City University of New York Graduate School
PhD Program in Biology–Plant Sciences First Examination 2008

INSTRUCTIONS: Questions will be answered by computer as Microsoft WORD *.doc files (in the format of "student no_session_no.doc; for example, for student 67 responding to session 1, the file will be named "67_session_1.doc"). For any drawings that can't be done on the computer, make note on your computerized response of any supplementary notes to be written on **one side only** of the answer sheet provided.

SESSION 1: Basic Plant Biology. Answer these 50 questions. Two points credit each.

Plant Molecular Biology/ Genetics

1. Describe one method, including controls that can be used to determine whether a protein is present in leaves.
2. A bacterial toxin can be used to kill insects foraging on corn leaves. How would you create a transgenic corn that accumulates the bacterial toxin only in the leaves but not in the seed?
3. A plant gene is interrupted in one of the introns by the insertion of a transposon, which carries several transcriptional terminators. Would this insertion result in the formation of a gain-of-function or loss-of-function mutation? Why?
4. If you had the cloned gene, how would you demonstrate that 50 amino acids at the N-terminus of the encoded protein are necessary and sufficient for targeting to the chloroplast?
5. You have identified an EST from water-stressed rice plants that is upregulated as judged using microarray chips, when comparing water stressed vs. non-stressed plants. Assuming that you have the corresponding DNA sequence, what other method could you use to confirm that the gene is upregulated by water-stress? Make sure to include a control.
6. What is GenBank and how does one get access to it?
7. What is the name for the region of DNA where RNA polymerase binds?
8. Why are transposable element insertion mutations generally unstable (they may revert to the nonmutant allele) as compared to mutation that is due to a small deletion?
9. Describe why plasmids are useful for propagating DNA?
10. What information and/or reagents/instrumentation are needed to amplify DNA by PCR?
11. What evolutionary advantage do gene duplications provide for an organism?
12. Give an example of a duplicated plant gene and how members of this gene family member differ in gene expression and/or function.
13. How are molecular markers useful in developing physical maps of a genome?
14. Give an example of how microorganisms can be used in the study of plant genes/gene products.
15. Where does carotenoid biosynthesis take place in plants and where are the enzymes encoded?
16. What is the difference between a genomic DNA library and a cDNA library?
17. Give one example of how you would repress function of a plant gene.
18. How is the application of comparative genomics useful in plant biology?
19. What is the substrate of a restriction enzyme?
20. How might you use molecular tools to test whether the variant levels of an anticancer phytochemical found in tissues of a particular plant species were due to differences in levels of transcripts for the biosynthetic enzymes, all of which the genes had been cloned?

Phytochemistry

21. Define ethnobotany, and explain how this can be useful for drug discovery.
22. What is paclitaxel, and what is the current source of paclitaxel?
23. What is the "doctrine of signatures", and what scientific basis is there for this "doctrine"?
24. What are the two building blocks for the acetate and melvalonate pathways? How do they differ?
25. How could chemotaxonomy assist you in locating plants that produce anthraquinones?
26. What analytical chemical method would you use to measure levels of *p*-menthane in *Mentha spicata* and why?

27. What plant produces thujone, and what are the effects of this compound on humans?
28. From what biosynthetic pathway are isoflavonoids produced?
29. Compare and contrast the chlorophylls to the anthocyanins.
30. Name a toxic alkaloid, and explain why it is toxic.
31. What is the amino acid building block for tropane alkaloids?
32. Name a phytoestrogen and its cellular target in humans.
33. Draw the chemical structure of catechin, and label the A, B, and C rings.
34. What extraction and initial separation strategy would you use to isolate alkaloids from a plant?
35. What plant family produces acetogenins, and what is their mechanism of action?
36. What is allelopathy? Give an example in nature.
37. What are the two major groups of compounds found in black cohosh (*Actaea racemosa*)?
38. What chemical building block is in common between carotenoids and gibberellins?

Biostatistics and Ecology

39. List three specific methods by which terrestrial plant productivity may be measured.
40. Briefly compare quadrat methods to transect methods for performing quantitative ecological inventory of woody plant communities.
41. What research questions can be answered by dendrochronology?
42. About how many species of vascular plants are found growing within a 50 miles radius of Columbus Circle in Manhattan?
43. What is a plant species?
44. Briefly describe the thermal energy environment of a terrestrial plant.
45. In the analysis of research data, how does one decide which of the many ANOVA models is appropriate to use?
46. What is statistical power analysis and how is it used?
47. Explain the percentile method for obtaining bootstrap confidence intervals.
48. The observations for two categorical variables are cross-classified in 2 x 2 contingency tables which are replicated in time. The investigators wish to understand the association, if it exists, between these two variables. Provide statistical advice.
49. What is the Weibull Probability Distribution and why is it useful in modeling plant size?
50. How does continuous logistic regression differ from nominal logistic regression in terms of 1) the methods themselves and 2) the research questions that may be answered?

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SESSION 2: Basic Plant Biology. Answer these 50 questions. Two points credit each.

Basic Botany

Very briefly define the following terms:

1. hypanthium
2. hyphae
3. aril
4. nucellus
5. companion cell
6. heterosporic
7. protonema
8. antheridium
9. sorus

10. What role does transpiration play in the movement of water through a plant?
11. The cell walls of fungi are primarily composed of what polysaccharide?
12. What are two pieces of evidence that support the origin of land plants from green algae.
13. What, in general, is a cymose inflorescence (or cyme)?
14. What is an archegonium? Which groups of land plants form archegonia?
15. What are two ways in which alternation of generations in ferns differs from mosses?
16. Most lichens are formed from a green alga or cyanobacterium and what type of fungus? What is the role of the fungal partner in a lichen?
17. What is secondary vascular tissue?
18. Describe the structure of the male gametophyte of angiosperms.
19. What is the difference between a microphyll and a megaphyll? Which plant groups are characterized by each type of phyll?
20. What becomes of the pericarp in a berry and in a capsule?
21. What is the function of the Casparian strip?
22. Explain how the ABC model of flower organ identity can be easily modified to produce flowers with two petaloid perianth whorls instead of one whorls of sepals and one whorls of petals.
23. What is an abscission zone?

City University of New York Graduate School
PhD Program in Biology–Plant Sciences First Examination 2008

Systematics

24. What is a carpel? How can you determine the number of carpels in an angiosperm flower?
25. What is the difference between connation and adnation of floral organs? Provide two examples of adnation and indicate the taxon in which it occurs.
26. Briefly describe the difference between orthologous and paralogous genes.
27. What is a gene tree? Provide three reasons why gene trees may differ from the phylogenetic relationships of a group of taxa.
28. Briefly characterize the parsimony criterion as employed in phylogenetic analysis.
29. What is a consensus tree? What are the different explanations for polytomies on consensus trees?
30. What is nomenclatural priority?
31. Briefly describe three different ways in which gaps can be coded for in a phylogenetic analysis of sequence data.
32. Diagram the life cycle of a typical angiosperm.
33. What is the difference between nomenclature and taxonomy?
34. What is the difference between a new species ("sp. nov.") and a new combination ("comb. nov.")?
35. What is the difference between a stipule and a bract?
36. What is character optimization? In what situation do you have alternative optimizations for a character?
37. Name three requirements necessary to name a new plant species according to the rules of the *International Code of Botanical Nomenclature.*
38. What is the difference between a multiple fruit and an aggregate fruit?
39. What is homology? Name three criteria that can be used as tests of, or evidence for, homology.
40. Indicate whether each of the following groups is monophyletic based on our current understanding of relationships:
    eudicots:
    Cronquist's Magnoliidae:
    Asteraceae:
    angiosperms with monosulcate pollen:

Ethnobotany/ Economic Botany

41. Name two plants in the same family as the egg plant and also economically important because their fruits are consumed by humans.
42. From what part of the plant is harvested to make cocaine and to what family does this plant belong?
43. Name two edible parts of a palm tree.
44. Describe the difference in the way a coconut palm and a pine tree grow.
45. Name at least one plant explorer and one economically important plant that the explorer introduced from one to another part of the world.
46. In what area of the world are bananas native and why are native bananas not cultivated for food?
47. What two spices are derived from *Myristica fragrans* ?
48. Name two plants that have been introduced from the New World into the Old World.
49. Name two plants related to Broccoli and also used as vegetables?
50. What is an ear of corn?

City University of New York Graduate School
PhD Program in Biology–Plant Sciences First Examination 2008

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SESSION 3: Essay questions. Answer any two questions (50 points each). Do not neglect the workers or the literature. Remember that the topics must be significantly different from your essay topic for session 4.

1. The maize *Y1* locus encodes phytoene synthase, a key enzyme for carotenoid biosynthesis in all photosynthetic organisms. The gene has been isolated and sequenced. After screening a cDNA library from leaves, you find two clones (*PSY1* and *PSY2*); after sequencing of the clones you find that they have slightly different sequences when compared to each other. When both are compared to the genomic DNA, neither matches completely, although *PSY1* matches perfectly in six regions that are interrupted by 5 regions in the genomic DNA that have no match at all in the *PSY 1* cDNA. When *PSY2* is aligned to the genomic DNA sequence, there is also fairly good, but not perfect, homology with *Y1* genomic DNA; again there are 5 regions in the genomic DNA that have no match at all in *PSY2*.
    a. Which is the more likely EST that is encoded by *Y1*? What is your evidence?
    b. Why are there gaps in the alignments between cDNA and genomic DNA; what can we say about the relationship between the two genes encoding *PSY1* and *PSY2*?
    c. How would you test whether *PSY1* and *PSY2* both encode functional enzymes?
    d. How would you test gene-specific and tissue-specific mRNA accumulation for *PSY1* and *PSY2*?
    e. How could you test whether these duplicated genes are also present in evolutionarily related plants?

2. Angiosperm shoots and roots both grow from apical meristems, but differ structurally in that shoots are modular, composed of phytomers, whereas roots are not. Describe the structure and function of the shoot and root apical meristems. Include discussion of the trade-off between meristem maintenance and cell differentiation, and differences between the function and products of the two meristems. Explain the ways in which they are alike and different including:
    a. Location and organization of meristems, including "stem" cells
    b. Processes that occur in different zones of meristems
    c. Production of primordia and differentiated tissues
    d. Resulting structure of root and shoot
    e. One specific example of a molecular process involved in meristem function and/or primordium initiation.

3. A wealth of traditional statistical methods exist for the analysis of biological research data. Computationally intensive statistical procedures (i.e., randomization, bootstrap, Monte Carlo) are also available. Provide some guidelines for the investigator in choosing between traditional statistical methods and computationally intensive methods.

4. You wish to address a question that requires generating a phylogenetic hypothesis of the relationships among several related genera. How would you go about investigating these relationships, from study design to data collection and analysis? Name the individual steps and the requirements for this analysis, and make sure that you justify your choice of methods given that there are many different analytical options available.

City University of New York Graduate School
PhD Program in Biology–Plant Sciences First Examination 2008

5. Plants often produce a variety of closely related metabolites, at great metabolic cost to the organism. Give examples of this phenomenon in two separate species, using two different classes of secondary metabolites. What is the evolutionary advantage for a plant to produce a variety of closely related secondary metabolites, rather than just one compound of a given class?

6. Select an economically important plant of your choice and discuss its placement in the plant kingdom, its native range, what part of the plant is used, and how it is used by mankind. Your answer will be stronger if you have any knowledge of how this plant evolved and/or was selected for to make it economically important.

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PhD Program in Biology–Plant Sciences First Examination 2008

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SESSION 4: (100 points)

Present a subject, problem, hypothesis, theory, or controversy you consider important to plant sciences. The essay should show relevance across the botanical subdisciplines. The essay should be both a review and a synthesis and demonstrate the level of scholarship, criticism, and independent thinking we require at the doctoral level. Your topic may be a large or a small one; broad or highly specialized; and you must communicate how the chosen topic is relevant to a major concept. We wish to measure the ability to understand and to synthesize information and ideas from more than one discipline of biology. Be sure to include something about the researchers and the literature. The essay must be significantly different from your responses to the questions of Session III. Finally, an essay based largely on the published work or grant proposals of faculty staff members or scientists at other institutions is not acceptable.