in situ *temperature*

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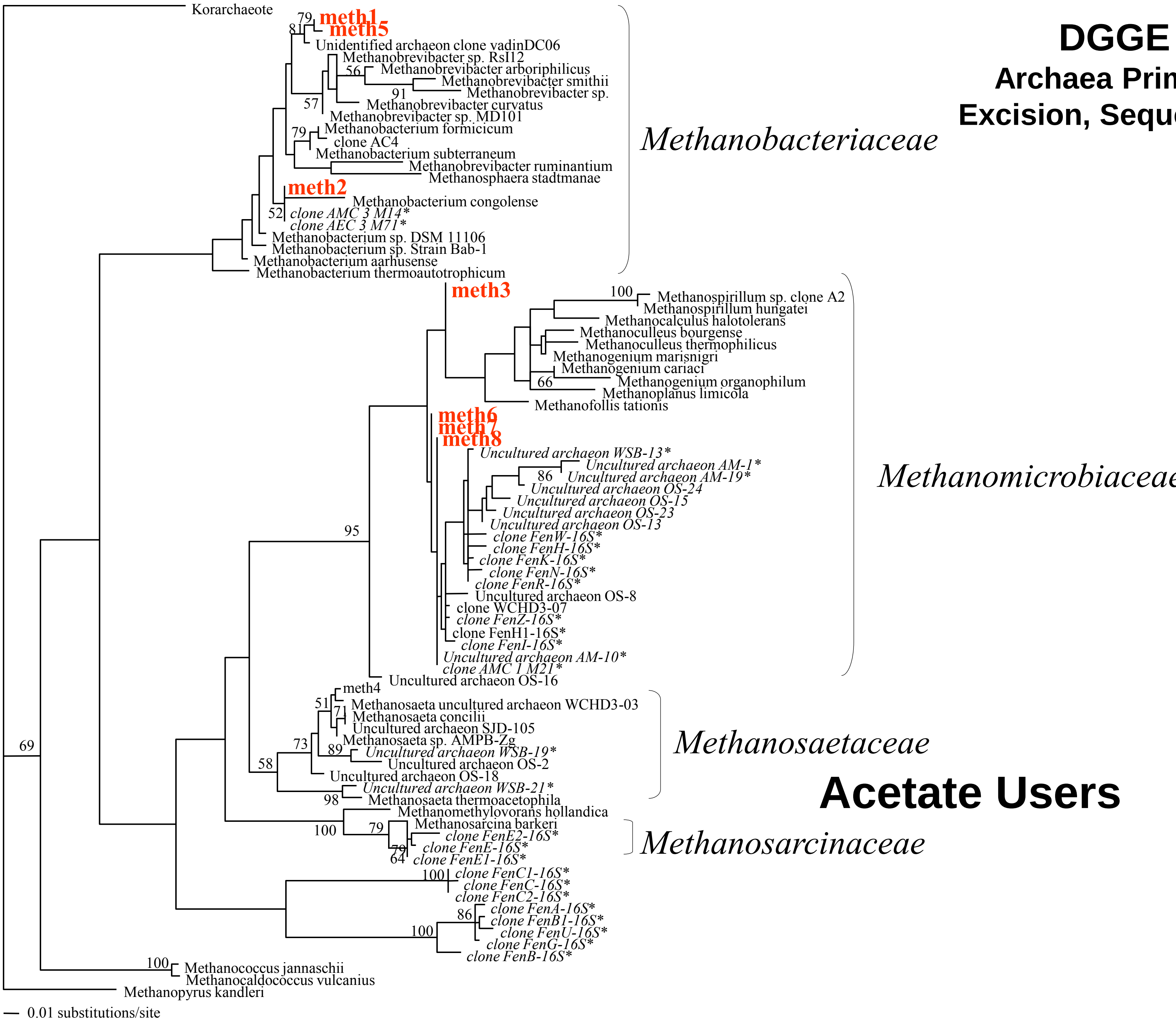
DGGE

Archaea Primers
Excision, Sequencing



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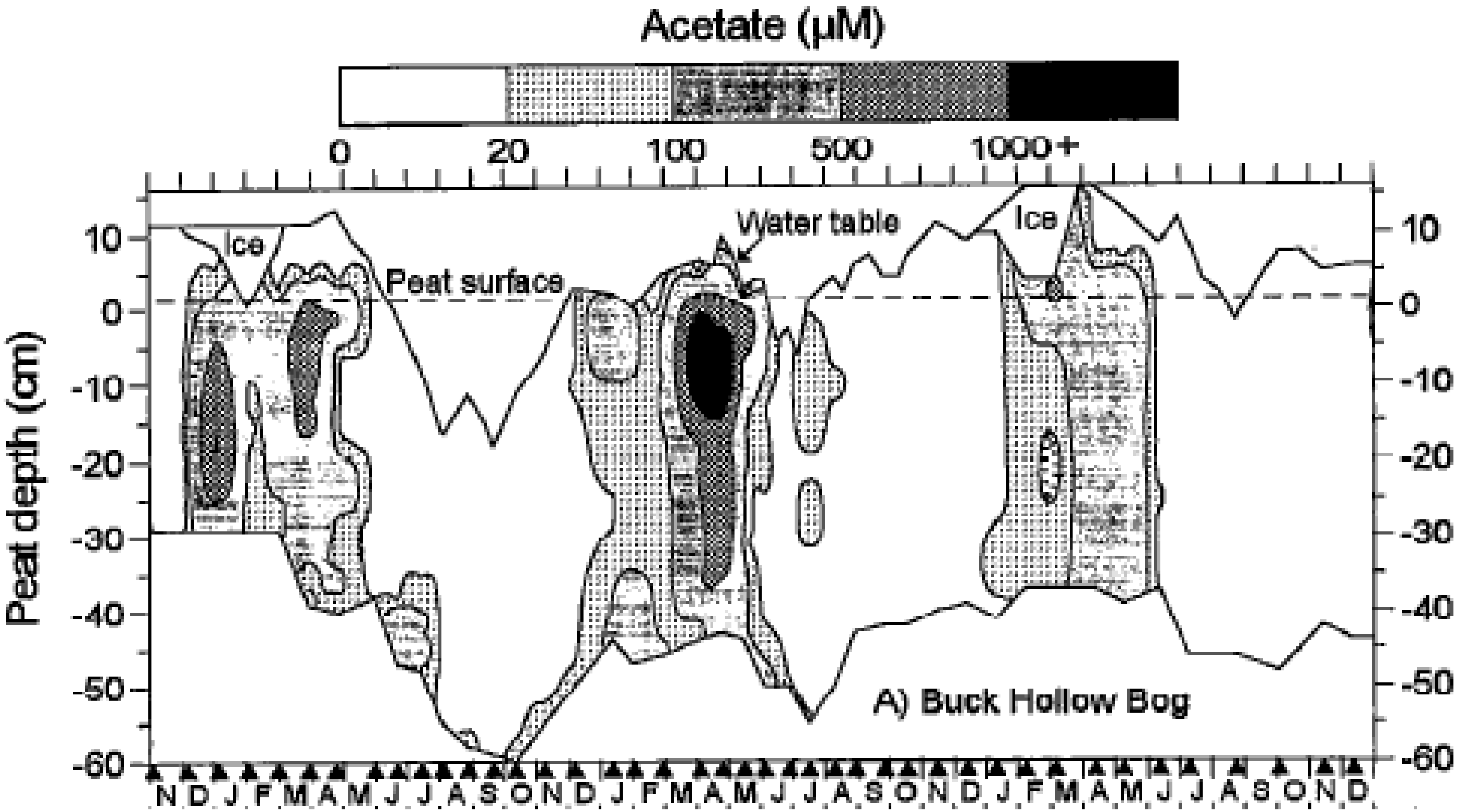
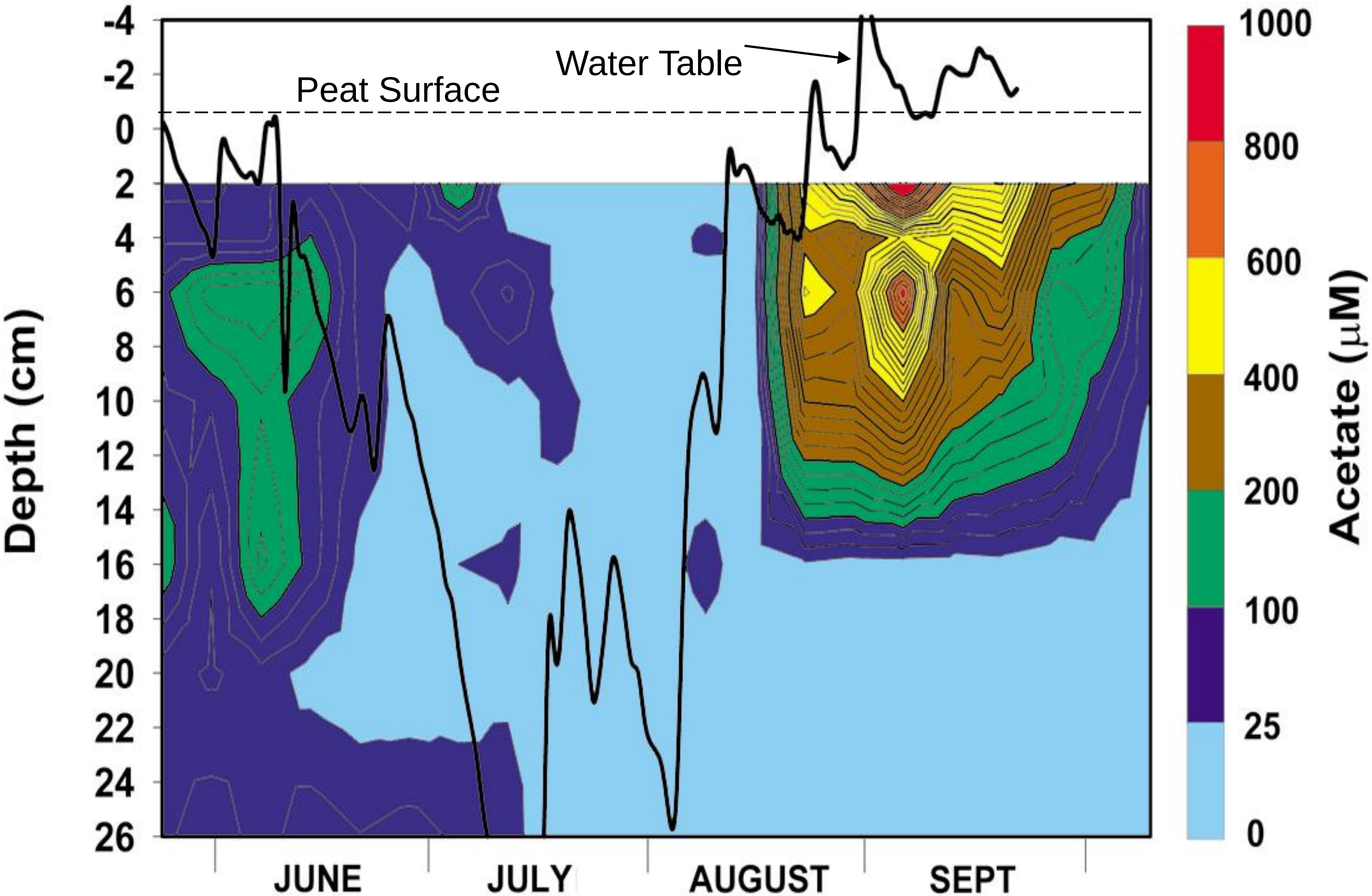
In Temperate Bogs, Acetate Becomes a Source of CH_4 After a Spring Lag ("Acetotrophic Switch")

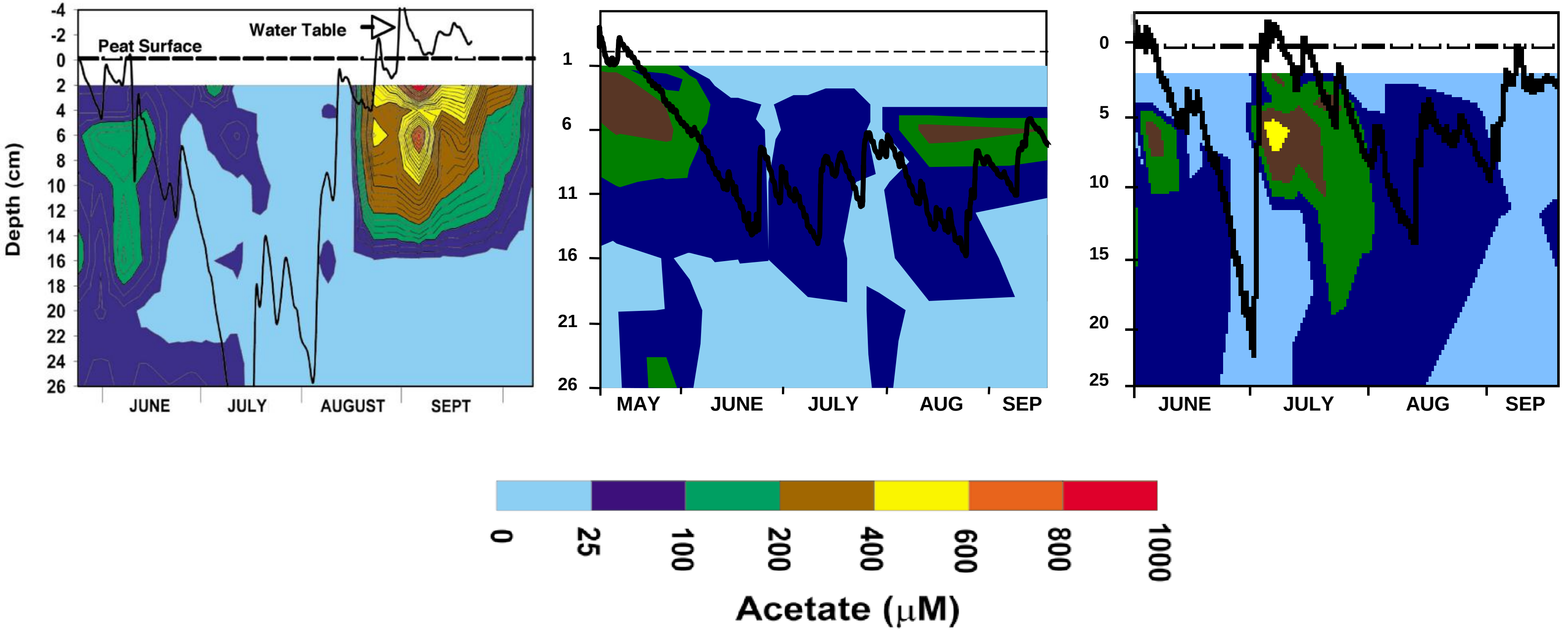


Shannon and White (1996)

Acetate in Bog Pore Water at Turnagain Bog



Controlled by hydrology without a temporal shift



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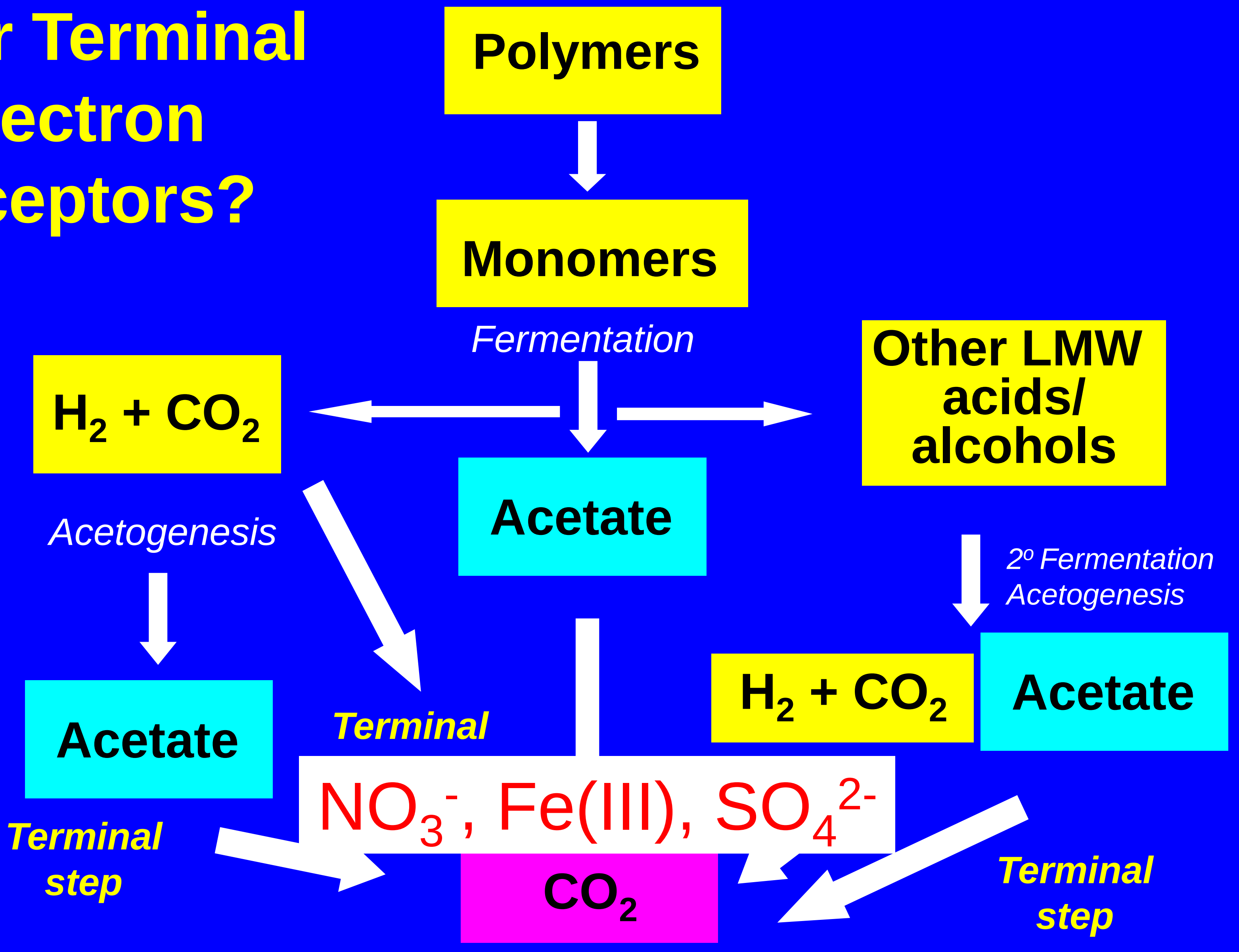
What About Other Terminal Electron Acceptors?

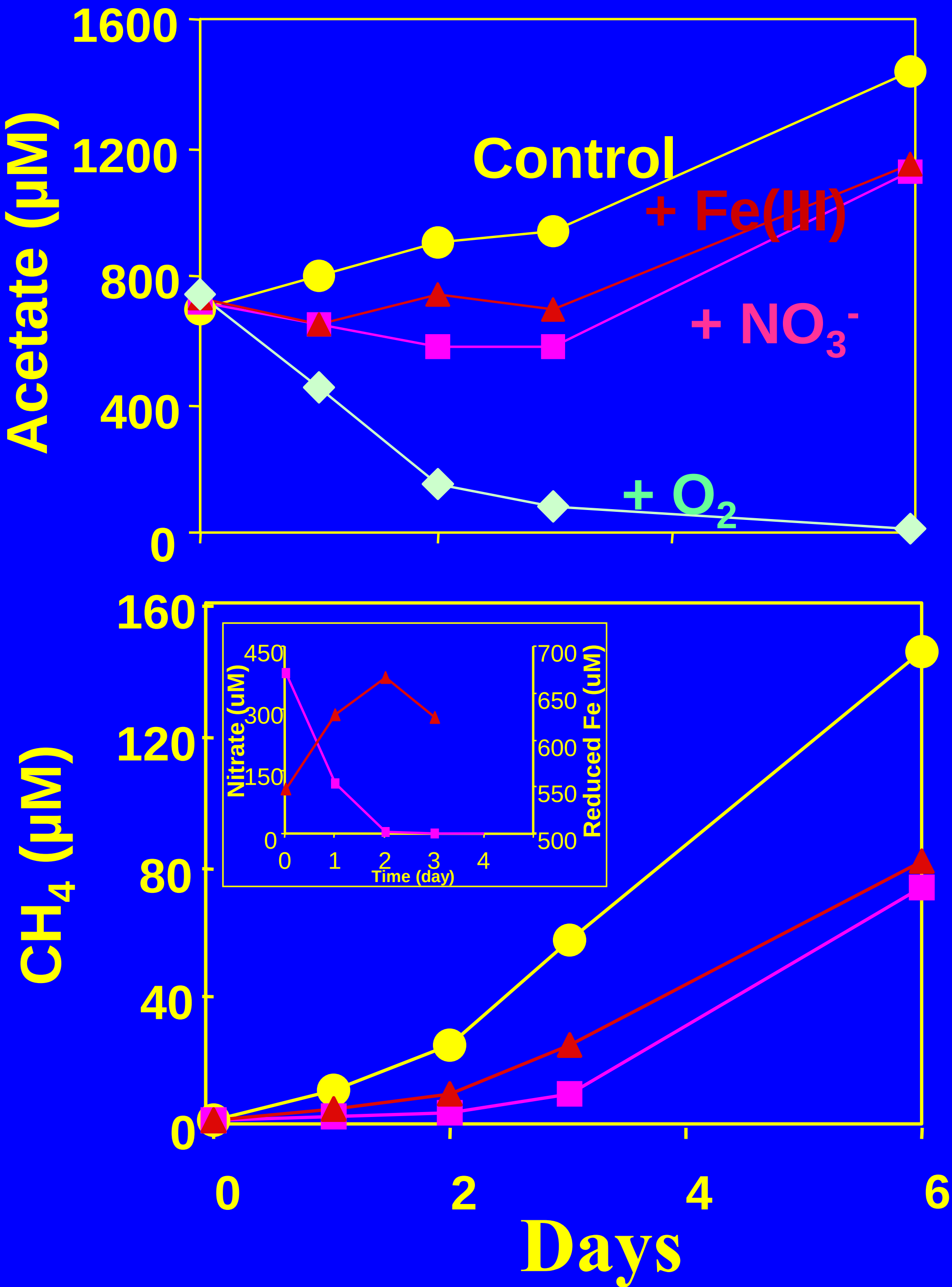


What happens to acetate that is produced in anaerobic environments?

Acetate is Consumed by all Other Processes

(Uncoupling only during CH_4 production)

Acetate C destined for CH_4 in methanogenic habitats is converted to CO_2



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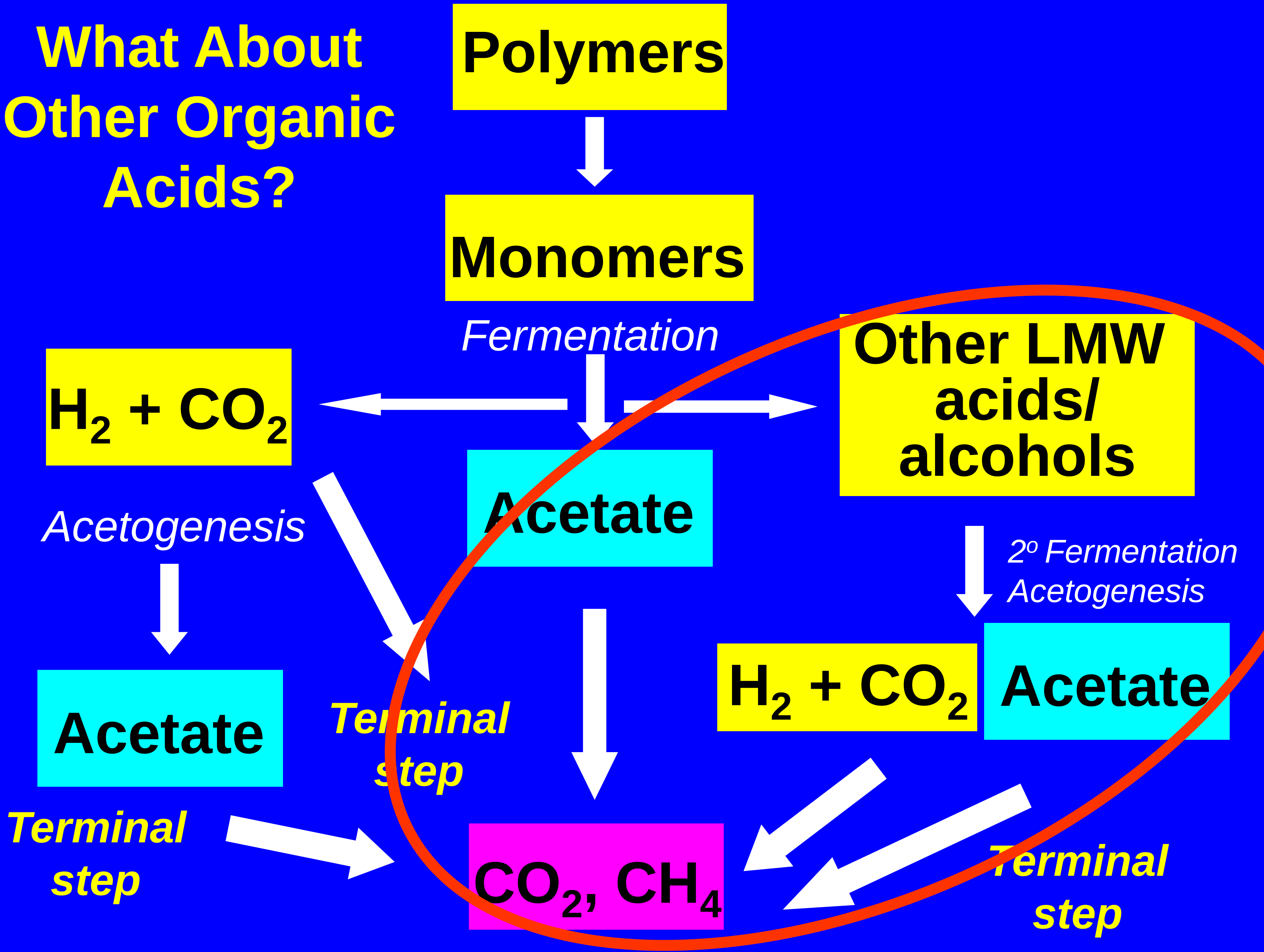
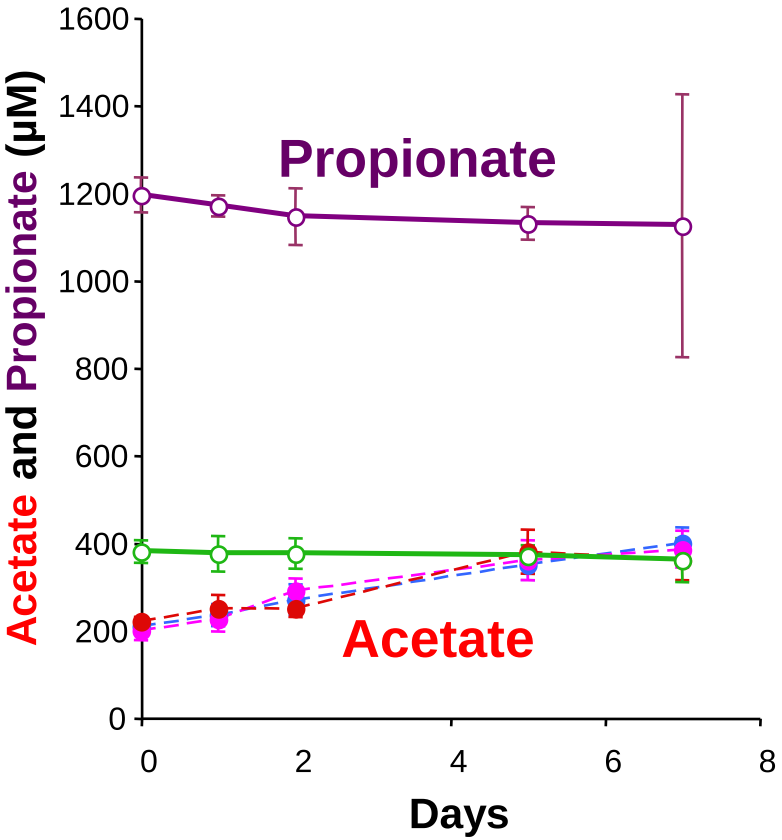
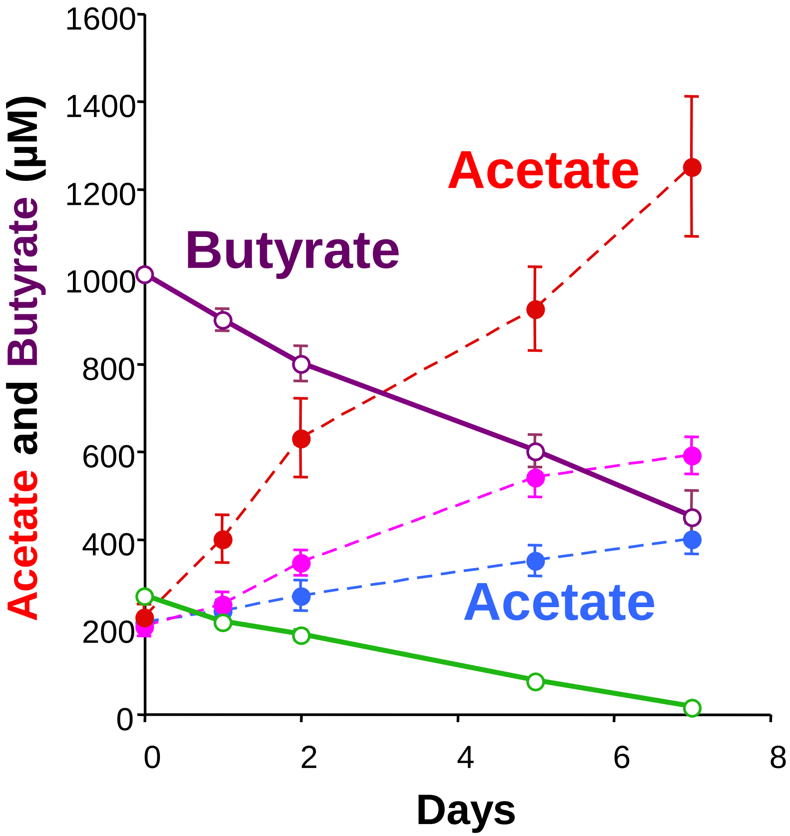
What About Other Organic Acids?



Other Organic Acids



Propionate → Acetate + CO_2 + H_2



Butyrate → 2 Acetate + 2 H_2

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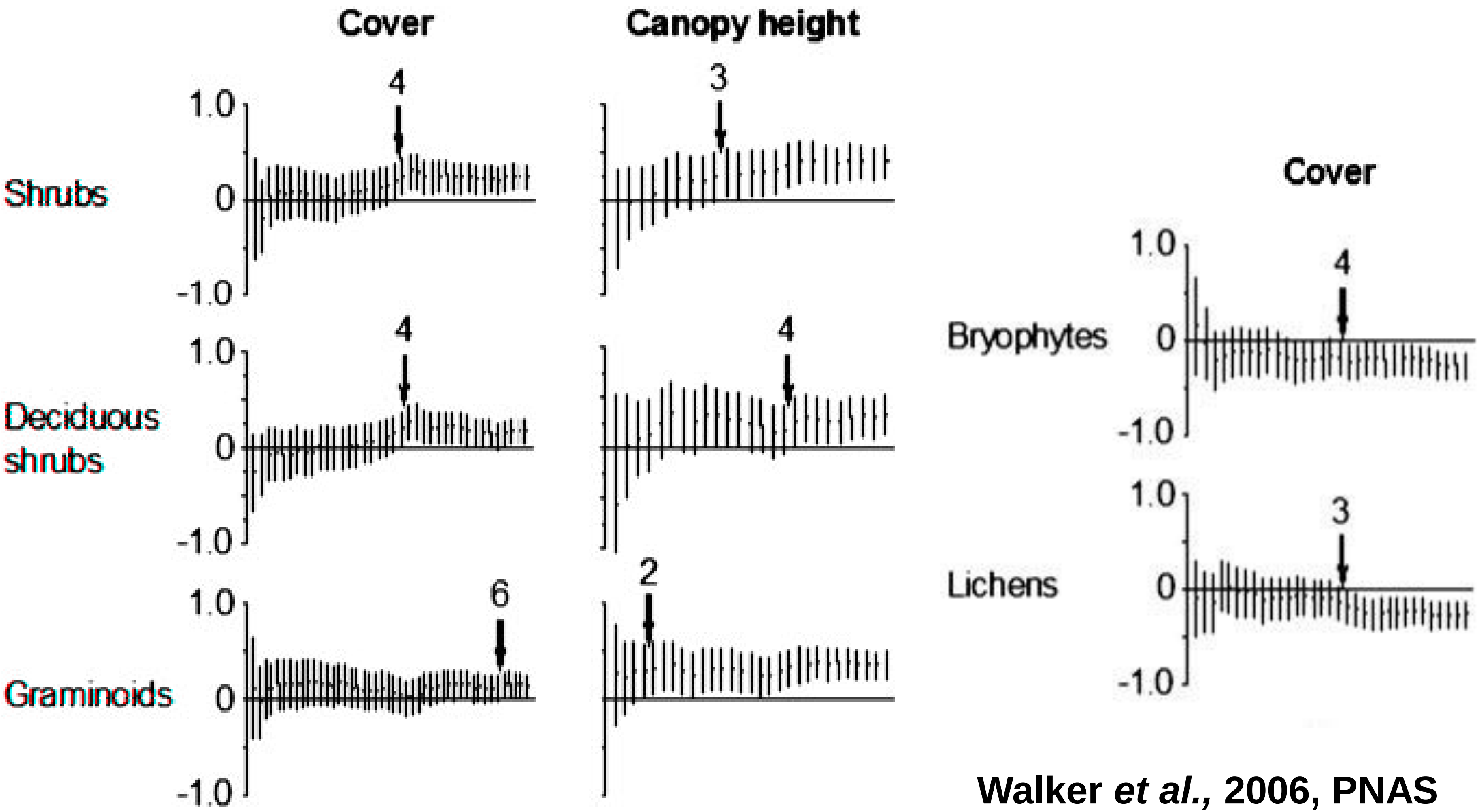
Plant response to 1-3° C warming



Walker *et al.*, 2006, PNAS

Replacement of mosses by vascular plants may lead to severe increases in CH_4 production

"Sites with small increases in sedges use much more acetate"

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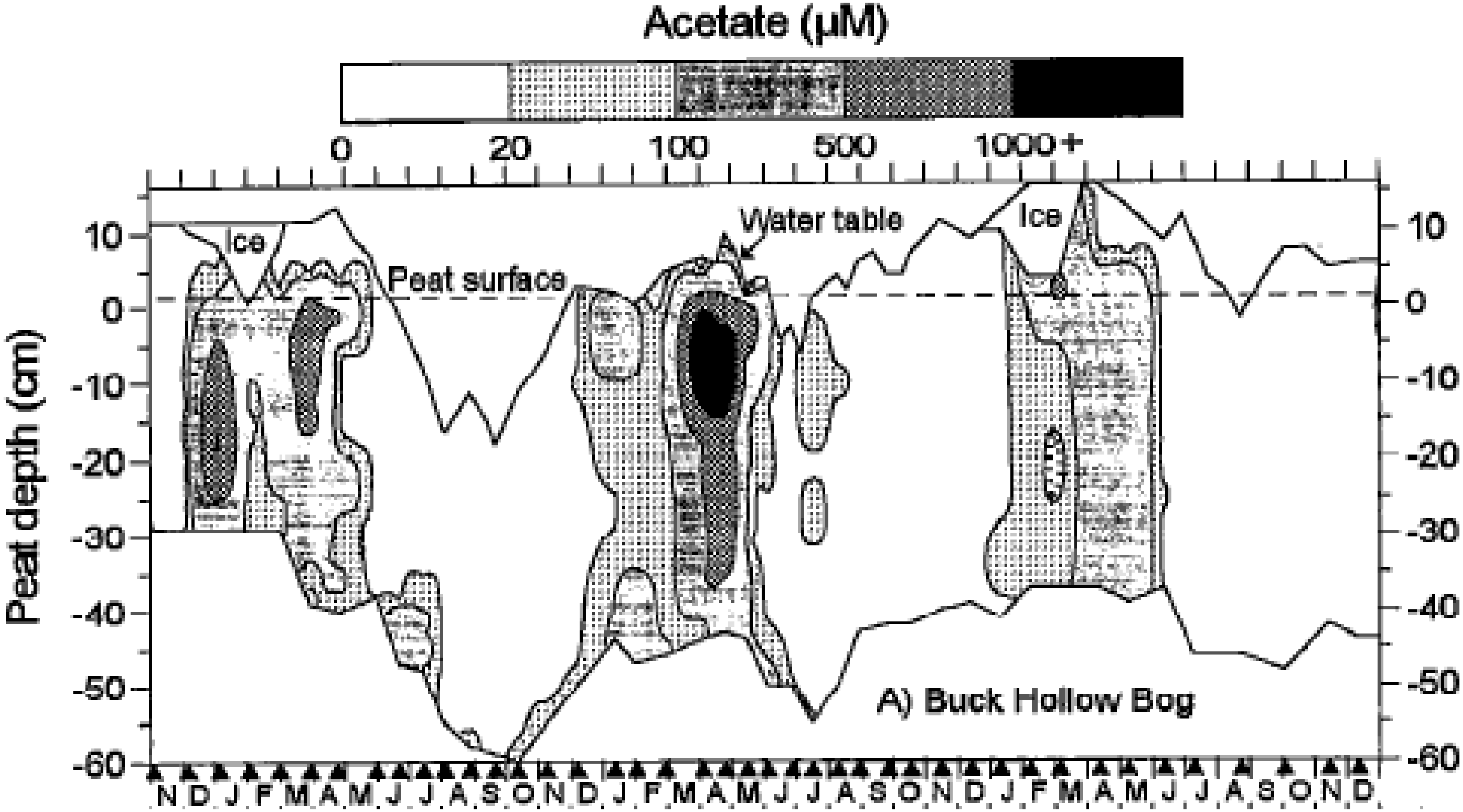
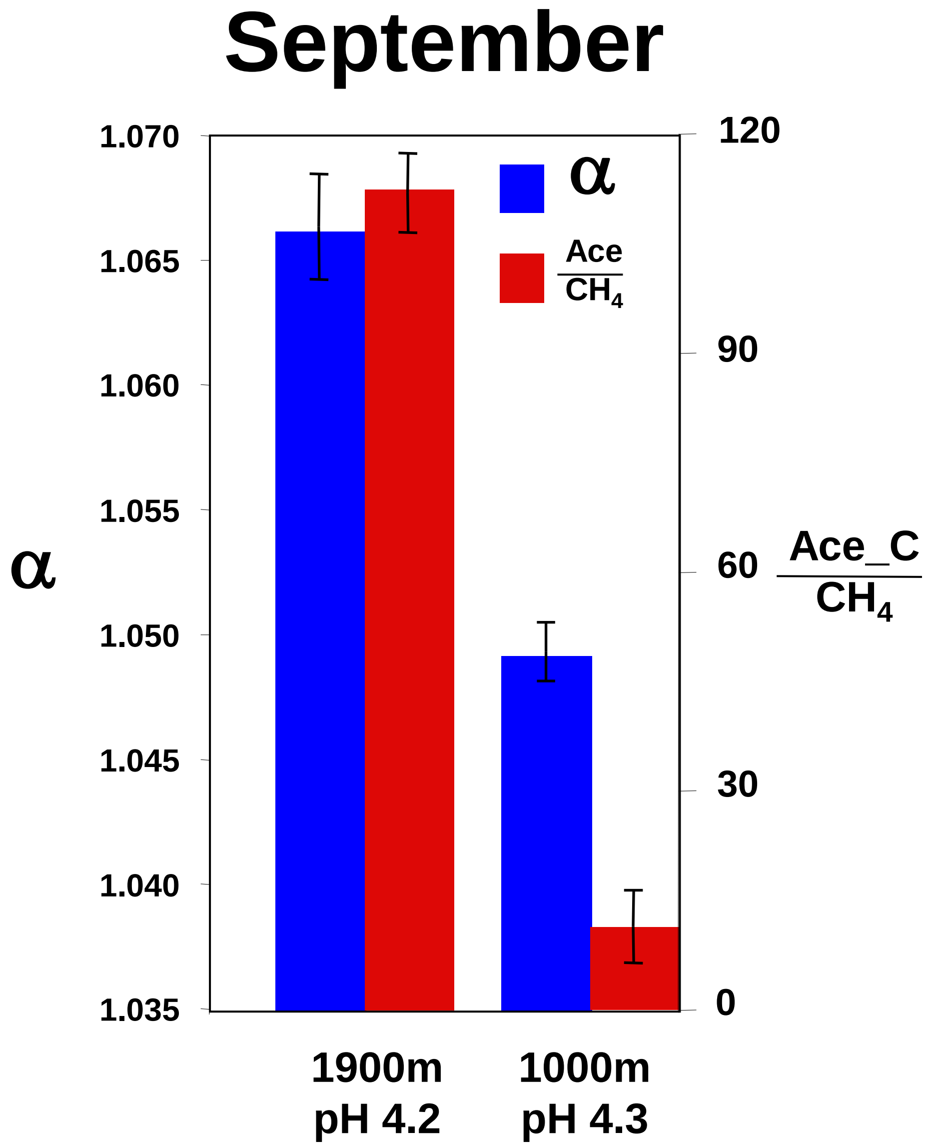


Shannon and White (1996)

Since higher latitude sites often accumulate acetate all season, this suggests that temperature may influence whether a shift occurs and when

Poor fen at 1000 m experienced an acetotrophic shift in May, but at ~1900 m, this had not occurred, even in September



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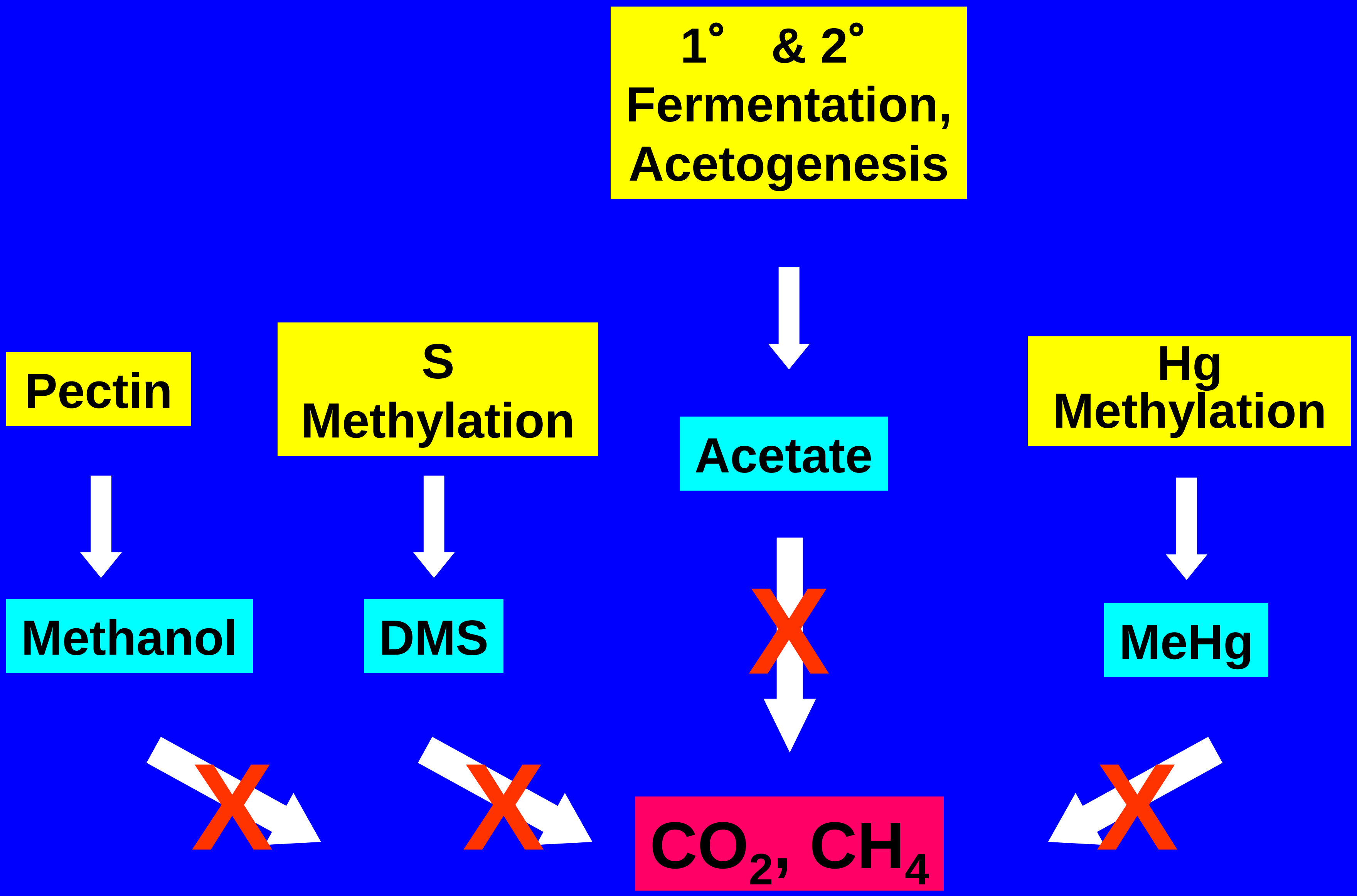
Uncoupling of Methanogenesis Affects Other Compounds



Implications

- The uncoupling of methanogenesis is a common phenomenon in the north that is linked to trophic status and temperature.
- Temperature seems to create a latitude and elevation gradient, in which seasonal effects observed in temperate bogs are postponed, sometimes indefinitely, as active seasons become colder and shorter.
- Uncoupling only occurs during methanogenesis, i.e., intermediates are consumed during respiration of other electron acceptors.
- Compounds similar to acetate are also not degraded to methane.
- Uncoupling appears to be an inhibition in which acetate use is more sensitive than CO_2 reduction.

Implications, con’t

- Local consequences of uncoupling of decomposition: 1) enhanced importance of fermentation and acetogenesis; 2) C flow to acetate that is degraded to CO_2 (fuels stream and other bacteria); 3) unique microbial population; 4) “recycling of C to mosses”
- Global consequences of decoupling: 1) slight increases in vascular plants (sedges) may lead to sharp increases in methane formation
- Worst case scenario: Climate warming leads to methanogenic use of acetate at current production rates (temp alone: 2° ↑ → ~15%↑; path change: 100x)

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WHERE DISCOVERIES BEGIN