SEQUESTERING CARBON IN WETLANDS THROUGH ENZYME SUPPRESSION

Prof. Chris Freeman,
School of Biological Sciences, Bangor University, Wales, UK

Wolfson Carbon Capture Laboratory

Our start point

- **The mysterious case of the head in the bog**
  - Cheshire 1983
  - Murder?
- **Routine testing**
  - Carbon dating
  - 1000+ yrs

A spectacular failure of decomposition

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Outline

- **Why is preservation so effective in peat bogs?**
- **What is the <u>enzymic latch</u>**
  - *How peat bogs affect a planet*
- **Implications of the enzymic latch**
  - *Use in geoengineering*

Identifying an "Enzymic Latch"

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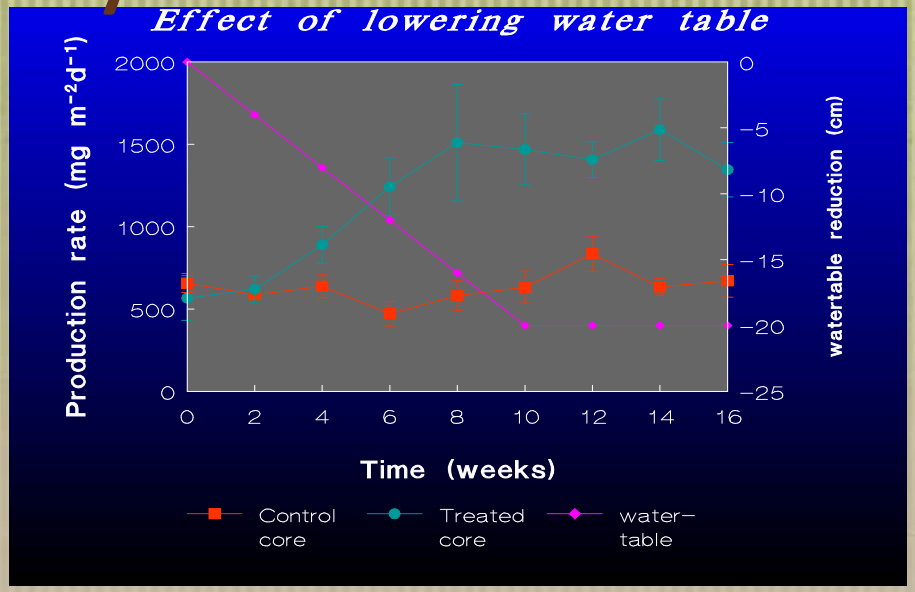
CO_2 is released if these 'wetlands' become 'drylands'

- **Assumptions:**
- **Waterlogging reduces 0_2 abundance**
- **Lack of O_2 restricts decomposition**

- **Because as everyone knows…..**
  - Microbes are far more active with O_2
  - Enzymes need O_2



O_2 as the regulator?

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Supporting evidence?

- Do studies of other O_2-free environments confirm the importance of O_2 ?
  - **Anaerobic sewage treatment; Rumen**

- *Do anaerobic conditions mean low hydrolase activity?*
- *Is decomposition / microbial metabolism inefficient?*

  - ***Little evidence to suggest that O_2 enrichment should favour enzymic decomposition***

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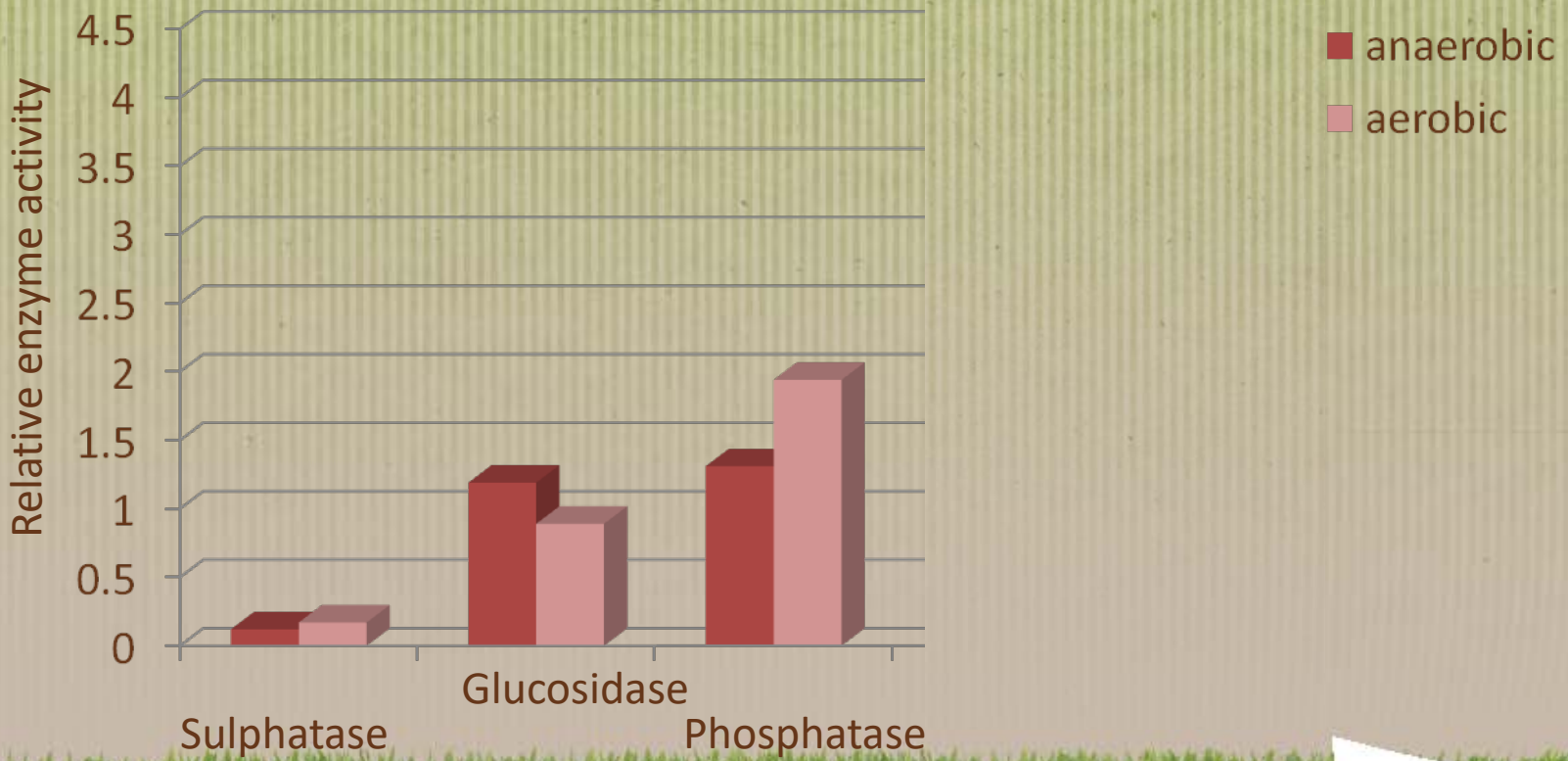
In fact peat enzymes behave like those other anaerobic enzymes



Hydrolases become more active in drier conditions despite being unaffected by O_2 - but why?

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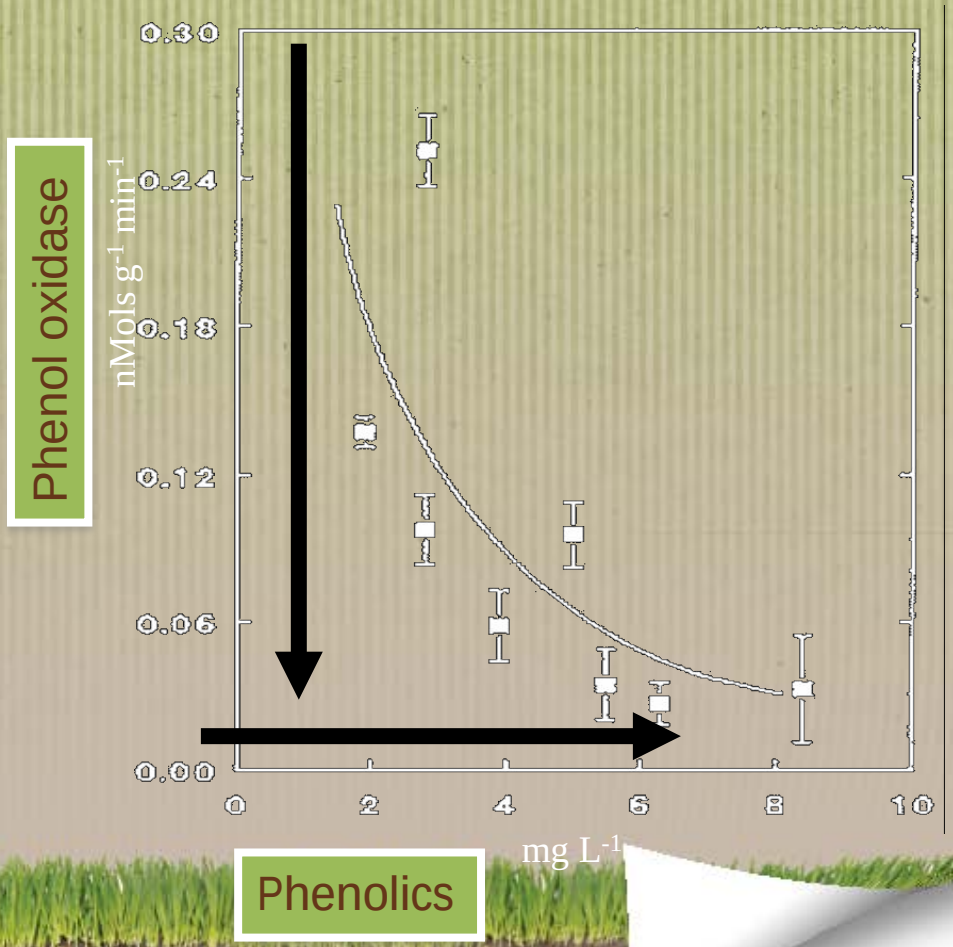
Clue 1: When Phenol Oxidase is highly active, phenolics become scarce

Phenol oxidase is one of the few enzymes able to degrade phenolics

Without Phenol Oxidase, phenolics accumulate



Finding the "Enzymic Latch"

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Clue 2: ONE OF THE KEY CHARACTERISTICS OF WETLANDS – BROWN WATERS

- Peatlands are full of….
  - Phenolics (polyphenols, tannins, humics)
  - Create background absorbance and quench

Phenolics are abundant in wetlands

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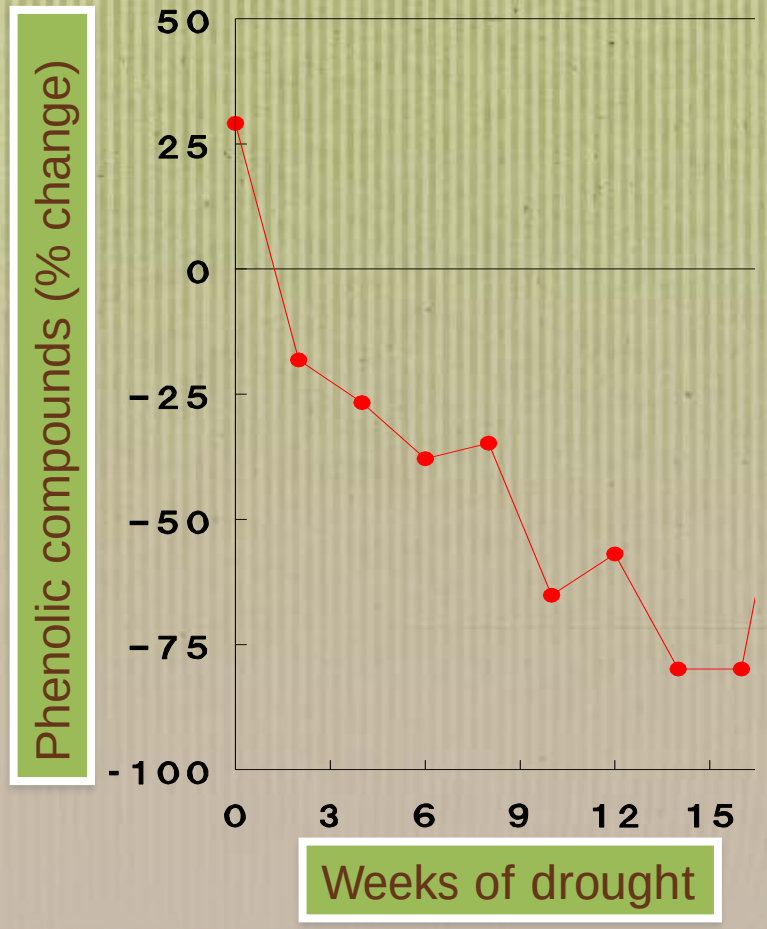
Clue 3: When peats become drier, phenolics disappear

- **When a drought introduces O_2 to the peat:**
  - Phenol oxidase soars
  - Phenolics disappear
- **One of the most dramatic impacts of droughts**



Those phenolics disappear under drier conditions

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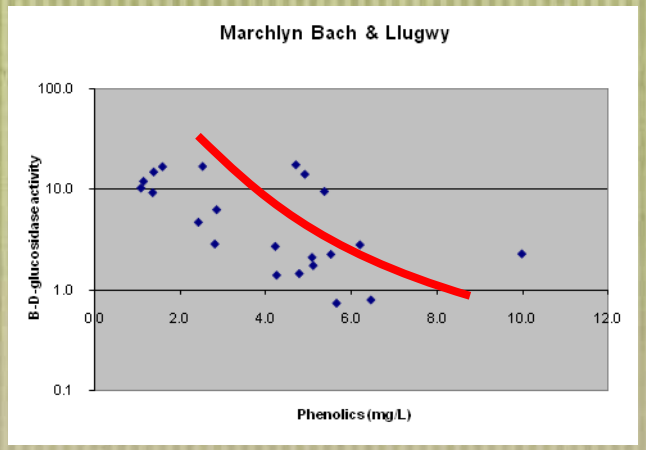
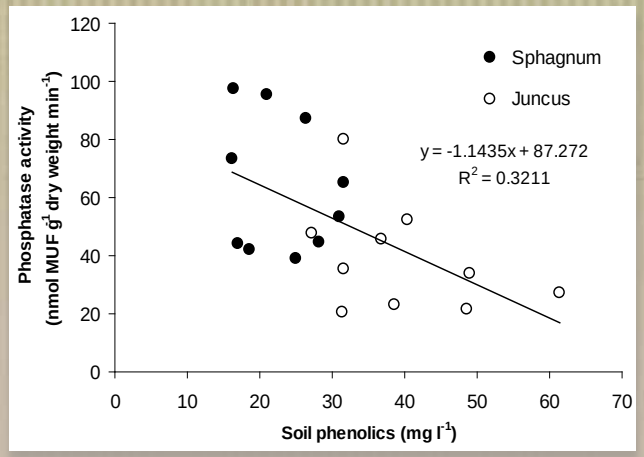
Clue **4:** Phenolics are potent hydrolase enzyme inhibitors

- **Phenolics inhibit enzymes**
- **Removing even small amounts of phenolics can increase hydrolase activity**
  - Freeman *et al* 1990
  - Wetzel 1992
  - Vuorinen A.H. Saharinen M.H. 1996





Phenolics inhibit hydrolases

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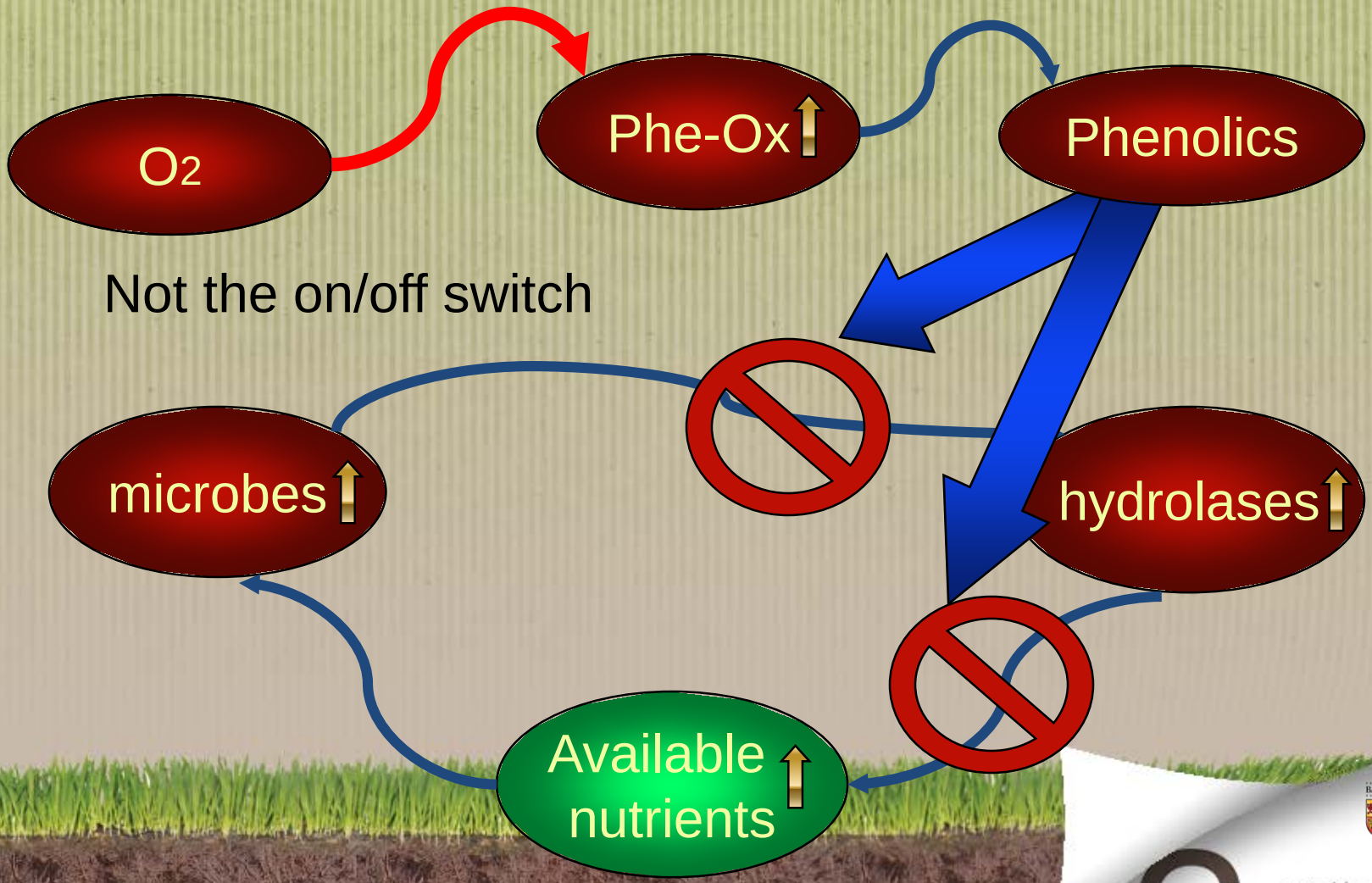
Can we link this all together?



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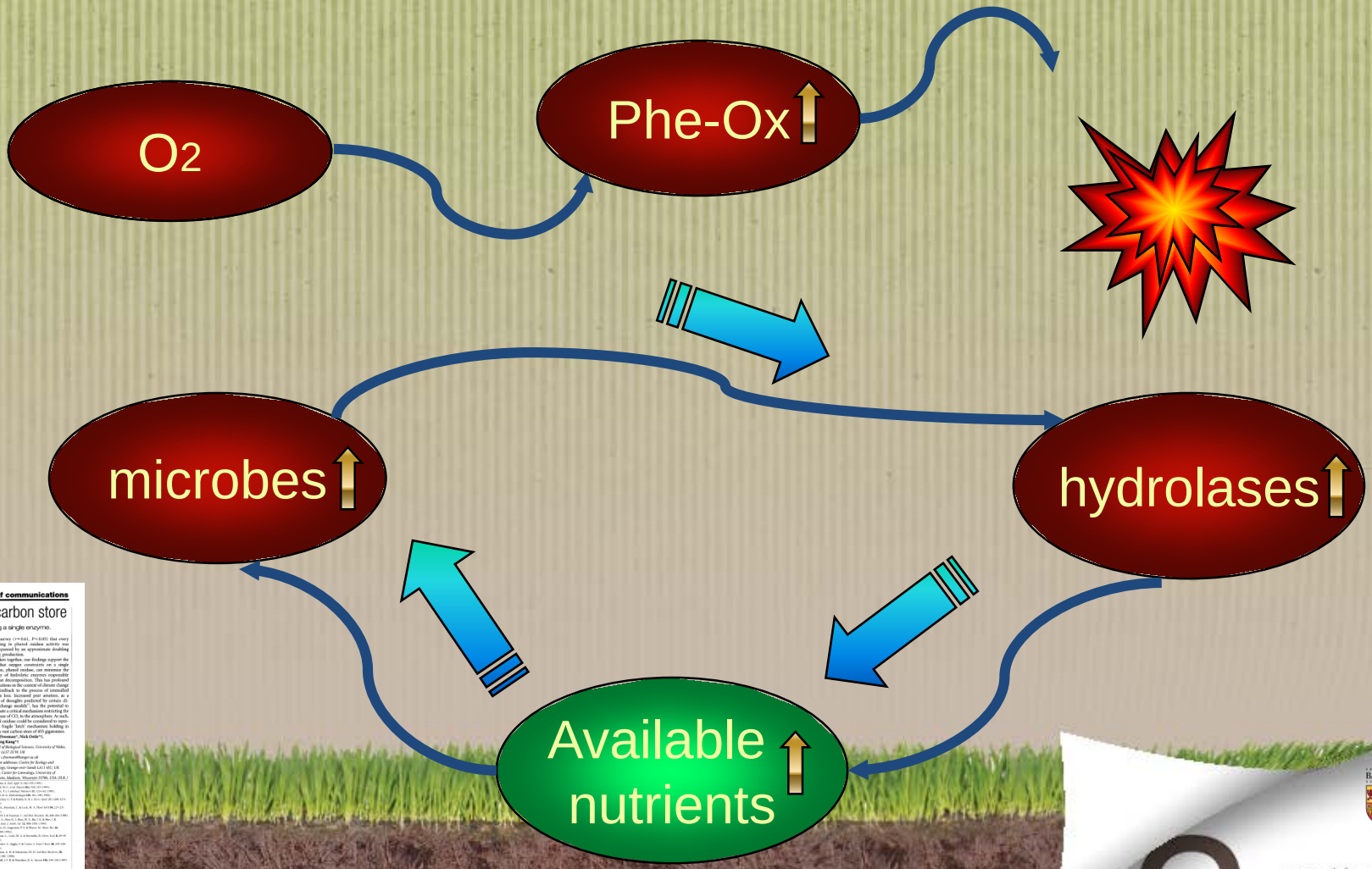
O_2 has an indirect impact on wetland hydrolases




brief communications

An enzymic 'latch' on a global carbon store

A shortage of oxygen locks up carbon in peatlands by restraining a single enzyme.

nature

Freeman *et al* 2001, an "enzymic latch"

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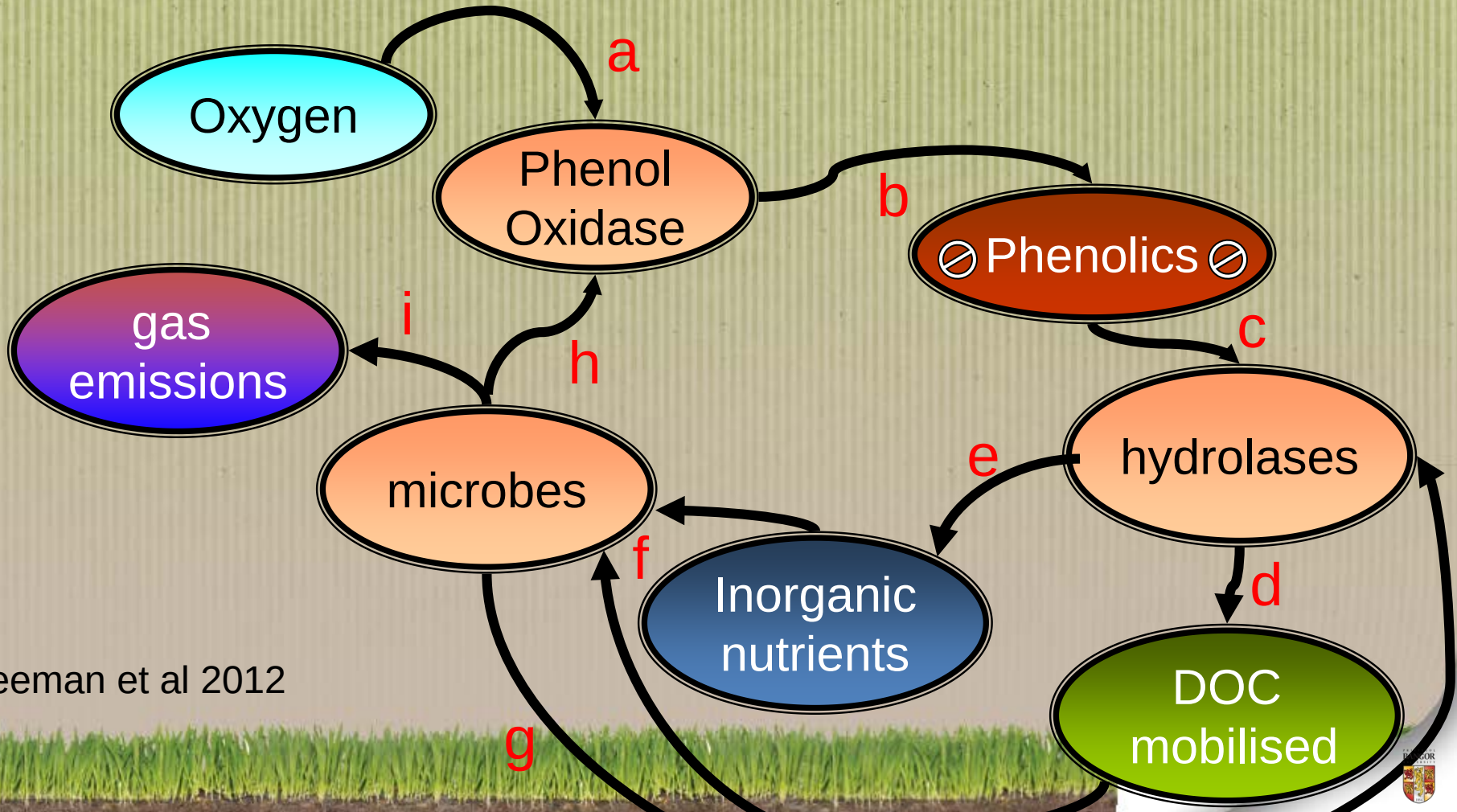
The enzymic latch in more detail



Freeman et al 2012

At each stage there is an opportunity for optimising carbon capture

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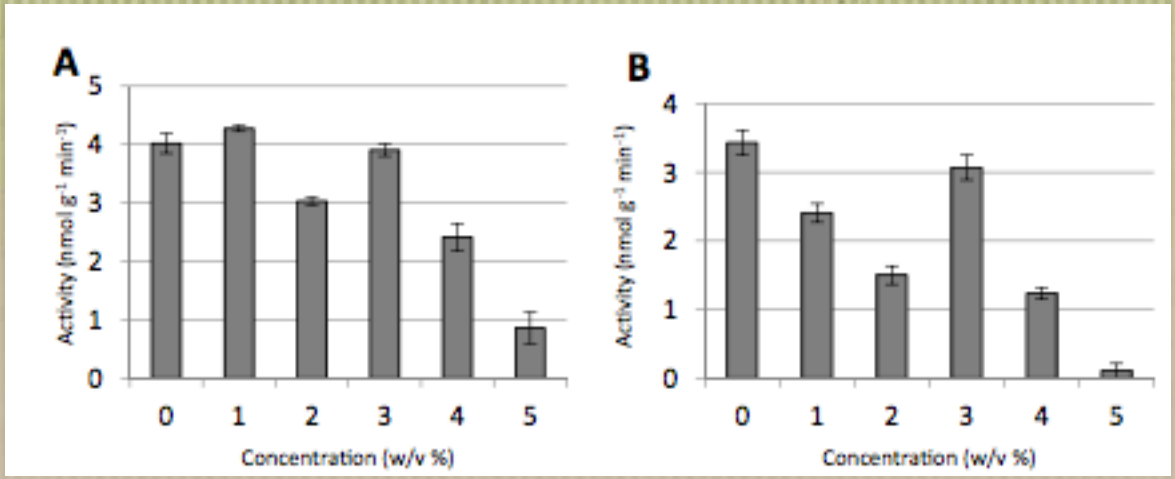
WE CAN INCREASE PHENOLIC ABUNDANCE



Dunn & Freeman (2018)

More phenolics create more suppression of decomposition

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WE CAN MODIFY PHENOL OXIDASE ACTIVITIES BY CHANGING PLANTS PRESENT

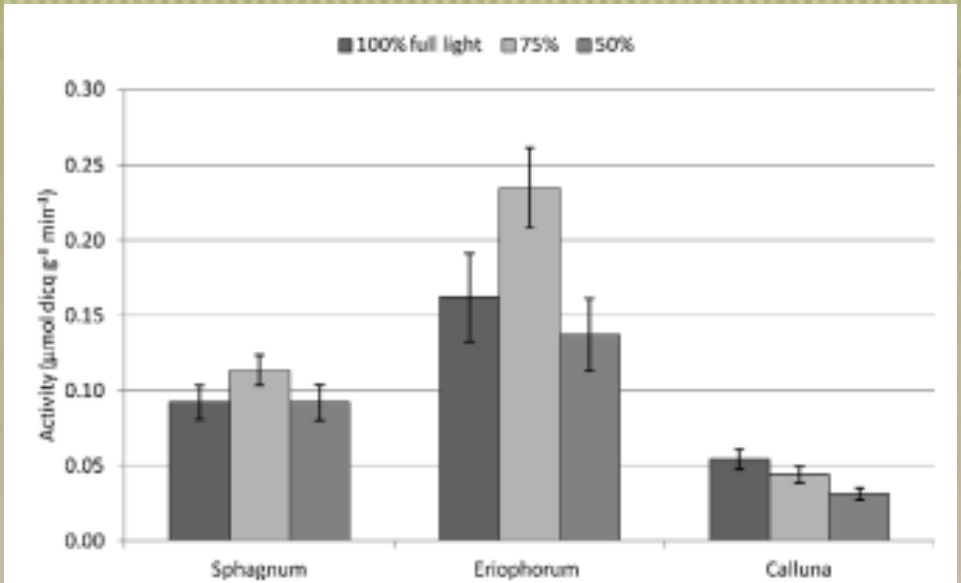

Fig. 3. Phenol oxidase activity in the rhizosphere of peatland plant species. Mean averages from the entire six week experiment are shown ($n = 35$). Error bars indicate ± standard error.

Dunn et al (2018)

Certain plants create more suppression of decomposition

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We can modify the environment & affect microbial biodiveristy / enzyme activity *and* inhibition

www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

Hydrological legacy determines the type of enzyme inhibition in a peatlands chronosequence

Received: 30 August 2016

Samuel Alexander Festing Bonnett[1], Edward Maltby[2] & Chris Freeman[3]

SCIENTIFIC REPORTS

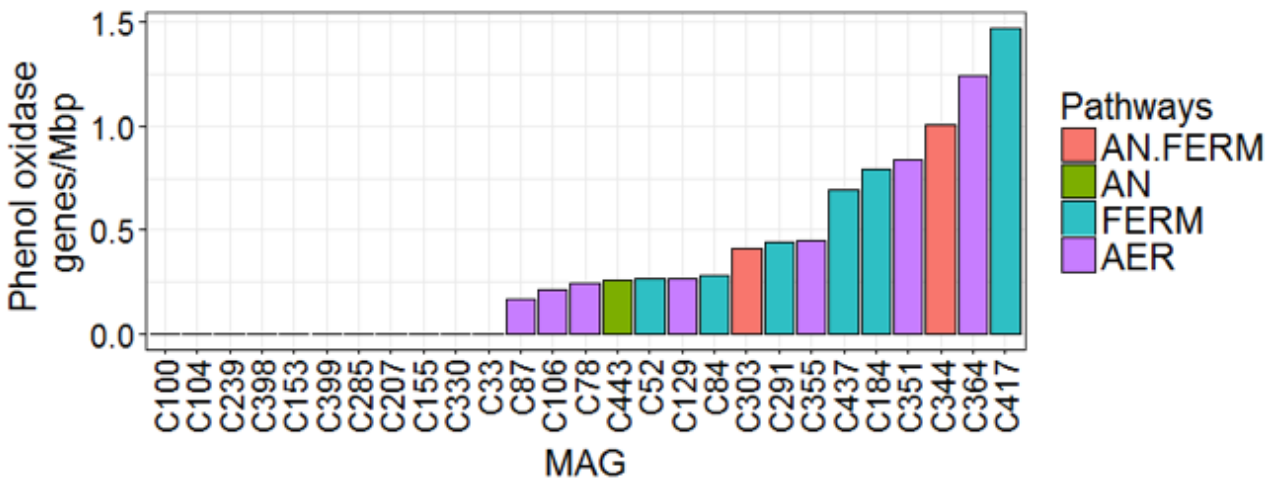
OPEN

Subtle shifts in microbial communities occur alongside the release of carbon induced by drought and rewetting in contrasting peatland ecosystems

Received: 5 April 2017
Accepted: 10 August 2017
Published online: 12 September 2017

Caitlin Potter[1], Chris Freeman[1], Peter N. Golyshin[2], Gail Ackermann[2], Nathalie Fenner[1], James E. McDonald[1], Abdassalam Ehbair[1,3], Timothy G. Jones[1], Loretta M. Murphy[1] & Simon Creer[1]

re 9 Number of hits to phenol oxidase genes per Mbp of sequence in all MAGs which were 97% reater complete.



(Bonnet et al 2018, Potter et al 2018)

Changing edaphic conditions can modify suppression of Decomposition – including via long term shifts in biodiversity

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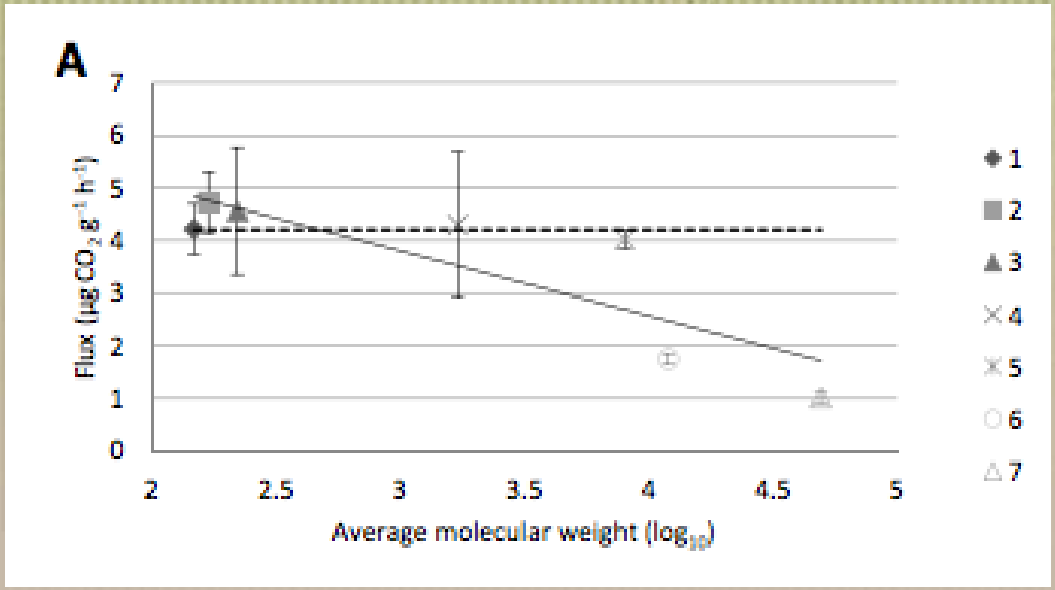
We need to consider the characteristics of individual phenolics



Dunn & Freeman (2018)

Higher molecular weight phenolics create greater suppression of decomposition

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Geoengineerng:

With careful planning, we should be able to use phenolics to optimise carbon sequestration

This may explain why Geoengineers are getting seriously interested in Peatlands

An application for the "Enzymic Latch"?

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- **Freeman C**, Lock MA, and Reynolds B. (1993). Fluxes of carbon dioxide, methane and nitrous oxide from a Welsh peatland following simulation of water table draw-down: Potential feedback to climatic change. Biogeochemistry, **19**: 51-60.
- **Freeman C**, Ostle J, Kang H (2001). An enzymic latch on a global carbon store. Nature. 409, 149.
- **Freeman, C**, Fenner, N, Shirsat A.H. (2012) Peatland geoengineering: an alternative approach to terrestrial carbon sequestration. Philosophical Transactions of the Royal Society (A) 370, 4404-4421
- Bonnett, S.A.F., Maltby, E. & Freeman, C. (2017), Hydrological legacy determines the type of enzyme inhibition in a peatlands chronosequence. Scientific Reports (Nature.com) , 7(9948), 1–14
- C Potter, C Freeman, PN Golyshin, G Ackermann, N Fenner, ... (2017) Subtle shifts in microbial communities occur alongside the release of carbon induced by drought and rewetting in contrasting peatland ecosystems Scientific reports (Nature.com) 7 (1), 11314
- C. Dunn, and C. Freeman (2018), The role of molecular weight in the enzyme-inhibiting effect of phenolics: the significance in peatland carbon sequestration. Ecol. Eng. 10.1016/j.ecoleng.2017.06.036
- C. Dunn, P. Zielinski, M. Kent, C. Freeman (2018), Investigating whether light intensity can modify decomposition rates in peatlands through control of the 'enzymic latch' Ecol. Eng. 10.1016/j.ecoleng.2017.06.060Potter et al

Applying the "Enzymic Latch"

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