City University of New York Graduate School
PhD Program in Biology–Plant Sciences First Examination 2005

SESSION 1: Basic Plant Biology. Answer these 50 questions. Two points credit each. -- PLEASE USE ANSWER SHEET.

Plant Physiology

1. The plastids are organelles peculiar of plant and algal cells. Give three examples of plastids and a brief description of their function(s).
2. Define the term "water potential" and express a general equation for water potential in plants (*hint*: use no more than three terms).
3. The water potential of a cultivated plant from a temperate climate is found to be –2 megapascals (MPa). Abscisic acid has accumulated in the leaves while cell expansion has decreased. Are these phenomena expected? Has the plant been under- or over-watered? Explain.
4. Molibdenum is a mineral nutrient that is found at 0.1 ppm of the dry matter of many plants; its deficiency may bring about a nitrogen deficiency and is manifested by a general chlorosis between veins and necrosis of the older leaves. How would you classify this element with respect to its abundance, its mobility and its biochemical function?
5. What is the Casparian strip? What is its function? From a functional standpoint, what is the most important substance in the cell walls of the Casparian strip?
6. What are the three molecules produced during the thylakoid-associated ("light") reactions in higher-plant photosynthesis?
7. What are the roles of carotenoids in the photosystems I and II?
8. Rubisco is the enzyme responsible for carbon dioxide fixation in the Calvin cycle (C3). What is the whole name of the enzyme? What are its substrates and the stable products?
9. What enzyme is responsible for carbon dioxide assimilation in the mesophyll of C4 plants such as sugarcane and maize?
10. Plant senescence can be defined as a normal, energy-dependent and genetically controlled process by which the organism recovers some of its metabolic resources, including sugars, nucleosides, amino acids, and mineral nutrients. True or false? Explain.
11. What is a bioassay? How did bioassays lead to the discovery of auxins?
12. The phytohormone _____ stimulates the production of hydrolases (e.g. amylase) in the cereal seed, whereas its antagonist, _____, causes the opposite effect.
13. What is a "long-day" plant? Is this term correct?
14. What is an action spectrum? Give an example of an action spectrum for a developmental phenomenon involving phytochrome.
15. During germination, several batches of lettuce seeds (*Lactuca sativa* cv. Grand Rapids) are given alternating treatments of red followed by far-red light. One of the batches was last illuminated with far-red light. Would these seeds germinate? Explain.

Cell and Developmental Biology

16. Name the meristems in flowering plants that give rise to secondary tissues.
17. Embryogenesis proceeds to different extents in different species. Name all the portions of a monocot embryo that might be considered extensively developed such as those of cereal grains.

18. What is/are the most fundamental distinction(s) between the processes of differentiation and morphogenesis?
19. The plant body is composed of tissue systems, each with its characteristic tissues. What are the three most characteristic tissues of the "Ground Tissue System" in flowering plants?
20. The life histories of plants are described as proceeding through an alternation of sporophytic and gametophytic generations. How many generations go into the composition of a seed?
21. How do adventitious, secondary, and primary roots differ from one another with respect to their site of origin?
22. Some seed-plant tissues are simple while others are complex. In the space provided next to the names of the following tissue types, specify with an "s" those which are simple and with a "c" those that are complex: collenchyma____, phloem____, xylem_____, epidermis____, parenchyma____, schlerenchyma_____.

Very briefly define the following terms:

23. Actinostele.
24. Phyllotaxy.
25. Shoot.
26. Annual species.
27. Tracheid.
28. Vessel element.
29. Sieve tube.

Plant Molecular Biology/ Genetics

30. Describe the general structure of the chloroplast genome in higher plants.
31. What is the difference between gene locus and gene allele?
32. Describe the molecular mechanism controlling chloroplast accumulation of a protein encoded by a nuclear gene?
33. Give one example and explain the utility of using reporter genes to characterize plant gene expression. What is one disadvantage in using the reporter gene?
34. Describe one method for introducing a transgene into Arabidopsis.
35. If two mutations belong to the same complementation group, what does it mean?
36. What is GenBank?
37. Give an example of a model plant organism and give three reasons for its choice?
38. What is a transposon?
39. What is an activator and where would it bind in order to affect the expression of a gene?
40. What are the typical temperatures used in a typical PCR (polymerase chain reaction) and what happens to DNA at each of the different temperatures?
41. If a plasmid is linearized with a restriction enzyme, can a DNA fragment digested with a different restriction enzyme be ligated to the plasmid? Why?
42. When a plant gene is transcribed, is the mRNA the same length as the gene itself? Why?
43. What can western blots be used to detect?
44. All of the cells in a plant have the same genome, which part of a gene and its surrounding sequence is used to determine which gene is expressed in what cell?

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Systematics

45. What is homology? Name three criteria that can be used as tests of, or evidence for, homology.
46. When we look at the results of a phylogenetic analysis, we often see homoplasy in the form of parallelisms and reversals of character states. What is homoplasy? What is the difference between parallelism and reversal? Give an example of each.
47. Can homoplasious characters serve as synapomorphies? Why or why not? Give an example.
48. What is a character? Give an example of an angiosperm character with 3 or more character states.
49. Draw a cladogram that shows the relationships among the following terminal taxa: prokaryotes, mosses, red algae, green algae, angiosperms, ferns, gymnosperms. Root this cladogram with the prokaryotes.
50. On the cladogram above, label the clades corresponding with green plants, land plants (Embryophytes), seed plants, vascular plants (Tracheophytes), and flowering plants.

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SESSION 2: Basic Plant Biology. Answer these 50 questions. Two points credit each. -- PLEASE USE ANSWER SHEET.

Basic Botany

51. Provide a single, well-formatted couplet of a dichotomous key that accurately distinguishes two plants (include at least two distinguishing features).
52. When did the first land plants appear in the fossil record?
53. What do fossils tell us about the age of taxa?
54. Name three apomorphies of monocots suggesting that they are monophyletic.
55. What are the major botanical ranks beginning with kingdom and progressing to species (at least 7)? Please provide the Latin names for each rank for corn (maize).
56. Name three families of flowering plants with opposite leaves.
57. Name a group of plants that produce seeds but not fruit?
58. Diagram a perfect flower and label the parts.
59. What type of pollen first appears in the fossil record?
60. Diagram a typical green-plant life cycle showing alternation of generations. Use the following terms: sporophyte, gametophyte, meiosis, zygote, fertilization, diploid (2n), haploid (n), sperm, and egg.
61. What portion of a moss is haploid? What portion of an angiosperm is haploid?
62. Name three families of flowering plants that capture and extract nutrients from insects.

Biostatistics and Ecology

63. What is a plant thermal energy budget and what does it tell us about the biology of the plant species in question?
64. You are sitting within the _____ biome and the terrestrial biome just North of here is the _____ biome, to the North of which lies the _____ biome.
65. In the New York City metropolitan area about _____% of our species of vascular plants are non-native.
66. In plant ecology, what's the difference between a Collector's Curve and a Species Area Curve?
67. In the 1930s and 1940s _____, _____, and _____ were among the major scientists who crafted our modern theory of evolution.
68. State the biological species concept. To whom is it attributed?
69. What would cause the distribution of a biological variable not to follow the normal probability distribution?
70. What's the difference between parametric and nonparametric statistical methods?
71. What are orthogonal comparisons in ANOVA?
72. Provide the general formula for calculating interval estimates in statistics.
73. In the statistical comparison of two samples of unpaired data, compare the Kolmogorov-Smirnov two sample test with the t-test.
74. What is analysis of variance (ANOVA)?

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Phytochemistry

75. Draw the basic structure of a phenylpropyl unit, and give an example of a class of phytochemicals that have phenylpropyl building blocks.
76. What is the key regulatory enzyme in flavonoid biosynthesis in which phenylalanine is a substrate?
77. Biosynthetically, what is the basic building block for the majority of alkaloids?
78. Draw a monoterpenoid, and circle its isoprenoid building blocks.
79. Define "allelopathy."
80. What is the mechanism of action of cardioactive glycosides?
81. Name a class of toxic diterpene esters found in many species of Euphorbia.
82. Name a quinolizidine alkaloid found in the Fabaceae that is associated with birth defects.
83. What is the yellow-colored alkaloid from in many members of the Berberidaceae family?
84. Name two plant pigments, one water-soluble and one fat-soluble.
85. What bioactivity is associated with the anthrones from senna?
86. What is the mechanism of action of the anticancer compound paclitaxel?
87. Name two groups of secondary compounds that are known to be phytoestrogens.
88. Name two edible plants rich in flavan-3-ols?

Ethnobotany/ Economic Botany

89. What is the difference between cultivation and domestication?
90. What is the Fertile Crescent?
91. Vavilov's Eight Centers of Domestication were identified using two major criteria. What were these criteria?
92. What is parthenocarpy? Provide an example of a parthenocarpic fruit.
93. Name two crops that are native to North America (i.e., north of Mexico).
94. Name two economically important plants from the Solanaceae.
95. "Chiles en nogada" is a traditional Mexican dish. It consists of a Poblano chile (*Capsicum*) covered in walnut sauce and sprinkled with pomegranate seeds. Is it likely that the Aztecs were eating "Chiles en nogada" before 1519? Why or why not?
96. From what part of the plant is chocolate derived?
97. Name two plant families known for their hallucinogenic properties.
98. Name one of the plant families that contributes to the ingredients of curare.
99. Walnuts, Brazil nuts, peanuts, and cashews are commonly referred to as "nuts." What does each of these "nuts" represent, morphologically speaking?
100. Apples, raspberries, and cherries are placed in the same plant family, the Rosaceae. Nevertheless, the fleshy tissues of these "fruits" are very different botanically (i.e., morphologically). What is the fleshy tissue derived from in apples? Raspberries? Cherries?

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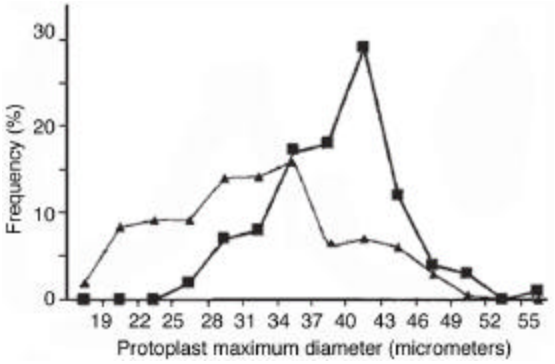
SESSION 3: Essay questions. Answer any two questions (50 points each). Do not neglect the workers or the literature. Remember that the topics must be significantly different from your essay topic for session 4. --PLEASE USE ANSWER SHEET.

1. Describe the process of ATP synthesis at the thylakoid membrane. Name reactants, energy source, participating enzyme, and role of light in the process. Discuss if ATP synthesis can take place in (a) thylakoid membranes kept in the dark or (b) in isolated thylakoids in which an artificial gradient of 4 pH units has been imposed with respect to the medium.

2. The following figure was adapted from Jones *et al.* (1998) Science 282:1114. The authors transformed tobacco plants with a full length *Arabidopsis* cDNA encoding auxin binding protein 1 (ABP1) that had been cloned in an appropriate vector. In one of their experiments, the authors prepared protoplasts from the leaves of a tobacco plant overexpressing the *ABP1* cDNA (squares) and from a control plant that had been transformed with the empty vector (triangles). They measured the protoplasts' diameter. The abscissa represents the frequency of protoplasts corresponding to different size classes according to their diameter in micrometers. Discuss what evidence can be obtained from this experiment in testing the hypothesis that ABP1 is a receptor controlling auxin-mediated plant cell expansion. Remember to consider the control protoplasts in your discussion.



3. The methods of phylogenetic systematics have proven useful in understanding current global biotic distributions. Explain how these techniques have been used to characterize the Pacific distributions of the southern beeches (genus *Nothofagus* of the family Nothofagaceae) as being the result of vicariance. Your answer should include both the development and use of phylogenetic and area cladograms.

4. The distribution of the southern beeches (genus *Nothofagus* of the family Nothofagaceae) has been studied using track analysis and the methods of panbiogeography originally developed by Croizat and expanded by Craw and others. These studies argue for a Pacific baseline consistent with the idea of the breakup of a Pacific continental landmass "Pacifica." Explain these methods, and how this differs from the notion of the breakup of Gondwana in the distribution of these plants. What geologic evidence supports these two differing hypotheses of the distribution of *Nothofagus*?

5. It has been said that phylogenetic systematics is the search for and resolution of paraphyly. Given an existing taxonomy for a group of interest to you explain in detail how you would go about determining if the group taxonomy exhibits a paraphyletic construct. If your study does indeed show that the current taxonomy is paraphyletic what are your next steps?

6. Describe seven of the most important morphological innovations in the evolution of land plants. What is the adaptive significance of these innovations? What groups do these innovations characterize?

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7. You are assigned a project to understand the regulatory network of anthocyanin biosynthesis in Arabidopsis. Previously, a group member isolated fifteen mutants that have been physiologically characterized to have defects in anthocyanin biosynthesis. What is your experimental strategy to continue this project towards the illustration of the network that regulates the biosynthesis of anthocyanins?

8. Recently, a novel carotenoid derivative has been suggested as a shoot branching- inhibiting "hormone" because mutations in carotenoid cleavage dioxygenases (CCDs) resulted in the failure of synthesis of this unknown, graft-transmissible inhibitor of shoot branching in pea and Arabidopsis. What kind of genetic or molecular approaches do you think will be more effective to 1) reveal the molecular identity of the carotenoid derivative, 2) demonstrate that the carotenoid derivative is a hormone, and 3) delineate the pathways for its biosynthesis and sensing?

9. How are natural products used as signaling agents? Give examples of natural products used for signaling: within a single plant; between two or more plants; and with another non-plant organism.

10. *Manihot esculenta* is of economic importance in tropical areas throughout much of the world. Where did this species originate? What parts of it are used? How is it cultivated? How are the products prepared? In other words discuss the economic botany of this plant.

11. Describe the importance of New World plants in the commerce of the world. Choose at least five plants from this region and discuss as many aspects of their economic botany as you can (i.e. where they originated, what parts are harvested, how they are prepared, etc.).

12. Compare and contrast computationally intensive methods with traditional statistical methods.

13. Why do some non-native plant taxa become invasive and others do not? What is the ecological impact of invasive plant species? Also include in your answer a treatment of the continuum that has been assigned categories ranging from "cultivated" to "invasive." Provide specific examples.

14. The composition and structure of the primary cell walls of plants undergo changes during the course of cellular differentiation. First describe the composition and structure of the primary cell walls of plants and then describe the changes that occur when it differentiates into each of the following cell types: 1. Collenchyma cell; 2. Sclerenchyma cell; 3. Tracheid; 4. Epidermal cell.

15. The species comprising extant land plants (Metaphyta, Embryophyta) have enough distinguishing features to enable their classification into at least seven phyla. Nevertheless, there are numerous features (chemical, cytological, physiological, and developmental) that are shared by all taxa of land plants. What are they?

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SESSION 4: (100 points) PLEASE USE ANSWER SHEET

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.