# Plant Metabolism

## Final Exam

**April 30, 2007**

**Name:** _____

**Please limit your answers to the space available for each question.**

1. (5 pts) Where can nitrate typically be stored at the whole plant level, (3) and where inside the cells (2)?

Generally in the leaves and roots, or stated another way, in the roots and shoots. In the leaves, higher levels of nitrate can be found in the midrib. At the subcellular level, nitrate is only accumulated (stored) in the vacuoles.

2. (5 pts) Where is nitrate reduced to $NH_3$ inside plants (2), and in what subcellular compartment(s) and in what organs (3)?

Nitrate to $NH_3$ predominately occurs in the leaves, but can also occur in the roots. Nitrate reductase is found in the cytosol and nitrite reductase if found in the stroma of chloroplasts (plastids).

3. (6 pts) Describe **two characteristics** of the enzyme itself (2) and the **general reaction catalyzed** by nitrate reductase (2). In addition, what major posttranslational mechanism acts to control nitrate reductase activity (2)?

$$\mathbf{NO_3^- + NADPH + H^+ \rightarrow NO_2^- + NADP^+ + H_2O}$$

Of course, nitrate is reduced to nitrite, and is NADPH dependent.

Has a mini-electron transport chain where NADPH is the electron donor and electron acceptor/donors include FAD, MoCo cofactor, Heme and $\mathbf{NO_3^-}$ is the final electron acceptor.

Phosphorylation/dephosphorylation or allostery is suitable

4. (4 pts) What is chlorate ($ClO_3^-$) used for (2)? What kind of loss-of-function mutants can it reveal (2)?

Chlorate is an anlog of nitrate and can be used to screen for loss of function nitrate uptake transporters in the roots or loss of function nitrate reductase mutants. In the absence of functional uptake transporter for nitrate or nitrate reductase, wt plants grown on chlorate will die, while the mutants will survive longer.

5. (4 pts) How does sulfate enter into the cells of roots (2)? What drives the uptake of sulfate in roots (2)?

Sulfate transporters in the roots use the energy derived from a proton electrochemical gradient across the cell membrane to drive the transport of sulfate into the cytosol by a symport mechanism. Proton gradient is created by proton pump ATPases where the proton concentration is high on the outside and lower in the cytosol. Generally the ratio of protons to sulfate transported is about 3.

6. (6 pts) Compare and contrast the major characteristics of nitrate and sulfate transporters.

| Nitrate Transporter | Sulfate Transporter |
|---|---|
| Nitrate normally limiting | Sulfate normally not limiting |
| Mediated by $H^+$ electrochemical gradient | Mediated by $H^+$electrochemical gradient |
| $2\ H^+/NO_3^-$ | $3\ H^+/SO_4^{2-}$ |
| Encoded by gene family | Encoded by gene family |
| High and/or low $NO_3^-$ affinity | High $SO_4^{2-}$ affinities in roots, low affinity in leaaves |
| Soil nitrate presence inducible | Inducible by plant $SO_4^{2-}$ starvation; low in soil |
| Nitrate proton symporter | Sulfate proton symporter |

7. (4 pts) $SO_4^{2-}$ to $S^{2-}$ is a more energy intensive reductive process than either nitrate or carbon dioxide fixation. How is this energy and reducing equivalent demand met in plants?

The ATP and reducing potential is largely provided by photosynthetic electron transport in the chloroplast in the form of $Fdx_{red}$ or NADPH although reduction can occur in the roots in plastids. In the latter case, then the reducing potential come from PPP produced NADPH, and ATP from respiration.

8. (3 pts) Briefly list or describe each of the three general steps of sulfate assimilation into a terminal organic form.

Activation of sulfate: requires ATP and forms 5′-adenylysufate (APS) or PAPS
Reduction to sulfide: reduction requiring reduced thioredoxin or $Fdx_{red}$, $glutathione_{red}$
Incorporation of sulfide to form cysteine: requires *O*-Acetylserine to form cysteine

9. (5 pts) OAS(thiol)lyase is located where in the plant cell (3)? What does it do (2)?

Chloroplast/plastid (high)
Cytosol (low)
Mitochondrion (intermediate)

This enzyme catalyzes the incorporation of sulfide in OAS to form cysteine and acetate.

10. (4 pts) What is significant about the compound *ent*-kaurene in phytohormone metabolism (2)? Where is *ent*-kaurene synthesized in plant cells (2)?

*ent*-kaurene is an intermediate derived from the terpenoid biosynthetic pathway precursor geranylgeranyl diphosphate and it is the product of the first committed step of GA biosynthesis.

Chloroplast/plastid

11. (5 pts) What is one important form of GA biosynthetic regulation?

Feed-back inhibition by $GA_1$ that reduces the levels of mRNAs by a repressor of pre-mRNA synthesis that reduces the oxidase and hydroxylase enzymatic activity earlier in the pathway from $GA_{53}$ to $GA_1$.

12. (5 pts) What is the biosynthetic pathway of origin of the ABA $C_{40}$ precursor (3)? How is this particular pathway of ABA synthesis related to abiotic stresses like water deficits (2)?

Terpenoid pathway and violaxanthin or neoxanthin are ABA precursors.

Neoxanthin cleavage is the first committed step of ABA synthesis. This step is closely linked with abiotic stresses like water deficits as a number of the genes for this step are highly sensitive to stress conditions showing increased expression. Under water deficits, ABA and other signals act to close stomata which will lower internal $CO_2$ and carbon assimilation. Under high light and low carbon assimilation, reducing potential becomes excessive and the xanthophyll cycle must act to dissipate excess electron supply. A component of the xanthophyll cycle is violaxanthin which is the precursor for neoxanthin. Activation of the xanthophyll cycle causes a reduction in violaxanthin levels but not neoxanthin.

13. (5 pts) What is the biochemical or functional purpose for the ABA derived metabolites phaseic acid, dihydrophaseic acid and their glucosides?

Inactivation and degradation of ABA.