Cryptic phosphorus in the environment: composition, behavior, and ecological significance

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What are cryptic forms of phosphorus?

Cryp·tic, adjective:

1. having a mysterious or hidden meaning

2. not recognized

3. serving to conceal

4. enigmatic

Organic and inorganic phosphorus that is….

- Hidden physically or chemically from organisms in the soil
- Hidden from our thinking about biological availability

Organic phosphorus and its importance in plant nutrition

- **Abundant in soil**

  – a large proportion of the phosphorus in most soils is organic (up to 90% in wetlands)

- **Abundant in phosphorus inputs to soil**

  – much of the phosphorus in fresh plant litter and microbial residues is organic

- **Biologically available**

  – organisms have evolved complex ways to access soil organic phosphorus

Why has organic phosphorus been overlooked?

1. Agronomic perspective

– most research has focused on mineral fertilizer and inorganic phosphate loss

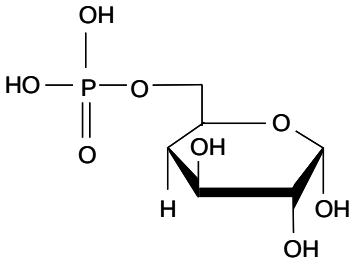
2. Bioavailability

– most organisms appear to take up phosphorus only as dissolved PO_4 ions

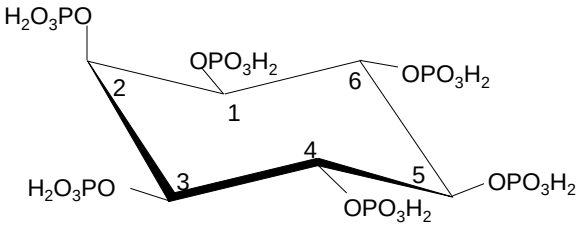
3. Analytical chemistry

– organic phosphorus has conventionally been difficult to identify and quantify in environmental samples

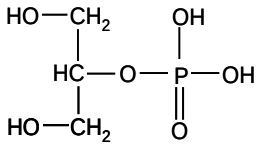
Phosphomonoesters



D-Glucose 6-phosphate

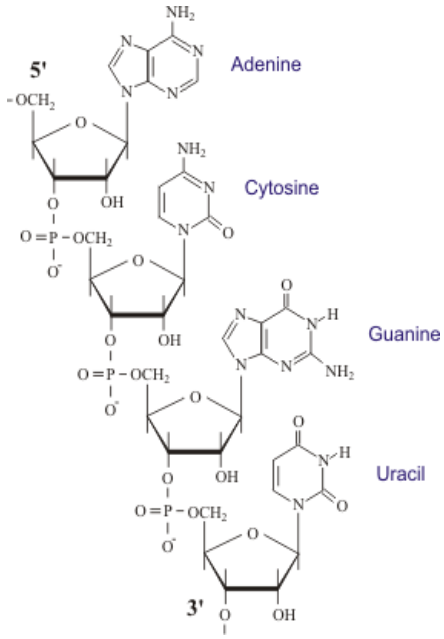


myo-Inositol hexakisphosphate

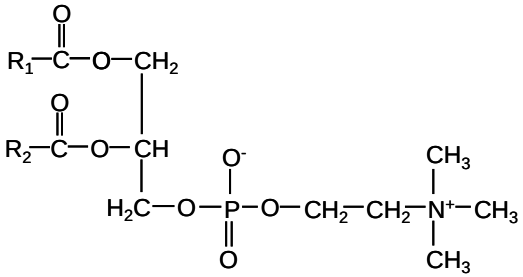


β-Glycerophosphate

Phosphodiesters

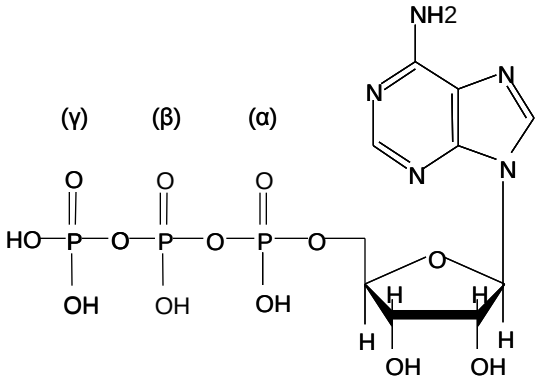


Ribonucleic acid



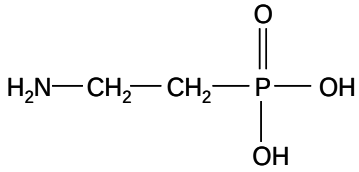
Phosphatidyl choline

Phosphoanhydrides



Adenosine 5'-triphosphate

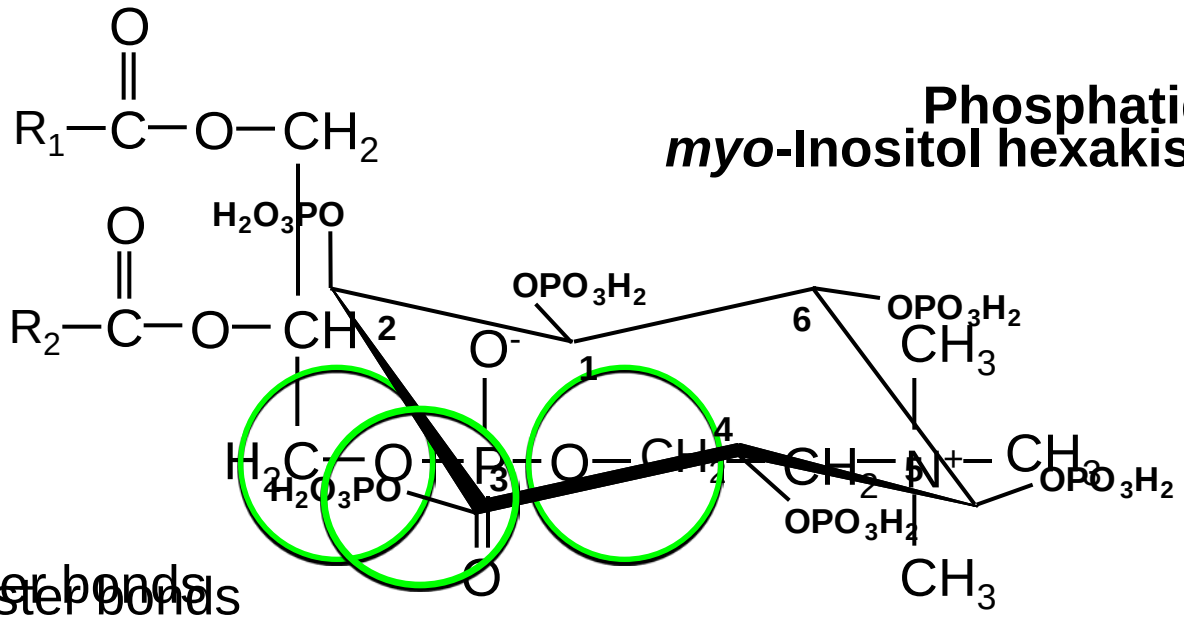
Phosphonates



2-Aminoethyl phosphonic acid

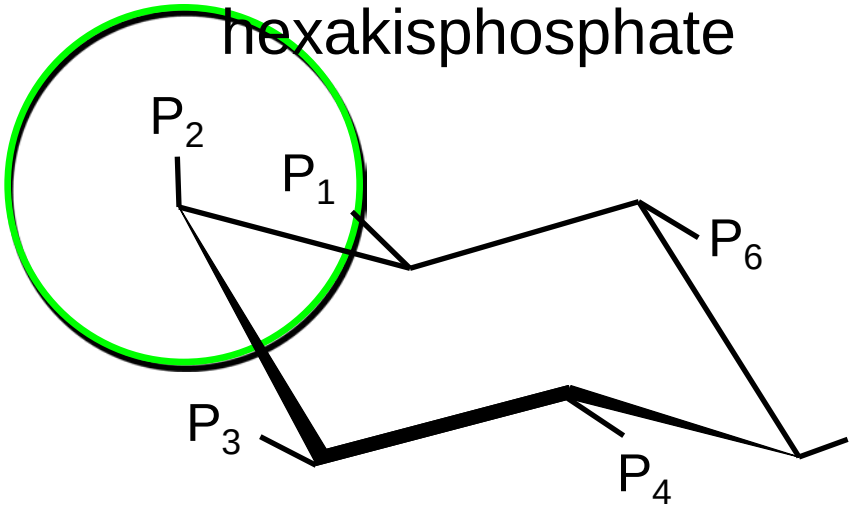
Behavior of organic phosphorus in soils

- Phosphate diesters (DNA, RNA, phospholipids)
- Inositol phosphates (phosphate monoesters)

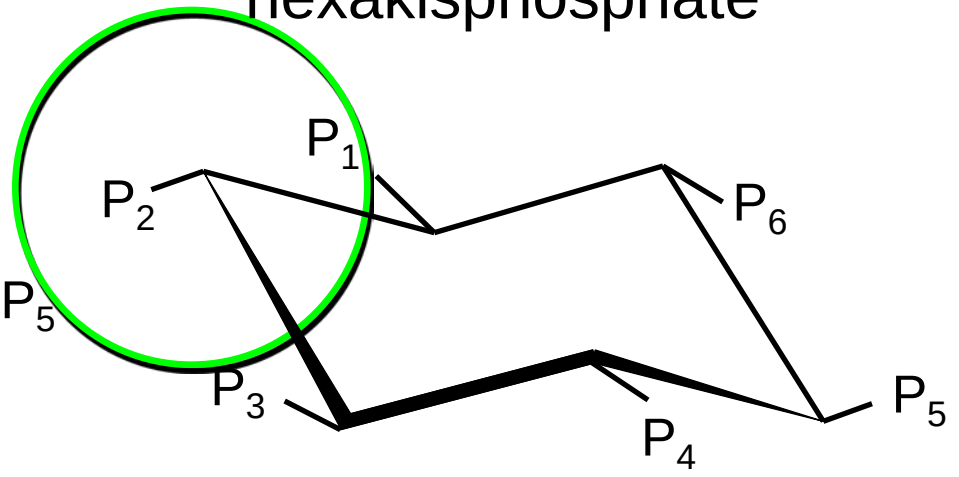


The phosphorylated inositol stereoisomers: very cryptic!

myo-inositol hexakisphosphate



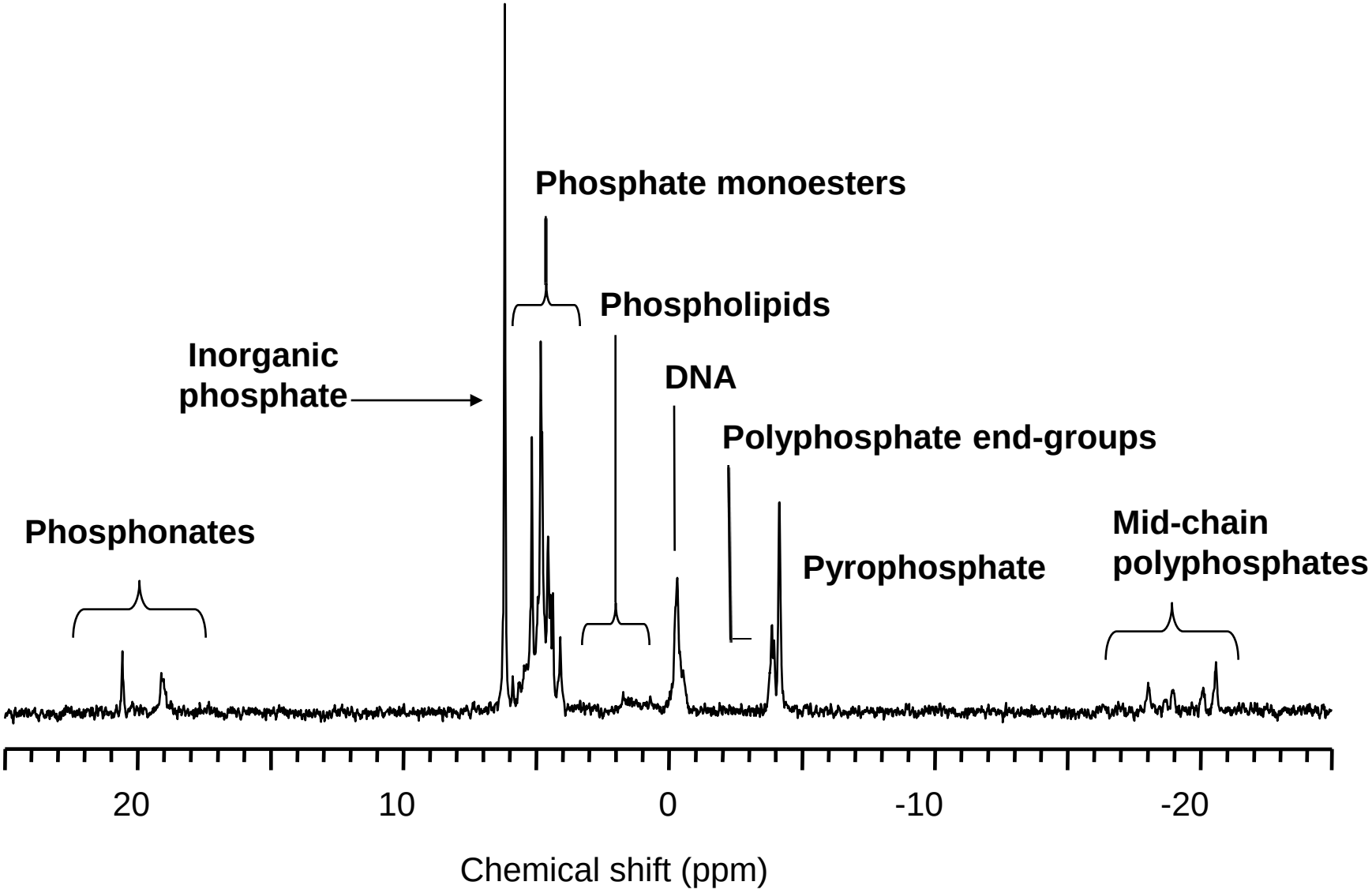
scyllo-inositol hexakisphosphate



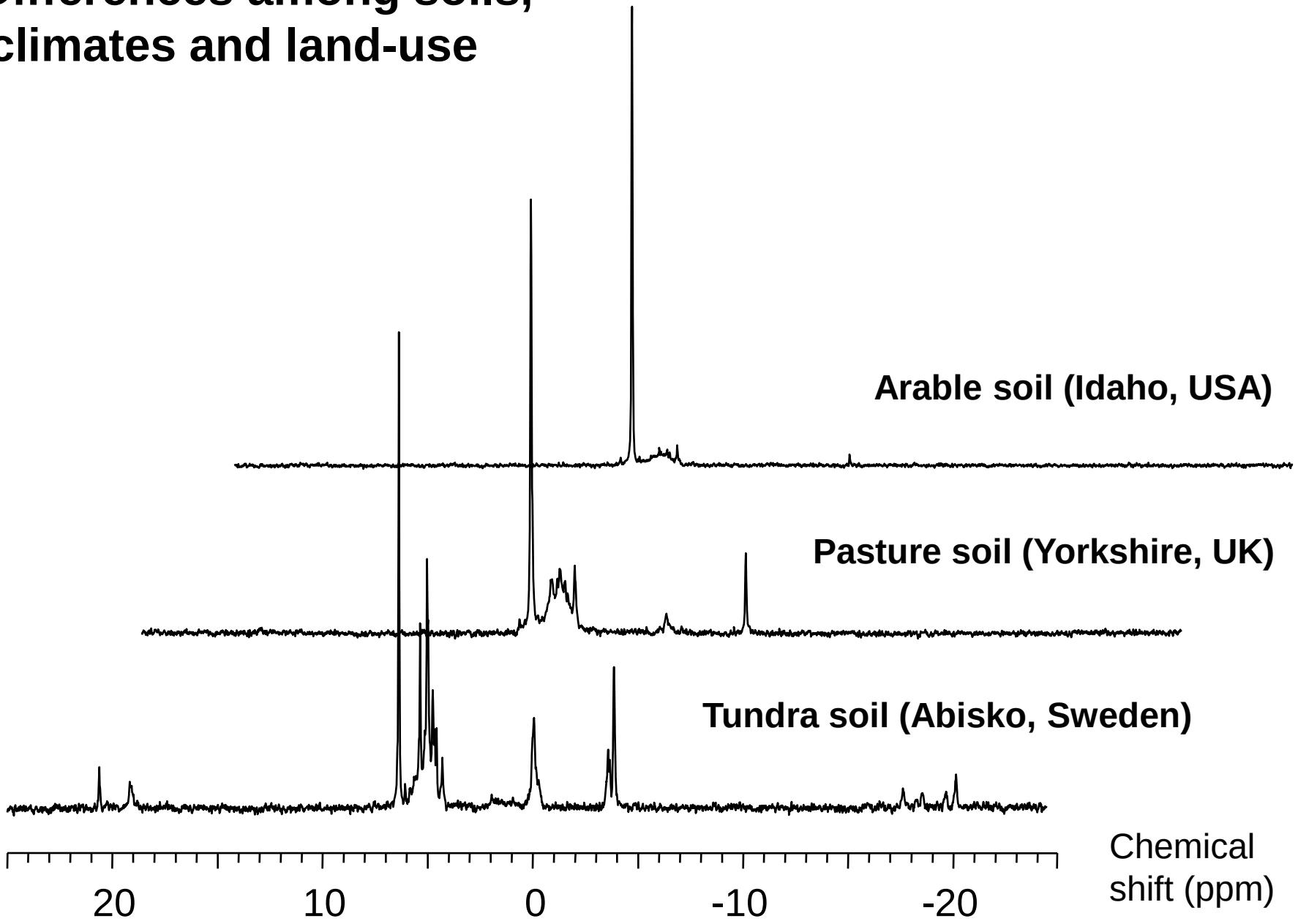
Difference in the orientation of a single phosphate group

Nuclear magnetic resonance spectroscopy

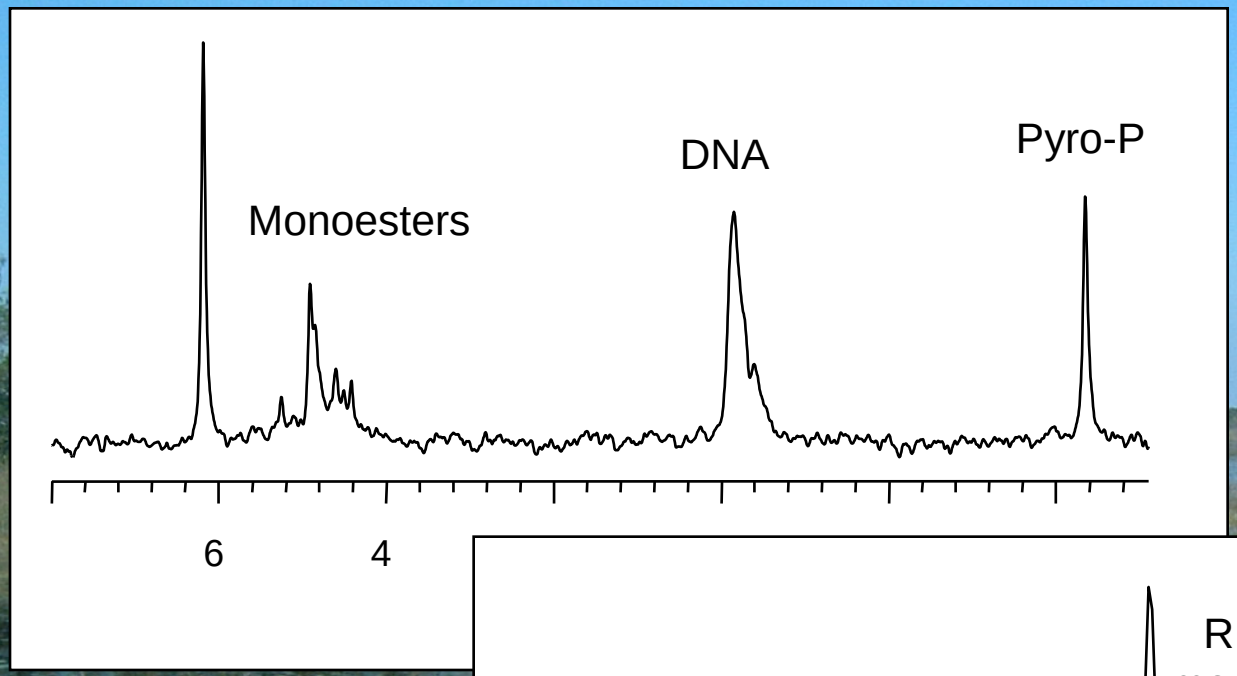
Solution ^{31}P NMR spectrum of an alkaline extract of a Swedish tundra soil



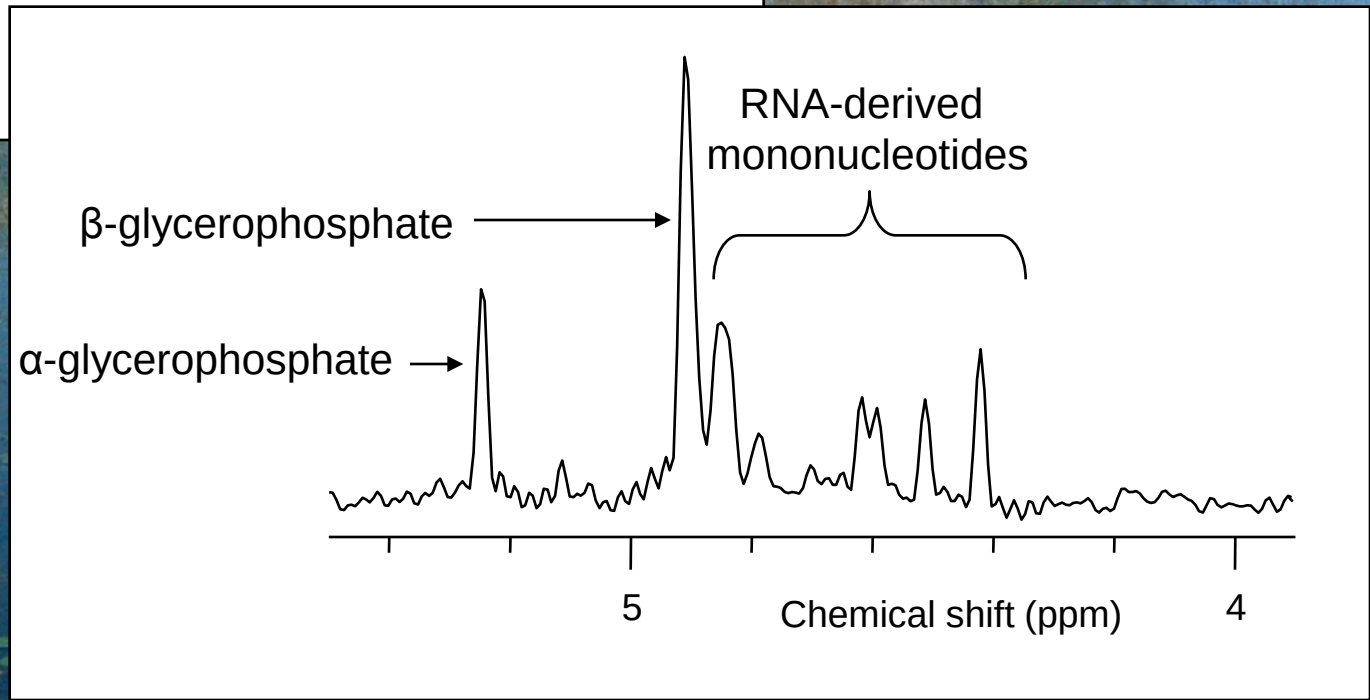
Differences among soils, climates and land-use



Cryptic phosphorus in a Florida marsh



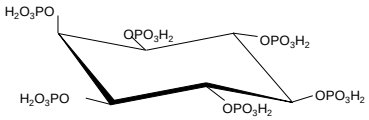
- Loxahatchee NWR
- Organic matter 90%
- pH 5.8



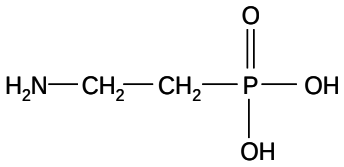
Phosphodiesters dominate the soil organic phosphorus

Cryptic phosphorus in a Carolina Bay wetland

- Savannah River, South Carolina
- Total carbon 31%
- pH 3.9



Inositol phosphates

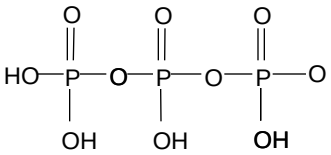


Phosphonates

Cryptic phosphorus in a tropical ombrotrophic bog

- San San Pond Sak wetland, Panama
- Organic matter >90%
- pH <4.0

Polyphosphate (25% of total P)

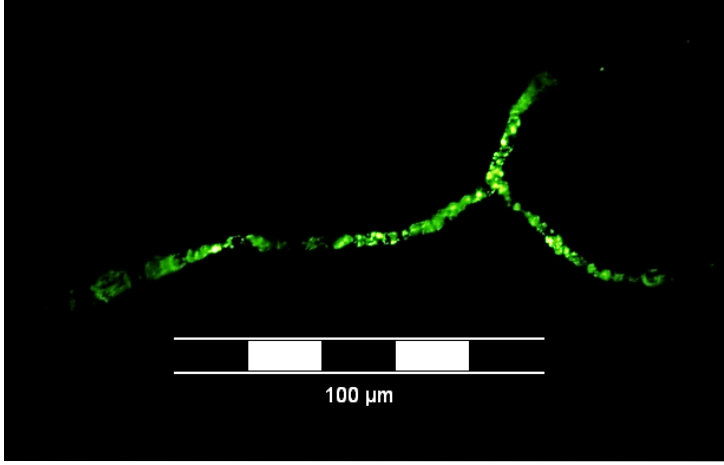


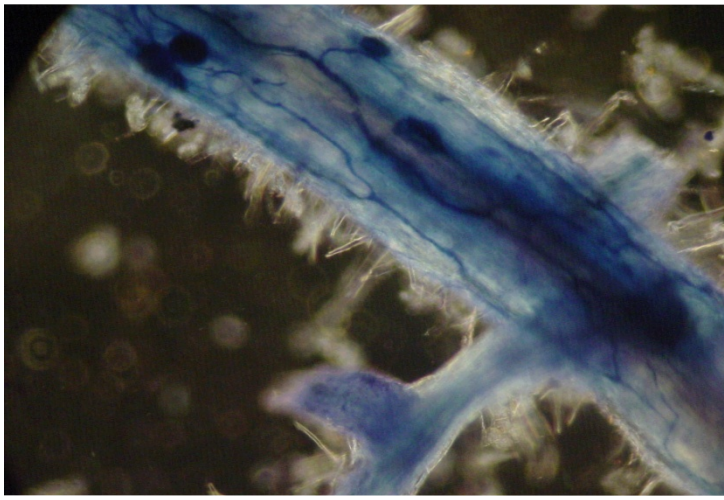
Plant strategies for acquiring soil organic phosphorus

- **Synthesis of phosphatase enzymes**
  – a ubiquitous response of plants to the need for phosphorus

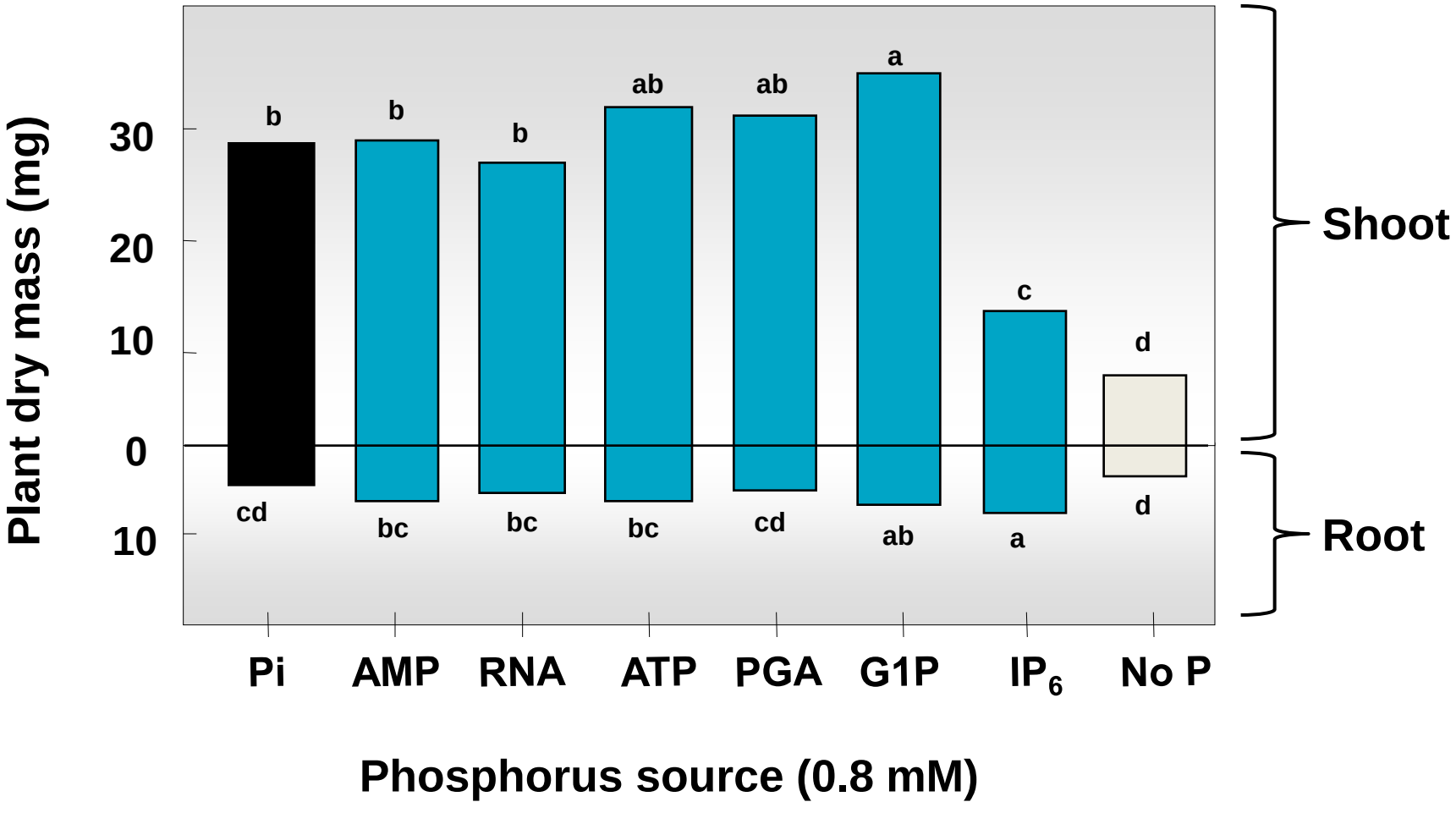
- **Formation of mycorrhizal symbioses**
  – some are extremely efficient at using organic phosphates (e.g., ericoids)

- **Secretion of organic anions**
  – compounds like citrate can solubilize large amounts of soil organic phosphorus

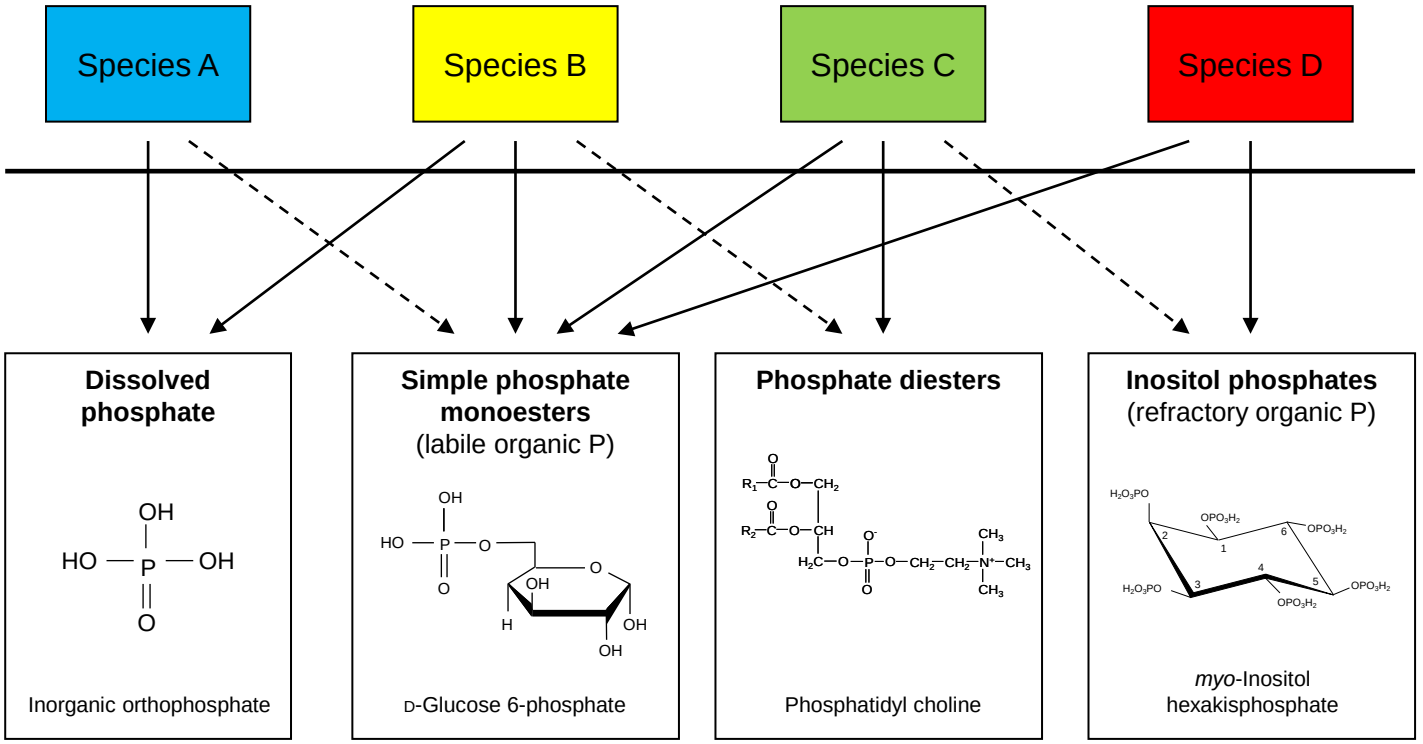




Organic phosphorus utilization by *Arabidopsis*



Resource partitioning for soil phosphorus?



From: Turner (2008) *Journal of Ecology* **96**, 698–702.

Summary

1. Importance in the environment

– abundance in soils (especially wetland soils), abundance in inputs to soils, variety of chemical forms

2. Plant strategies for acquisition of cryptic phosphorus

– phosphatase enzymes, organic acids, mycorrhizal symbioses

3. Ecological significance

– contribution to plant nutrition

– distribution of plant species in nature

– **particular importance in freshwater wetlands....**

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