Cheat Sheet

Table 39.1

Table 39.1 Overview of Plant Hormones

Hormone	Where Produced or Found in Plant	Major Functions
Auxin (IAA)	Shoot apical meristems and young leaves are the primary sites of auxin synthesis. Root apical meristems also produce auxin, although the root depends on the shoot for much of its auxin. Developing seeds and fruits contain high levels of auxin, but it is unclear whether it is newly synthesized or transported from maternal tissues.	Stimulates stem elongation (low concentration only); promotes the formation of lateral and adventitious roots; regulates development of fruit; enhances apical dominance; functions in phototropism and gravitropism; promotes vascular differentiation; retards leaf abscission
Cytokinins	These are synthesized primarily in roots and transported to other organs, although there are many minor sites of production as well.	Regulate cell division in shoots and roots; modify apical dominance and promote lateral bud growth; promote movement of nutrients into sink tissues; stimulate seed germination; delay leaf senescence
Gibberellins (GA)	Meristems of apical buds and roots, young leaves, and developing seeds are the primary sites of production.	Stimulate stem elongation, pollen development, pollen tube growth, fruit growth, and seed development and germination; regulate sex determination and the transition from juvenile to adult phases
Abscisic acid (ABA)	Almost all plant cells have the ability to synthesize abscisic acid, and its presence has been detected in every major organ and living tissue; it may be transported in the phloem or xylem.	Inhibits growth; promotes stomatal closure during drought stress; promotes seed dormancy and inhibits early germination; promotes leaf senescence; promotes desiccation tolerance
Ethylene	This gaseous hormone can be produced by most parts of the plant. It is produced in high concentrations during senescence, leaf abscission, and the ripening of some types of fruits. Synthesis is also stimulated by wounding and stress.	Promotes ripening of many types of fruit, leaf abscission, and the triple response in seedlings (inhibition of stem elongation, promotion of lateral expansion, and horizontal growth); enhances the rate of senescence; promotes root and root hair formation; promotes flowering in the pineapple family
Brassinosteroids	These compounds are present in all plant tissues, although different intermediates predominate in different organs. Internally produced brassinosteroids act near the site of synthesis.	Promote cell expansion and cell division in shoots; promote root growth at low concentrations; inhibit root growth at high concentrations; promote xylem differentiation and inhibit phloem differentiation; promote seed germination and pollen tube elongation
Jasmonates	These are a small group of related molecules derived from the fatty acid linolenic acid. They are produced in several parts of the plant and travel in the phloem to other parts of the plant.	Regulate a wide variety of functions, including fruit ripening, floral development, pollen production, tendril coiling, root growth, seed germination, and nectar secretion; also produced in response to herbivory and pathogen invasion
Strigolactones	These carotenoid-derived hormones and extracellular signals are produced in roots in response to low phosphate conditions or high auxin flow from the shoot.	Promote seed germination, control of apical dominance, and the attraction of mycorrhizal fungi to the root

Chapter 39 Questions

1. **What is etiolation?**
2. **What is de-etiolation?**
3. **What is a phytochrome?**
4. **What is the *aurea* mutant?**
5. **Describe the role of second messengers in phytochrome signal transduction.**
6. **What two hormones enhance stem elongation?**
7. **What is a hormone?**
8. **What are plant growth regulators?**
9. **Describe the 8 plant hormones (where they are produced and their functions).**
10. **What is tropism?**
11. **What is phototropism?**
12. **What plant organ is responsible for sensing light?**
13. **What is the the most common natural auxin?**
14. **What are auxins?**
15. **Where are auxins produced and how are they transported?**
16. **What concentration of auxin is required for growth stimulation?**
17. **What is the acid growth hypothesis?**
18. **What contributes to branching patterns?**
19. **How is phyllotaxy determined?**
20. **How does inhibition of polar auxin transport affect pattern of leaf veins?**
21. **What controls the vascular cambium's activity?**
22. **What happens to auxin transport when a plant becomes dormant at ends of growing season?**
23. **What is indolebutyric acid (IBA)?**
24. **What is 2,4-dichlorophenoxyacetic acid (2,4-D)?**
25. **What are cytokinins?**
26. **How do cytokinins move through the plant?**
27. **How do cytokinins interact with auxins?**
28. **How is apical dominance controlled?**
29. **What happens when the apical bud is cut off?**
30. **How do cytokinins slow aging?**
31. **What is *Gibberella*?**
32. **How do gibberellins enhance cell elongation and cell division?**
33. **What is bolting?**
34. **What is the most important commercial application of gibberellins?**
35. **What causes the seed to break dormancy and germinate?**
36. **What is the aleurone?**
37. **What is abscisic acid?**
38. **How does ABA control seed germination?**
39. **How does ABA play a role in drought signaling?**

40. **What is ethylene?**
41. **What is the triple response?**
42. **What are *ein* mutants?**
43. **What are *eto* mutants?**
44. **What are *ctr* mutants?**
45. **What is senescence?**
46. **How do autumn leaves fall?**
47. **How does ethylene contribute to fruit ripening?**
48. **How is fruit ripening prevented commercially?**
49. **What are brassinosteroids?**
50. **What are jasmonates?**
51. **What is the main ingredient that produces jasmine (*Jasminum grandiflorum*) fragrance?**
52. **What are strigolactones?**
53. **What is *Striga*?**
54. **What is photomorphogenesis?**
55. **What is an action spectrum?**
56. **What are the two major classes of light receptors?**
57. **What are cryptochromes?**
58. **What is phototropin?**
59. **What are circadian rhythms?**
60. **What are free-running periods?**
61. **What controls circadian rhythms?**
62. **How do plants entrain their biological clocks?**
63. **What is photoperiodism?**
64. **What is Maryland Mammoth?**
65. **What is a short-day plant?**
66. **What are long-day plants?**
67. **What are day-neutral plants?**
68. **What is the cocklebur (*Xanthium strumarium*)?**
69. **How do red and far-red lights affect the plant's sense of photoperiod?**
70. **What is vernalization?**
71. **What is florigen?**
72. **What is gravitropism?**
73. **What are statoliths?**
74. **What is thigmomorphogenesis?**
75. **What is thigmotropism?**
76. **What are pulvini?**
77. **What are action potentials?**
78. **How do plants combat oxygen deprivation in roots?**
79. **How do plants combat salt stress?**
80. **What are heat-shock proteins?**
81. **How do plants respond to cold stress?**

82. How do antifreeze proteins work?
83. What is PAMP-triggered immunity?
84. What are effectors?
85. What is effector triggered immunity?
86. What is the hypersensitive response?
87. What is systemic acquired resistance?
88. What 3 types of compounds do plants produce to deter attackers?
89. What are idioblasts?
90. What is benzyl alcohol?
91. What is masting?

Chapter 39 Answers

1. Morphological adaptations for growing in darkness
2. Changes that occur when plant reaches light (aka greening)
3. Member of a class of photoreceptors that is involved with de-etiolation
4. Has reduced levels of phytochrome, greens less when exposed to light
5. Phytochrome activation opens Ca^{2+} channels (100-fold increase in cytosolic Ca^{2+} levels). Light causes phytochrome to shape change, leads to activation of guanylyl cyclase (produces cGMP), both Ca^{2+} and cGMP must be produced for de etiolation.
6. Auxin and brassinosteroids
7. signaling molecule produced in (in plants, very) low concentrations by one part of an organisms body and transported to other parts
8. Broader than hormone, describes organic compounds that modify physiological processes
9. see picture
10. Growth response that results in organs curving away or towards stimuli
11. Growth of shoot toward or away from light (positive/negative respectively), results from differential growth of cells on opposite sides of the shoot
12. tip of the coleoptile
13. indoleacetic acid (IAA)
14. Chemical substance that promotes elongation of coleoptiles
15. predominantly in shoot tip, transported cell to cell at rate of 1 cm/hr (only moves from tip to base, called polar transport, caused by polar distribution of auxin transport proteins (concentrated at basal end of cell))
16. 10^{-8} to 10^{-4} M, at higher may inhibit cell elongation by inducing ethylene production
17. Proton pumps play major role in growth response. Auxin stimulates H^{+} pumps, increasing membrane potential, lowering cell wall pH, activates proteins called expansins (break down cross-links between microfibrils and rest of cell wall)
18. Synthesis of auxin in shoot tips (carries integrated information about branches, allows plant to decide where branches are needed.
19. Arrangement of leaves, polar auxin transport leads to peaks in concentration that determine leave positions
20. Results in leaves without vascular continuity through petiole, have broad, loosely organized main veins, more secondary veins, dense band of irregularly shaped vascular cells next to leaf margins
21. auxins
22. Reduction in auxin transport capacity and expression of genes
23. natural auxin used in vegetative propagation to help grow adventitious roots
24. Synthetic auxin used as herbicide, monocots can inactivate it but eudicots can’t, die to hormone overdose
25. Modified forms of adenine, stimulate cell division, most common natural one is zeatin (discovered first in maize)

26. Move from production site (roots) by xylem sap
27. Only lead to cell division when together, cytokinin:auxin ratio controls cell differentiation (at certain levels, cells remain as mass called callus, if cytokinin levels increase shoots form, if auxin levels increase then roots form
28. Sugar demand of apical meristem reduces availability for axillary buds. Auxins, cytokinins, and strigolactones determine how much each axillary elongates, auxins from apical bud inhibit axillary bud growth but flow of auxins triggers synthesis of strigolactones (directly repress bud growth). Cytokinins entering from roots counter auxin and strigolactones
29. axillary buds closest to surface grow most vigorously, one will take over apical bud (auxin levels reduced, so less growth repression)
30. Inhibit protein breakdown, stimulate RNA and protein synthesis, mobilize nutrients from surrounding tissues
31. genus of fungi, one causes “foolish seedling disease” (rice grows so tall that it topples over, fungus causes hyper elongation by secreting gibberellins)
32. Activate enzymes that loosen cell walls to allow entry of expansins
33. Rapid growth of floral stalk
34. Spraying of Thompson seedless grapes (causes individual grapes to grow larger, grapes more spaced because internodes of grape bunch elongate, reduces infection)
35. Embryo releases gibberellins
36. Thin outer layer of endosperm
37. Slows growth, causes seed dormancy and drought tolerance
38. Levels increase 100 fold during seed maturation, inhibiting germination, induces production of proteins that help seed withstand harsh climate. When ABA removed/inactivated seed germinates, ratio ABA to gibberellin decides dormant or not, inactivated ABA can cause precocious germination (early)
39. When plant begins wilting, accumulates in leaves and stomata close rapidly. Causes potassium channels in guard cells to open, causes potassium ions to leave cells (water follows, closing stomata)
40. Gas produced by plants in response to stresses and high concentrations of external auxins and during fruit ripening/programmed cell death
41. Growth maneuver that enables shoot to avoid obstacle (initiated when tip hits obstacle and produces ethylene). Slowing of stem elongation, thickening of stem, curving so that stem begins growing horizontally (until ethylene effects lessen)
42. ethylene insensitive mutants, fail to undergo triple response after exposure to ethylene
43. ethylene overproducing mutants, produce ethylene 20 times normal speed
44. Constitutive triple response mutants, undergo triple response in air but do not respond to ethylene synthesis inhibitors, in mutants a protein kinase (negative regulator) doesn’t work
45. Programmed death of certain cells/organs/entire plant, burst of ethylene associated with apoptosis of cells
46. Essential elements stored in parenchyma cells in stem, Detach from stem at an abscission layer (develops near base of petiole, made up of small parenchyma cells

have thin walls, no fiber cells around vascular tissue), enzymes hydrolyze polysaccharides in cell walls of abscission layer. Cork forms protective scar on twig side of abscission layer. aging leaf produces less auxin, so ethylene-auxin ratio increases, causing cell to produce cellulose digesting proteins.

47. Burst of ethylene production triggers ripening process (enzymatic breakdown of cell wall softens fruit and conversion of starches/acids to sugars makes fruit sweet), ethylene triggers ripening, ripening triggers ethylene production, signal to ripen can spread from fruit to fruit (ethylene=gas)
48. Flushed with CO_2 (air movement prevents ethylene accumulation, CO_2 inhibits synthesis of more ethylene.
49. Steroids similar to cholesterol, induce cell elongation/division at concentrations as low as 10^{-12} M, slow leaf abscission and promote xylem differentiation
50. Include jasmonate(JA) and methyl jasmonate(meJA), fatty acid-derived molecules, play roles in plant defense and plant development.
51. meJA
52. Xylem-mobile chemicals, stimulate seed germination, suppress adventitious root formation, help establish mycorrhizal associations, help control apical dominance
53. genus of rootless parasitic plants, penetrate roots of other plants, aka witchweed
54. Key events in plant growth/development triggered by light
55. Effectiveness of different wavelengths of radiation in driving a particular process
56. blue-light receptors - initiates phototropism, opening of stomata, slowing of hypocotyl elongation (when seedling breaks ground)
    phytochromes - regulate seed germination and shade avoidance, cause blue-light-stimulated phototropism. Flip between red form (P_r) and far-red form (P_{fr}), P_{fr} triggers many of plants developmental responses to light. P_r absorbs red to become P_{fr} which absorbs far-red to become P_r. Conversion to P_{fr} is faster, so ratio of P_{fr} to P_r increases in sunlight, ratio tells the percents of far-red and red light
57. Molecular relatives of DNA repair enzymes, involved in blue-light-induced inhibition of stem elongation
58. protein kinase involved in mediating blue-light-mediated stomatal opening
59. Cycles with frequency of about 24 hours
60. Duration of one cycle when organism is kept in constant environment
61. Oscillations in transcription of certain genes, 24-hours periods arises from negative-feedback loops involving transcription of a few central “clock genes”
62. P_r synthesized and P_{fr} degraded faster than P_r, in darkness P_r to P_{fr} ratio increases, clock resets when P_{fr} suddenly increases in morning.
63. Response to specific night/day lengths (photoperiod = day length)
64. Mutant variety of tobacco, Grew tall but failed to flower during summer, bloomed in a greenhouse in Dec, shortened days stimulated flowering (14 hrs or shorter)
65. Plant that requires dark period longer than a critical length to flower (continuous darkness)
66. Plant that flower in late spring/early summer, need dark period shorter than certain number of hours (continuous darkness)

67. plants that flower regardless of photoperiod
68. short-day plant, flowers only when nights longer than 8 hours (continuous darkness)
69. Red light interrupts night length, far-red counter red light because phytochrome detects the light
70. Use of pretreatment with cold to induce flowering (used to make winter wheat flower)
71. Hypothetical signaling molecule for flowering, triggers flowering in both short- and long-day plants. Found to be programmed by *FLOWERING LOCUS T (FT)*, activated in leaf cells during conditions favoring flowers
72. responses to gravity, roots display positive gravitropism, shoots negative
73. dense cytoplasmic components that settle under influence of gravity to lower portions of cell, may help plants detect gravity (in vascular plants are specialized plastids containing dense starch grains), triggers redistribution of calcium that causes lateral transport of auxin within root (causing high concentration at lower side, inhibiting cell elongation)
74. changes in form resulting from mechanical perturbation
75. Directional growth in response to touch
76. Specialized motor organs, located at joints of leaves of *Mimosa pudica*, lose potassium ions when the leaf is touched (lose turgor, leaves fold in)
77. Electrical impulse traveling at about 1 cm/sec in plants, resemble nerve impulses in animals but slower
78. Produce ethylene (causes cells in root cortex to die, creating air tubes that are like snorkels
79. Increase solute concentrations within cell (halophytes have salt glands that pump salts across leaf epidermis)
80. Produced above certain temp (about 40ºC), help protect other proteins from heat stress
81. Change lipid composition of membranes. Freezing reduces cell wall water content, causing water to exit cytosol, so plants increase cytosol solute concentrations
82. Bind to small ice crystals to inhibit growth or prevent crystallization
83. First line of immune defense, depends on plants ability to recognize pathogen-associated molecular patterns (formerly called elicitors, molecular sequences that are specific to certain pathogens). Bacterial flagellin (found in flagella) is a PAMP. Toll-like receptor perceives amino acid sequence on PAMP, recognition leads to local production of antimicrobial chemicals (phytoalexins). Plant cell wall is toughened
84. Pathogen-encoded proteins that cripple plant's innate immune system
85. Hundreds of disease resistant ® genes, each codes for R protein that can be activated by specific effector, can lead to hypersensitive or systemic acquired resistance
86. Local cell and tissue death that occurs at/near infection site, restricts spread of pathogen
87. Arises from plant-wide expression of defense genes, nonspecific, provides protection against diversity of pathogens, methylsalicylic acid (signaling molecule) produced near infection site/carried by phloem throughout plant, converted to salicylic acid far away from infection, poises defense system to respond to infection rapidly
88. Terpenoids, phenolics, alkaloids (terpenoids mimic insect hormones to cause insects to molt prematurely and die)(tannins (type of phenolic) have unpleasant taste, hinder protein digestion)(alkaloids include narcotic morphine, heroin, and codeine (found in

poppy, *Papaver somniferum*) that accumulate in secretory cells called laticifers that exude milky white opium when plant is damaged)

89. Specialized cells found in leaves and stems of many species including taro that contain needle-shaped crystals of calcium oxalate (raphides) that penetrate soft-tissues of tongue to allow protease to cause swelling
90. chemical that attracts hawk-moths
91. Population synchronously produces massive amount of seeds after a long interval.