Instructor Guide

Greenhouse Operation and Management

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Foreword

The revised edition of *Greenhouse Operation and Management* is designed as a semester course for 11th and 12th grade students who are interested in various aspects of greenhouse production. The curriculum comprises seven units that reflect relevant issues of concern to a greenhouse owner: (1) The Greenhouse Industry, (2) Growing Structures, (3) Plant Science Basics, (4) Plant Growth, (5) Plant Propagation, (6) Plant Health, and (7) Greenhouse Business Management.

Each lesson per unit in the Instructor Guide includes motivational techniques, discussion of the study questions, an assessment, transparency masters, and activity sheets. Answers to the assessment and activity sheets are provided. The Instructor Guide also includes features to assist the classroom teacher: a summary of competencies/objectives, references and materials, a table relating the competencies to the Show-Me Standards and Missouri's Frameworks for Curriculum Development, competency profile, and a suggested time frame for teaching this material. Details concerning advance preparation for activities in Unit IV are also given.

The appendix in this revision includes the following forms pertaining to the State Floriculture Contest: (1) Floriculture Plant Identification List, (2) Floriculture Identification Scorecard (Forms 60a and 60b), and (3) Floriculture/Greenhouse Items (Form 64). These forms are further identified as Floriculture-2001 (09-25-01). At the end of the Student Reference there is a glossary of technical terminology used in greenhouse operations.

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Greenhouse Operation and Management

Table of Contents

Acknowledgments iii

Foreword iv

Competencies/Objectives ix

References and Materials x

Greenhouse Operation and Management - Competency Crosswalk xxix

Greenhouse Operation and Management - Competency Profile xxxi

Suggested Time Frame for Teaching xxxv

Planning for Unit IV Activities xxxvii

Appendix - Forms Pertaining to State Floriculture Contest

Floriculture Plant Identification List xxxix
Floriculture Identification Scorecard (Form 60a) xliii
Floriculture Identification Scorecard (Form 60b) xlv
Floriculture/Greenhouse Items (Form 64) xlix

Unit I: The Greenhouse Industry

Lesson 1: Scope and Development of the Greenhouse 1

TM 1.1 1999 Missouri Floriculture Crops 11
TM 1.2 2000 U.S. Floriculture Crops 13
TM 1.3 2000 U.S. Bedding and Garden Plant Sector 15
AS 1.1 Growing Possibilities 17
AS 1.2 Investigating a New Product in the Greenhouse Industry 19
AS 1.3 Global Greenhouses 21

Lesson 2: Career Opportunities in the Greenhouse Industry 23

TM 1.4 Organizational Structure of a Large Greenhouse Operation 33
AS 1.4 Greenhouse Careers: Which One? How to Succeed? 35
AS 1.5 Getting Involved in the Greenhouse Industry 37

Unit II: Growing Structures

Lesson 1: Greenhouse Parts, Structures, and Coverings....39

TM 2.1 Frame Types....51
TM 2.2 Ridge and Furrow Construction....53
TM 2.3 Lean-To Greenhouse....55
TM 2.4 Parts of a Greenhouse....57
TM 2.5 Interior Layout of a Greenhouse....59
TM 2.6 Other Outdoor Growing Structures....61
AS 2.1 Plan Your Own: Part I....63

Lesson 2: Environmental Controls....65

TM 2.7 Devices to Monitor Temperature....79
TM 2.8 Methods of Ventilation....81
AS 2.2 Plan Your Own: Part I....83

Lesson 3: Energy Conservation and Environmental Protection....85

AS 2.3 Windbreak....91

Unit II Activity: Greenhouse Portfolio....93

Unit III: Plant Science Basics

Lesson 1: Plant Parts, Structures, and Functions....95

TM 3.1 Basic Structure of a Plant Cell....113
TM 3.2 Cross-Sections of Monocot and Dicot Seeds....115
TM 3.3 Monocot vs. Dicot....117
TM 3.4 Parts of a Plant....119
TM 3.5 Types of Roots....121
TM 3.6 Specialized Stems....123
TM 3.7 Cross-Section of a Leaf....125
TM 3.8 Leaf Shapes....127
TM 3.9 Leaf Margins....129
TM 3.10 Leaf Attachments....131
TM 3.11 Parts of a Complete Flower....133
AS 3.1 Plant Parts, Structures, and Functions Work Sheet....135
AS 3.2 Stem Poster....141
AS 3.3 Leaf Poster....143
AS 3.4 Identifying Monocot and Dicot Plants....145

Lesson 2: Plant Processes 147

TM 3.12 Photosynthesis..155
AS 3.5 The Five Plant Processes 157

Lesson 3: Plant Classification and Nomenclature 159

TM 3.13 Stem Growth 165
TM 3.14 Major Classification Categories..167
AS 3.6 Plant Pictionary: Part I..169
AS 3.7 Plant Pictionary: Part II..171

Unit IV: Plant Growth

Lesson 1: Environmental Effects 173

TM 4.1 Radiant Light Spectrum 185
AS 4.1 Foot-Candle Demonstration..187
AS 4.2 Effect of Light on Plants..189
AS 4.3 Photoperiod in Plants..191
AS 4.4 Greenhouse Air Pollutants..193

Lesson 2: Growing Media and Containers..195

TM 4.2 Composition of Soil-Based Growing Medium 209
TM 4.3 Soil Texture Triangle 211
TM 4.4 pH Scale..213
TM 4.5 Peat Containers 215
TM 4.6 Identifying Cell Packs..217
TM 4.7 Container Shapes 219
AS 4.5 Growing Media and Containers..221
AS 4.6 Materials Update..223
AS 4.7 Container Shopping 225

Lesson 3: Irrigation..227

TM 4.8 Interaction Between Growing Medium's Porosity and Depth..237
TM 4.9 Capillary Action of Water in Growing Medium..239
AS 4.8 Over-, Under-, and Proper Watering 241
AS 4.9 Water Delivery Systems 243

Lesson 4: Nutrients 245

TM 4.10 Effect of Field Soil's pH on Nutrient Availability..255
TM 4.11 Effect of Soilless Medium's pH on Nutrient Availability 257
AS 4.10 Specific Nutrients 259

Lesson 5: Fertilizer 261

TM 4.12 Hose-Siphoning Device Used to Apply Fertilizer 269
TM 4.13 Dosmatic Injector....................271
AS 4.11 Healthy Plant....................273
AS 4.12 Calculating Fertilizer Dilution Ratios....................277

Unit IV Activity: Plant Portfolio....................279

Unit V: Plant Propagation

Lesson 1: Sexual Propagation....................281

TM 5.1 Steps in Seed Germination of a Monocot 291
TM 5.2 Steps in Seed Germination of a Dicot....................293
AS 5.1 Transplanting Seedlings....................295

Lesson 2: Asexual Propagation....................297

TM 5.3 Cutting Locations....................307
TM 5.4 Cuttings....................309
TM 5.5 Division....................311
TM 5.6 Grafting....................313
TM 5.7 Layering....................315
AS 5.2 Asexual Propagation....................317
AS 5.3 Budding and Tissue Culture 319

Unit VI: Plant Health

Lesson 1: Greenhouse Pests and Diseases....................321

TM 6.1 Types of Mouth Parts....................331
TM 6.2 Gradual Metamorphosis....................333
TM 6.3 Complete Metamorphosis 335
TM 6.4 Aphid....................337
TM 6.5 Fungus Gnat....................339
TM 6.6 Mealybug 341
TM 6.7 Scale....................343
TM 6.8 Thrips 345
TM 6.9 Whitefly 347
TM 6.10 Spider Mites....................349
TM 6.11 Other Pests 351
AS 6.1 Path of Destruction Part I: Insects and Arachnids....................353
AS 6.2 Path of Destruction Part II: Other Pests and Diseases....................355

Lesson 2: Pest Control 357

AS 6.3 Applied Pest Management 365
AS 6.4 Integrated Pest Management 367

Lesson 3: Pesticide Use and Safety 369

TM 6.12 Sample Pesticide Label 385
TM 6.13 Types of Sprayers Used to Apply Pesticides 387
TM 6.14 Pesticide Application Log 389
AS 6.5 Pesticide Dilution Ratios 391
AS 6.6 Pesticide Update 393

Unit VII: Greenhouse Business Management

Lesson 1: Commercial Greenhouse Crops 395

TM 7.1 Missouri's Commercial Floriculture Crops 405
TM 7.2 Missouri's Popular Floriculture Crops 407
AS 7.1 Selecting Commercial Crops and Devising a Growing Schedule 409
AS 7.2 Cost Analysis of a Commercial Crop 411
AS 7.3 Plant Care After Harvest and During Marketing 413

Lesson 2: Marketing Plan 415

AS 7.4 Creating a Marketing Plan 423

Unit VII Activity: Designing a Garden 425

COMPETENCIES/OBJECTIVES

Unit I: The Greenhouse Industry

1. Identify the scope and development of the greenhouse industry.
2. Outline career paths and SAE (Supervised Agricultural Experience) opportunities available in the greenhouse industry.

Unit II: Growing Structures

1. Distinguish types of greenhouses by materials, structure, and layout.
2. Describe how environmental factors in a greenhouse are controlled.
3. Identify energy- and cost-saving factors in greenhouse structures.

Unit III: Plant Science Basics

1. Distinguish plant parts, structures, and functions.
2. Identify the growth processes of a plant.
3. Distinguish plants by characteristics and purpose.

Unit IV: Plant Growth

1. Describe environment necessary for optimal plant growth.
2. Distinguish components of growing media, their uses, and basic types and sizes of containers.
3. Explain factors involved in proper greenhouse irrigation.
4. Identify nutrients essential for plant growth and development and signs of deficiency or toxicity.
5. Identify the need for fertilizer.

Unit V: Plant Propagation

1. Demonstrate the correct method for sexual propagation in the greenhouse environment.
2. Differentiate between various types of asexual propagation procedures.

Unit VI: Plant Health

1. Identify pests and diseases in the greenhouse and factors that contribute to their presence.
2. Differentiate between various pest management methods.
3. Explain safe usage and application of pesticides.

Unit VII: Greenhouse Business Management

1. Plan a commercial greenhouse crop.
2. Develop a basic marketing plan.

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Lesson 5: Fertilizer

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Unit V: Plant Propagation

Lesson 1: Sexual Propagation

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Lesson 1: Greenhouse Pests and Diseases

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Lesson 2: Pest Control

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Lesson 3: Pesticide Use and Safety

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Unit VII: Greenhouse Business Management

Lesson 1: Commercial Greenhouse Crops

<u>Books and Web Sites</u>

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Biernbaum, John A. “Greenhouse Crop Production: Counting the Costs and Making Cents.” Michigan State University. <http://www.hrt.msu.edu/HortLinks/pdf_files/Production_Costs_Article.pdf> accessed 3/19/02.

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Greenhouse Operation and Management - Competency Crosswalk

Duty Band & Task Statement	SHOW-ME STANDARDS		CURRICULUM FRAMEWORKS FOR GRADES 9-12					
	Knowledge (Content)	Performance (Goals)	Communication Arts	Fine Arts	Health/ Physical Education	Math	Science	Social Studies
A-1	MA1; SS2,4	1.6	I\3b,c; II\4i					IV.C\1d,g; IV.D\2k
A-2	CA1,4,6; HP2; SC8	1.1, 1.2, 1.3, 1.8, 1.10, 2.3, 2.6, 3.1, 4.1, 4.8	I\2a,c, e; I\3a,f; IV\1e, 2d		V.B\2b			II.D\4m,n
B-1	FA1,2; MA2	1.4, 1.8, 3.7, 4.1	I\6a,d	IV.D\c, d				IV.E\4c,d,k
B-2	CA1,4; SC4,8	1.2, 1.4, 1.6, 3.1, 3.5, 4.1	I\2a,c,e;I\3 b,c				VII.B\1a	IV.E\4c,d,k; I.E4\c,d,e,g,h
B-3	SC3,4,8	1.2, 1.3, 1.7, 2.7, 3.5	I\2a,c,e;I\3 b,c; II2\c; II\4i	IV.D\2a,d			III.B\2a	IV.E\4c,d,k
C-1	CA1,4,6; FA1; SC3	1.1, 1.2, 1.3, 1.6	I\2a,c,e;I\3 b,c; III\1d,j	IV.D\2,a,d; IV.D\6b			VII.A\1a, 2a	
C-2	SC3,4; CA1,4	1.3, 1.10	I\2a,c,e;I\3 b,c; II\4i				VII.A\1a, 2a; VII.B\1a, 2a, 3a	
C-3	CA6,7;FA4	1.6, 1.8		IV.D\1g			VII.A\4a	
D-1	CA1; SC1,3,4,8	1.3, 1.6	I\2a,c,e;I\3 b,c				VI.B\3a	I.A\6 b; I.D\5,d,
D-2	SC5;MA1	1.3, 1.6	I\2a,c,e; III\1d,j			I\4d; IV\2c,d	VI.A\1a	I.A\4 c,d,g,h
D-3	SC5;CA1,4	1.2, 1.3, 1.6	I\2a,c,e				VI.B\1a, 3a	III.A\2 b,d,e,f
D-4	SC3; CA1, 6	1.2, 1.3, 1.4	I\2a,c, e; III\1d, j				VII.A\2a	
D-5	SC3, 4, 8; MA1, 5	1.3	I\2a,c, e;I\3 b, c; II\2c; III\1d, j			I\4 d; III\2 b, c	VII.A\2a	
E-1	SC3, 4, 5	1.2, 1.4, 1.5, 1.6, 1.10, 2.4	I\3b,c				VII.A\3a; VII.D\1a, 2a, 5a	
E-2	SC3, 4, 5, 8; MA1; CA1	1.2, 1.3, 1.4, 2.1	I\3b,c				VII.D\2c	

xxix

Duty Band & Task Statement	SHOW-ME STANDARDS		CURRICULUM FRAMEWORKS FOR GRADES 9-12					
	Knowledge (Content)	Performance (Goals)	Communication Arts	Fine Arts	Health/ Physical Education	Math	Science	Social Studies
F-1	SC3, 4, 8; FA1, 4	1.2, 1.3	I\2a,c, e; II\1a,d; III\1d,j	IV.D\2a,bI V.D\6b			VIII.B\1a	
F-2	SC3, 4, 8; CA1, 4, 6	1.2, 1.4 1.6, 3.1, 3.2, 3.3, 3.4, 3.7, 4.1	I\2a,c, e				VIII.B\1a	
F-3	SC3, 4, 8; MA1; HP6, 7	1.2, 1.4, 1.6, 1.8, 1.10, 3.2, 3.3, 3.7	I\2a,c,e;I\3 b, c; II\4i		III.D\1a: III.D\2a; V.B\2b	I.A\4d; III\2 b, c	VIII.B\1a	
G-1	CA1, 4; MA1; SS4	1.4, 1.8, 1.10, 2.1, 2.2, 2.6, 3.1, 3.8	I\3b			V\4a		
G-2	CA1, 4, 6; FA1, 2; MA1, 2, 3; SS4	1.6, 1.8, 1.10, 2.1, 2.2, 2.3, 2.5, 2.6, 2.7, 3.2, 3.3, 3.4, 4.5	I\6a, c, d; II\2c; II\3a, b, c; II\4a, b, c, g, h, i; II\5e	IV.C\3a; IV.C\5c; IV.D\4b		III\2 b, c; IV\2 c, d; IV\3 c, d; V\4a, c; VII\2 c, d; VII\5 c, d		

Name: ____

Greenhouse Operation and Management Competency Profile (Catalog Number 10-2010-C)

Directions: Evaluate the student by checking the appropriate number to indicate the degree of competency. The rating for each task should reflect **employability readiness** rather than the grades given in class.	**Student Rating Scale:** **3 – Mastered** – can work independently with no supervision **2 – Requires Supervision** – can perform the job completely with limited supervision **1 – Not Mastered** – requires instruction and close supervision **N – No Exposure** – no experience or knowledge in this area **Revised 2002**

3	2	1	N	**A. The Greenhouse Industry**
				1. Identify the scope and development of the greenhouse industry.
				2. Outline career paths and SAE (Supervised Agricultural Experience) opportunities available in the greenhouse industry.
				Other: ______________________________

3	2	1	N	**B. Growing Structures**
				1. Distinguish types of greenhouses by materials, structures, and layout.
				2. Describe how environmental factors in a greenhouse are controlled.
				3. Identify energy- and cost-saving factors in greenhouse structures.
				Other: ______________________________

3	2	1	N	**C. Plant Science Basics**
				1. Distinguish plant parts, structures, and functions.
				2. Identify the growth processes of a plant.
				3. Distinguish plants by characteristics and purpose.
				Other: ______________________________

3	2	1	N	**D. Plant Growth**
				1. Describe environment necessary for optimal plant growth.
				2. Distinguish components of growing media, their uses, and basic types and sizes of containers.
				3. Explain factors involved in proper greenhouse irrigation.
				4. Identify nutrients essential for plant growth and development and signs of deficiency or toxicity.
				5. Identify the need for fertilizer.
				Other: ______________________________

3	2	1	N	**E. Plant Propagation**
				1. Demonstrate the correct method for sexual propagation in the greenhouse environment.
				2. Differentiate between various types of asexual propagation procedures.
				Other: ______________________________

3	2	1	N	**F. Plant Health**
				1. Identify pests and diseases in the greenhouse and factors that contribute to their presence.
				2. Differentiate between various pest management methods.
				3. Explain safe usage and application of pesticides.
				Other: ______________________________

3	2	1	N	**G. Greenhouse Business Management**
				1. Plan a commercial crop.
				2. Develop a basic marketing plan.
				Other: ______________________________

Greenhouse Operation and Management

Student Names															
															UNIT I - THE GREENHOUSE INDUSTRY
															1. Identify the scope and development of the greenhouse industry.
															2. Outline career paths and SAE (Supervised Agricultural Experience) opportunities available in the greenhouse industry.
															UNIT II - GROWING STRUCTURES
															1. Distinguish types of greenhouses by materials, structures, and layout.
															2. Describe how environmental factors in a greenhouse are controlled.
															3. Identify energy and cost-saving factors in greenhouse structures.
															UNIT III - PLANT SCIENCE BASICS
															1. Distinguish plant parts, structures, and functions.
															2. Identify the growth processes of a plant.
															3. Distinguish plants by characteristics and purpose.
															UNIT IV - PLANT GROWTH
															1. Describe environment necessary for optimal plant growth.
															2. Distinguish components of growing media, their uses, and basic types and sizes of containers.
															3. Explain factors involved in proper greenhouse irrigation.
															4. Identify nutrients essential for plant growth and development and signs of deficiency or toxicity.
															5. Identify the need for fertilizer.

															UNIT V - PLANT PROPAGATION
															1. Demonstrate the correct method for sexual propagation in the greenhouse environment.
															2. Differentiate between various types of asexual propagation procedures.
															UNIV VI - PLANT HEALTH
															1. Identify pests and diseases in the greenhouse and factors that contribute to their presence.
															2. Differentiate between various pest management methods.
															3. Explain safe usage and application of pesticides.
															UNIV VII - GREENHOUSE BUSINESS MANAGEMENT
															1. Plan a commercial crop.
															2. Develop a basic marketing plan.

Suggested Time Frame for Teaching

Unit-Lesson	Classroom Instruction (Hours)	Activity Sheet (AS) (Minutes)
I-1	3	AS 1.1 30 AS 1.2 60 **Begin sowing plants for Unit IV activities. See page xxxvii for details.**
I-2	5	AS 1.3 30 AS 1.4 60
II-1	5	AS 2.1 60
II-2	5	AS 2.2 60
II-3	3	UNIT II ACTIVITY 120
III-1	6	AS 3.1 30 AS 3.2 30 AS 3.3 30
III-2	5	AS 3.4 30
III-3	3	AS 3.5 30
IV-1	5	AS 4.1 30 AS 4.2 60 AS 4.3 60
IV-2	5	AS 4.4 30 AS 4.5 30
IV-3	5	AS 4.6 30 AS 4.7 60
IV-4	5	AS 4.8 60
IV-5	4	AS 4.9 30 UNIT IV ACTIVITY 120
V-1	5	AS 5.1 30 **Seedlings are required for this activity. Plan on sowing fast-growing plants before teaching this lesson.**
V-2	5	AS 5.2 60 AS 5.3 60
VI-1	5	AS 6.1 60 AS 6.2 60
VI-2	5	AS 6.3 60 AS 6.4 60
VI-3	5	AS 6.5 60
VII-1	3	AS 7.1 60 AS 7.2 60
VII-2	3	AS 7.3 60 UNIT VII ACTIVITY 120

Planning for Unit IV Activities

The activity sheets described in Lessons 1, 2, 3, and 5 in Unit IV require planning. The instructor should **start preparing during Unit I, Lesson 1**. For the instructor's reference, the following web address cites a publication about starting plants from seeds: <http://muextension.missouri.edu/xplor/agguides/hort/g06570.html>

1. Give each student two clay pots and two plastic pots. Provide field soil and soilless growing media. Allow students to choose the type of plant they want to grow: a bedding, vegetable, or fast-growing flower. Randomly assign half the class to plant one container in field soil.

2. Students plant the four containers with seeds. Make sure all containers are labeled with the date, name of the seed, student's name, and designated soil group.

3. Students will manipulate the growing conditions for each of their four plants according to the information presented in four of the lessons in Unit IV. The activity sheets in these lessons focus on different growing-related variables, as summarized below.

Lesson Number	Activity Sheet (AS) Number and Title	Pot Number	Variable Examined
1	4.2 Effect of Light on Plants	1	Light
2	4.5 Growing Media and Containers	2	Growing media/field soil
3	4.8 Over-, Under-, and Proper Watering	3	Water
5	4.11 Healthy Plant	4	Nutrients/fertilizer

4. For AS 4.2 in Lesson 1, take one plant from each student. Have students label their own plants. Divide the plants into three groups; label them A, B, or C. Expose the three groups of plants to various amounts of light as follows:

   - Group A plants receive 4 hours of light per day and then are put in a closet or under a cardboard box.

   - Group B plants receive natural light during normal daylight hours (leave plant on a window sill).

   - Group C plants receive 17 hours of light per day with additional artificial light (identify type of artificial light).

5. In preparation for AS 4.8 in Lesson 3 (irrigation), take one plant from each student. Organize plants into three groups labeled D, E, and F. For at least 3 weeks, have students water plants in each group using a specific type of measuring cup.

    - Use a measuring cup that is larger than needed for Group D plants so plants receive too much water.

    - The measuring cup for Group E has the correct amount.

    - Use a measuring cup that is smaller than necessary for Group F so that the plants receive very little water

6. To prepare for AS 4.11 in Lesson 5 (fertilizer), split another batch of plants into Groups G, H, and I. Have several forms of fertilizer available: slow release, water-soluble concentrate, and granular. Ask students to give plants in each group the following amounts of fertilizer:

    - Group G - no fertilizer
    - Group H - too much
    - Group I - the appropriate amount.

    As the plants grow, students should characterize how the plants in each group react to fertilizer during three stages of development: seedling/cutting, vegetative, and flowering. Be sure that students identify the type of fertilizer used on each plant.

Appendix

Floriculture Plant Identification List

No. Common Name / Botanical Name

1. African Violet / *Saintpaulia ionantha*
2. Ageratum / *Ageratum houstonianum*
3. Aglaonema / *Aglaonema commutatum*
4. Aluminum Plant / *Pilea cadierei*
5. Amaryllis / *Hippeastrum hybrid*
6. Anthurium, Wax Flower / *Anthurium x andraeanum*
7. Aphelandra, Zebra Plant / *Aphelandra squarrosa*
8. Artillery Plant / *Pilea microphylla*
9. Asparagus “Fern” / *Asparagus setaceus*
10. Astilbe / *Astilbe* hybrid
11. Azalea / *Rhododendron* hybrids
12. Baby’s Breath / *Gypsophila elegans*
13. Bearded Iris / *Iris* hybrids
14. Benjamin Fig / *Fiscus benjamina*
15. Bird-of-Paradise / Sterlitzia reginae
16. Blushing Bromeliad / *Neoregelia carolinae* ‘Tricolor’
17. Boston Fern / *Nephrolepis exaltata*
18. Bromeliad / *Aechmea chantinii*
19. Bunny Ears Cactus / Opuntia microdaysis
20. Camellia / *Camellia japonica*
21. Canna / *Canna x generalis*
22. Carnation / *Dianthus caryophylus*
23. Cattleya Orchid / *Cattleya* hybrids
24. China Aster / *Callistephus chinensis*
25. Christmas Cactus / *Schlumbergia bridgesii*
26. Cineraria / Senecio x hybridus
27. Clematis / *Clematis jackmanii* Group
28. Cockscomb / *Celosia plumosis*
29. Coleus / *Coleus x hybridus*
30. Corn Plant / *Dracaena fragrans* ‘Massangeana’
31. Creeping Charley / *Pilea nummularifolia*
32. Creeping Fig / *Ficus pumila*
33. Croton / *Codiaeum variegatum pictum*
34. Crown of Thorns / *Euphorbia splendens*
35. Cutleaf “Philodendron” /*Monstera deliciosa*
36. Cyclamen / *Cyclamen x persicum*
37. Cymbidium Orchid / *Cymbidium* hybrids
38. Daylily / *Hemerocallis* species and hybrids
39. Dusty Miller / *Senecio cineraria*
40. Dutch Iris / *Iris xiphium*
41. Dwarf Schefflera / *Schefflera arbicola*
42. Emerald Ripple Peperomia / *Peperomia caperata*

43. English Ivy / *Hedera helix*
44. Fairy Primrose / *Primula malacoides*
45. Fancy-Leaved Caladium / *Caladium x hortulanum*
46. Florist's Chrysanthemum / *Dendranthemum x morifolium*
47. Florist's "Huckleberry" / *Vaccinium ovatum*
48. Florist's Hydrangea / *Hydrangea macrophylla*
49. Flowering Stock / *Matthiola incana*
50. Freesia / *Freesia x hybrida*
51. Friendship Plant / *Pilea involucrate*
52. Gardenia / *Gardenia jasminoides*
53. Geranium (Zonal) / *Pelargonium x hortorum*
54. Gerbera (Transvaal Daisy) / *Gerbera jamesonii*
55. Gladiolus / *Gladiolus x hortulanus*
56. Gloxinia / *Sinningia speciosa*
57. Golden Barrel Cactus / *Echinocactus grusonii*
58. Golden Pothos, Devil's Ivy / *Epipremnum aureum*
59. Grape Ivy / *Cissus rhombifolia*
60. Heartleaf Philodendron / *Philodendron scandens oxycardium*
61. Hen and Chickens / *Echeveria* species
62. Hosta (Plantain Lily) / *Hosta* species and hybrids
63. Hyancinth / *Hyacinthus orientalis*
64. Hybrid (Garden) Lily / *Lilium x hybridum*
65. Hybrid Tea Rose / *Rosa hybrida*, Class Hybrid Tea
66. Impatiens / *Impatiens wallerana*
67. Ivy Geranium / *Pelargonium peltatum*
68. Jade Plant / *Crassula argentea*
69. Jerusalem Cherry / *Solanium pseudocapsicum*
70. Kalanchoe / *Kalanchoe x blossfeldiana*
71. Ladyslipper Orchid / *Paphiopedilum* x hybrid
72. Leatherleaf Fern / *Rumohra adiantiformis*
73. Liatris / *Liatris spicta*
74. Marguerite Daisy / *Argyranthemum frutescens*
75. Marigold / *Tagetes* species
76. Narcissus / *Narcissus* species and hybrids
77. Nephthytis / *Syngonium podophyllum*
78. Nerve Plant / *Fittonia verschaffeltii argyroneura*
79. Norfolk Island Pine / *Araucaria heterophylla*
80. Pansy / *Viola x wittrockiana*
81. Parlor Palm / *Chamaedorea elegans*
82. Peace Lily, White Anthurium / *Spathiphyllum clevelandii*
83. Peony / *Paeonia* hybrids
84. Persian (German) Violet / *Exacum affine*
85. Peruvian Lily / *Alstroemeria aurantiaca*
86. Petunia / *Petunia x hybrida*
87. Phalaenopsis (Butterfly) Orchid / *Phalanopsis* hybrids
88. Picaback Plant / *Tolmeia menziesii*

89. Pocketbook Plant / *Calceolaria crenatiflora*
90. Poinsettia / *Euphorbia pulcherrima*
91. Prayer Plant / *Maranta leuconeura kerchoveana*
92. Primrose / *Primula* species
93. “Purple Passion”, Velvet Plant / *Gynura aurantiaca* ‘ Sarmentosa’
94. Red Edge Draceana / *Dracaena marginata*
95. Regal (Martha Washington) Geranium / *Pelargonium x domesticum*
96. Rubber Plant / *Ficus elastica*
97. Salvia / *Salvia splendens*
98. Shasta Daisy / *Leucanthemum x superbum*
99. Shrimp Plant / *Justicia brandegeana*
100. Silver Dollar Gum / *Eucalyptus polyanthemos*
101. Snake Plant / *Sansevieria trifasciata*
102. Snapdragon / *Anthirrhinum majus*
103. Spider Plant / *Chlorophytum commosum* ‘Vittatum’
104. Spotted Dumbcane / *Diffenbachia maculata*
105. Sprengri “Fern” / *Asparagus densiflorous* ‘Sprengeri’
106. Spring Heather / *Erica carnea*
107. Statice / *Limonium sinuatum*
108. Stephanotis / *Stephanotis floribunda*
109. Strawberry Begonia / *Saxifraga stolenifera*
110. Swedish Ivy / *Plectranthus australis*
111. Sweet Alyssum / *Lobularia maritime*
112. Thanksgiving Cactus, Crab Cactus / *Schlumbergera truncata*
113. Trumpet (Easter) Lily / Lilium longiflorum
114. Tuberose / *Polianthes tuberosa*
115. Tuberous Begonia / *Begonia x tuberhybrida*
116. Tulip / *Tulipa* species and hybrids
117. Variegated Peperomia / *Peperomia obtusifolia* ‘Variegata’
118. Vinca / *Catharanthus roseus*
119. Wandering Jew / *Zebrina pendula*
120. Watermelon Peperomia / *Peperomia sandersii*
121. Wax Begonia / *Begonia x semperflorens-cultorum*
122. Wax Plant / *Hoya carnosa*
123. Waxflower / *Chamaelaucium uncinatum*
124. Zinnia / *Zinnia elegans*

Floriculture Identification Scorecard (Form 60a)

Name: ________________________________ Contestant No: __________________________

School: ________________________________ School No: ______________________________

Plant Number

1. ________	21. ________	44. ________
2. ________	22. ________	45. ________
3. ________	23. ________	46. ________
4. ________	24. ________	47. ________
5. ________	25. ________	48. ________
6. ________	26. ________	49. ________
7. ________	27. ________	50. ________
8. ________	28. ________	51. ________
9. ________	29. ________	52. ________
10. ________	30. ________	53. ________
11. ________	31. ________	54. ________
12. ________	32. ________	55. ________
13. ________	33. ________	56. ________
14. ________	34. ________	57. ________
15. ________	35. ________	58. ________
16. ________	36. ________	59. ________
17. ________	37. ________	60. ________
18. ________	38. ________	
19. ________	39. ________	
20. ________	40. ________	
	41. ________	
	42. ________	
	43. ________	

Floriculture Identification Scorecard (Form 60b)

No. Common Name / Botanical Name

1. African Violet / *Saintpaulia ionantha*
2. Ageratum / *Ageratum houstonianum*
3. Aglaonema / *Aglaonema commutatum*
4. Aluminum Plant / *Pilea cadierei*
5. Amaryllis / Hippeastrum hybrid
6. Anthurium, Wax Flower / *Anthurium x andraeanum*
7. Aphelandra, Zebra Plant / *Aphelandra squarrosa*
8. Artillery Plant / *Pilea microphylla*
9. Asparagus "Fern" / *Asparagus setaceus*
10. Astilbe / *Astilbe* hybrid
11. Azalea / *Rhododendron* hybrids
12. Baby's Breath / *Gypsophila elegans*
13. Bearded Iris / *Iris* hybrids
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16. Blushing Bromeliad / *Neoregelia carolinae* 'Tricolor'
17. Boston Fern / *Nephrolepis exaltata*
18. Bromeliad / *Aechmea chantinii*
19. Bunny Ears Cactus / *Opuntia microdaysis*
20. Camellia / *Camellia japonica*
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22. Carnation / *Dianthus caryophylus*
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27. Clematis / *Clematis jackmanii* Group
28. Cockscomb / *Celosia plumosis*
29. Coleus / *Coleus x hybridus*
30. Corn Plant / Dracaena fragrans 'Massangeana'
31. Creeping Charley / *Pilea nummularifolia*
32. Creeping Fig / Ficus pumila
33. Croton / Codiaeum variegatum pictum
34. Crown of Thorns */ Euphorbia splendens*
35. Cutleaf "Philodendron" / *Monstera deliciosa*
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39. Dusty Miller / Senecio cineraria
40. Dutch Iris / *Iris xiphium*
41. Dwarf Schefflera / *Schefflera arbicola*
42. Emerald Ripple Peperomia / *Peperomia caperata*
43. English Ivy / *Hedera helix*
44. Fairy Primrose / *Primula malacoides*

45. Fancy-Leaved Caladium / *Caladium x hortulanum*
46. Florist's Chrysanthemum/ *Dendranthemum x morifolium*
47. Florist's "Huckleberry" / *Vaccinium ovatum*
48. Florist's Hydrangea / *Hydrangea macrophylla*
49. Flowering Stock / *Matthiola incana*
50. Freesia */ Freesia x hybrida*
51. Friendship Plant / *Pilea involucrate*
52. Gardenia / *Gardenia jasminoides*
53. Geranium (Zonal) / *Pelargonium x hortorum*
54. Gerbera (Transvaal Daisy) / *Gerbera jamesonii*
55. Gladiolus / *Gladiolus x hortulanus*
56. Gloxinia / *Sinningia speciosa*
57. Golden Barrel Cactus / *Echinocactus grusonii*
58. Golden Pothos, Devil's Ivy / *Epipremnum aureum*
59. Grape Ivy / *Cissus rhombifolia*
60. Heartleaf Philodendron / *Philodendron scandens oxycardium*
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70. Kalanchoe / *Kalanchoe x blossfeldiana*
71. Ladyslipper Orchid / *Paphiopedilum* x hybrid
72. Leatherleaf Fern / *Rumohra adiantiformis*
73. Liatris / *Liatris spicta*
74. Marguerite Daisy / *Argyranthemum frutescens*
75. Marigold / *Tagetes* species
76. Narcissus / *Narcissus* species and hybrids
77. Nephthytis / *Syngonium podophyllum*
78. Nerve Plant / *Fittonia verschaffeltii argyroneura*
79. Norfolk Island Pine / *Araucaria heterophylla*
80. Pansy / *Viola x wittrockiana*
81. Parlor Palm / *Chamaedorea elegans*
82. Peace Lily, White Anthurium / *Spathiphyllum clevelandii*
83. Peony / *Paeonia* hybrids
84. Persian (German) Violet / *Exacum affine*
85. Peruvian Lily / *Alstroemeria aurantiaca*
86. Petunia / *Petunia x hybrida*
87. Phalaenopsis (Butterfly) Orchid / *Phalanopsis* hybrids
88. Picaback Plant / *Tolmeia menziesii*
89. Pocketbook Plant / *Calceolaria crenatiflora*
90. Poinsettia / *Euphorbia pulcherrima*
91. Prayer Plant / *Maranta leuconeura kerchoveana*
92. Primrose / *Primula* species

93. “Purple Passion”, Velvet Plant */ Gynura aurantiaca* ‘Sarmentosa’
94. Red Edge Draceana / *Dracaena marginata*
95. Regal (Martha Washington) Geranium / *Pelargonium x domesticum*
96. Rubber Plant / *Ficus elastica*
97. Salvia / *Salvia splendens*
98. Shasta Daisy / *Leucanthemum x superbum*
99. Shrimp Plant / *Justicia brandegeana*
100. Silver Dollar Gum / *Eucalyptus polyanthemos*
101. Snake Plant / *Sansevieria trifasciata*
102. Snapdragon */ Anthirrhinum majus*
103. Spider Plant / *Chlorophytum commosum* ‘Vittatum’
104. Spotted Dumbcane / *Diffenbachia maculata*
105. Sprengri “Fern” / *Asparagus densiflorous* ‘Sprengeri’
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107. Statice / *Limonium sinuatum*
108. Stephanotis / *Stephanotis floribunda*
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111. Sweet Alyssum / *Lobularia maritime*
112. Thanksgiving Cactus, Crab Cactus / *Schlumbergera truncata*
113. Trumpet (Easter) Lily / *Lilium longiflorum*
114. Tuberose / *Polianthes tuberosa*
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116. Tulip / *Tulipa* species and hybrids
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118. Vinca / *Catharanthus roseus*
119. Wandering Jew / *Zebrina pendula*
120. Watermelon Peperomia / *Peperomia sandersii*
121. Wax Begonia / *Begonia x semperflorens-cultorum*
122. Wax Plant / *Hoya carnosa*
123. Waxflower / *Chamaelaucium uncinatum*
124. Zinnia / *Zinnia elegans*

Floriculture/Greenhouse Items (Form 64)

Name:________________________________ Contestant No:________________________

School:_______________________________ School No:___________________________

1.___________
2.___________
3.___________
4.___________
5.___________
6.___________
7.___________
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21.___________
22.___________
23.___________
24.___________
25.___________

1. # 3 Ribbon
2. # 9 Ribbon
3. 606 Cell Pack
4. 804 Cell Pack
5. 806 Cell Pack
6. 1204 Cell Pack
7. 1206 Cell Pack
8. 1801 Cell Pack
9. 1803 Cell Pack
10. Anvel Pruner
11. Aspen Pad
12. Azalea Pot
13. Ball Valve
14. Bamboo Stake
15. Boutineer Pins
16. Bud Vase
17. Bulb Pot
18. Bypass Pruner
19. Calcined Clay
20. Care Tag
21. Casket Saddle
22. Coconut Industrial Residue (COIR)
23. Compressed Air Sprayer
24. Conductivity Meter
25. Corsage Bags
26. Corsage Pins
27. Dibble
28. Drip Irrigation Tube
29. Dry Foam
30. Fertilizer Granules
31. Fertilizer Tablets
32. Floral Greening Pins
33. Floral Snips
34. Floral Tape
35. Florist's Foil
36. Florist Shears
37. Fluorescent Lamp
38. Fogg-it Nozzle
39. Full-face Gas Mask
40. Gate Valve
41. H.I.D. Lamp
42. Hanging Basket
43. Hose Saver
44. Hot Glue Gun
45. Hydrophilic Polymer
46. Impulse Sprinkler
47. Incandescent Lamp
48. Inline Filter
49. Insect Monitoring Card
50. Jiffy Pots
51. Kool Cell
52. Latex Rubber Gloves
53. Mist Nozzle
54. Neoprene Rubber Gloves
55. Nitrate Rubber Gloves
56. Oasis Block
57. Oasis Cage
58. Oasis Wedge
59. Orchid Bark
60. Oscillating Sprinkler
61. Paddle Wire
62. Paper Mache Container
63. Peat Moss
64. Perlite
65. Petal Preservative
66. pH Pen
67. Pic Machine
68. Pin Flower Holder
69. Plant Shine
70. Plant Sleeve
71. Plug Flat
72. Pot Cover
73. Potting Medium
74. Processed Pine Bark
75. Propagation Dome
76. Propagation Mat
77. Raffia
78. Respirator
79. Ribbon Shears
80. Rockwool Cube
81. Seeding Flat
82. Shade Cloth
83. Siphon Mixer
84. Slow-release Fertilizer
85. Solenoid Value
86. Sphaghnum Moss
87. Squeeze Bulb Duster
88. Standard Pot
89. Staple Gun
90. Stapler
91. Stem Stripper
92. Stem Wire
93. Styrofoam Cutter
94. Sure-Stik Tape
95. Tickler Vase
96. Tyvek Suit
97. Vermiculite
98. Water-breaker/Wand
99. Water-soluble Fertilizer
100. Wooden Pic

GREENHOUSE OPERATION AND MANAGEMENT

Unit I: The Greenhouse Industry

Lesson 1: Scope and Development of the Greenhouse Industry

Competency/Objective:

Identify the scope and development of the greenhouse industry.

Study Questions

1. **What are the four areas of horticulture?**
2. **How has the greenhouse industry developed throughout history?**
3. **What are recent changes in the greenhouse industry?**
4. **What is the economic importance of the greenhouse industry?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.
2. Transparency Masters

   TM 1.1 1999 Missouri Floriculture Crops
   TM 1.2 2000 U.S. Floriculture Crops
   TM 1.3 2000 U.S. Bedding and Garden Plant Sector

3. Activity Sheets

   AS 1.1 Growing Possibilities
   AS 1.2 Investigating a New Product in the Greenhouse Industry
   AS 1.3 Global Greenhouses

4. Local Yellow Pages (several copies)
5. "Floriculture Crops 2000 Summary." USDA National Agricultural Statistics Service, Agricultural Statistics Board, April 2001. <http://usda.mannlib.cornell.edu/reports/nassr/other/zfc-bb/> accessed 2/21/02.

6. “Floriculture Crops.” USDA National Agricultural Statistical Service. <http://www.usda.gov/nass/aggraphs/ws_tenyr.htm> accessed 2/20/02.

7. USDA National Agricultural Statistics Service. *1997 Census of Agriculture - Census of Horticultural Specialties* (1998) Volume 3, Special Studies, Part 2.

8. “Value of Sales at Wholesale.” USDA National Agricultural Statistics Service, <http://www/usda.gov/nass/aggraphs/val_type.htm> accessed 2/20/02.

9. *Greenhouse Grower*, *Greenhouse Business*, *Grower Talks*, *Greenhouse Product News*

Teaching Procedures

IMPORTANT NOTE: Please refer to the Suggested Time Frame for Teaching (page xxxv) and to Planning for Unit IV Activities (page xxxvii) for information about initiating four activities in selected lessons in Unit IV. It is recommended that preparation begin during Unit I, Lesson 1**.**

A. Introduction

This unit examines facets of the greenhouse industry and identifies available career opportunities. In this lesson students discover how greenhouse production relates to four divisions within the field of horticulture. Lesson 1 also describes the history, developments, and economic importance of the greenhouse industry. Be sure to note that there is a discussion of recording-keeping procedures in Unit VII, Lesson 2.

B. Motivation

Divide the class into cooperative groups and give each group a copy of the Yellow Pages. (Yellow Pages from neighboring communities also can be used for contrast.) Have students identify local growers who produce flowers, vegetables, landscaping supplies, etc. If possible, invite an owner/manager to class to discuss how his/her business has changed over the years and contributed to the local economy.

C. Assignment of Study Questions

Be sure the classroom has many different types of potted plants, in varying stages of development.

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. Instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. **What are the four areas of horticulture?**

   Ask students if they have ever heard the word "horticulture" and if so, in what context. Explain that its original meaning is derived from two words: "garden" and "cultivate." However, today horticulture is broadly defined as the cultivation of plants. Write "horticulture" on the board and ask students to name the types of plants that may be cultivated. Record and organize their responses into the four categories listed below. Point out that a greenhouse owner may produce crops from any of the four horticultural groups.

   A. Horticulture – cultivation of plants and vegetables
   B. Floriculture - flowers (cut flowers, bedding plants, foliage plants, potted plants)
   C. Olericulture - vegetables
   D. Ornamental horticulture - plants grown for their beauty (annuals, perennials, shrubs, ground cover, landscaping)
   E. Pomology - fruit and nuts

2. **How has the greenhouse industry developed throughout history?**

   Ask students to estimate when the first greenhouse was built. During the discussion, consider how environmental factors, transportation, building materials, and available markets have affected the growth and development of the greenhouse industry. Also remind the class how references to centuries relate to actual years. For example, the 16th century refers to 1500-1599.

   A. Roman emperor Tiberius (30 AD) built "specularia."
   B. In 13th century, Dominican monk Albertus Magnus tried to force blooms out of season.
   C. By 1599, the first practical greenhouse was built in Holland.
   D. "Orangeries" were constructed in France during the 17th century.
   E. Andrew Faneuil built the first U.S. greenhouse in 1737.
   F. During the 19th century in England, greenhouse construction developed most fully. By 1825, greenhouses were common.
   G. By 1950, improvements in transportation allowed growers to reach broader markets. New materials became available for constructing greenhouses.
   H. In 1960, greenhouses were made from film plastic and galvanized steel. Noteworthy botanical greenhouses were built during that decade: Missouri Botanical Garden (1960), Hamburg Botanic Gardens (Germany, 1963), and the Exhibition Plant Houses at Edinburgh (Scotland, 1967).
   I. By 1980, floriculturists in the Netherlands became renown for concentrating on specific or related crops, relying on automated production, and selling crops by the auction market system.

3. What are recent changes in the greenhouse industry?

Ask students who have had experience raising livestock or crops to identify advanced techniques or procedures used to promote efficient growth. Relate these developments to greenhouse-grown crops. Have students complete AS 1.1. Before students begin working on AS 1.2, talk about RootShield and PlantShield and explain how these products have helped greenhouse personnel produce healthy plants. If possible, apply one of these fungicides to a plant in the classroom that exhibits root disease. Encourage students to explore facets of the greenhouse industry that have developed over the years.

A. Growing structures
B. Coverings
C. Equipment
D. Growing methods
E. Plant varieties (colors, forms, resistance to disease)
F. Biotechnology

4. What is the economic importance of the greenhouse industry?

Engage students in a discussion about the economic importance of the greenhouse industry. Guide them to the discovery that this industry provides employment and income locally, nationally, and worldwide and that the greenhouse business has evolved over time. Remind the class of the businesses they identified during the Motivation. Ask them to name floriculture crops or greenhouse-grown vegetables that are produced in their community. How have these crops helped the local economy?

Display a map of the United States. Have students infer what types of crops are grown throughout the country. Point out the significance of regional differences in climate and environmental factors. Also display a globe or world map. Ask students to interpret the impact of the global greenhouse industry upon the United States and especially upon Missouri.

A. Missouri - 1999 statistics for wholesale floriculture production (TM 1.1)
   1. Value from growers grossing $10,000 or more - $41.6 million
   2. Value from growers grossing $100,000 or more - $34.3 million
   3. Bedding/garden plants and potted flowering plants - major floriculture crops
   4. Compared nationwide - based on combination of greenhouse sales, nurseries, landscaping outlets, etc.
      a. 26th nationwide in floriculture production
      b. 28th nationwide in ornamental horticulture production
      c. 28th nationwide in pomology production
      d. 31st nationwide in production of commercial vegetables
B. United States
   1. In 2000, the wholesale value of floriculture production grossing $100,000 or more in sales was nearly $4.7 billion. See TM 1.2. Five states contributing the most to that amount are California (20%), Florida (18%), Michigan, Texas, and Ohio.

2. Bedding and garden plants production represents 50% of the wholesale value of all reported crops and is made up of the following crops: (TM 1.3)
   a. Potted bedding and garden plants (48% of total)
   b. Bedding and garden flats (42% of total)
   c. Flowering hanging baskets (10% of total)
3. Potted flowering plants
   a. 3% increase in production from 1999
   b. California - 18% of total sales
   c. Top sellers - poinsettias, orchids, azaleas, and chrysantheums
4. Foliage plant
   a. 12% increased production from 1999
   b. Florida - 69% of total market
   c. 85% of total sales - potted foliage plants
5. Cut flowers
   a. 1% decreased production from 1999
   b. 23% drop in number of growers from 1999
   c. California - 67% of total market
   d. Top sellers: roses, lilies, gladioli
6. Herbaceous perennials - with hardy garden mums as 25% of this market
7. Propagative materials - used to grow various types of plants; 44% of all propagative materials used for annual bedding and garden plants.
8. Cut greens
   a. 2% decreased production from 1999
   b. Florida - 81% of total market

C. World (major exporters) Have students complete AS 1.3.
1. The Netherlands
   a. Exports tulip flowers and bulbs
   b. Is the international leader in floriculture enterprises.
2. Central and South America (Mexico, Costa Rica, Colombia, and Brazil)
   a. Favorable climate
   b. Government-sponsored subsidies for the industry
   c. Access to labor force
   d. Produce cut flowers (e.g., roses and carnations), flower seeds, foliage plants
3. Kenya, Africa - floriculture producer since early 1970s
   a. Flower producer (mainly roses) and seeds for geranium, petunia, and impatiens
   b. Simple greenhouses; require no supplementary heat
   c. Cheap, abundant labor
4. Australia and New Zealand - orchids

F. Other Activities and Strategies

1. Show the class video(s) on growing plants in a greenhouse. Three videos are available from CATER (Career & Technical Education Resources), 2 London Hall, University of Missouri-Columbia: *How to Grow Plants in a Greenhouse: Bedding Plant Production*, Volume I (AG V162); *Foliage Plant Production*, Volume II (AG V163); *Potted Plant Production*, Volume III (AG V164).

2. Have students investigate how the auction market system operates in the Netherlands when selling greenhouse-grown crops.

3. Ask students to identify and summarize the contributions of famous plant scientists and researchers by searching the Internet and referring to science/history textbooks, magazines, and biographies, and other resources.

G. Conclusion

Horticulture comprises four fields: floriculture, olericulture, ornamental horticulture, and pomology. For centuries, people have been interested in cultivating these types of plants. As building materials and means of transportation developed, the greenhouse industry has become increasingly sophisticated. The greenhouse industry has developed thanks to state-of-the-art equipment, improved coverings, and biotechnology. The greenhouse industry contributes employment and economic support to the state of Missouri, the United States, and several countries throughout the world.

H. Answers to Activity Sheets

AS 1.1 Growing Possibilities

Instructor's discretion

AS 1.2 Investigating a New Product in the Greenhouse Industry

Instructor's discretion

AS 1.3 Global Greenhouses

Instructor's discretion

I. Answers to Assessment

1. C
2. B
3. D
4. E
5. A
6. D
7. A
8. D
9. C
10. A
11. D
12. The student may list any three of the following:
    A. Growing structures

B. Coverings
C. Equipment
D. Growing methods
E. Plant varieties (colors, forms, resistant to disease)
F. Biotechnology

Unit I: The Greenhouse Industry

Name________________________________

Lesson 1: Scope and Development of the Greenhouse Industry

Date___________________________

ASSESSMENT

Matching: The terms on the left-hand side refer to the cultivation of certain types of plants, which are listed on the right side. Write the correct letter in the space provided.

____	1.	Floriculture	A.	fruits and nuts
____	2.	Horticulture	B.	plants and vegetables
____	3.	Olericulture	C.	flowers and foliage plants
____	4.	Ornamental horticulture	D.	vegetables
____	5.	Pomology	E.	shrubs and other plants for landscaping

Multiple Choice: Circle the letter of the best answer.

6. When and where did greenhouse construction develop completely and become common?

   A. 30 AD, Rome
   B. 16th century, Holland
   C. 18th century, America
   D. 19th century, England

7. What is the wholesale value for Missouri greenhouse operations grossing $100,000 or more in 1999?

   A. $34.3 million
   B. $41.6 million
   C. $34.7 billion
   D. $4.7 billion

8. Which of the following are the two major floriculture crops in Missouri?

   A. Cut flowers and potted flowering plants
   B. Foliage plants and bedding/gardening plants
   C. Cut flowers and foliage plants
   D. Potted flowering plants and bedding/gardening plants

9. How does Missouri rank among all 50 states in floriculture production?

   A. 31st
   B. 28th
   C. 26th
   D. 16th

10. What is the correct ranking of the top five states involved in U.S. floriculture sales, from the highest to lowest amount contributed?

    A. California, Florida, Michigan, Texas, and Ohio
    B. Michigan, Ohio, Florida, Texas, and California
    C. Florida, California, Texas, Michigan, and Ohio
    D. Texas, Florida, California, Ohio, and Michigan

11. Who is the international leader in floriculture production?

    A. Australia/New Zealand
    B. Central America
    C. Kenya
    D. The Netherlands

Short-Answer Question: Write the answer in the space provided.

12. What are three recent changes in the greenhouse industry?

    A.

    B.

    C.

TM 1.1

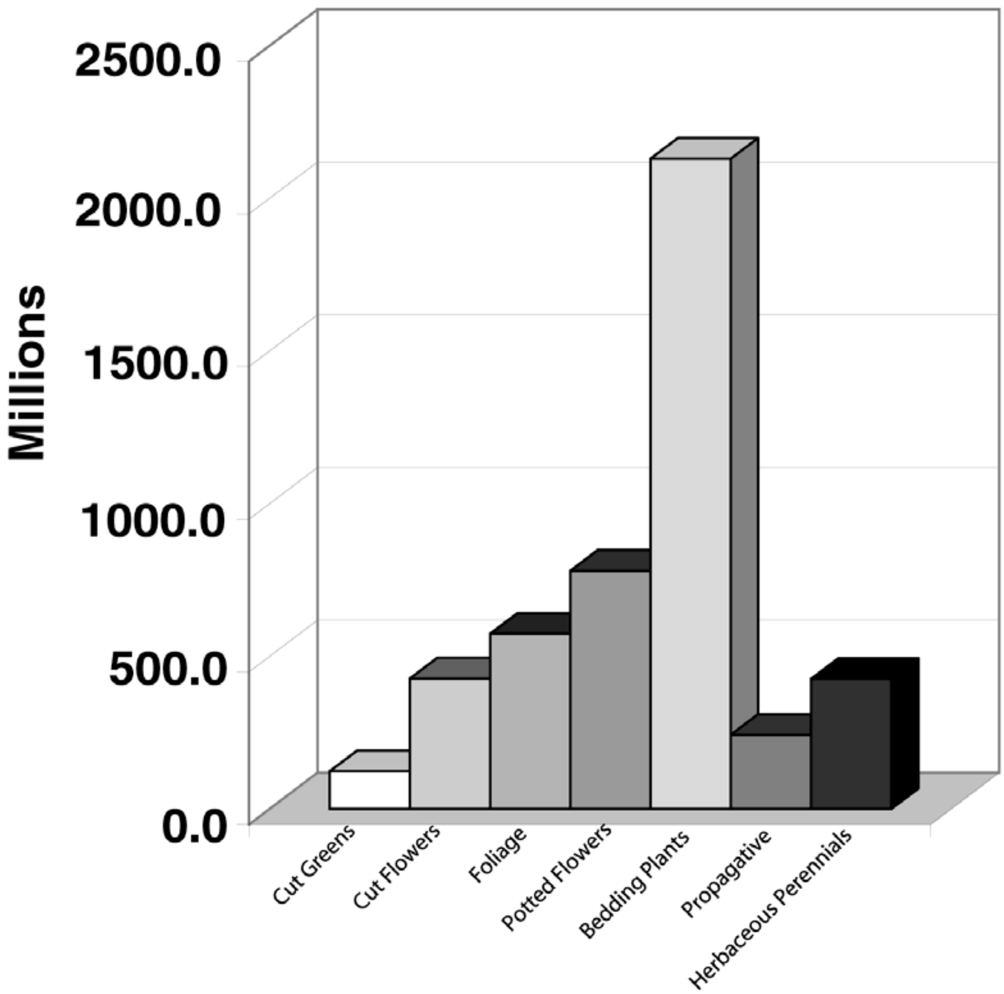
1999 Missouri Floriculture Crops

Crop	Wholesale Value
Cut Flowers	$ 281,000
Foliage Plants	2,192,000
Potted Flowering Plants	11,711,000
Bedding and Garden Plants	20,085,000
TOTAL	$34,269,000

Wholesale value for operations grossing $100,000 in sales
“Floriculture.” *Missouri Farm Facts*, 2000.

TM 1.2

2000 U.S. Floriculture Crops



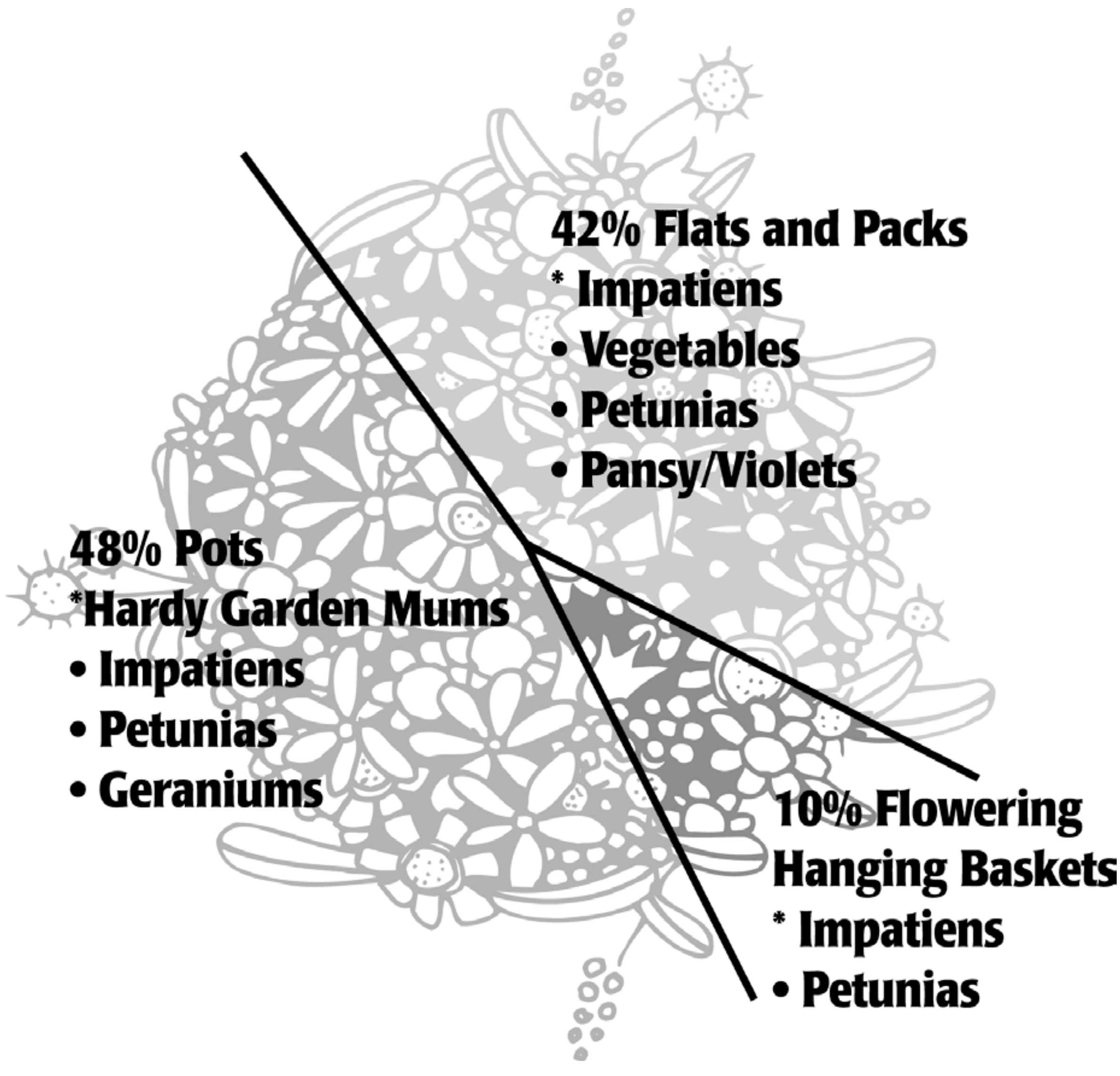
	Millions
Cut Greens	123.7
Cut Flowers	427.5
Foliage	574.0
Potted Flowers	780.2
Bedding Plants	2130.0
Propagative	242.9
Herbaceous Perennials	426.0
Total Value	4704.2

Source: http://www.usda.gov/nass/aggraphs/val_type.htm

Wholesale value for operations grossing $100,000 or more in sales
"Floriculture Crops." USDA National Agricultural Statistics Service,
<http://www.usda.gov/nass/aggraphs/ws_tenyr.htm> accessed 2/20/02

TM 1.3

2000 U.S. Bedding and Garden Plant Sector



"Floriculture Crops 2000 Summary." National Agricultural Statistics Service, Agricultural Statistics Board, USDA, April 2001. <http://usda.mannlib.cornell.edu/reports/nassr/other/zfr-bb/> accessed 2/21/02.

UNIT I: THE GREENHOUSE INDUSTRY

AS 1.1

Lesson 1: Scope and Development of the Greenhouse Industry

Name____________________

Growing Possibilities

Objective: Appraise biotechnological advancements in the greenhouse industry.

Directions: Work in small cooperative groups. Select one of the biotechnological advancements listed below. Access the Internet, university Extension publications, trade journals, or any other reliable resources for information. As you evaluate how the biotechnological advancement affected the greenhouse industry, consider the questions listed below but do not limit your focus to them. Present your findings to the class. (Suggested approaches are giving a PowerPoint presentation, displaying graphs or other visual aids, making an oral presentation, creating a model, etc.)

Biotechnological Advancements

- Improving performance and handling during production and after harvest
- Incorporating selected pathogen-resistant genes into new plants
- Producing leaves that stay greener longer
- Delaying leaves' aging process
- Stimulating plant growth
- Improving tolerance to herbicides
- Reducing amount of pesticide application required
- Developing strategies for managing disease to increase production
- Improving quality and taste of fruits and vegetables

Suggested Web Sites

Clark, David G. "Floriculture Biotechnology." <http://hort.ifas.ufl.edu/people/clark.htm> accessed 2/20/02.

Giacomelli, Gene A. "Controlled Environment Agricultural Center." Agricultural & Biosystems Engineering Department, University of Arizona. <http://ag.arizona.edu/ceac/research/archive/structures.htm#glazings> accessed 2/25/02.

1. How has this advancement affected the greenhouse environment? Does it also affect the outside environment?

2. Does it have any adverse consequences?

3. How does this biotechnological advancement help the greenhouse industry?

4. How does it affect plant growth?

5. How does this technique affect working conditions in the greenhouse?

6. How does it impact trade relations and/or economic status among states and countries? Is it profitable?

7. What is the justification for using this advancement in an average greenhouse operation?

UNIT I: THE GREENHOUSE INDUSTRY

AS 1.2

Lesson 1: Scope and Development of the Greenhouse Industry

Name____________________

Investigating a New Product in the Greenhouse Industry

Objective: Identify one new product currently used in the greenhouse industry and evaluate how well it performs.

Directions: Refer to recent professional greenhouse journals such as *Greenhouse Grower*, *Greenhouse Product News*, *Grower Talks*, and *Greenhouse Business* and search the Internet in order to identify a new product used in the greenhouse industry. Respond to the following questions. Share your findings with the class. For example, demonstrate the product, create a diorama or illustration of it, give a PowerPoint presentation, etc.

1. What is the purpose of this product?

2. Does it replace an older, similar device?

3. What new features does it have?

4. How does the product work?

5. Do greenhouse personnel need special training in order to use it?

6. Where can this product be obtained?

UNIT I: THE GREENHOUSE INDUSTRY

AS 1.3

Lesson 1: Scope and Development of the Greenhouse Industry

Name____________________

Global Greenhouses

Objective: Compare and contrast greenhouse operations in two different countries.

Directions: Work in small groups of three or four students. Select two countries that export greenhouse-grown crops. Use the Internet, books, magazines, and science and social studies textbooks to answer the following questions. Relate your findings to the class in a PowerPoint presentation, poster, collage, oral presentation, or any other format that answers the questions.

Country #1__________________________ Country #2____________________________

Exported Greenhouse Crops

#1____________________________ #2____________________________

1. What are the distinguishing features of the climate, topography, and environmental factors in each country?

2. How do these factors affect the construction of a greenhouse (building materials, site selection, etc.)?

3. How much of each country's economy depends upon this major greenhouse crop?

4. Where do these countries export their crops? Are those markets increasing or declining?

5. What forms of assistance are available to the greenhouse owners in each country?

6. How much labor is available for greenhouse operations in each country? What training or benefits are provided?

7. How and where are the crops sold?

GREENHOUSE OPERATION AND MANAGEMENT

Unit I: The Greenhouse Industry

Lesson 2: Career Opportunities in the Greenhouse Industry

Competency/Objective:

Outline career paths and SAE (Supervised Agricultural Experience) opportunities available in the greenhouse industry.

Study Questions

1. **How do the responsibilities of grower, retailer, and wholesaler differ?**
2. **What career opportunities are available in the greenhouse industry?**
3. **How is the structure of a greenhouse operation organized?**
4. **How does continuing education enhance career opportunities in the greenhouse industry?**
5. **What opportunities does the greenhouse industry offer the agricultural education program?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.
2. Transparency Master

   TM 1.4 Organizational Structure of a Large Greenhouse Operation

3. Activity Sheets

   AS 1.4 Greenhouse Careers: Which One? How to Succeed?
   AS 1.5 Getting Involved in the Greenhouse Industry

4. Help wanted ads in trade journals: *Greenhouse Grower, Greenhouse Business, Grower Talks, Greenhouse Product News*
5. “Greenhouse Positions.” New Haven Gardens. <http://www.nhg.com/empgh.htm>.

6. “Jobs in Horticulture” <hortjobs.com>

7. “Nursery and Greenhouse Worker.” <http://www.edinetconnect.com/cat/careers/nurserysw.html>

8. Yahoo! Careers. “Landscaping, Groundskeeping, Nursery, Greenhouse, and Lawn Service Occupations.” <http://careers.yahoo.com/employment/oco/ocos172.html>

9. GrowNative! <www.conservation.state.mo.us/programs/grownative>

10. “Key #2 - SAE” <www.ffa.org/programs/lps/html/sae.html>

11. “Welcome to SAE Central” <www.cals.ncsu.edu/agexed/sae/toolbox/index.html>

12. Garton, Bryan L. and Scott Stone. Agricultural Education, University of Missouri-Columbia. Joint State Staff in Agricultural Education *Agricultural Education Program Planning Handbook for Missouri Schools*. pp. 109-111, 1997.

TEACHING PROCEDURES

A. Review

After defining the four fields included in horticulture, the previous lesson surveyed the past and recent developments in the greenhouse industry and assessed its economic importance to Missouri, the United States, and the world. This lesson focuses on various careers available in this industry and styles of management structures, and it justifies why continuing education is valuable to someone interested in pursuing a career in the greenhouse industry. Lesson 2 also describes opportunities that the greenhouse industry offers agricultural education programs - SAE (Supervised Agricultural Experience) in particular.

B. Motivation

Ask the class if anyone has planted a garden or raised a crop. Find out if they have participated in FFA or 4-H activities that involved growing vegetables or flowers. Then ask them to describe activities they enjoyed performing while working with plants. As you record their responses on the board, continue the discussion by asking students to identify the types of greenhouse-related jobs that appeal to them the most.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. Instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students’ responses and information with additional materials when needed.

1. How do the responsibilities of grower, retailer, and wholesaler differ?

Explain that the greenhouse industry is generally divided into three sectors: growers, retailers, and wholesalers. Career opportunities exist in all categories.

A. Grower
   1. Produces one or more crops for sale to wholesaler
   2. Is skilled in cultivation, irrigation, and other cultural practices
   3. Usually delegates marketing to wholesaler if operation is small

B. Retailer
   1. Sells greenhouse crops to public
   2. Is found in various marketing areas: grocery stores, florist shops, malls, etc.

C. Wholesaler
   1. Sells crops and related products to retailer
   2. Sells plants from growers on consignment

2. What career opportunities are available in the greenhouse industry?

The broad categories listed above may suggest specific career opportunities. Ask students to identify the types of tasks required to run a greenhouse. Write their responses on the board and organize them under the job titles listed below. Remind the class that these job titles,descriptions, and duties may vary in different greenhouse operations. The following list should be used only as an example. Have the class complete AS 1.4.

A. Assistant grower (entry level)
   1. Helps grower as directed
   2. May work in maintenance, shipping, and/or delivery

B. Grower
   1. Prepares growing medium for bulbs, seeds, and cuttings
   2. Grafts plants and transplants seedlings and rooted cuttings
   3. Irrigates plants as required
   4. Fertilizes plants according to specific needs
   5. Responds to customers’ questions, as needed

C. Greenhouse service technician
   1. Maintains physical facilities in greenhouse
   2. Supervises maintenance crew
   3. Oversees irrigation, electricity, and drainage systems; in charge of construction, etc.

D. Production specialist
   1. Stays up-to-date on technical developments
   2. Schedules when crops should be planted

3. Manages space allocation within greenhouse

E. Marketing manager
  1. Oversees sales operations
  2. Handles customer relations (both existing and potential customers)
  3. Assesses postharvest crops: grades and stores plants and flowers
  4. Prepares each crop for shipment

F. Manager/owner
  1. Organizes and prioritizes work flow
  2. Maintains financial records; develops marketing plan
  3. Selects types and quantities of plants to be grown
  4. Selects and orders growing supplies (fertilizer, seeds, etc.)
  5. Hires, supervises, and evaluates staff
  6. Responds to customers' questions

3. How is the structure of a greenhouse operation organized?

Ask students why it is important to understand how employees fit within the industry's organization. How does the management structure affect their choice of jobs within that industry? Display TM 1.4 as an example of how a large greenhouse operation may be organized.

A. Small greenhouse operations
  1. One manager/owner oversees all aspects of the business.
  2. Several assistants may help the manager.
  3. Owner/manager specializes in all greenhouse operations.

B. Large greenhouse operations
  1. Manager may or may not be the owner.
  2. Multiple greenhouse specialists contribute to different aspects of the operation.
  3. Each department (e.g., marketing, production) has its own manager.
  4. Employees work in various departments.

4. How does continuing education enhance career opportunities in the greenhouse industry?

Refer to the activities mentioned in the Motivation. Now ask students how they could make them more challenging. What would they need to know and do in order to advance? Explain that the term "continuing education" applies to more than just schoolwork.

A. Reading professional literature (trade journals, publications from county Extension services, etc.)
B. Joining greenhouse-related organizations
C. Participating in meetings sponsored by professional groups
D. Keeping up-to-date in latest advances in greenhouse operations
E. Sharing technological information with coworkers, supervisors, and greenhouse experts
F. Taking advanced courses in area(s) of interest

5. What opportunities does the greenhouse industry offer the agricultural education program?

Engage the class in a discussion about various agriculture-related activities that they have participated in, as sponsored by 4H and FFA. Agricultural education embraces many opportunities for growth. Mention that Supervised Agricultural Experience is a dynamic program that helps students gain practical knowledge and apply skills they've learned in the classroom to the real world. As you generate a discussion about the benefits of SAE, ask students to infer how these opportunities apply to employment in the greenhouse industry. Have the class complete AS 1.5.

A. Workplace readiness for students
   1. Develop successful work habits and skills
      a. Responsibility
      b. Work ethic (being prompt, communicating clearly and honestly, cooperating with coworkers and supervisor, taking pride in one's work, etc.)
      c. Record-keeping skills
      d. Critical-thinking skills
      e. Decision-making skills
   2. Provide real-world experience
      a. On-the-job training
      b. Gain management skills
      c. Develop job-seeking skills
      d. May earn a salary while learning
      e. Receive guidance from individuals experienced in greenhouse operations
B. Supervised Agricultural Experience opportunities
   1. Entrepreneurship program
      a. Students plan, organize, and operate enterprise and are financially responsible for own horticulture-related business.
      b. Students own all necessary materials needed to run the operation and keep financial records in order to assess how well their investment is performing.
      c. Students participate in entrepreneurial projects sponsored by GrowNative! (www.conservation.state.mo.us/programs/grownative). Individuals or chapters grow plugs or produce seeds of native plants.
      d. Examples include growing bedding plants in school greenhouse and raising poinsettias for sale.
   2. Placement program
      a. Students are placed in an agricultural business that interests them.
      b. This can be a paid position or an unpaid internship.
      c. Placement program occurs outside of regular school hours.
      d. Examples include working in a florist shop and in a nursery on weekends.
   3. Directed work experience
      a. Students, instructors, and parents help plan activity.
      b. This is an unpaid position.
      c. Examples include working in the school greenhouse.

C. Agriscience research projects
   1. Experimental activity
      a. Key features
         i. Has a specific, measurable objective
         ii. Follows scientific process
         iii. Involves several steps and requires time commitment
         iv. Relates to significant scientific/agricultural principle, issue, or question
         v. Supervised by instructor
      b. Examples:
         i. Comparing effect of different amounts of light on plant growth
         ii. Comparing two types of fertilizer on plant development
         iii. Analyzing effectiveness of different display techniques on amount of plant sales in a nursery
         iv. Demonstrating effect of various levels of soil acidity on plant growth
   2. Analytical (nonexperimental) activity
      a. Key features
         i. Collecting information from different sources then evaluating the data
         ii. Creating a finished product
      b. Examples:
         i. Planning a perennial garden for a senior center
         ii. Constructing a landscaping ad campaign directed toward new home owners
D. Award/activities
   1. Career Development Events
      a. Floriculture
      b. Nursery/landscape
      c. Agricultural sales
   2. Proficiency awards
      a. Horticulture
      b. Turf and landscape management
      c. Floriculture
      d. Fruit and/or vegetable production
      e. Specialty crops
   3. School/community service
      a. Building Our American Communities grant
      b. Partnerships with groups, such as chambers of commerce and garden clubs
      c. Providing landscaping on school grounds
      d. Providing arrangements/plants for special school occasions, such as banquets and graduation
      e. Examples: For school grounds or a community center, create a hummingbird habitat, plant a garden with all-native Missouri plants, create garden to attract songbirds and butterflies, create garden made up of shade-loving plants

F. Other Activities and Strategies

1. Show the class the following video, available from CATER (Career & Technical Education Resources), 2 London Hall, University of Missouri-Columbia: *Growing Futures - Career Opportunities in the Green Industry* (AG V157).

2. Take students to a local, commercial greenhouse, nearby florist, or nursery. Have them ask the owner/manager about the types of jobs needed to run the operation. Have students observe one of the growers or production specialists and ask questions about their jobs. As an alternative, ask members of the greenhouse industry to visit the class to discuss how their businesses are run. Before the guests arrive, have students prepare interview questions.

3. Ask a representative from the community college level to talk about Postsecondary Agriculture Students (PAS), which is similar to FFA.

G. Conclusion

Before identifying a career in the greenhouse industry, it is important to distinguish between growers, retailers, and wholesalers. Each of the various positions within the industry offers unique opportunities. Typically, small greenhouse operations have a simple management structure, with the owner/manager assuming most of the responsibilities, whereas larger organizations have multiple layers of managers and workers. By continuing one's education through diverse means, a greenhouse worker can advance within the profession. The greenhouse industry offers many programs in agricultural education, especially SAE.

H. Answers to Activity Sheets

AS 1.4 Greenhouse Careers: Which One? How to Succeed?

(For each of the following, information about continuing training/education is at the instructor's discretion.)
1. Greenhouse service technician
2. Production specialist
3. Grower
4. Marketing manager

AS 1.5 Getting Involved in the Greenhouse Industry

Instructor's discretion.

I. Answers to Assessment

1. B
2. A
3. B
4. C

5. A
6. C
7. B, K
8. C, G, J
9. E
10. F, H
11. D, I, L
12. A
13. Small greenhouse operations: Students may list any two of the following:
    A. One manager/owner oversees all aspects of the business.
    B. Owner/manager specializes in all greenhouse operations.
    C. Several assistants may help the manager.

    Large greenhouse operations: Students may list any two of the following:
    A. Manager may or may not be the owner.
    B. Each department (e.g., marketing, production) has its own manager.
    C. Employees work in various departments.
    D. Multiple greenhouse specialists contribute to different aspects of the operation.
14. The student may list any four of the following:
    A. Reading professional literature (journals, publications from county extension service, etc.)
    B. Joining greenhouse-related organizations
    C. Participating in meetings sponsored by professional groups
    D. Keeping up-to-date in latest advances in greenhouse operations
    E. Sharing technological information with coworkers, supervisors, and greenhouse experts
    F. Taking advanced courses in area(s) of interest
15. Instructor’s discretion

UNIT I: THE GREENHOUSE INDUSTRY

Name ______________________

Lesson 2: Career Opportunities in the Greenhouse Industry

Date______________________

ASSESSMENT

Match the three parts of the greenhouse industry with their tasks. Write the correct letter in the space provided.

_____	1.	Sells directly to the public	A.	Grower
_____	2.	Is skilled in cultural practices	B.	Retailer
_____	3.	Is located in shopping areas	C.	Wholesaler
_____	4.	Sells to retail businesses		
_____	5.	May delegate marketing responsibilities		
_____	6.	Sells plants on consignment		

Match the job titles listed on the left with the description of their responsibilities. Some job titles have multiple descriptions. Write the correct letter(s) in the space provided.

_____	7.	Greenhouse service technician	A.	Keeps current on plant technology
_____	8.	Grower	B.	Takes care of maintenance
_____	9.	Assistant grower	C.	Irrigates and fertilizes plants
_____	10.	Marketing manager	D.	Hires, supervises, evaluates staff
_____	11.	Manager/owner	E.	Helps grower
_____	12.	Production specialist	F.	Supervises sales
			G.	Prepares growing medium
			H.	Handles customer relations
			I.	Plans workload of greenhouse workers
			J.	Transplants seedlings

K. Supervises electrical and irrigation systems

L. Selects and orders growing supplies

Short-Answer Questions: Write the answers in the space provided.

13. What are two differences in the organizational structure of small and large greenhouse operations?

Small Greenhouse Operations	Large Greenhouse Operations
A.	A.
B.	B.

14. What are four ways to continue education and/or training in the greenhouse industry?

A.

B.

C.

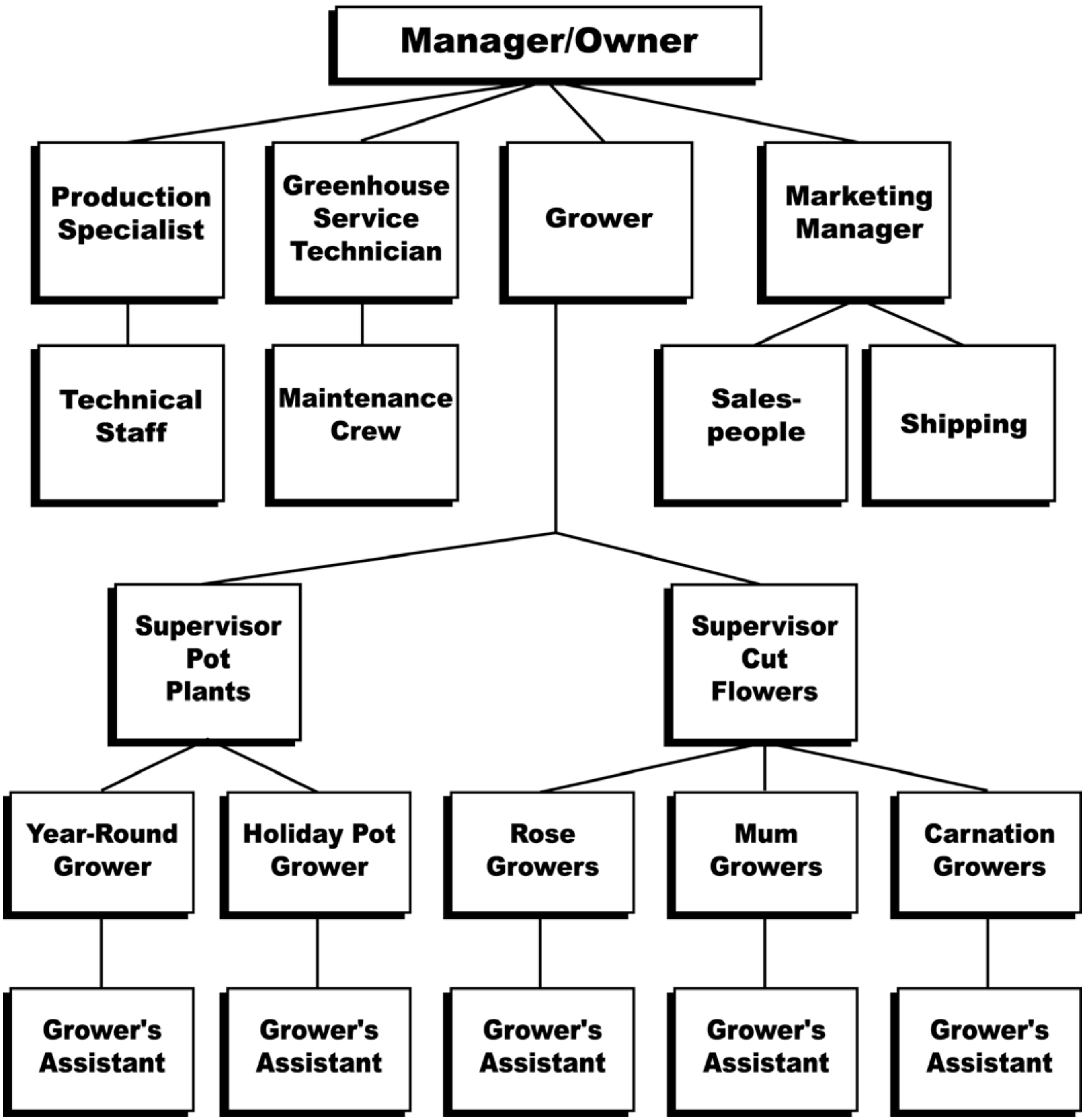
D

15. For each type of SAE program listed below, what are five activities related to the greenhouse industry? (Select activities that were **not** mentioned in the Student Reference.)

Placement Program	Entrepreneurship Program	Agriscience Projects
A.	A.	A.
B.	B.	B.
C.	C.	C.
D.	D.	D.
E.	E.	E.

TM 1.4

Organizational Structure of a Large Greenhouse Operation



UNIT I: THE GREENHOUSE INDUSTRY

AS 1.4

Lesson 2: Career Opportunities in the Greenhouse Industry

Name____________________________

Greenhouse Careers: Which One? How to Succeed?

Objective: Appraise which greenhouse career is appropriate and infer how continuing education would enhance this career.

Directions: Read the scenarios below that describe various interests and skills of several individuals. Assume that everyone wants to expand his or her skills by working in a greenhouse. Identify which greenhouse-related career suits each person. Then suggest a type of training or form of continuing education that would help this person improve his or her skills in the greenhouse industry. Discuss your choices with the class.

1. Betty likes to work with her hands. On her farm, she built a sheep shed and repaired it as needed. She also installed a watering system for the lambs.

   Career ____

   Continuing Training/Education____

2. Isabella's favorite class is science, with a special interest in chemistry. She enjoys investigating how things work. At home, she exposed her oregano and basil plants to different fertilizers.

   Career ____

   Continuing Training/Education____

3. Ron's tomatoes, herbs, and roses won awards at FFA contests. He would like to cultivate orchids, tropical foliage, and ferns. Hydroponics also interests him.

   Career ____

   Continuing Training/Education____

4. Thaddeus has had his own lawn service throughout high school. He maintains all financial records and keeps in touch with his clients. Currently, he is seeking new customers.

   Career ____

   Continuing Training/Education____

UNIT I: THE GREENHOUSE INDUSTRY

AS 1.5

Lesson 2: Career Opportunities in the Greenhouse Industry

Name______________________

Getting Involved in the Greenhouse Industry

Objective: Devise an SAE (Supervised Agricultural Experience) activity for a job in the greenhouse industry.

Directions: Select one of the following careers and identify a task required in that area. First assess your interests and skills and then develop an SAE activity that exposes you to this job. If possible, organize placement in that job.

Assistant grower	Marketing manager
Grower	Manager/owner
Greenhouse service technician	Wholesaler
Production specialist	Retailer

Career ___________________________ Specific Job______________________________

Assessing Personal Interests and Skills

To identify a specific job within a career that interests you, review the Student Reference, search the Internet for additional information, or read greenhouse-related publications. Then respond to the following questions.

1. Why does this job appeal to you?
2. What personal skills or traits do you have that would complement this job?
3. What demands would this job make upon your time, talents, and efforts?
4. How would you handle these challenges?
5. Does this job lead to other careers that interest you?
6. What types of questions and requirements would an employer have for someone who is seeking this position? Role-play as the employer and then as the employee.

Developing an SAE Activity

With the guidance of your instructor, create an SAE activity that accommodates your interests.

1. Find a greenhouse operation that offers the type of work that interests you.

2. Identify a supervisor at the greenhouse who is willing to give you hands-on experience.

3. List several tasks that are required for the job you selected.

4. Outline a procedure for performing these tasks.

5. Create a self-assessment tool for the job you are pursuing.

If you are placed in a job related to greenhouses, complete the following section.

Recording Your Progress

Track your experiences in your new job in the greenhouse industry. Listed below are some suggestions for recording your SAE activity.

- Compile a scrapbook, including
  - Your time sheet and wage statements (if applicable)
  - Photographs of each stage of the job and of your coworkers and supervisor
  - Articles related to this career

- Prepare a PowerPoint presentation of your experience for the class

- Relate your experiences orally to the class using visual aids

- Demonstrate to the class one or more of the skills you acquired

GREENHOUSE OPERATION AND MANAGEMENT

Unit II: Growing Structures

Lesson 1: Greenhouse Parts, Structures, and Coverings

Objective/Competency:

Distinguish types of greenhouses by materials, structure, and layout.

Study Questions

1. **What are the primary considerations in selecting a site for a greenhouse operation?**

2. **What are different types of greenhouse structures?**

3. **What is the basic construction of a growing structure?**

4. **What are the interior parts of a greenhouse?**

5. **What other structures and areas are part of most commercial greenhouse operations?**

6. **What are some considerations for the interior layout of buildings and work areas?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 2.1 Frame Types
   TM 2.2 Ridge and Furrow Construction
   TM 2.3 Lean-To Greenhouse
   TM 2.4 Parts of a Greenhouse
   TM 2.5 Interior Layout of a Greenhouse
   TM 2.6 Other Outdoor Growing Structures

3. Activity Sheet

   AS 2.1 Plan Your Own: Part I

4. A current copy of Hummert's Horticultural Supply Catalog

5. Stuppy Greenhouse Manufacturing Inc. <http://www.stuppy.com/stuppy_site_map.html>

TEACHING PROCEDURES

A. Introduction

This unit involves the growing structure, environmental controls, and energy conservation and environmental protection. Lesson 1 describes the physical aspect of the greenhouse itself: what the building looks like, what materials are used, and what the floor plan is. The greenhouse owner must resolve how climate, topography, resources, zoning, and economics affect the growing structure before building can occur.

B. Motivation

Have the students discuss both the environmental and human factors that influence a greenhouse operation. How or why would the selection of the site be important? Why is the availability of resources such as roads, water, and labor a vital consideration?

C. Assignment of Study Questions

Encourage students to keep the activity sheets for Lessons1-3 as a reference for the Unit II Activity.

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the questions before the discussion. Another option is to have students work in cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What are the primary considerations in selecting a site for a greenhouse operation?

A profitable greenhouse operation does not just plop down on an empty spot of land. There are many environmental and human-related factors to consider: climate, topography, accessibility to resources, marketing, and zoning.

A. Climate
   1. Desirable locations
      a. High, natural light levels
      b. Moderate climate
   2. Locations that could increase energy and maintenance costs
      a. Very cold locations

   b. Locations with very high temperatures and humidity
   c. High elevations (wind)
   d. Valleys (frost)

B. Topography
   1. Location of the greenhouse
      a. Optimal site is where the greenhouse receives the most morning sunlight, thereby promoting the plant food production process (photosynthesis).
      b. Specific location depends on geography. For example, in Maryland, the best site for a greenhouse is toward the south or southeast; the next best option is toward the southwest.
      c. In Missouri, the ridge of the greenhouse should run north and south to permit the light to enter from a sidewall, not an endwall. Winter light is maximized and shadows are reduced.
      d. For states whose latitude is 40^{o} north or above, an east-west direction is best.
   2. Surface
      a. Level
      b. Able to provide good drainage
   3. Creation of windbreak to shelter structure from winter wind
   4. Prevention of obstacles in front of greenhouse
      a. Should be clear of large trees or structures
      b. May shade the greenhouse

C. Availability of resources
   1. Water
      a. Ample supply
      b. High quality
   2. Utilities (e.g., electricity, natural gas)
   3. Materials (e.g., soils, fertilizers, pesticides)
   4. Labor for regular operation and during harvest
   5. Services (e.g., waste removal services)

D. Land considerations
   1. Costs (e.g., purchase price, taxes)
   2. Proximity to roads and utilities
   3. Neighbors and how they may be affected by the operation
   4. Expansion potential

E. Marketing considerations
   1. Proximity to markets
   2. Competition

F. Legal considerations
   1. Permits and licenses
   2. Zoning regulations

2. What are different types of greenhouse structures?

The three styles of growing structures are freestanding, connected, and attached. Freestanding greenhouses come in five frame styles. Connected is a string of greenhouses sharing a roof. Attached greenhouses share a wall with another building.

A. Freestanding (detached) structures
    1. Frame styles (TM 2.1)
        a. Even span (gabled)
        b. Uneven span (placed on hillside/southern exposure)
        c. Gothic arch
        d. Quonset
        e. A-frame
    2. Advantages:
        a. Easy to maintain (e.g., snow removal from roof)
        b. Uniform light (minimal shadows)
    3. Disadvantages:
        a. More costly to construct (more sidewalls)
        b. Occupy more space (several freestanding structures vs. single connected structure)
        c. Less efficient (more surface exposed to elements)
B. Connected structures (TM 2.2)
    1. Framing styles similar to freestanding structures; connected by a common roof
    2. Advantages:
        a. Occupies less land
        b. Greater spans of interior space
        c. Less energy required to heat and cool
    3. Disadvantages:
        a. Gutters collect snow.
        b. Gutters create shadows.
C. Lean-to structures (attached) (TM 2.3)
    1. Attaches to common wall of an existing building (facing east or south)
    2. Advantages:
        a. Lower construction cost
        b. Heat from adjacent building
    3. Disadvantages:
        a. Limited space
        b. Less roof support
D. Innovative European energy-efficient growing structures
    1. "Venlo greenhouse" from the Netherlands - galvanized steel superstructure
        a. Gable roof
        b. Self-supporting glazing bar system
            i. Bars opposite each other - less materials needed, more available light
            ii. Rust free, no maintenance, lasts for years
            iii. Strong and stable
        c. Polycarbonate sidewalls and endwalls
            i. Provide thermal insulation
            ii. Regulate temperature
        d. High-light glass glazing
            i. Transmits light very well
            ii. Promotes high-quality growing environment for crops
        e. Roof vents

i. Controlled thermostatically or by computer
ii. Cut energy costs by using natural ventilation

2. “Rovero” greenhouse from the Netherlands
   a. Retractable roof
   b. Roof’s positions
      i. Closed
      ii. Half closed
      iii. Open
   c. Roof covering - clear or diffused polyethylene
   d. Sidewall and endwall
      i. Motorized
      ii. 8-mm-polycarbonate roll-up curtain
   e. Greenhouse environment - fully computer controlled
3. Field-scale and conventional tunnel greenhouses; originally developed in France (single span) and Spain (multispan)
4. Cantilevered roof vent units (from “National Polytunnels,” Lancashire, England)
   a. Positioned on top of each roof span
   b. Winch mechanism able to open five vents in a row
5. Folding roof - folds back into gutter
   a. “Max Air” model from National Polytunnels
   b. Model from Polybuild (Surrey, England, and Dutch company HCT)

3. What is the basic construction of a growing structure?

The greenhouse structure is composed of two basic parts: the frame and the covering. Construction options are limited and must be considered not only in terms of cost but also durability, reliability, frequency of repair or replacement, and adaptability to expansion.

A. Greenhouse framing
1. Framing considerations
   a. Cost (construction and maintenance)
   b. Strength
   c. Choice of covering material
   d. Amount of light blocked
2. Framing materials
   a. Wood
      i. Must be decay resistant (e.g., redwood or other wood treated with waterborne, salt-type preservatives that are safe for plants)
      ii. Must NOT be treated with chemicals that emit fumes toxic to plants (e.g., creosote)
      iii. Can be painted with light-reflecting, white, water-based paint for further protection
   b. Aluminum alloy
      i. Flexible
      ii. Durable
      iii. Affordable

c. Steel or iron

B. Greenhouse covering
1. Considerations
   a. Style of greenhouse
   b. Durability (ability to withstand snow, wind, and extreme temperatures)
   c. Cost (construction and maintenance)
   d. Type of framing required for support
   e. Availability of materials
   f. Interior environment created
      i. Heat retention
      ii. Light penetration
      iii. Light diffusion
      iv. Condensation potential
      v. Static electricity charge
2. Types of covering materials
   a. Glass
      i. Usually heavy, tempered glass
      ii. Advantages:
         (a) Strong
         (b) Inexpensive to maintain
         (c) Excellent light transmission
         (d) Long lasting
      iii. Disadvantages: requires a heavier, more costly framing structure, breakable
   b. Polyethylene (PE) film
      i. Advantages:
         (a) Lightweight
         (b) Flexible
         (c) Easy to install
         (d) Can be supported by a lightweight frame
         (e) Transmits light as well as glass
      ii. Disadvantages:
         (a) Susceptible to weather damage
         (b) Needs repeated rinsing to get rid of dust
         (c) Must be replaced every 2-4 years
   c. Rigid panels
      i. Common materials
         (a) Polycarbonate - examples: Lexan, Verolite (double walled and similar to Lexan), Dyan-Glas, and Green-Lite
         (b) Fiber-reinforced polyester (FRP) (fiberglass) - flammable (requires fire insurance)
         (c) Polymethyl methacrylate (PMMA) acrylic
      ii. Advantages:
         (a) Lightweight
         (b) Sturdier than film,
         (c) Durable (replace 10-20 years)
      iii. Disadvantage: can be damaged by elements over time

4. What are the interior parts of a greenhouse?

A key concern in the layout of a greenhouse is the type of market it serves. Is this operation wholesale or retail? This answer impacts the decision of bench layout, bench construction, and flooring. Encourage students to discuss why this is true.

A. Interior layout
   1. Type of layout depends primarily on greenhouse purpose
      a. Wholesale
      b. Retail
   2. Aisles - wide enough to accommodate equipment and people
   3. Common layout designs (TM 2.5)
      a. Lengthwise benching
      b. Crosswise benching
      c. Peninsular benching
B. Flooring
   1. Considerations
      a. Must be able to accommodate equipment and work flow
      b. Must include proper drainage
      c. Bare ground not acceptable
         i. Risk of pathogens
         ii. Difficult to provide proper drainage
   2. Materials
      a. Concrete
         i. Include drain basins
         ii. Slope toward drains
      b. Gravel
         i. Weed mat covered with gravel
         ii. Porous enough to allow water to drain
C. Benches
   1. Considerations
      a. Retail or wholesale
      b. Sturdy enough to hold plants
      c. Provide air movement and water drainage
   2. Types
      a. Fixed
      b. Moveable
         i. Can be moved outdoors
         ii. Used for double-crop production (one crop on floor, second bench moved outdoors)
      c. Rolling
         i. Maximizes use of floor space
         ii. Uses less aisle space
         iii. For wholesale use only
   3. Materials
      a. Wood

b. Concrete
c. Metal
d. Plastic

5. What other structures and areas are part of most commercial greenhouse operations?

A greenhouse does not exist alone as a growing environment. Coldframes, hotbeds, and lath houses are additional ways to grow crops in a managed setting. The three use a combination of structure and nature. Other areas that may be a part of a greenhouse operation include offices, rest rooms, and loading zones. If the operation is retail, there are parking lots and display areas.

A. Other growing structures
   1. Coldframes
      a. Outdoor growing structure with transparent covering
      b. Heated only by the sun
      c. Top opened during the day, closed at night
      d. Used to harden and protect plants from frost; winter storage of bulbs
   2. Hotbeds
      a. Outdoor growing structure with transparent covering
      b. Heated by steam, hot water, or electricity
      c. Used to start seedlings and cuttings
   3. Lath houses
      a. Outdoor growing structures covered with lath or shade fabric supported by vertical poles
      b. Reduce light intensity
      c. Used in summer in temperature climates or year-round in warm climates

B. Additional areas
   1. Work spaces (e.g., soil mixing and propagation areas)
   2. Storage areas
   3. Roadways
   4. Loading and shipping areas
   5. Parking areas
   6. Display areas
   7. Offices
   8. Break room/kitchen area
   9. Rest rooms

6. What are some considerations for the interior layout of buildings and work areas?

The orientation of the greenhouses and the other buildings is essential to an efficient greenhouse operation. AS 2.1 instructs students how to design a layout of a greenhouse operation using the information contained in this lesson.

A. Wholesale or retail operations have different types of work areas.

B. Generally, a good layout provides the following:
   1. Efficient work flow (does not interfere with customer visits)

2. Efficient labor practices
3. Maximum use of space
4. Minimal impact on the environment (e.g., water runoff, pollution)
5. Optimal orientation for greenhouses (e.g., south or southeast)
6. Expansion possibilities
7. Regulatory compliance

F. Other Activity and Strategy

Invite a commercial builder to discuss the practical details of building a greenhouse. Ask this individual to bring samples of exterior coverings. Ask how greenhouses are priced. What are the advantages of pre-engineered packages versus entirely new construction? Is it better to plan expansions and equipment upgrades before construction begins on the initial building?

G. Conclusion

A greenhouse is a complex system. Although it is a protected environment for growing plants, the greenhouse is influenced by the climate and topography around it. The shape, framing, and covering materials are dictated by cost, durability, and type of operation.

H. Answers to Activity Sheet

Instructor's discretion

I. Answers to Assessment

1. C
2. D
3. D
4. A. Must be able to accommodate equipment and work flow
   B. Must include proper drainage
   C. Bare ground not acceptable
5. A. Coldframes
   B. Hotbeds
   C. Lath houses
6. The student may list any one of the following advantages
   A. Excellent light transmission
   B. Long lasting
   The student may list any one of the following disadvantages
   A. Breakable
   B. Requires a heavier frame structure
7. The student may list any one of the following advantages
   A. Lightweight material
   B. Sturdier than film
   C. Durable
   The student may list any one of the following disadvantages

   A. Can be damaged by the elements
   B. Must be replaced frequently
8. D
9. B
10. C
11. E
12. A

UNIT II: GROWING STRUCTURES

Name____________________________

Lesson 1: Greenhouse Parts, Structures, and Coverings

Date__________________

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. What are the basic parts of the greenhouse structure?

   A. Frame and layout
   B. Covering and ventilation
   C. Frame and covering
   D. Flooring and covering

2. What are three interior parts of a greenhouse?

   A. Display area, flooring, and layout
   B. Benches, layout, and loading area
   C. Flooring, Quonset, and benches
   D. Layout, benches, and flooring

3. What is the correct direction of the ridges in a greenhouse built in Missouri that allows light to enter from the sidewalls?

   A. East and west
   B. North northeast
   C. South and southwest
   D. North and south

Short-Answer Questions: Write the answers in the space provided.

4. What are three major considerations in determining the layout of flooring in a greenhouse?

   A.

   B.

   C.

5. What are three other types of growing structures?

   A.

   B.

   C.

6. What is an advantage and disadvantage of glass as a covering material?

   <u>Advantage</u> <u>Disadvantage</u>

7. What is one advantage and one disadvantage of polycarbonate as a covering material?

   <u>Advantage</u> <u>Disadvantage</u>

Matching. The terms on the left refer to freestanding frame styles, which are pictured on the right side. Write the correct letter in the space provided.

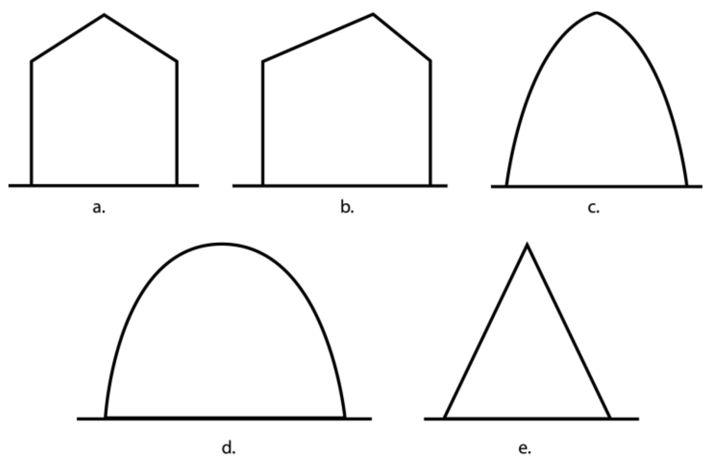
______8. Quonset

______9. Uneven span

______10. Gothic arch

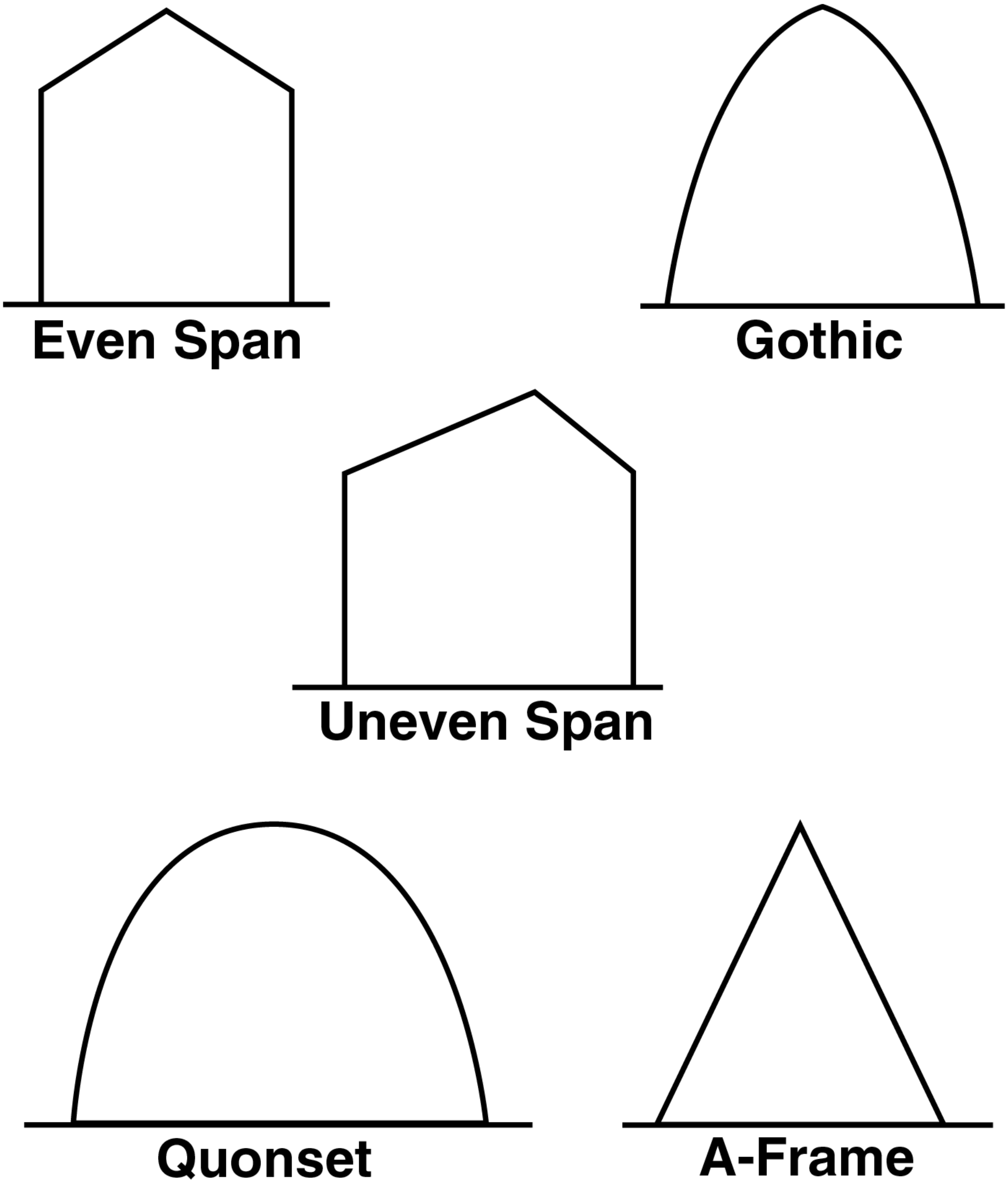
______11. A-frame

______12. Even span



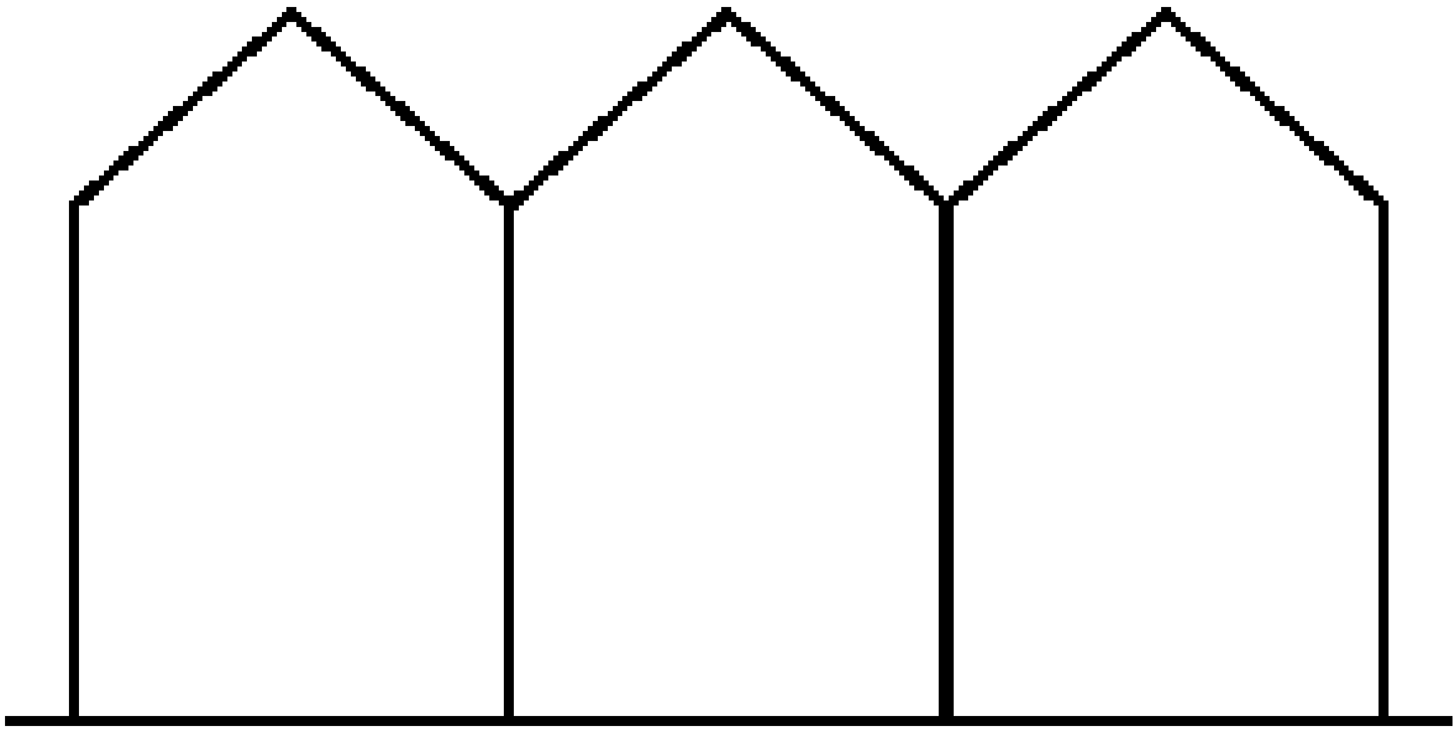
TM 2.1

Frame Types



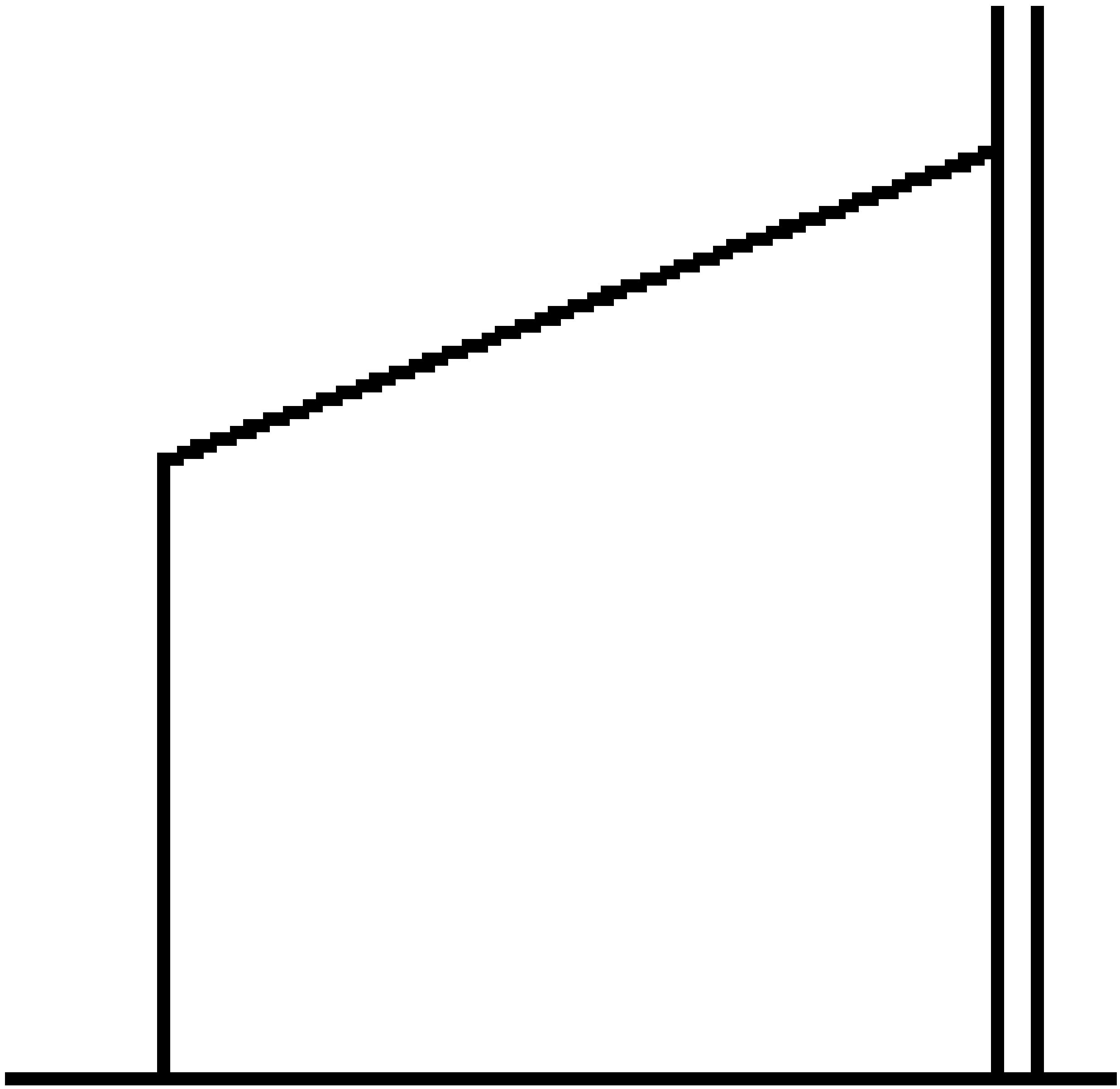
TM 2.2

Ridge and Furrow Construction



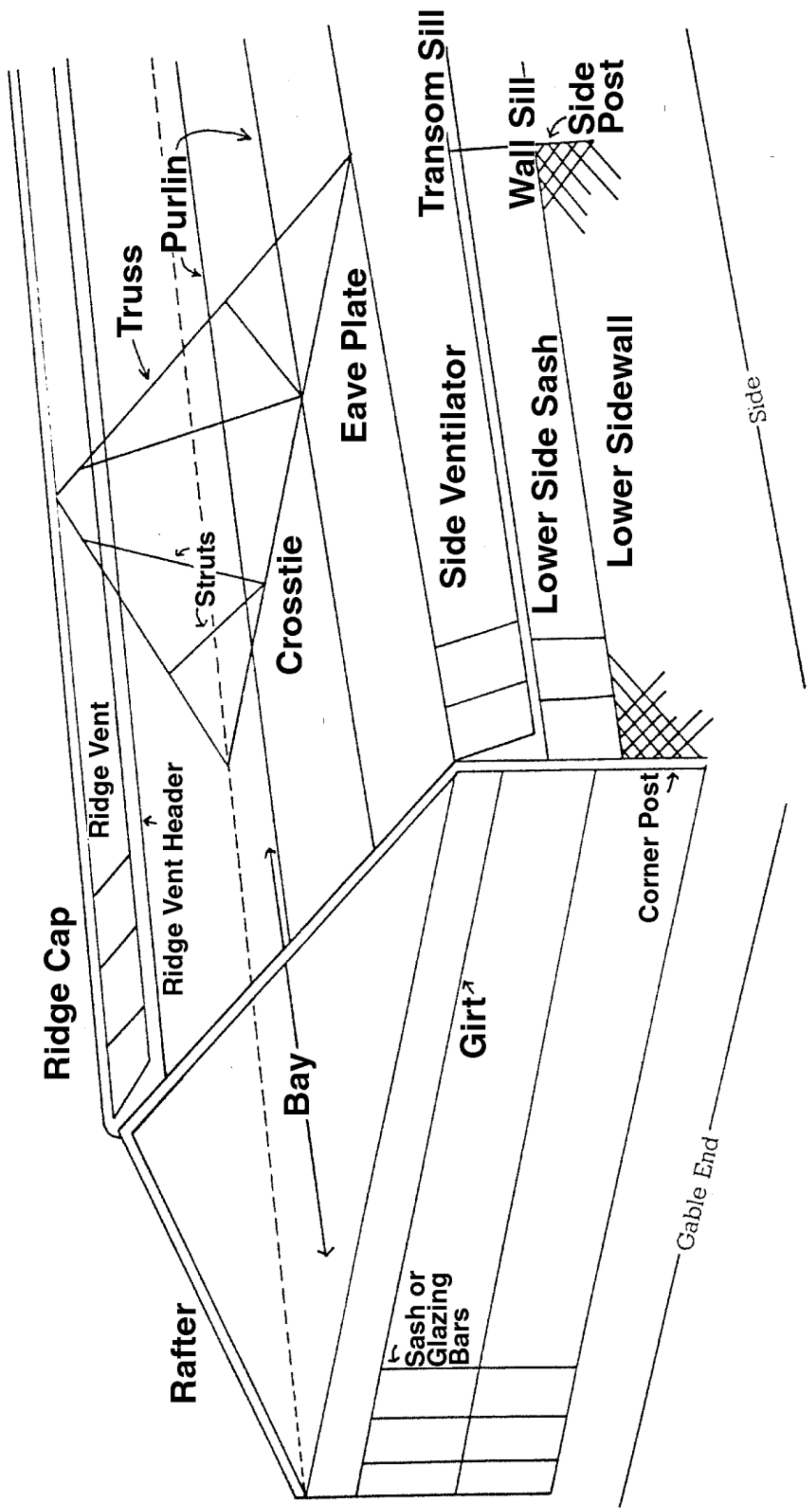
TM 2.3

Lean-To Greenhouse



TM 2.4

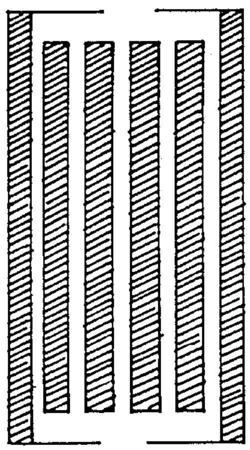
Parts of a Greenhouse



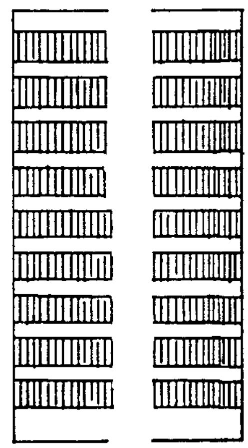
TM 2.5

Interior Layout of a Greenhouse

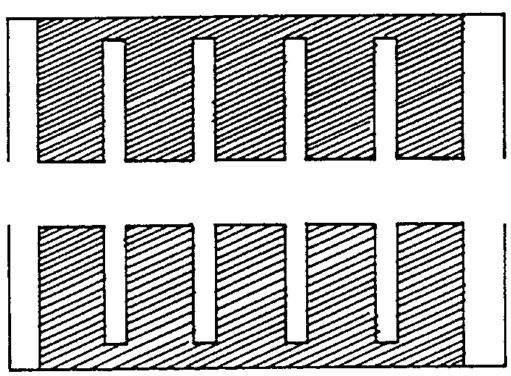
Lengthwise Benching (Longitudinal)



Crosswise Benching (Island)

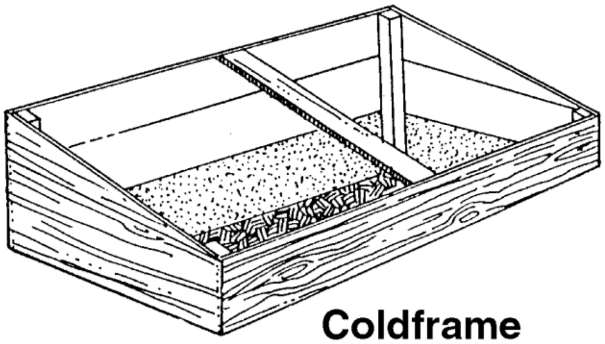


Peninsular Benching

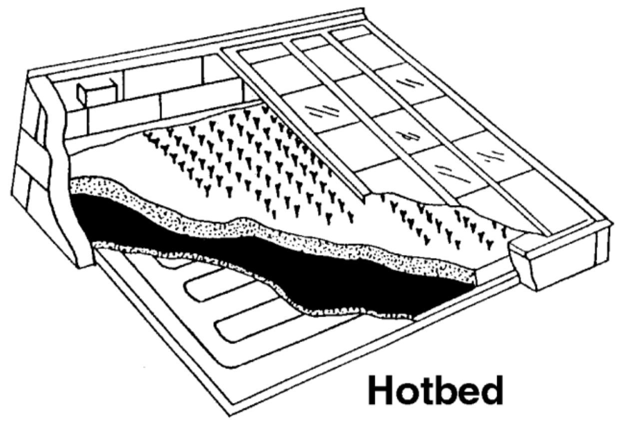


TM 2.6

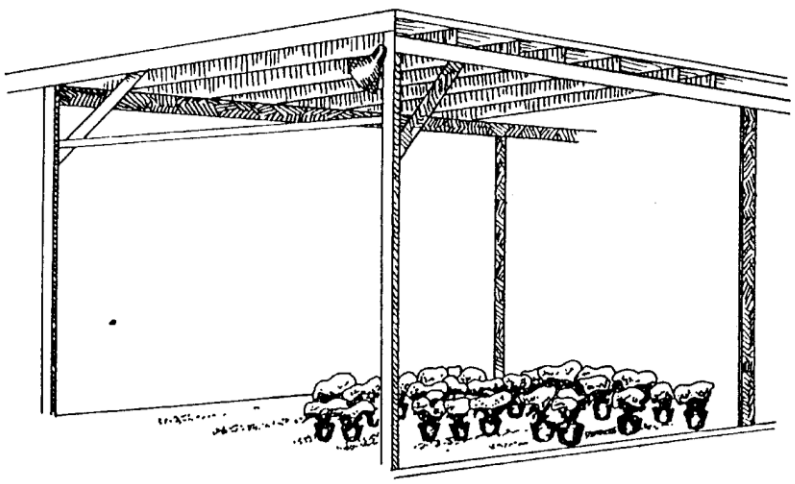
Other Outdoor Growing Structures



Coldframe



Hotbed



Lath House

UNIT II: GROWING STRUCTURES AS 2.1

Lesson 1: Greenhouse Parts, Structures, and Coverings Name____________

Plan Your Own: Part I

Objective: Develop a greenhouse structure.

Directions: Select one of the following topics. Work in a small cooperative group to answer the questions related to the selected topic. Use textbooks, the Internet, professional greenhouse magazines, and other resources to gather information, sketches, and pictures. Remember to discuss cost, complexity of setup, repair and upgrade. Keep this activity sheet; it will be helpful in Lessons 2 and 3 of this unit and in the unit activity.

Group One: Site Selection

1. Where are you building your greenhouse: on top of a hill, in a valley, etc.? Why?
2. What is the direction of the growing structure?
3. What types of energy costs are required with this site?
4. What sort of infrastructure is available at this site?
5. How accessible is this site for materials delivery?
6. Are utilities readily obtainable?

Group Two: Legal

1. How much does the land cost?
2. What is the expansion potential?
3. Are there any neighbors? How does the business affect them?
4. Is this a wholesale or retail operation?
5. How close is the competition? How close is your customer base?
6. What are the zoning regulations for your land?
7. What permits or licenses do you need to build the greenhouse?

Group Three: Design

1. What type of structure is this? Why?
2. How easy or complex is it to set up, repair, and upgrade?
3. What framing material are you going to use? Why?
7. 4. What type of covering material are you going to use? Why?
5. What are the initial costs and costs of repair? How often does the covering need to be repaired or replaced?
6. Is the material flammable?

Group Four: Layout

1. What is the interior layout?
2. What material is used on the flooring? Why?
3. What material is used for the benches? Why?
4. What type of bench is used? Why?
5. Are there any other types of growing structures? If yes, what kind and why?
6. What other work areas are needed?
7. Do these choices reflect a good layout for a commercial greenhouse operation?

GREENHOUSE OPERATION AND MANAGEMENT

Unit II: Growing Structures

Lesson 2: Environmental Control

Objective/Competency:

Describe how environmental factors in a greenhouse are controlled.

Study Questions

1. **What types of environmental controls may be found in a greenhouse?**
2. **How is the temperature in a greenhouse monitored and controlled?**
3. **How can a greenhouse be kept warm during cold weather?**
4. **Why must a greenhouse be ventilated?**
5. **How is a greenhouse kept cool during warm weather?**
6. **How is greenhouse humidity controlled?**
7. **What equipment is used to irrigate plants in a greenhouse?**
8. **How are carbon dioxide and light levels controlled in a greenhouse?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 2.7 Devices to Monitor Temperature
   TM 2.8 Methods of Ventilation

3. Activity Sheet

   AS 2.2 Plan Your Own: Part II

4. Ball, Vic, Editor. *Ball Red Book Greenhouse Growing*, 14th ed., Reston, VA: Reston Publishing, Inc., 1985.

5. A current copy of Hummert's Helpful Hints

TEACHING PROCEDURES

A. Review

Students are starting to look beyond the obvious and consider unseen aspects in the design of a greenhouse. Lesson 2 explores elements of the environment that personnel should control to produce optimal crops.

B. Motivation

1. Once the greenhouse owner assesses the land, climate, and resources, the actual structure is built. But it is just a shell to be converted into a controlled environment to raise crops. Ask the students what environmental elements have to be manipulated to raise the best crops in the shortest amount of time.

2. To demonstrate elements of a greenhouse environment on a reduced scale, have students work in small cooperative groups to create terrariums. Encourage each group to select a different type: desert, tropical forest, etc. Use small glass fish tanks or wide-mouth glass containers. Other materials needed are gravel, charcoal chips, small rocks, and a selection of small plants and ground cover, such as moss. As students develop their terrariums, discuss how light, water, and temperature affect the growth of plants.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the questions before the discussion. Another option is to have students work in cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What types of environmental controls may be found in a greenhouse?

There are seven environmental factors to adjust inside the greenhouse. The methods of control are discussed here. Subsequent units detail why these factors need monitoring.

A. Natural elements to control in a greenhouse
   1. Temperature

2. Humidity
3. Water
4. Light
5. Carbon dioxide
6. Pests
7. Disease

B. Basic methods of control
1. Manual
2. Automated
3. Integrated control system
   a. Analog and integrated control systems
   b. Multiple sensors throughout greenhouse
   c. Sense and control elements such as air and soil temperature, light intensity, relative humidity, and carbon dioxide levels
   d. Record data for evaluation and troubleshooting
   e. Provide data for planning future crops

2. How is the temperature in a greenhouse monitored and controlled?

Have students anticipate how plant development is influenced by temperature. What would result if the temperature becomes too cold or too warm?

A. Primary considerations in selecting temperature control systems
1. Cost of equipment
   a. Installation
   b. Maintenance
2. Ability to provide uniform control
   a. Minimize hot and cold spots throughout greenhouse
   b. Can be enhanced with horizontal airflow
3. Capacity
   a. Ability to handle temperature extremes
   b. Ability to meet needs of the entire operation
4. Reliability
   a. Power failure alarm that alerts a power outage
   b. Emergency generator in case of power failure
5. Fuel
   a. Cost
   b. Availability
   c. Type of storage required
   d. Type of transportation required

B. Monitoring and control methods (TM 2.7)
1. Thermometers (measure air temperature)
2. High/low thermometers (measure day and night air temperatures)
3. Thermostats
   a. On-off control of air temperature
   b. Step control (stages) of air temperature

4. Aspirated thermostats
    a. Read temperature of air blown across thermostat
    b. More accurate control than standard thermostat
5. Thermistors
    a. Electronic semiconductora used in computerized greenhouses
    b. Sense even subtle temperature changes; signal controller

C. Proper placement of monitoring devices
    1. At level of the plants throughout the greenhouse
    2. In an area shaded from direct sunlight and cooled fans

3. How can a greenhouse be kept warm during cold weather?

Discuss with students why heat is important to greenhouse-grown crops. What are desired qualities in sources of heat? Are some sources more conducive to specific crops?

A. Heating considerations
    1. Heat loss occurs in three ways.
        a. Conduction
        b. Infiltration
        c. Radiation
    2. Lost heat must be replenished to protect plants.
    3. There are several desirable heat source features.
        a. Energy efficiency
        b. Reliable
        c. Safety
    4. Heat is measured in Btu.

B. Solar energy
    1. Solar energy provides only some heat.
        a. Greenhouse collects and stores the heat energy from the sun that passes through the covering during the day.
        b. This heat warms the plants and other objects inside the greenhouse.
        c. The heat that is radiated back does not have enough energy to pass back through the covering (greenhouse effect).
        d. Heat is retained at night. (The amount retained varies with the type of covering.)
    2. Solar heat alone is not sufficient heat for greenhouses in most northern climates.
    3. An additional source of heat must be provided.

C. Heating equipment
    1. Unit heaters
    2. Central heaters
    3. Radiant (infrared) heat
        a. Infrared lights heat surfaces (plants, soil, benches, etc.) not the air.
        b. Air is warmed only by heat radiated from surfaces.
    4. Emergency generators
        a. Powered by gas or fuel
        b. Necessary if there is a power outage that cuts power to the electric fans, which are essential parts of most heating systems

c. Necessary to keep cooling in greenhouse operation

D. Heat distribution
   1. Forced hot air
      a. Hot air - from burning several fuels, such as natural gas
         i. Distributed throughout the greenhouse
         ii. Ventilated to the outside to prevent buildup of air pollutants
      b. Horizontal discharge unit heaters
         i. Mounted on the ground or overhead
         ii. Push air through perforated polyethylene tubing that hangs above plants
      c. Vertical discharge unit heaters fans
         i. Mounted overhead
         ii. Move air downward
      d. Unit heaters - use HAF (horizontal airflow) fans to distribute heat evenly
      e. Fans at the peak of the greenhouse pushing down the hot air that rises
   2. Hot water
      a. Water is piped through greenhouse by metal piping that is placed along walls and under benches.
      b. Temperature is variable.
      c. A circulating pump moves the water.
   3. Steam
      a. Piped through greenhouse by metal pipes
      b. Temperature not as variable as hot water
      c. Carries more heat and moves farther

E. Fuel options
   1. Coal
   2. Kerosene oil
   3. Propane/natural gas
   4. Wood
   5. Electric (not an efficient fuel for most commercial greenhouse operations)

F. Venting
   1. Any heating system that burns fuel can be lethal to humans.
      a. Oxygen is depleted from the air.
      b. Oxygen shortage creates carbon monoxide - a gas that is fatal to humans.
   2. Impurities in fuel and incomplete combustion can create other toxic fumes.
      a. Ethylene gas
      b. Sulfur dioxide gas
   3. Safety measures are needed.
      a. Fuel-burning heat sources must be vented to the outdoors through a chimney.
      b. Ventilation system must be installed to bring fresh air into the greenhouse.

G. Circulation
   1. Circular air movement is an essential part of heating process.
   2. Air-mixing fans push the hot air that rises back down to plants.

4. Why must a greenhouse be ventilated?

Have students discuss why ventilation is important in a greenhouse. Have the students contemplate the lack of fresh air. What effect would it have on the plants?

A. Purpose of greenhouse ventilation
   1. Brings fresh air into greenhouse
   2. Reduces temperature
   3. Reduces relative humidity
      a. Excessive humidity causes condensation on plants.
      b. Condensation left on plants increases risk of disease.
   4. Replenishes carbon dioxide (CO_2)
      a. CO_2 is necessary for plant growth.
      b. Plants consume CO_2 during photosynthesis process.

B. Types of ventilation (TM 2.8)
   1. Ridge and side vents
      a. Chimney effect
      b. May be automated or manually operated
   2. Exhaust fans on sidewalls and endwalls
      a. Draws in fresh air
      b. Most beneficial in late spring, summer, and early autumn
   3. Perforated convection tube heater/fan system
      a. Motorized louvers let in fresh air.
      b. Fans mix air with inside air then distribute air through a convection tube.
      c. Convection tube running the length of the greenhouse overhead distributes air through the perforated openings.

5. How is a greenhouse kept cool during warm weather?

Ask students why cool air and reduced light are important in maintaining the greenhouse environment. Which factors from Lesson 1 of this unit also apply?

A. Basic measures
   1. Provide even flow of cool air
   2. Reduce light intensity

B. Methods of providing cool air
   1. Ventilators, vents
   2. Forced air ventilation
   3. Fan and pad systems
   4. Fog system
      a. Water is forced through tiny nozzles to create fine mist.
      b. Evaporating water cools the air.
   5. Mechanical A/C system - inefficient cooling method for most commercial greenhouse operations

C. Methods of reducing light intensity
   1. Shade fabric
      a. Fabric is available in various types of fabrics.
         i. Woven polyethylene cloth from greenhouse supplier
         ii. “Aluminet” - knitted polyaluminum
      b. Weave density of fabric determines the amount of light that is shaded out.
         i. Fabric is selected according to its percent of density.
         ii. Weave densities range from 20 to 90%.
         iii. The percent approximates how much the light intensity is decreased. For example, a 55% shade fabric blocks about 55% of the ambient (surrounding) light.
      c. The best way to reduce heat is to drape the cloth on the outside of the greenhouse. Be sure to maintain ventilation.
   2. Shade paint
      a. Diluted, weak-binding latex paint
      b. Sprayed on outside of glazing, usually twice yearly
      c. Should wear off gradually over the summer and fall
      d. Wash off with soap and water to prevent light reduction in winter
   3. Blinds
      a. Wooden, plastic, or plastic-coated aluminum slats
      b. Mounted outside greenhouse like shade fabric
      c. Mounted inside blinds - adjustable
   4. Thermal screens - installed on ceilings and walls

6. How is greenhouse humidity controlled?

Specific plants thrive at specific ranges of humidity. Ask students to describe how humidity influences plants they cultivated at home.

A. Relative humidity (RH)
   1. How much water is dissolved in the air at a specific temperature
   2. Measured as a percentage

B. Range
   1. Ideal RH for most plants is 45-85% - examples:
      a. Greenhouse peppers - 75% RH
      b. African orchids - 40-60% RH
      c. Roses - 80% RH
   2. Too high
      a. Above 85% RH (However, cut tulips and cut daffodils are best stored at over 90% RH.)
      b. Water condensing on plants and increasing risk of fungal pathogens and disease
   3. Too low
      a. Below 45% RH (Note: For succulents and cacti, 5-15% RH is the ideal range.)
      b. May stunt plant growth or cause leaf burn
      c. Requires more watering

C. Methods of maintaining proper RH
   1. Use shading to reduce temperature and light.

2. Use cooling pads (evaporative cooling).
3. Keep greenhouse filled with plants. (They generate RH.)
4. Do not water plants late in the day. Ensure that floor of greenhouse drains well.
5. Hook up a fan in the greenhouse and set it to start running at 9:00 p.m. or 10:00 p.m. for 30-60 minutes.
   a. Exchanges moist, warm, inside air with moist, cool, outside air
   b. Enables heating system to warm air to its set point, which reduces level of water in the greenhouse
6. Open the roof ventilators to let hot air escape. Maximize exchange of air by having wide roof ventilators and a double row of sidewall ventilators.
   a. Prevents a buildup of moisture
   b. Prevents water vapor from condensing on plants, which can cause spread of disease
7. Install fans for ventilation.
   a. Introduce cooler outside air into the greenhouse during late spring, summer, or early fall.
   b. During late autumn, winter, and early spring, air is introduced into greenhouse through perforated polyethylene tubes.
      i. This prevents harsh, extremely cold outside air from harming plants.
      ii. When cold air leaves tubes, it mixes with warm greenhouse air and this prevents plants from suddenly getting chilled.
   c. Exhaust fans exchange greenhouse air with outside air.

7. What equipment is used to irrigate plants in a greenhouse?

Ask students to describe equipment they have used to water their own plants. Unit IV, Lesson 3, details how equipment and systems are used to irrigate greenhouse crops and it describes different irrigation systems.

A. Manual method
   1. Handheld hose
   2. Wand
B. Automated method
   1. Delivery through mist systems
   2. Spaghetti tubes, which are controlled by timers
   3. Drip emitters
   4. Ooze tubes
   5. Water loop
   6. Capillary mat system
   7. Ebb and flood system
   8. Boom system
   9. Spray stake/nozzle system
   10. Fertigators

8. How are carbon dioxide and light levels controlled in a greenhouse?

Carbon dioxide is vital for plants. Plants use CO_2 to produce energy during photosynthesis. The greenhouse owner can manipulate the amount of CO_2 to control a crop's growth cycle. Light must also be controlled carefully. More details are provided in Units III and IV.

A. Carbon dioxide
1. Essential for plant survival
2. Consumed by plants during photosynthesis
3. Deficiency of CO_2 - if greenhouse is tightly closed, allowing no exchange of air
4. Lost CO_2 to be replenished by a CO_2 generator
    a. Generators provide a maximum amount of CO_2 with a minimum of heat as a by-product.
    b. A timer regulates when to introduce CO_2 into the greenhouse.
        i. Add CO_2 when photoperiod begins or at sunrise.
        ii. Discontinue CO_2 enrichment during dark hours.
        iii. Average recommended level of CO_2 is 1,000-2,000 ppm (parts per million).
    c. Generator operates by burning propane or natural gas.
    d. A thermocouple monitors the pilot light.
    e. If pilot flame goes out, a safety valve closes to prevent unburned fuel from releasing into greenhouse.
    f. Larger generators allow the greenhouse owner to set a shorter cycle time. A shorter cycle time adds CO_2 into the greenhouse more efficiently.

B. Light
1. Required light intensity depends on plant.
2. Intensity of available light is measured in foot-candles, ranging from 500 f.c. on an overcast winter day to 10,000 f.c. on a clear summer day.
3. Light intensity can be affected by several environmental factors.
    a. Geographic location
    b. Season
    c. Time of day
    d. Pollution
    e. Cloud cover
4. Light intensity can be read in two ways.
    a. Light meter
    b. Computerized photocell
5. Light intensity can be increased or decreased to meet plant's requirements.
    a. Light intensity/day length can be increased with supplemental lights.
        i. Fluorescent lights
        ii. High-intensity discharge (HID) lights
    b. Light intensity/day length can be decreased by several means.
        i. Blocking plants from light with black material
        ii. Putting plant under a bench to reduce exposure to light
        iii. Spraying a shading compound on growing structure
        iv. Placing a shade cloth above plants or over the growing structure

F. Other Activity and Strategy

Have students go through greenhouse supply catalogs to find examples of environmental control systems. Which are appropriate for your area? Which systems would be appropriate for someone specializing in olericulture in Florida or floriculture in North Dakota?

G. Conclusion

The interior of a greenhouse is a blank slate. Although the size and shape affect the interior, so do environmental factors such as temperature, light intensity, humidity, and carbon dioxide. These considerations affect the design of a growing environment.

H. Answers to Activity Sheet

Instructor's discretion

I. Answers to Assessment

1. D
2 C
3. C
4. D
5. D
6. C
7. B
8. D
9. The student may list any three of the following:
   A. Geographical location
   B. Season
   C. Time of day
   D. Pollution
   E. Cloud cover
10. The student may list any four of the following:
    A. Temperature
    B. Humidity
    C. Carbon dioxide
    D. Pests
    E. Diseases
11. Increases chances of fungi attacking plant
12. Between 45 and 85%
13. A. Ridge and side vents
    B. Exhaust fans
    C. Perforated convection tube heater/fan

UNIT II: GROWING STRUCTURES

Name__________________

Lesson 2: Environmental Controls

Date___________________

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. What are four considerations in selecting a temperature control system?

   A. Humidity level, installation, uniformity, and conduction
   B. Cost analysis, fuel, reliability, and light intensity
   C. Uniformity, storage requirements, location, and cost of equipment
   D. Capacity, reliability, uniformity, and fuel

2. How can light intensity be reduced?

   A. Horizontal airflow
   B. Ooze tube
   C. Thermal screen
   D. Thermistors

3. What methods can distribute heat?

   A. Hot air/steam, thermal screens, and infrared heat
   B. Radiant heat, fire tube, and fog system
   C. Forced hot air, hot air, and steam
   D. Thermal screens, fire tube, and solar energy

4. What is one purpose of ventilation?

   A. Deplete oxygen
   B. Collect dust
   C. Replenish carbon monoxide
   D. Replenish carbon dioxide

5. What does a high/low thermometer measure?

   A. Seasonal temperature inside the greenhouse
   B. Indoor/outdoor temperature
   C. Air blown across the thermostat
   D. Day and night temperature

6. When does a CO_2 generator introduce carbon dioxide in the greenhouse?

   A. During dark hours
   B. At noon
   C. Sunrise
   D. At midday

7. What are three types of equipment used to irrigate plants using the automatic method?

   A. Ebb and flood, handheld wand, and capillary mat
   B. Ooze tube, drip emitters, and water loop
   C. Tube system, subirrigation, and overhead
   D. Spray stake, boom system, and tube system

8. What is a fan and pad system used for?

   A. Heating
   B. Catching insects
   C. Increasing carbon dioxide
   D. Cooling

Short-Answer Questions: Write the answers in the space provided.

9. What are three environmental elements that affect light intensity?

   A.

   B.

   C.

10. What are four environmental factors that a greenhouse owner should monitor?

    A.

    B.

    C.

    D.

11. What damage can high humidity inflict on plants?

12. What is the ideal range of relative humidity for most plants?

13. What are the three types of ventilation systems?

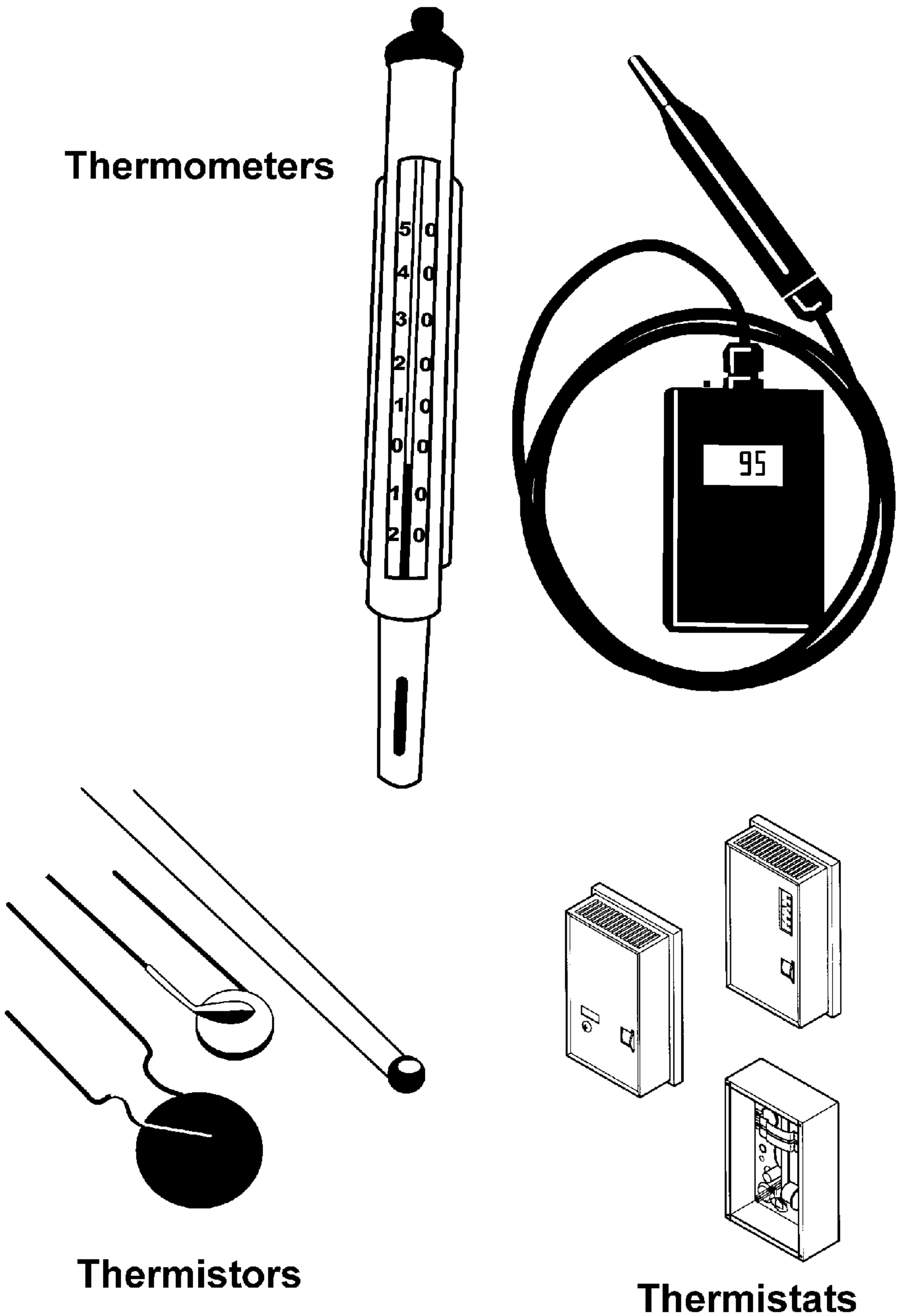
A.

B.

C.

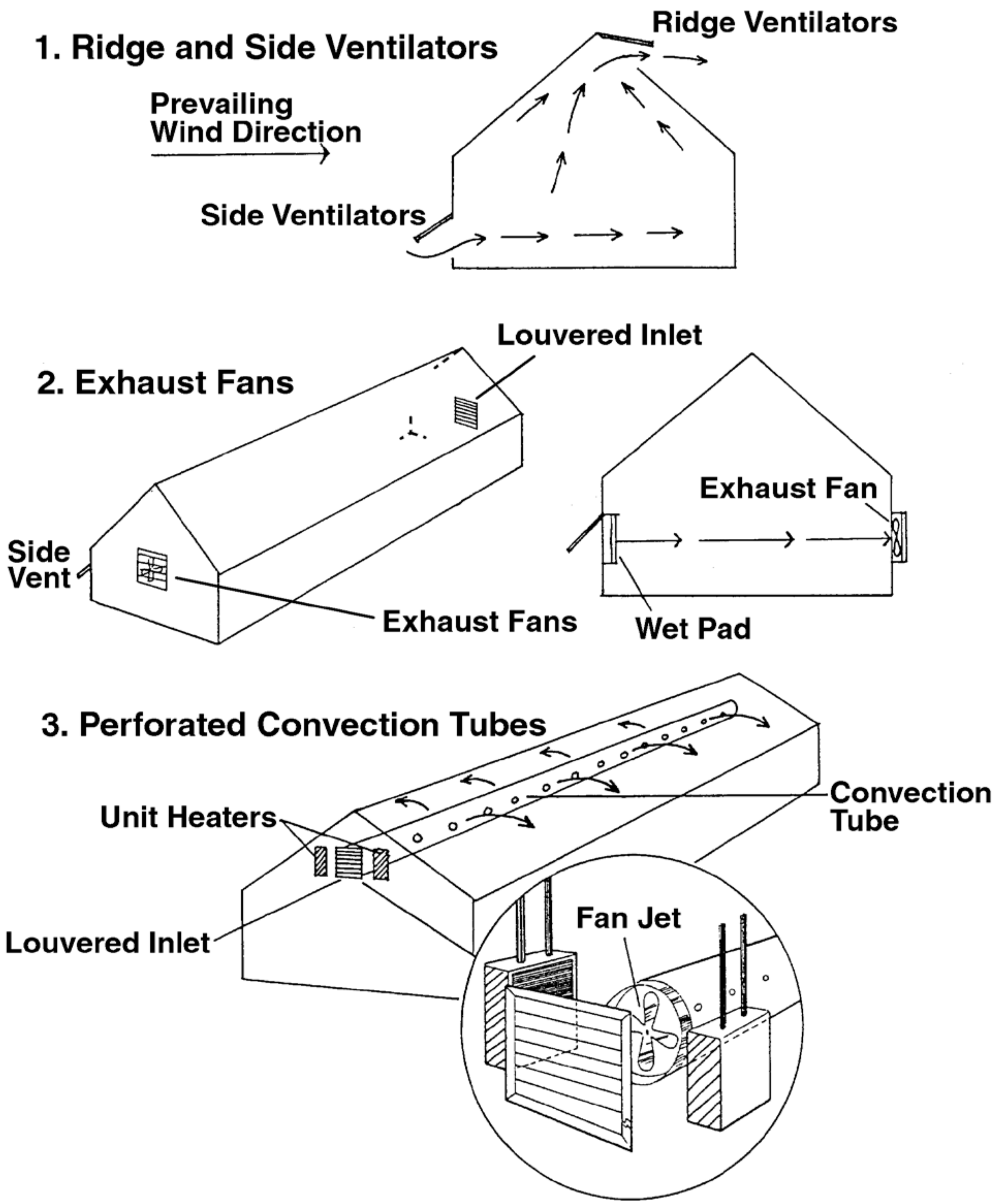
TM 2.7

Devices to Monitor Temperature



TM 2.8

Methods of Ventilation



UNIT II: GROWING STRUCTURES

AS 2.2

Lesson 2: Environmental Controls

Name__________________

Plan Your Own: Part II

Objective: Integrate environmental controls into a strategic plan of a greenhouse.

Directions: Select one of the following topics. Work in a small cooperative group to answer the questions related to the selected topic. Build upon information from AS 2.1 to answer how you would control the greenhouse environment. Remember to discuss cost, complexity of setup, repair, and upgrade. Share your answers with the rest of the class.

Group One: Heat

1. How do you plan to monitor the temperature in your greenhouse? Why?
2. How do you intend to keep the greenhouse at the optimal temperature during the cold months?
3. What type of distribution system are you using?

Group Two: Cooling

1. How do you plan to monitor the temperature in your greenhouse? Why?
2. What method of cooling are you using: one or more than one means to control temperature?
3. How are you ventilating the greenhouse? Why this method?

Group Three: Humidity

1. How do you plan to monitor the relative humidity in your greenhouse?
2. How do you plan on regulating the humidity?
3. Does this system have more than one function?

Group Four: Light

1. How do you plan to monitor light intensity? Why this approach?
2. How do you plan to control the light intensity: one approach or multiple methods?
3. What is the cost of your solution?

Group Five: Carbon Dioxide

1. How do you plan to monitor carbon dioxide in the greenhouse?

2. How will you control, augment, and release the amount of carbon dioxide?

3. Why is it important to control CO_2?

Group Six: Irrigation

1. Which method of irrigation will work best?

2. How will you integrate fertilizer injections?

3. What happens to the runoff water?

GREENHOUSE OPERATION AND MANAGEMENT

Unit II: Growing Structures

Lesson 3: Energy Conservation and Environmental Protection

Objective/Competency:

Identify energy- and cost-saving factors in greenhouse structures.

Study Questions

1. **What greenhouse modifications and procedures can be used to conserve energy?**

2. **What modifications and procedures can be used in a greenhouse to protect the environment?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Activity Sheet

   AS 2.3 Windbreak

3. Scott, S. V., Master Gardener. "Evergreens in the Landscape." <http://outreach.missouri.edu/jasper/hort/mg/globe/069.htm>

4. Slusher, John P. "Planning Tree Windbreaks in Missouri." School of Natural Resources, University of Missouri-Columbia. <http://muextension.missouri.edu/xplor/agguides/forestry/g05900.htm>

5. Starbuck, Christopher J. "Landscape Plantings for Energy Savings." Department of Horticulture, University of Missouri-Columbia. <http://muextension.missouri.edu/xplor/agguides/hort/g06910.htm>

TEACHING PROCEDURES

A. Review

   Building on Lessons 1 and 2 regarding greenhouse structures and the mechanical workings, Lesson 3 explores both energy conservation and environmental protection and their relationship to greenhouse operations.

B. Motivation

Why are energy conservation and environmental protection important to the greenhouse owner? Ask students to explain the pros and cons of both topics. Ask for specific examples of how a greenhouse owner can conserve energy and protect the environment.

C. Assignment of Study Questions

Encourage students to keep and update the portfolio they are creating for Unit II Activity.

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the questions before the discussion. Another option is to have students work in cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What greenhouse modifications and procedures can be used to conserve energy?

If not planned properly, a greenhouse can consume a lot of resources and cut into the greenhouse owner's profits. Proactive steps can be taken.

A. Optimize natural light intensity.
   1. Minimize need for supplemental electric lighting.
   2. Ensure large trees, buildings, etc., do not shadow growing structures.
   3. Paint inside surfaces (benches, frames, etc.) with white latex paint. Do not use oil-based paint.

B. Optimize heating and cooling efficiency.
   1. Invest in quality heating, cooling, and ventilation systems.
      a. Energy efficient
      b. Using economical and available fuel
   2. Routinely maintain for optimal efficiency.

C. Create energy-saving structures.
   1. Check structure for air leaks.
      a. Make sure vents and fan louvers seal tightly.
      b. Seal holes or cracks in greenhouse covering.
      c. Install weather stripping around doors, etc.
   2. Protect from extremes in the elements.
      a. Insulate north-facing side during winter.
      b. Create windbreaks to protect plants from harsh weather.
      c. When needed, provide shade if there is high-intensity light and high temperature.

d. Install thermal blankets inside walls and roof.
3. Consider direction and intensity of natural elements (wind, sun, snow, frost) when selecting a site.

2. What modifications and procedures can be used in a greenhouse to protect the environment?

These solutions are particular to a greenhouse operation, but some of the ramifications are global. The misuse of chemicals can injure the person applying them and can also affect the environment. Care must be taken when draining fertilizer because those compounds can leach into the water table and contaminate it. Humidity and pests affect the crops directly.

A. Minimize the use of hazardous chemicals.
   1. Know and follow federal, state, and local regulations governing the use of chemicals in a greenhouse.
   2. Use the least toxic method of controlling pests.

B. Minimize risk for plant disease.
   1. Maintain the proper level of humidity.
   2. Use appropriate watering method.

C. Minimize risk of infestation.
   1. Place screens over vents.
   2. Construct screened entry.
   3. Inspect all new material upon arrival before placing them in the greenhouse.

D Minimize runoff pollution.
   1. Have good drainage to avoid contaminating the water table.
   2. Have an irrigation system that can be recycled.

F. Other Activity and Strategy

Invite a speaker from the Department of Natural Resources to talk about the interactions between a greenhouse operation and the natural environment.

G. Conclusion

Energy conservation and environmental protection are important concepts to a greenhouse grower. The implications extend beyond a greenhouse operation and can adversely affect many individuals.

H. Answers to Activity Sheet

Instructor’s discretion

I. Answers to Assessment

1. Risk of pests entering the greenhouse
2. Optimizes natural light intensity
3. The student may list any two of the following:

A. Insulate north-facing side during winter
B. Install thermal blankets inside walls and roof
C. Screen high-intensity light bursts in spring

4. The student may list any three of the following:
A. Minimize chemical usage
B. Minimize risk of pest infestation
C. Keep humidity at the appropriate level for the crop
D. Drain waste liquids properly to avoid runoff pollution

5. A. Optimize natural light intensity
B. Optimize heating and cooling efficiency
C. Create energy-saving structures

UNIT II: GROWING STRUCTURES

Name__________________

Lesson 3: Energy Conservation and Environmental Protections

Date__________________

ASSESSMENT

Short-Answer Questions: Write the answers in the space provided.

1. When placed over ventilation openings, what do tight-fitting covers help reduce?

2. What is the benefit of painting interior structures with white latex paint?

3. What are two methods to protect a greenhouse from extremes in the elements?

   A.

   B.

4. What are three procedures used in a greenhouse that protect the environment?

   A.

   B.

   C.

5. What are three modifications that help conserve energy in the greenhouse?

   A.

   B.

   C.

UNIT II: GROWING STRUCTURES

AS 2.3

Lesson 3: Energy Conservation and Environmental Protections

Name_____________

Windbreak

Objective: Justify how a windbreak helps conserve energy.

Directions: Use information from AS 2.1 and AS 2.2 in which you designed the structure and environmental controls for a model greenhouse. Now devise a windbreak that helps conserve energy. Use textbooks, magazines, catalogs, university Extension publications, and the Internet to find information. Three suggested web sites are listed below. Answer the following questions. (You may work with another student.)

- Scott, S. V., Master Gardener. "Evergreens in the Landscape <http://outreach.missouri.edu/jasper/hort/mg/globe/069.htm>
- Slusher, John P. "Planning Tree Windbreaks in Missouri." School of Natural Resources, University of Missouri-Columbia. <http://muextension.missouri.edu/xplor/agguides/forestry/g05900.htm>
- Starbuck, Christopher J. "Landscape Plantings for Energy Savings." Department of Horticulture, University of Missouri-Columbia. <http://muextension.missouri.edu/xplor/agguides/hort/g06910.htm>

1. Where is the windbreak placed?

2. Why? Be specific and name sources that justify your choice.

3. What is the windbreak made of?

4. Why?

5. How much energy can be saved? Estimate but cite reference.

UNIT II ACTIVITY

Growing Structures

Name__________________

Greenhouse Portfolio

Objective: Generate a portfolio that incorporates information from the three lessons in Unit II.

Directions: In groups, use information from completed activity sheets, photographs, sketches, and other references including the Internet to create a greenhouse portfolio. Include information about all the structural and internal mechanisms needed to build a new commercial greenhouse. Because this is a group project, the work is based on consensus. Be sure you and your coworkers agree on the contents of your portfolio. Include all of the information listed below. Once completed, give the portfolio to the instructor who will give your group another group's portfolio for Phase II of this activity.

Phase I: The Portfolio

- Wholesale or retail operation
- Type of crop: floriculture, olericulture, or ornamental
- Site selection
- Climate
- Topography
- Availability of resources: water, utilities, materials, labor
- Land considerations
- Marketing concerns
- Legal considerations
- Type of structure
- Framing and covering material
- Interior layout
- Flooring
- Benches
- Temperature monitoring system
- Heating and cooling systems
- Ventilation
- Irrigation method
- Control of light intensity
- Monitor and control of carbon dioxide
- Energy conservation ideas
- Attention to environmental protection

Phase II: The Critique

***Objective**:* Appraise another group's portfolio.

Directions: Evaluate how thoroughly each topic was discussed in the other group's portfolio. Answer the following questions and prepare a professional-looking critique. Give your answers and the critique to the instructor upon completion.

1. How complete is this plan? Are all of the questions answered? (Blueprints are not necessary.)

2. Are there any areas insufficiently addressed or forgotten altogether?

3. Is this plan practical or unrealistic? Why?

4. What energy conservation measures are indicated?

5. What environmental considerations are indicated?

6. Are the costs of materials discussed?

7. Is the cost and ease of upgrade discussed?

GREENHOUSE OPERATION AND MANAGEMENT

Unit III: Plant Science Basics

Lesson 1: Plant Parts, Structures, and Functions

Competency/Objective:

Distinguish plant parts, structures, and functions.

Study Questions

1. **What is a plant cell?**
2. **What are general differences between monocots and dicots?**
3. **What are the basic types of specialized plant tissues?**
4. **What is a seed?**
5. **What are the functions and types of roots?**
6. **What are the functions, structures, and types of stems?**
7. **What are the functions, structure, and types of leaves?**
8. **What are the functions, parts, and types of flowers?**
9. **What are the differences between a monoecious and a dioecious plant?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 3.1 Basic Structure of a Plant Cell
   TM 3.2 Cross-Sections of Monocot and Dicot Seeds
   TM 3.3 Monocot vs. Dicot Seeds
   TM 3.4 Parts of a Plant

TM 3.5 Types of Roots
TM 3.6 Specialized Stems
TM 3.7 Cross-Section of a Leaf
TM 3.8 Leaf Shapes
TM 3.9 Leaf Margins
TM 3.10 Leaf Attachments
TM 3.11 Parts of a Complete Flower

3. Activity Sheets

AS 3.1 Plant Parts, Structures, and Functions Work Sheet
AS 3.2 Stem Poster
AS 3.3 Leaf Poster
AS 3.4 Identifying Monocot and Dicot Plants

TEACHING PROCEDURES

A. Introduction

Unit III examines plant science basics by first providing fundamental information about plant science. Parts and functions of plants and flowers are illustrated down to the cellular level. The next lesson explains plant processes and the final lesson in this unit describes how plants are classified and named.

B. Motivation

Ask students why understanding plants' structures and functions is vital to having a successful greenhouse operation. Compare a greenhouse owner to a doctor: Why does a doctor need to understand human anatomy in order to care for patients? What situations could occur in the greenhouse that would necessitate understanding plant parts and how they function?

C. Assignment of Study Questions

Be sure to have illustrations of a variety of plants displayed throughout the classroom.

AS 3.1 is a work sheet to guide students as they learn about plant parts, structures, and functions. They should answer each question as the relevant material is covered. Students may work in small groups or alone and they should consult the Student Reference and the transparency masters.

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one question at a time or have the students answer all of the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What is a plant cell?

The elements making up the plant cell are discussed. As you cover this material, remind students to answer the appropriate questions on AS 3.1.

A. Basic structural unit of plants (TM 3.1)
B. Cell structure
   1. Cell wall
      a. Primary wall (first to develop)
      b. Middle lamella (layer between walls of two cells)
      c. Secondary wall (woody part of plant that develops inside primary wall)
   2. Plasma membrane (outer membrane)
      a. Surrounds the cell, just inside the cell wall
      b. Molecules of proteins, carbohydrates, phosphorous, fat
      c. Functions
         i. Controls entrance and exit of substances from the cell
         ii. Relays information about environmental conditions to cell nucleus
   3. Cytoplasm
      a. Liquid within cell
      b. Contains organelles
      c. Site of most life processes
      d. Organelles within cytoplasm
         i. Mitochrondria
            (a) Small, dense
            (b) Control many chemical reactions in cell
            (c) Provide site for respiration
         ii. Plastids
            (a) Contain chloroplasts (green pigment, known as chlorophyll)
            (b) Contain chromoplasts (red, orange, and yellow pigment)
         iii. Vacuoles
            (a) Large, fluid filled
            (b) Store water, dissolved minerals, and other materials
            (c) Mature and join to form large, central vacuoles
   4. Nucleus
      a. Control center of cell
      b. Location for genetic material (chromosomes)
      c. Functions
         i. Controls physiological characteristics of plant

ii. Controls appearance of plant
iii. Passes characteristics to offspring

2. What are general differences between monocots and dicots?

Plants have either one or two cotyledon (seed leaves). About 50,000 monocot plants exist; there are 200,000 dicots. Ask students why they think this occurs. TM 3.2 illustrates cross-sections of monocot and dicot seeds. TM 3.3 depicts the differences between monocot and dicot plants.

A. Monocot plants
   1. One cotyledon
   2. Leaves with parallel veins
   3. Vascular bundles scattered within stem
   4. Flower parts in multiples of three (e.g., three stamens, six petals)
   5. Examples: corn, grass
B. Dicot plants
   1. Two cotyledons
   2. Leaves with branched veins
   3. Vascular bundles in circular pattern
   4. Flower parts in fours or fives (or multiples of fours and fives)
   5. Examples: most flowering plants, deciduous trees

3. What are the basic types of specialized plant tissues?

The combination of cells functioning together is referred to as tissue. Two main types of plant tissue are meristem and permanent. Meristem tissue actively divides to form new growth for the plant, whereas the permanent tissue is made up of mature cells.

A. Meristem tissues (cells that actively divide to form new growth)
   1. Apical meristem tissues (TM 3.4)
      a. Located at tips of roots and stems
      b. Increase plant length
   2. Cambium meristem tissues
      a. Located in stems
      b. Increase plant diameter
   3. Intercalary zone meristem tissues
      a. Located just above nodes in monocot plants
      b. Increase stem height
B. Permanent tissues (mature cells that do not actively divide)
   1. Epidermis tissues (outside covering)
   2. Vascular system tissues (path from roots to stems to leaves)

4. What is a seed?

Ask students to identify the five basic parts of a plant. If possible, have illustrations of all plant parts available to show the class. One of the basic plant parts in the earliest stage is the seed.

A. Seed
   1. Contains an embryo (miniature plant)
   2. Dormant until environmental conditions permit germination
B. Basic seed parts
   1. Seed coat
      a. Tough exterior surface
      b. Protects embryo from drying out or from injury
   2. Embryo
      a. Cotyledon
         i. Seed leaves
         ii. Monocots - one cotyledon (protects the epicotyl)
         iii. Dicots - two cotyledons (protect the epicotyl and provide food storage for new plants)
      b. Epicotyl (plumule)
         i. Growth bud of embryo located above cotyledons
         ii. Develops into shoot that emerges from germinating seed
      c. Hypocotyl
         i. Stem section located below the cotyledon
         ii. First tree stem
         iii. Lengthens plant; cotyledons and epicotyl emerging from germinating seed
      d. Radicle
         i. Root tip, located at end of hypocotyl
         ii. First root of plant
         iii. First part to emerge from germinating seed
         iv. Holds plant in soil, absorbing water and nutrients
   3. Endosperm
      a. Food storage tissues
      b. Nourish the developing embryo upon germination
      c. Only in monocots

5. What are the functions and types of roots?

Another basic part is the plant's root system. There are five types of roots, all of which absorb water and nutrients for the plant.

A. Primary functions
   1. Anchor plant
   2. Absorb water and nutrients
B. Specialized functions

1. Synthesize hormones for plant growth
2. Store carbohydrates
3. Aerial support in come cases - climbing roots, such as ivy

C. Root features
1. Root hairs
   a. Single-cell, hairlike extensions
      i. More hairs are produced under dry conditions.
      ii. Fewer hairs are produced under moist conditions.
   b. Located near tip of roots
   c. Functions
      i. Absorb water and minerals from soil
      ii. Expand root area for greater absorption
2. Radicle roots
   a. Emerge from the seed
   b. Grow into true roots or die in formation of fibrous roots

D. Types of roots (TM 3.5)
1. Taproot (primary or true root)
   a. Large central roots from which lateral roots grow
   b. Excellent anchorage and food storage
   c. Penetrates deep into soil
   d. Common in dicots
   e. Example: carrot
2. Fibrous roots
   a. No central root
   b. Finely branched secondary roots spread shallow and wide
   c. Excellent in absorbing water and minerals
   d. Hold soil and prevent erosion
   e. Common in monocots
   f. Example: grass
3. Aerial roots (two types)
   a. Clinging air roots
      i. Grow out horizontally from stem
      ii. Fasten plant to a form of support
      iii. Example: English ivy
   b. Absorptive air roots
      i. Thick outer covering of dead tissue
      ii. Roots absorb and store water
      iii. Example: orchids
4. Adventitious roots
   a. Develop in places other than nodes
   b. Can form on cuttings and rhizomes
   c. Example: blackberries
5. Aquatic roots
   a. Develop adventitious roots in shallow water from the submerged shoots
   b. Absorb nutrients and oxygen from water
   c. Example: water lilies

6. What are the functions, structures, and types of stems?

Ask students what stems do for plants. Have them complete AS 3.2.

A. Functions
   1. Support other plant parts (e.g., branches, leaves, flowers, fruit)
   2. Capture light for photosynthesis
   3. Move water, minerals, and food manufactured during photosynthesis to other parts of plant
   4. In some cases, store water, food, and nutrients (e.g., Irish potato, cactus)

B. Basic stem structure
   1. Monocots
      a. Vascular bundles (xylem and phloem tissues) scattered throughout the cortex
      b. No pith (parenchyma cells) in center
   2. Dicots
      a. Vascular bundles arranged in a ring
      b. Pith in center

C. Modified stems (not upright and vertical) (TM 3.6)
   1. Corms
      a. Underground
      b. Thickened stems
      c. Examples: gladiolus, crocus
   2. Tubers
      a. Underground
      b. Swollen stems
      c. Food storage
      d. Examples: yam, white potato
   3. Bulbs
      a. Compressed, thickened stems
      b. Modified leaves wrap around the stem to form the bulb
      c. Examples: onion, tulip
   4. Crowns
      a. Similar to bulb's compressed stem
      b. Leaf and flower buds that grow on crown, just above the ground
      c. Examples: asparagus, fern
   5. Spurs
      a. Short stems that form on branches of woody plants
      b. Examples: pear, apple
   6. Rhizomes
      a. Horizontal, underground
      b. Produce roots on lower surface
      c. Send leaves and flow shoots aboveground
      d. Examples: iris, bamboo
   7. Stolons
      a. Horizontal, aboveground
      b. Roots forming at nodes

c. Examples: Bermuda grass, strawberry

7. What are the functions, structure, and types of leaves?

Discuss the variety of shapes, margins, and arrangements Ask students why a particular plant might have a leaf shaped in a certain way, e.g., a cactus. Have them complete AS 3.3.

A. Functions
   1. Manufacture food through photosynthesis
   2. Protect vegetative and floral buds
      a. Bud scales (catphylls)
         i. Modified leaves
         ii. Protect buds during winter
         iii. Examples: juniper, mango
      b. Floral bracts (hyposophylls)
         i. Protect buds during development
         ii. May be leafy (poinsettia) or fleshy (globe artichoke)
   3. Store food
      a. Cotyledons (seed leaves) store food while seed germinates.
      b. Cotyledons store food until plant matures and begins photosynthesis.

B. Basic leaf structure (TM 3.7)
   1. Epidermis (upper and lower)
      a. Cuticle
         i. Waxy substance covering the epidermis of stems and leaves
         ii. Usually thicker on the top side of leaf
         iii. Keeps water in plants
      b. Stomata
         i. Openings in epidermis (usually on underside of leaves)
         ii. Allow for exchange of gases (carbon dioxide, oxygen, water vapor)
         iii. Not present in submerged plants, such as some water lilies
      c. Guard cells
         i. Located on each side of stomata
         ii. Open and close the stomata
   2. Mesophyll layer
      a. Palisade mesophyll
         i. Elongated cells under the upper epidermis
         ii. Contains chloroplasts
         iii. Primary site of photosynthesis
      b. Spongy mesophyll
         i. Between palisade mesophyll and lower epidermis
         ii. Mass of irregularly shaped cells
         iii. Contains chloroplasts
         iv. Air space between cells
         v. Site of photosynthesis and gas exchange

3. Vascular bundles (located in spongy mesophyll)
    a. Phloem tissues move food from site of photosynthesis to rest of plant.
    b. Xylem tissues move water and minerals to photosynthesizing cells in leaves and stems.

C. Modified leaves
1. Xeromorphic foliage
    a. Thick-walled epidermis covered with a waxy cuticle
    b. Protects plant in arid climates
    c. Example: cactus
2. Thorns
    a. Short, hard leaves with sharp points
    b. Protect plant
    c. Example: honey locust
3. Tendrils
    a. Thin, stringy leaves
    b. Twine to support plant
    c. Examples: pea, grapevine
4. Sacs
    a. Pouchlike
    b. Hold water and capture insects
    c. Example: Venus flytrap
5. Submerged foliage (hydrophytes)
    a. Thin cell walls
    b. Gas chambers trapping internally generated gases, enabling leaves to float
    c. Example: water lily
6. Prickle
    a. Grows from epidermis
    b. Can be easily removed
    c. Example: rose

D. Leaf shapes (TM 3.8)
E. Leaf margins (TM 3.9)
F. Leaf tips, bases, and attachments (TM 3.10)

8. What are the functions, parts, and types of flowers?

Ask students to characterize various flowers in terms of shape and function. Have illustrations of diverse flowers displayed in the classroom.

A. Basic functions
1. Reproductive organs of flowering plants (angiosperms)
2. Produce seeds and fruit

B. Basic parts of complete flower (TM 3.11)
1. Sepals (calyx)
    a. Vegetative part
    b. Outer covering of flow bud
    c. Protect stamens and pistils in bud stage

2. Stamens - male reproductive parts (androecium)
    a. Anther (produces pollen grains)
    b. Filament (supports the anther)
3. Petals (corolla)
    a. Vegetative part
    b. Bright color/fragrance to attract pollinating insects
    c. Protect stamens and pistils in bud stage
    d. Usually drop shortly after pollination
4. Pistil - female reproductive parts (gynoecium)
    a. Stigma receives and holds pollen grains.
    b. Style connects stigma with ovary and supports the stigma so that it may be pollinated.
    c. Ovary is the enlarged portion at base of pistil and is the site for fertilization. It produces ovules that develop into seeds.

C. Basic types of flowers
1. Solitary (individual flower)
2. Inflorescence (bunch or cluster)
    a. Head, e.g., alstroemeria
    b. Spike, e.g., gladiolus
    c. Umbel, e.g., amaryllis

D. Complete and incomplete flowers
1. Complete flowers
    a. Contain both male and female parts
    b. All four parts of a flower present
    c. Usually self-pollinating
    d. Example: rose
2. Incomplete flowers
    a. One or more flower parts missing
    b. Flower either male or female
    c. Must cross-pollinate
    d. Example: apple

9. What are the differences between a monoecious and dioecious plant?

Classify illustrated flowers as either monoecious or dioecious.

A. Monoecious plants
1. Both male and female flowers on different parts of the same plant
2. Pollination occurring on same plant
3. Examples: cucumber, corn

B. Dioecious plants
1. Plant is either male or female.
2. Pollination requires both a male and a female plant in proximity.
3. Examples include holly and asparagus.

F. Other Activity and Strategy

For a rudimentary illustration of a cell, fill a balloon with water and place it in a cardboard box just a little bit bigger than the balloon. The cardboard box is the cell wall; the balloon is the plasma membrane. It is porous and the liquid inside is the cytoplasm.

G. Conclusion

In this introduction to plant science, the five basic plant parts and functions are identified: seeds, roots, stem, leaves, and flowers.

H. Answers to Activity Sheets

AS 3.1 Plant Parts, Structures, and Functions Work Sheet

1. A. Chloroplast
   B. Plasma membrane
   C. Cell wall
   D. Cytoplasm
   E. Vacuole
   F. Mitochondrion
   G. Nucleus
2. A. Control entrance and exit of substances into and out of cell
   B. Relays information about environmental condition to cell nucleus
3. A. Mitochondria - One of the following: control many chemical reactions in cell; site of respiration
   B. Plastids - One of the following: contain chloroplasts; contain chromoplasts
   C. Vacuoles - One of the following: store water, dissolved minerals, and other materials; mature and join to form large, central vacuoles
4. A. Controls physiological characteristics of plant
   B. Controls appearance of plant
   C. Passes characteristics to offspring
5. A. Meristem
   B. Permanent
6. A. Meristem - actively divides to form new growth
   B. Permanent - mature cells that do not actively divide
7. A. Apical - increase plant length
   B. Cambium - increase plant diameter
   C. Intercalary zone - increase stem height
8. A. Epidermis - outside covering
   B. Vascular system - path from roots to stem to leaves
9. A. Seed coat - protects embryo from drying out or from injury
   B. Embryo - miniature plant
   C. Endosperm - nourishes embryo
10. Endosperm
11. A. Cotyledon

B. Epicotyl
C. Hypocotyl
D. Radicle
12. Cotyledon
13. A. Monocot
B. Dicot
14. A. Synthesize hormones for plant growth
B. Store carbohydrates
C. Provide aerial support
15. A. Taproot
B. Fibrous
C. Aerial
D. Adventitious
E. Aquatic
16. Parenchyma cells
17. Floral bracts - protect buds during development
18. A. Phloem
B. Xylem
C. Cuticle
D. Upper epidermis
E. Chloroplast
F. Lower epidermis
G. Cuticle
H. Stomata
I. Guard cell
J. Spongy mesophyll
K. Palisade mesophyll
19. A. Manufacture food through photosynthesis
B. Protect vegetative and floral buds
20. Submerged plants
21. Thick-walled epidermis covered with waxy cuticle
22. Sac
23. Petals - protect stamen and pistil in bud stage; attract pollinating insects
24. Female reproductive parts
25. Types of inflorescence flowers
26. A. Contain male and female parts
B. All four parts of flower are present
C. Usually self-pollinating

AS 3.2 Stem Poster

Instructor's discretion

AS 3.3 Leaf Poster

Instructor's discretion

AS 3.4 Identifying Monocot and Dicot Plants

Instructor's discretion

I. Answers to Assessment

1. C
2. C
3. B
4. A. Stamen
   B. Petal
   C. Pistil
   D. Sepal
5. A. Epidermis
   B. Mesophyll layer
   C. Vascular bundles
6. A. Cell wall
   B. Plasma membrane
   C. Cytoplasma
   D. Nucleus
7. Monoecious
8. Stores food until plant matures and begins photosynthesis
9. A. Seeds
   B. Roots
   C. Stems
   D. Leaves
   E. Flowers
10. Food storage tissue only in monocot plants
11. A. Anchor plants
    B. Absorb water and nutrients
    C. Synthesize hormones
    D. Store carbohydrates
    E. Provide aerial support

UNIT III: PLANT SCIENCE BASICS

Name________________________

Lesson 1: Plant Parts, Structures, and Functions

Date________________________

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. What grows horizontally underground and produces roots on the lower surface?

   A. Bulbs
   B. Corms
   C. Rhizomes
   D. Spurs

2. What does the cambium meristem tissue increase?

   A. Stem height
   B. Plant length
   C. Plant diameter
   D. Stem diameter

3. What is a modified stem with a thick, compressed stem whose leaves and flower buds grow just above the ground?

   A. Corm
   B. Crown
   C. Stolon
   D. Tuber

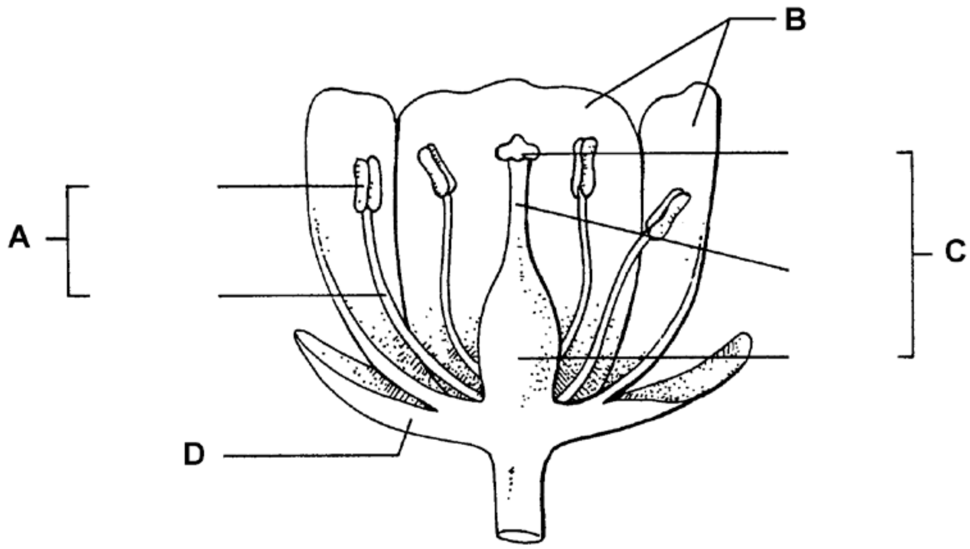
4. What are the four parts of this flower?

   A.

   B.

   C.

   D.



Short-Answer Questions: Write the answers in the space provided.

5. What are the three basic structures of leaves?

   A.

   B.

   C.

6. What are the four elements of the cell structure?

   A.

   B.

   C.

   D.

7. If male and female flowers on the same plant are in different places, what kind of plant is it?

8. What is the function of the cotyledon?

9. What are the five basic parts of a plant? Draw and label each part.

   A.

   B.

   C.

   D.

   E.

10. What is the endosperm and where is it located?

11. What are five functions of roots?

   A.

   B.

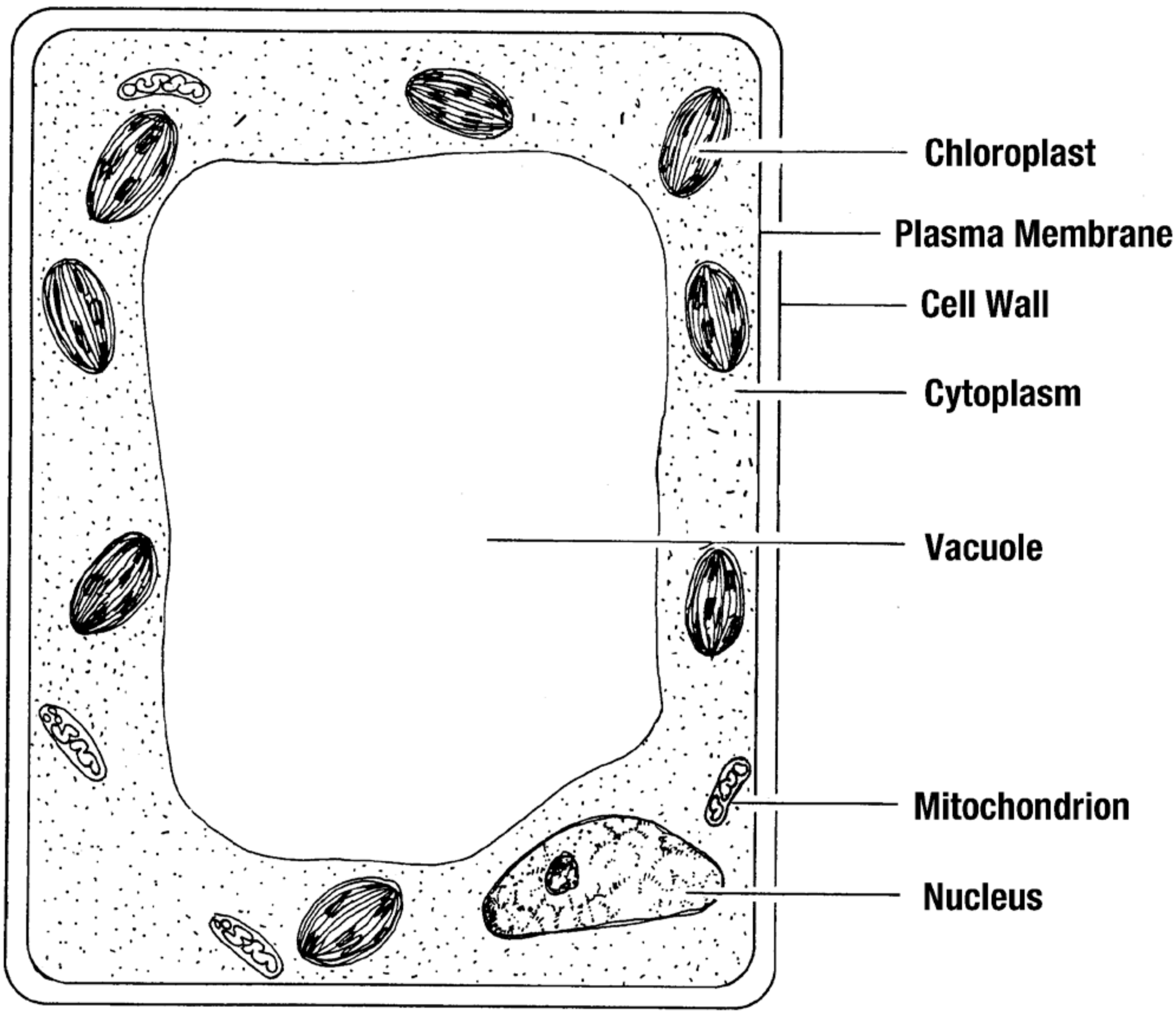
   C.

   D.

   E.

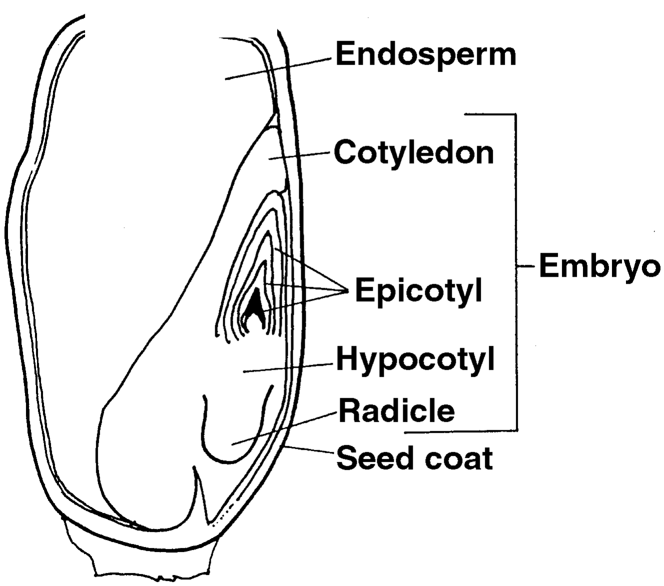
TM 3.1

Basic Structure of a Plant Cell

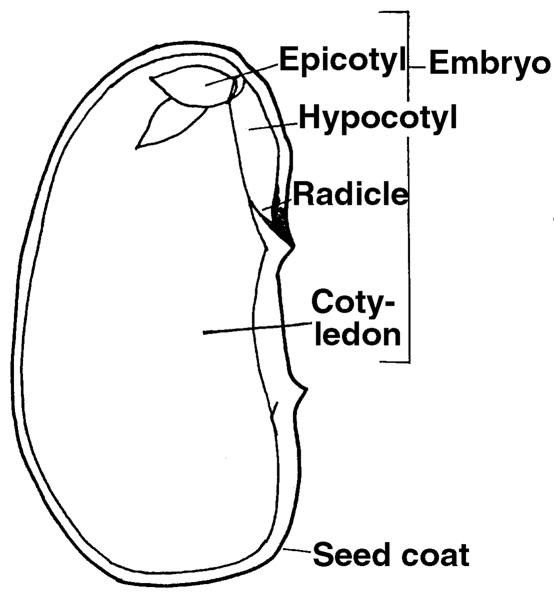


TM 3.2

Cross-Sections of Monocot and Dicot Seeds



Moncot (corn)

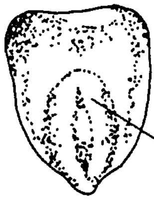


Dicot (bean)

TM 3.3

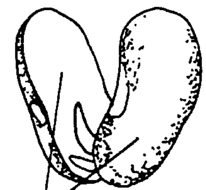
Monocot vs. Dicot

Monocot (e.g., corn)

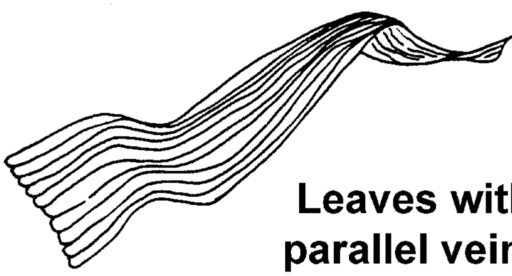


One cotyledon

Dicot (e.g., bean)

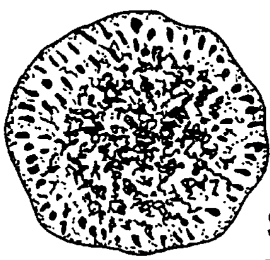


Two cotyledons

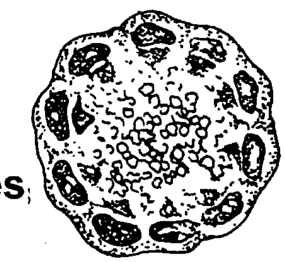


Leaves with parallel veins

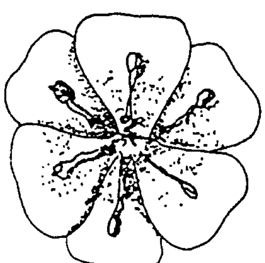
Leaves with network of veins



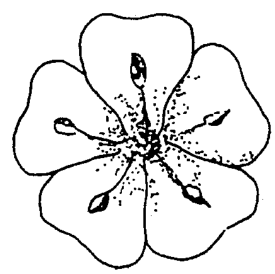
Stems with randomly scattered vascular bundles



Stems with vascular bundles in a ring



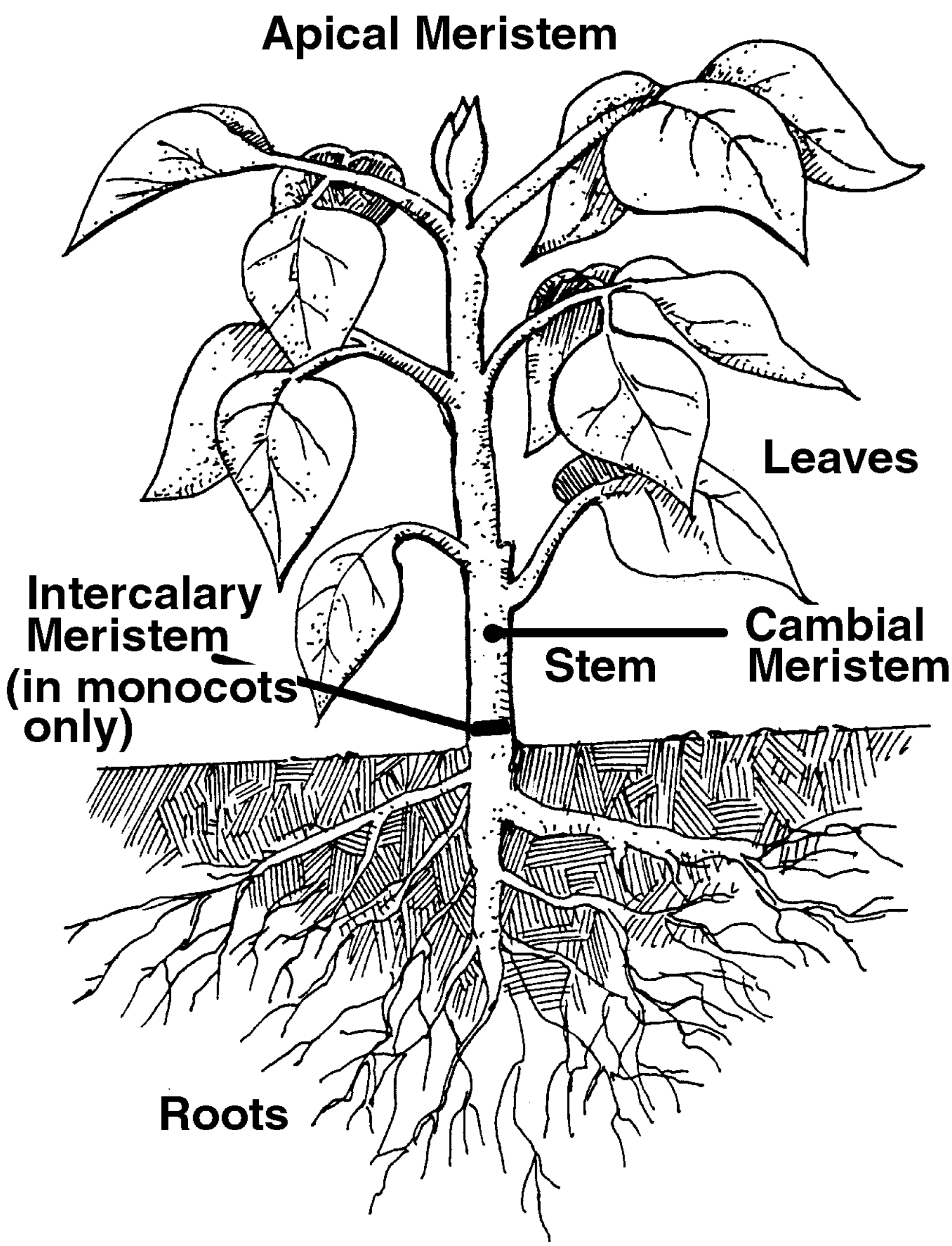
Flower parts in 3s or multiples of 3



Flower parts in 4s or 5s or multiples of 4 or 5

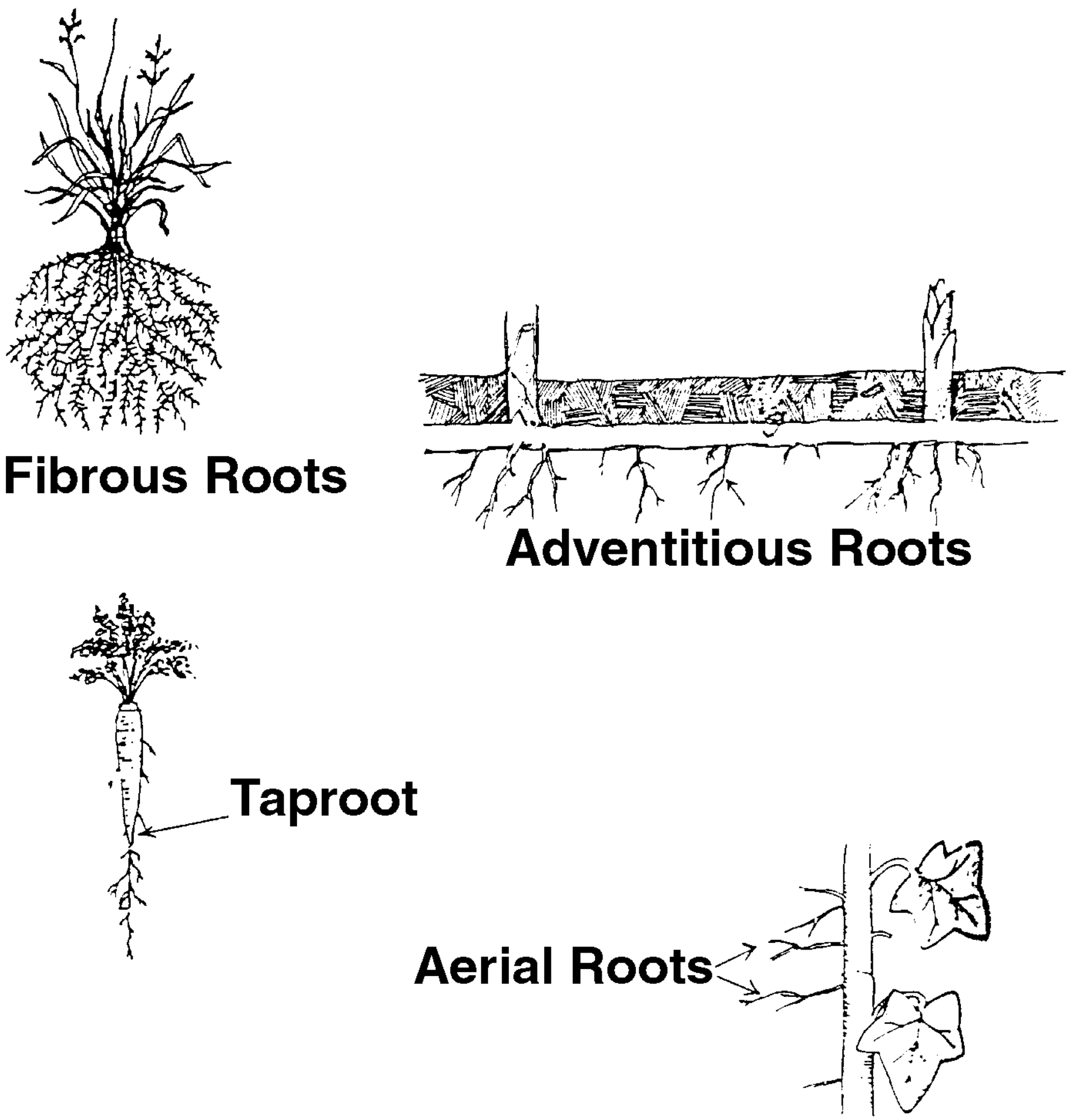
TM 3.4

Parts of a Plant



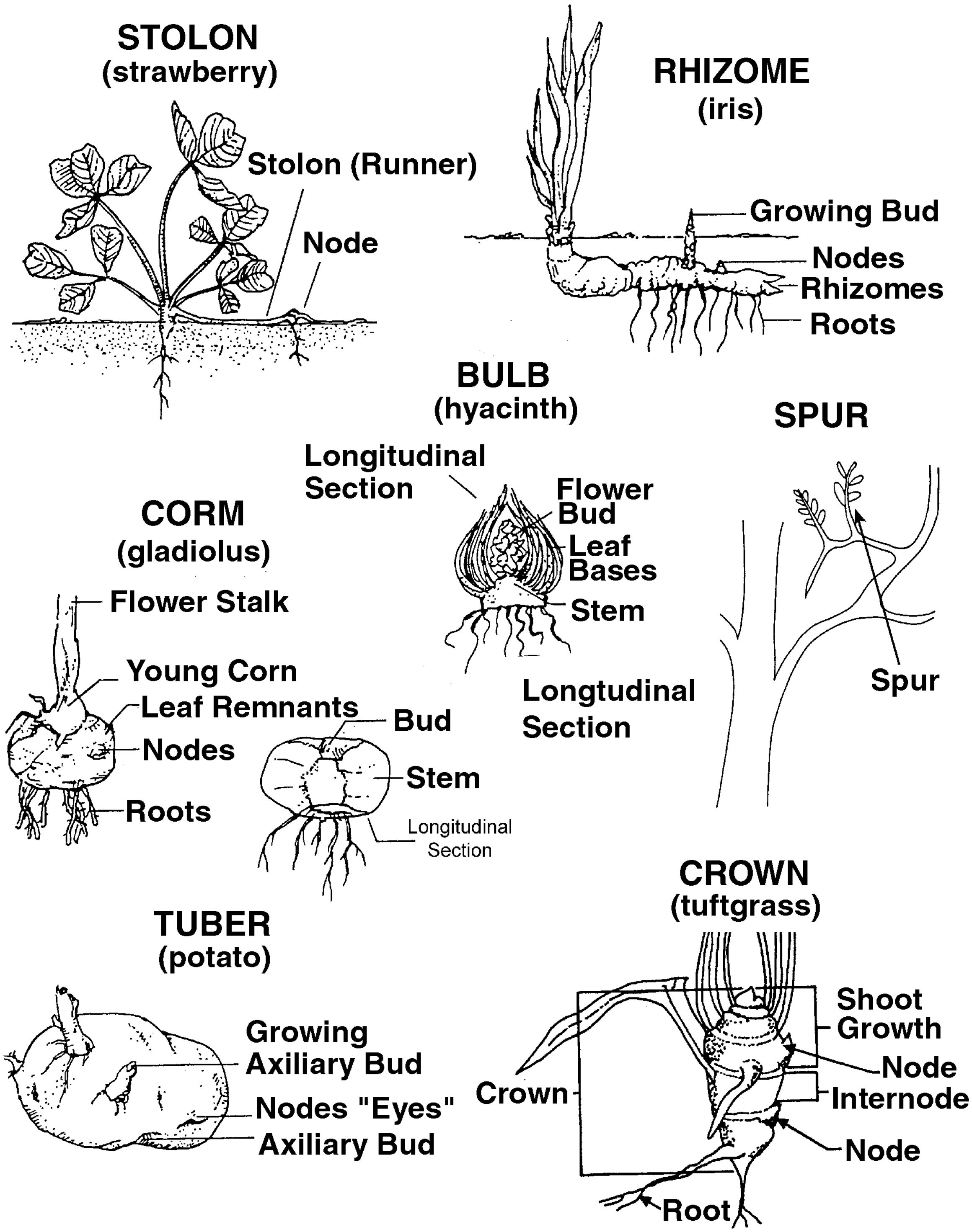
TM 3.5

Types of Roots



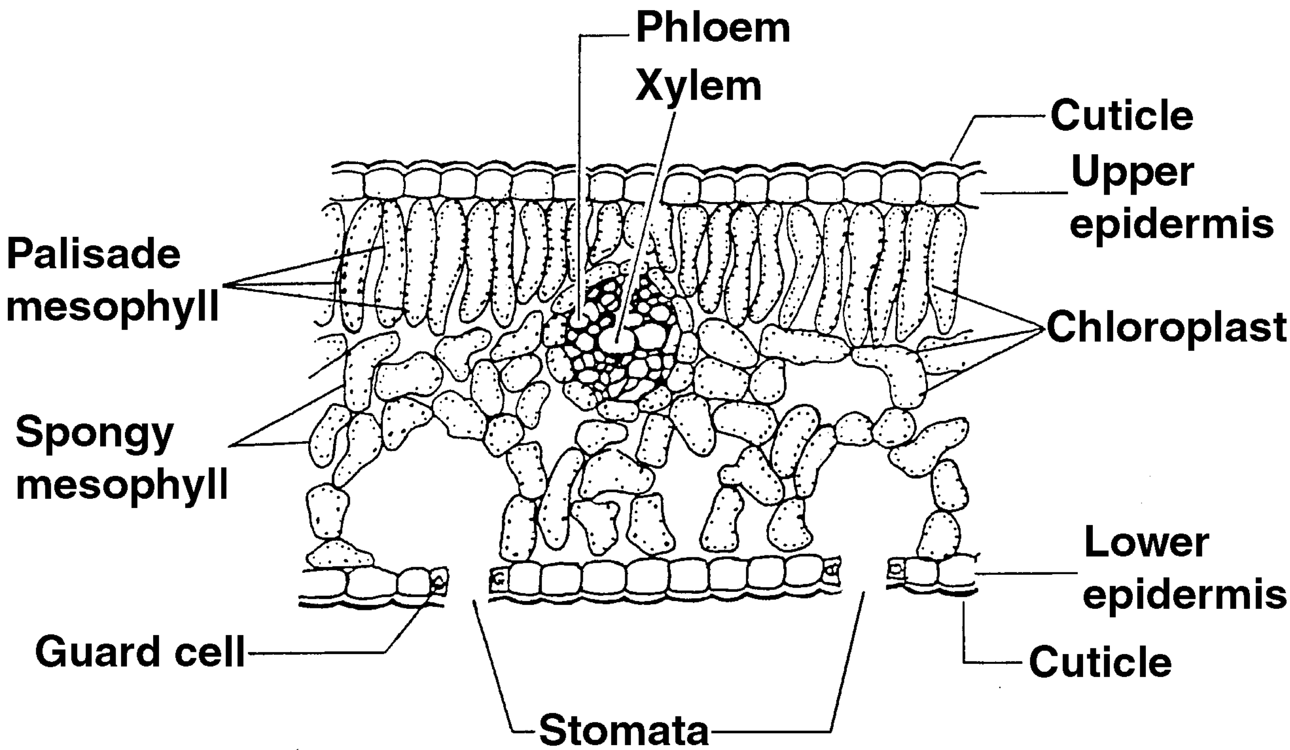
TM 3.6

Specialized Stems



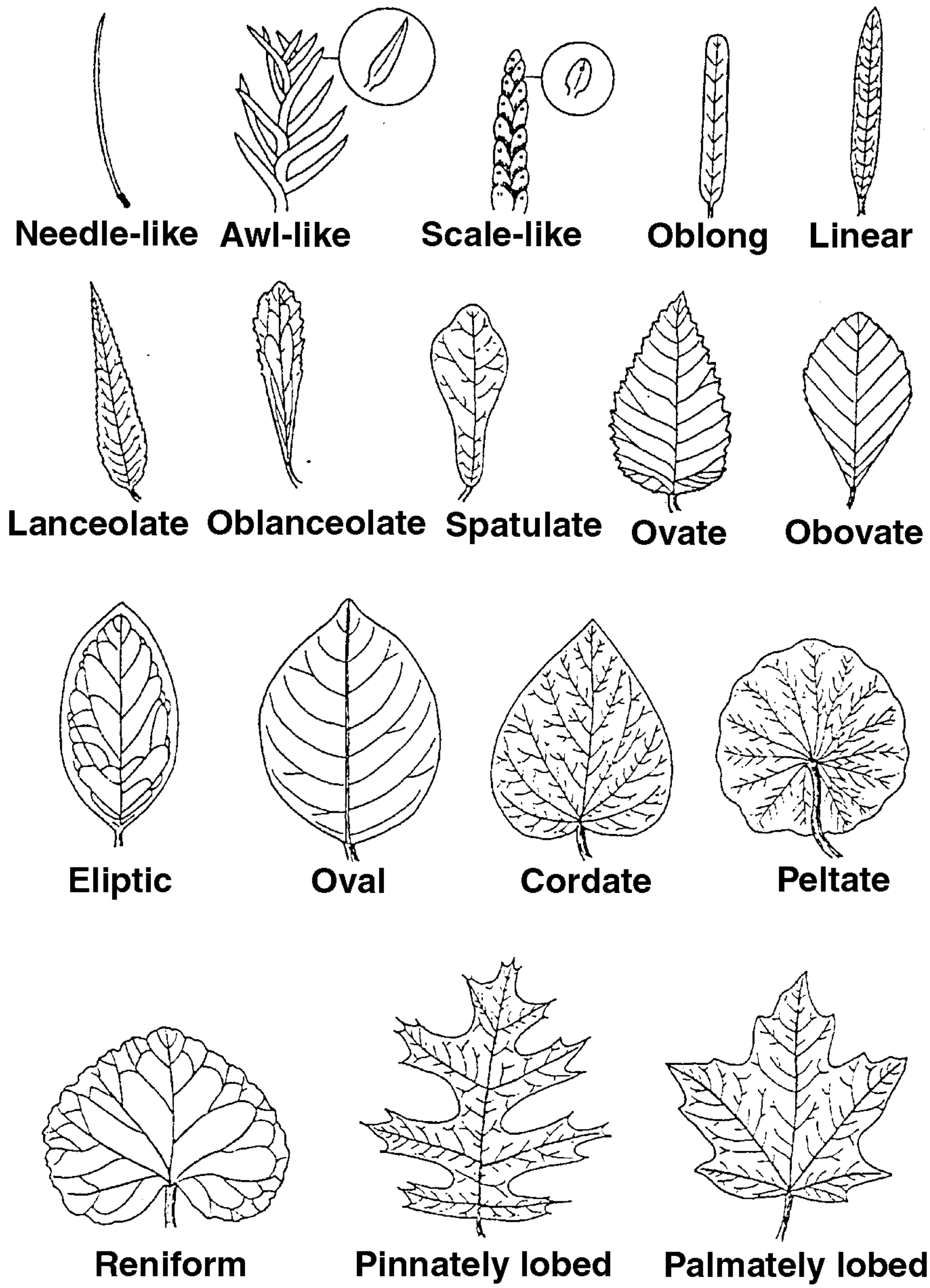
TM 3.7

Cross-Section of a Leaf



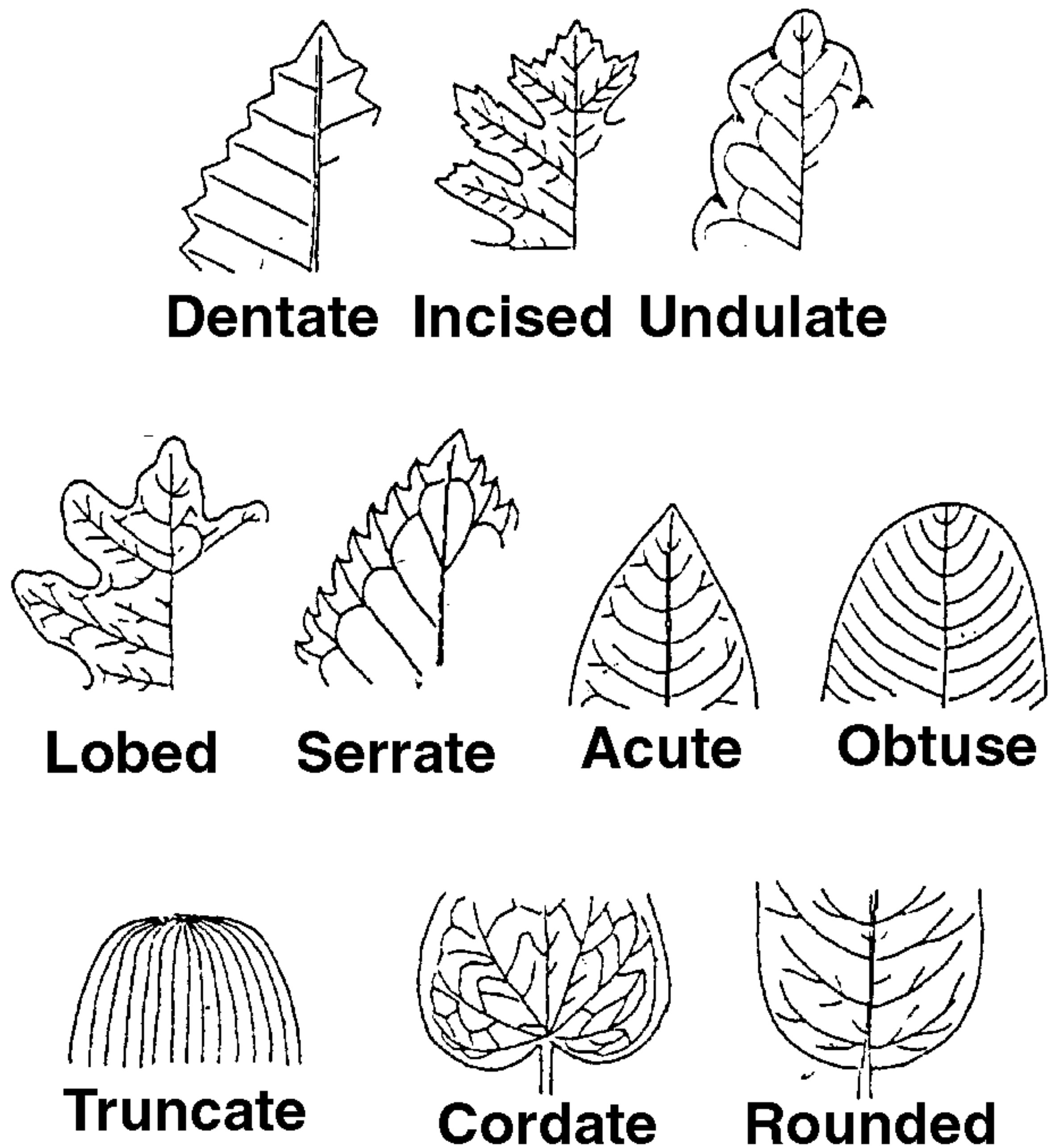
TM 3.8

Leaf Shapes



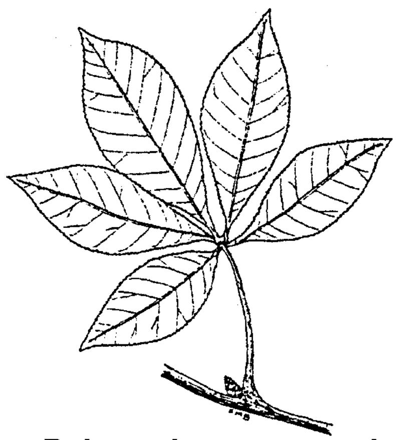
TM 3.9

Leaf Margins

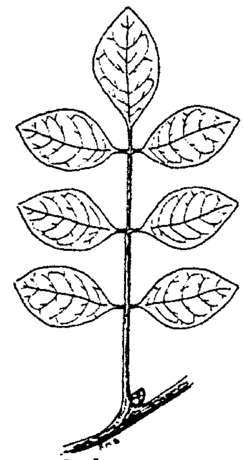


TM 3.10

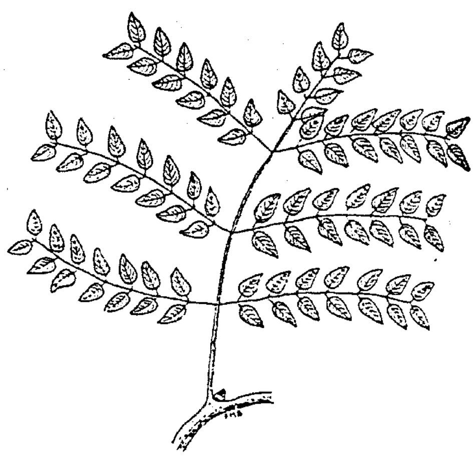
Leaf Attachments



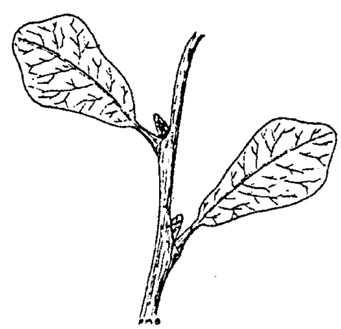
Palmately compound



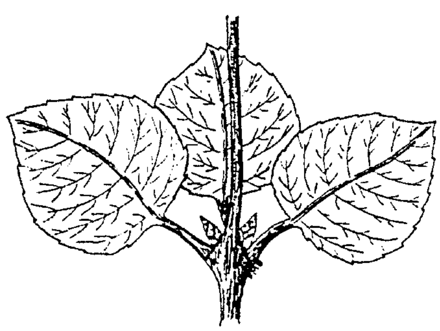
Pinnately compound



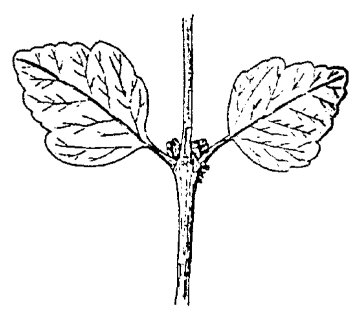
Bipinnately compound



Alternate



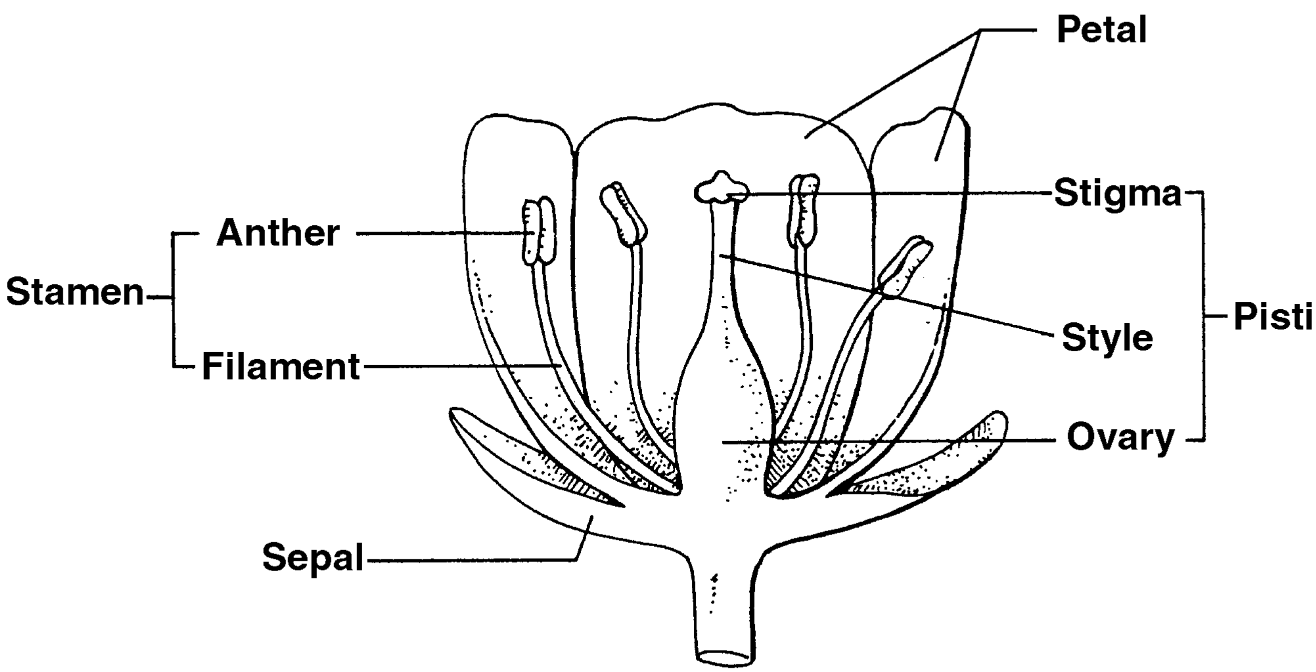
Whorled



Opposite

TM 3.11

Parts of a Complete Flower



UNIT III: PLANT SCIENCE BASICS

AS 3.1

Lesson 1: Plant Parts, Structures, and Functions

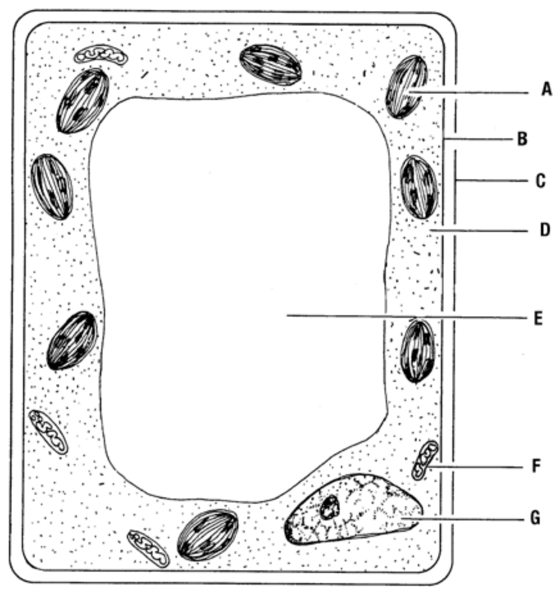
Name___________________

Plant Parts, Structures, and Functions WorkSheet

Objective: Identify plant parts, structures, and functions.

Directions*:* Answer the following questions by using the Student Reference and transparency masters. You may work individually or in small collaborative groups. Use this work sheet as a guide as you examine all of the study questions.

1. Identify the parts of a plant cell.



   A.

   B.

   C.

   D.

   E.

   F.

   G.

2. What are two functions of the plasma membrane?

   A

   B.

3. What are the three organelles in the cytoplasm? Identify one function for each organelle.

<u>Organelle</u>	<u>Function</u>
A.	A.
B.	B.
C.	C.

4. What are three functions of the nucleus?

   A.

   B.

   C.

5. What are the two basic types of plant tissue?

   A.

   B.

6. What are the differences between the two basic types of plant tissue?

7. What are the three types of meristems? What are their functions?

Type of Meristem	Function
A.	A.
B.	B.
C.	C.

8. What are the two types of permanent plant tissue? What are their characteristics?

Types of Permanent Plant Tissue	Characteristics
A.	A.
B.	B.

9. What are three basic parts of monocot seeds? Describe what each part does or provide a brief description of what the part is.

Seed Part	Function/Description
A.	A.
B.	B.
C.	C.

10. Which of the three basic parts of seeds is found **only** in a monocot?

11. What are the four parts of a seed embryo?

    A.

    B.

    C.

    D.

12. What is another term for “seed leaves”?

13. A. What type of plant has one leaf?

    B. What type of plant has two leaves?

14. What are three specialized functions of plant roots?

    A.

    B.

    C.

15. What are the five types of roots?

    A.

    B.

    C.

    D.

    E.

16. What is pith?

17. What is another name for hyposophylls? What does it do?

18. Identify the interior parts of a leaf. (Hint: One interior leaf part is listed twice.)

    A.

    B.

    C.

    D.

    E.

    F.

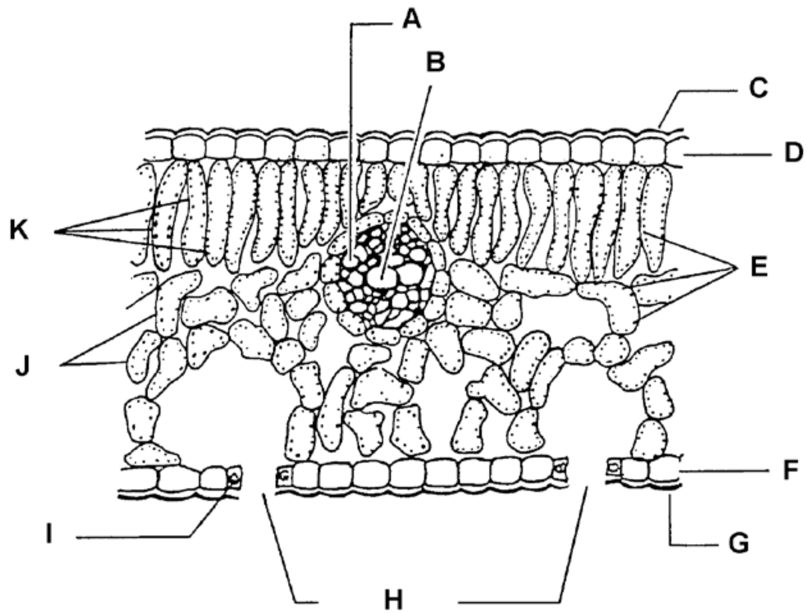
    G.

    H.

    I.

    J.

    K.



19. What are two basic functions of leaves?

    A.

    B.

20. Which plants do **not** have stomata?

21. What are the characteristics of xeromorphic foliage?

22. What type of modified leaf does a Venus flytrap have?

23. What is the corolla? What is its function?

24. Gynoecium refers to what part of a flower?

25. What do head, spike, and umbel refer to?

26. What are three characteristics of perfect flowers?

A.

B.

C.

UNIT III: PLANT SCIENCE BASICS

AS 3.2

Lesson 1: Plant Parts, Structures, and Functions

Name________________

Stem Poster

***Objective*:** Create a visual representation of various stems.

Directions: Bring in samples of stems from your home, school, or the community. In small groups, generate a poster or PowerPoint presentation about the stems you found. Other representations of stems may be photos or drawings. Identify each of the seven stem types and give two examples of each.

UNIT III: PLANT SCIENCE BASICS

AS 3.3

Lesson 1: Plant Parts, Structures, and Functions

Name____________________

Leaf Poster

Objective: Create a visual representation of leaf shapes, margins, and arrangements.

Directions: Bring to class samples of leaves from your home, school, or the community. Individually or in small groups generate a poster or PowerPoint presentation on leaves. Other representations of leaves may be photos or drawings. Identify the type, shape, margin, and typical arrangement of each type of leaf.

UNIT III: PLANT SCIENCE BASICS

AS 3.4

Lesson 1: Plant Parts, Structures, and Functions

Name___________________

Identifying Monocot and Dicot Plants

Objective: Identify parts of two plants.

Directions: Choose one monocot and one dicot plant. One of the plants may be a plant sown earlier for the Unit IV activity. Obtain a physical representation of the plants, either a photo or sketch. Answer the following questions and present the information to the class.

1. Which plant is a monocot and which plant is a dicot?

2. What type of root does each plant have? Describe the roots.

3. What type of stem does each plant have? Describe the stem.

4. What is the name of the leaf shape for both plants? Describe the leaf shape.

5. What type of leaf margin and leaf arrangement do both plants have? Describe them.

6. What type of flower does each plant have? Describe each one.

7. Does either plant require pollination?

GREENHOUSE OPERATION AND MANAGEMENT

Unit III: Plant Science Basics

Lesson 2: Plant Processes

Competency/Objective:

Identify the growth processes of a plant.

Study Questions:

1. **What is photosynthesis?**
2. **What is respiration?**
3. **How do plants absorb water?**
4. **What is translocation?**
5. **What is transpiration?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia, Instructional Materials Laboratory, 2002.
2. Transparency Master

   TM 3.12 Photosynthesis

3. Activity Sheet

   AS 3.5 The Five Plant Processes

4. Capon, Brian. *Botany for Gardeners: An Introduction and Guide*, Portland, OR: Timber Press, 1990.

TEACHING PROCEDURES

A. Review

Students now have a better understanding of plant parts, structures and functions. This lesson continues with the information on the five basic processes that signal plant growth.

B. Motivation

Ask students to name the major physical processes all human beings must undergo in order to stay alive. As students identify these life processes, list them on the board. During the following discussion, ask them to draw parallels between plant processes and human processes wherever possible. To be able to grow successful greenhouse crops, it is important to identify basic processes in plant development.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What is photosynthesis?

This is the process in which plants convert carbon dioxide and water into sugar and oxygen. Temperature, intensity of light, duration of light, and a plant's photoperiod affect photosynthesis. (TM 3.12) These environmental qualities are discussed briefly here and in more detail in Unit IV. The stage of a plant's growth and development also affects this process.

A. Process by which plants, in the presence of light, convert carbon dioxide and water into simple sugars, releasing oxygen in the process
   1. Carbon dioxide is a gas that enters the plant through stomata, which are located on the leaves.
   2. Then water is absorbed by the plant's hair roots and enters the leaves through the xylem tissues.
   3. Light hits the chlorophyll.
   4. Light energy is absorbed and triggers a chemical reaction between carbon dioxide and water.

5. Glucose, a simple sugar, is produced and transported by the phloem tissues to other plant parts.
6. Oxygen is a by-product that is released through the stomata.
7. When the stomata open, water is released.

B. Important chemical reaction that impacts oxygen content of air

C. Environmental factors that affect photosynthesis
1. Temperature
2. Water availability
3. Intensity and duration of light
4. Amount of carbon dioxide
5. Photoperiod
6. Growth

D. Expressed as a formula (CO_2 = carbon dioxide; H_2O = water; $C_6H_{12}O_6$ = glucose; and O_2 = oxygen)

$$6\,CO_2 + 6\,H_2O \;\frac{\underline{\text{chlorophyll}}}{\text{light energy}}\; > \; C_6H_{12}O_6 + 6\,O_2$$

2. What is respiration?

Once CO_2 and water are converted into sugar and oxygen, the energy must be released so that the plant can use the energy to grow. Respiration is the method by which the energy is released and used.

A. Reverse of photosynthesis

B. The controlled breaking down of glucose, releasing energy for plant growth, absorption, translocation, and other metabolic processes

C. A basic life process
1. Enables plant cells to release energy that is then used in many energy-requiring chemical reactions within cells
2. Releases water and CO_2 into the atmosphere

3. How do plants absorb water?

Ask students how they think this process occurs, drawing upon their knowledge of plant parts and functions from the previous lesson.

A. Hair roots take up water and dissolved minerals from the soil through the process of osmosis.

B. Water moves from the roots and through the plant via the xylem vessels.

4. **What is translocation?**

The vascular system of a plant is a conduit for water and food. Ask the students which tissues move food and which move water.

A. Movement of water and nutrients within plant
B. Occurs within vascular system
   a. Xylem tissues pull water upward.
   b. Phloem tissues move food from leaves to the rest of the plant.

5. **What is transpiration?**

Encourage the students to discuss why environmental factors may affect the rate of transpiration. After all of the plant processes are discussed, have students complete AS 3.5.

A. Loss of water from plant
   1. Primarily from evaporation
   2. Primarily through leaf surfaces (some from stems and petals)
B. Occurs when stomata open to take in CO_2
C. Regulated by guard cells
D. Reduces pressure in plant cells
E. Environmental factors that affect transpiration rate
   1. Light
   2. Temperature
   3. Humidity
   4. Wind

F. Other Activities and Strategies

1. To track the path of the vascular system, place several drops of food coloring in a quarter cup of warm water and put a white carnation in the mixture. Make sure the stem is freshly cut and allow the plant to translocate the liquid. Once the color of the flower has changed, remove the flower from the liquid and bisect the stem and flower. Ask students to characterize what has occurred.

2. Show the class the following video, available from CATER (Career & Technical Education Resources), 2 London Hall, University of Missouri-Columbia: *Photosynthesis and Respiration* (AG V113).

G. Conclusion

Photosynthesis, respiration, absorption, translocation, and transpiration are the five plant processes necessary in the development of healthy plants. It is important to know about these plant processes and how they can be encouraged and manipulated in the greenhouse to produce better plants.

H. Answers to Activity Sheet

Instructor's discretion

I. Answers to Assessment

1. B
2. E
3. D
4. A
5. C
6. Any four of the following:
   A Temperature
   B. Light intensity or duration
   C. Amount of carbon dioxide
   D. Plant's photoperiod
   E. Water availability
   F. Plant's growth cycle affect photosynthesis
7. Light, temperature, humidity and wind.
8. $6\ CO_2 + 6\ H_2O \xrightarrow[\text{light energy}]{\text{chlorophyll}} C_6H_{12}O_6 + 6\ O_2$
9. A. Carbon dioxide is a gas that enters the plant through stomata, which are located on the leaves.
   B. Then water is absorbed by the plant's hair roots and enters the leaves through the xylem tissues.
   C. Light hits the chlorophyll.
   D. Light energy is absorbed and triggers a chemical reaction between carbon dioxide and water.
   E. Glucose, a simple sugar, is produced and transported by the phloem tissues to other plant parts.
   F. Oxygen is a by-product that is released through the stomata.
   G. When the stomata open, water is released.

UNIT III : PLANT SCIENCE BASICS

Name___________________

Lesson 2: Plant Processes

Date____________________

ASSESSMENT

Match the statement on the left with the plant process on the right. Write the letter in the space provided.

_____1. Evaporation through leaf surfaces	A. Translocation
_____2. Break down and release of glucose	B. Transpiration
_____3. Taking up of water and dissolved minerals	C. Photosynthesis
_____4. Movement of water and dissolved minerals	D. Absorption
_____5. Creation of glucose	E. Respiration

Short-Answer Questions: Write the answers in the space provided.

6. What are four environmental factors that affect photosynthesis?

   A.

   B.

   C.

   D.

7. What are four environmental factors that affect transpiration?

   A.

   B.

   C.

   D.

8. What is the formula for photosynthesis?

9. What seven steps occur during photosynthesis?

   A.

   B.

   C.

   D.

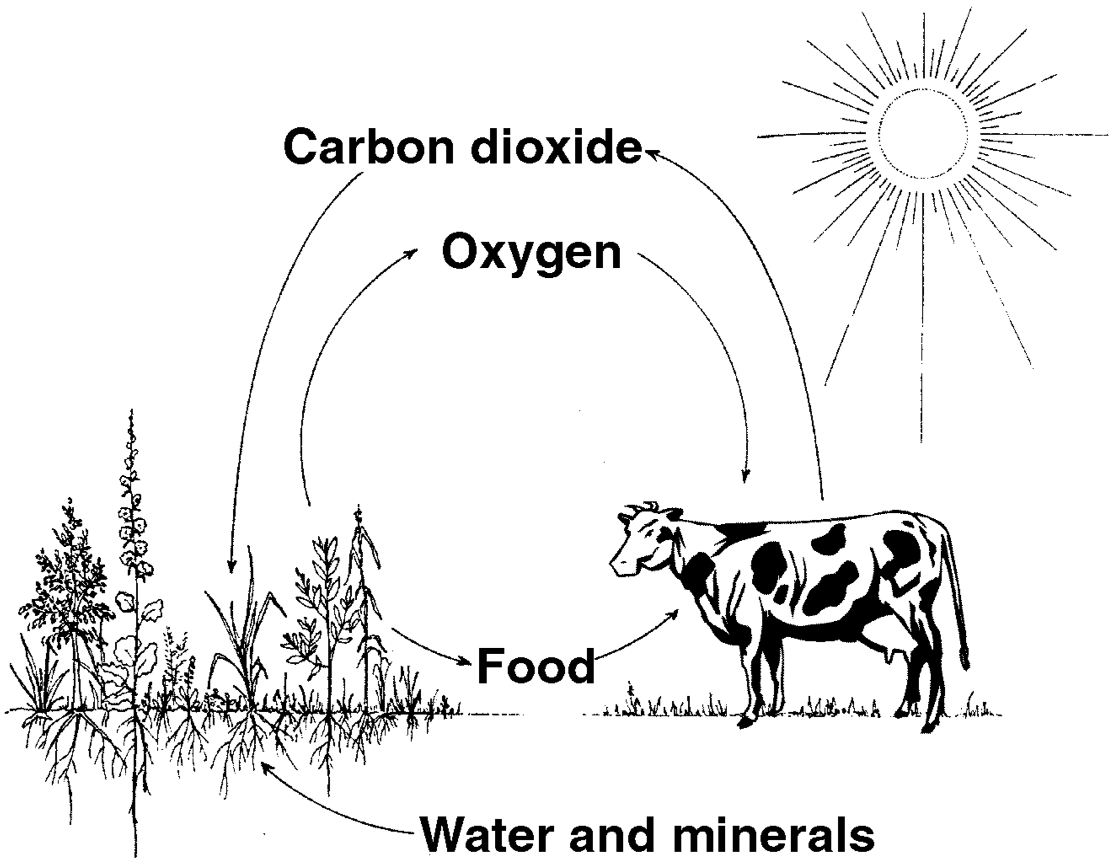
   E.

   F.

   G.

TM 3.12

Photosynthesis



Adapted from Capon, Brian. *Botany for Gardeners: An Introduction and Guide*, Portland, OR: Timber Press, 1992.

UNIT III : PLANT SCIENCE BASICS

AS 3.5

Lesson 2: Plant Processes

Name___________________

The Five Plant Processes

Objective: Relate the five plant processes to the greenhouse environment and design.

Directions: Drawing on your knowledge of plant processes, greenhouse environment, and greenhouse design, answer the following questions for **each** of the five plant processes. First, list the five plant processes. When answering the two questions below, follow the same A-E sequence as listed below.

A.

B

C.

D.

E.

1. How could a greenhouse owner <u>encourage</u> each of the following plant processes?

A.

B.

C.

D.

E.

2. How could a greenhouse owner discourage each of the following plant processes?

   A.

   B.

   C.

   D.

   E.

GREENHOUSE OPERATION AND MANAGEMENT
Unit III : Plant Science Basics

Lesson 3: Plant Classification and Nomenclature

Competency/Objective:

Distinguish plants by characteristics and purpose.

Study Questions

1. **How are plants classified?**

2. **What is the scientific system of classification and naming?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 3.13 Stem Growth
   TM 3.14 Major Classification Categories

3. Activity Sheets

   AS 3.6 Plant Pictionary: Part I
   AS 3.7 Plant Pictionary: Part II

4. Magazines with pictures of plants, glue, scissors, and paper to use in the activities

TEACHING PROCEDURES

A. Review

   Plants are categorized in terms of physical characteristics and purpose. This lesson applies information students learned earlier in this unit to the classification of plants.

B. Motivation

   Ask students if there is an advantage to having a systematic means of classifying and naming plants. What might occur without such a system? By knowing how plants are classified and named, students can begin to identify the physical characteristics of plants when given the scientific names. Ask students to infer how a greenhouse owner would use this information to select suitable specific plants.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the questions before the discussion. Another option is to have students work in cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. How are plants classified?

Plants are grouped by characteristics or function. Activity 3.6 allows students to practice what they are learning.

A. Classified by plant characteristics
   1. Stem type
      a. Single main trunk (trees)
      b. No main trunk (shrubs)
         i. Herbaceous (soft, nonwoody)
         ii. Woody
   2. Stem growth (TM 3.13)
      a. Climbing (creeping)
      b. Erect
      c. Decumbent
   3. Type of fruit
      a. Dry
      b. Fleshy
   4. Life cycle
      a. Annual (completes life cycle in 1 year)
      b. Biennial (completes life cycle in 2 years)
      c. Perennial (continues to grow from year to year)
   5. Foliage
      a. Deciduous (loses leaves in winter)
      b. Evergreen (keeps leaves all year)
   6. Hardiness
      a. Hardy (withstands temperature extremes)
      b. Tender (sensitive to temperature extremes)

B. Classified by plant purpose
   1. Edible
   2. Ornamental

2. What is the scientific system of classification and naming?

Taxonomy is the science of identifying, naming, and classifying organisms. Botanist Carolus Linnaeus created the system of binomial nomenclature to give each plant a unique name that would be understood universally. AS 3.7 provides an opportunity for students to apply binomial nomenclature when given plant characteristics.

A. Binomial nomenclature (two-word name)
   1. Gives each plant a unique scientific name
      a. Latin
      b. Used throughout the world to identify a specific plant
   2. Avoids confusion caused by the wide variety of common names given to a single plant
B. Structure of the scientific name (TM 3.14)
   1. Genus
      a. First part of name
         i. First letter capitalized
         ii. In italics
      b. Identifies plant group that shares similar characteristics
   2. Species
      a. Second part of name
         i. All lowercase letters
         ii. In italics
      b. Provides additional information such as geographic location, origin, and physical characteristics
   3. Cultivar (variety) - from the words "cultivation" and "variety"
      a. Occasionally added to the binomial; enclosed in single quotes or preceded by the abbreviation cv
      b. Identifies variations of the species
      c. Developed by botanists and agronomists (does not occur in the wild)
      d. Hybridization among cultivars of same species

F. Other Activities and Strategies

1. Select two different plants and classify their characteristics.

2. Select two different plants and write their complete taxonomy.

G. Conclusion

By understanding how plants are categorized, the greenhouse operator can make better choices regarding greenhouse crops. Binomial nomenclature is a universal way of identifying plants and promotes clearer communication between greenhouse owners and horticulturalists.

H. Answers to Activity Sheet

Instructor's discretion

I. Answers to Assessment

1. C
2. C
3. B
4. A
5. D
6. B

UNIT III : PLANT SCIENCE BASICS

Name__________________

Lesson 3: Plant Classification and Nomenclature

Date__________________

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. What elements are in a binomial nomenclature of a plant?

   A. Family and genus
   B. Phylum and species
   C. Genus and species
   D. Phylum and cultivar

2. What are three plant characteristics used to classify plants?

   A. Edible, ornamental, type of fruit
   B. Stem growth, leaf type, and cultivar
   C. Life cycle, foliage, and stem type
   D. Foliage, hardiness, and variety

3. What identifies a plant group that shares similar characteristics?

   A. Cultivar
   B. Genus
   C. Species
   D. Variety

4. What identifies variations of the species?

   A. Cultivar
   B. Genus
   C. Species
   D. Subphylum

5. What identifies the origin, geographical location, and physical characteristics of a plant?

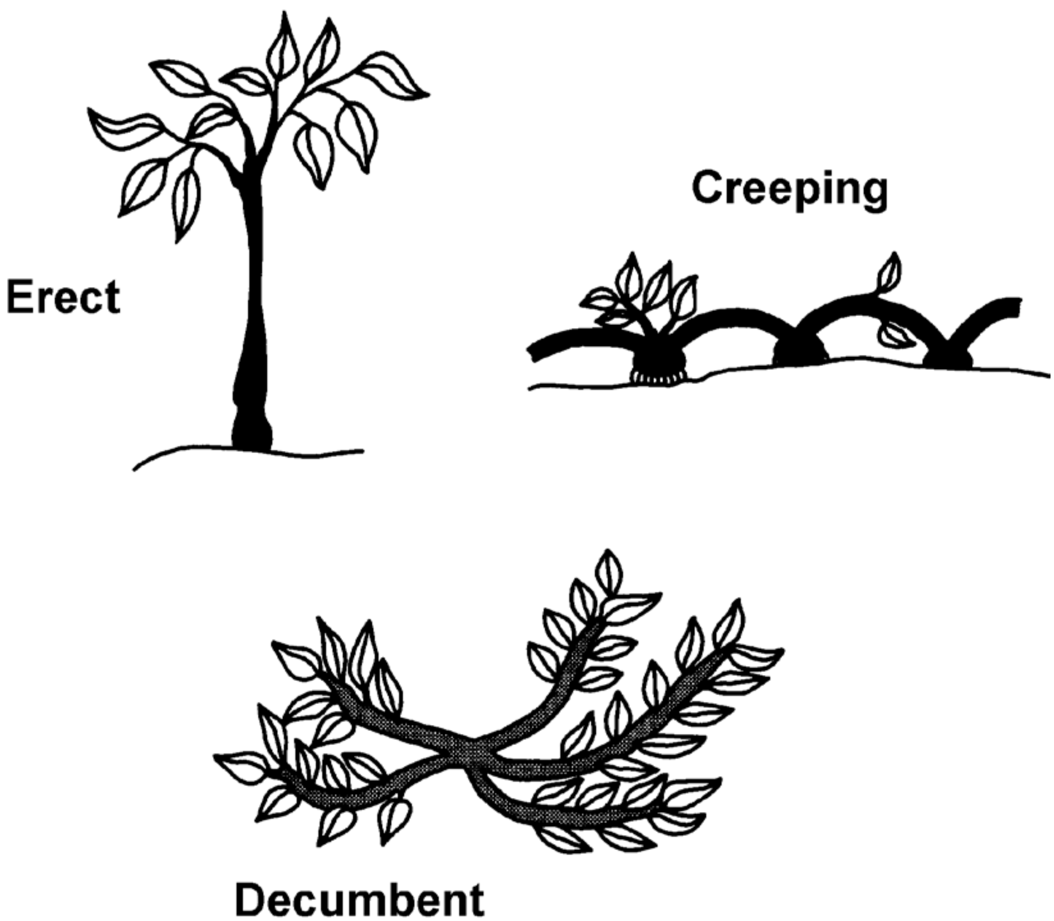
   A. Cultivar
   B. Genus
   C. Phylum
   D. Species

6. What characteristics are used to classify plant function?

    A. Perennial and biennial
    B. Edible and ornamental
    C. Species and foliage
    D. Cultivar and hardiness

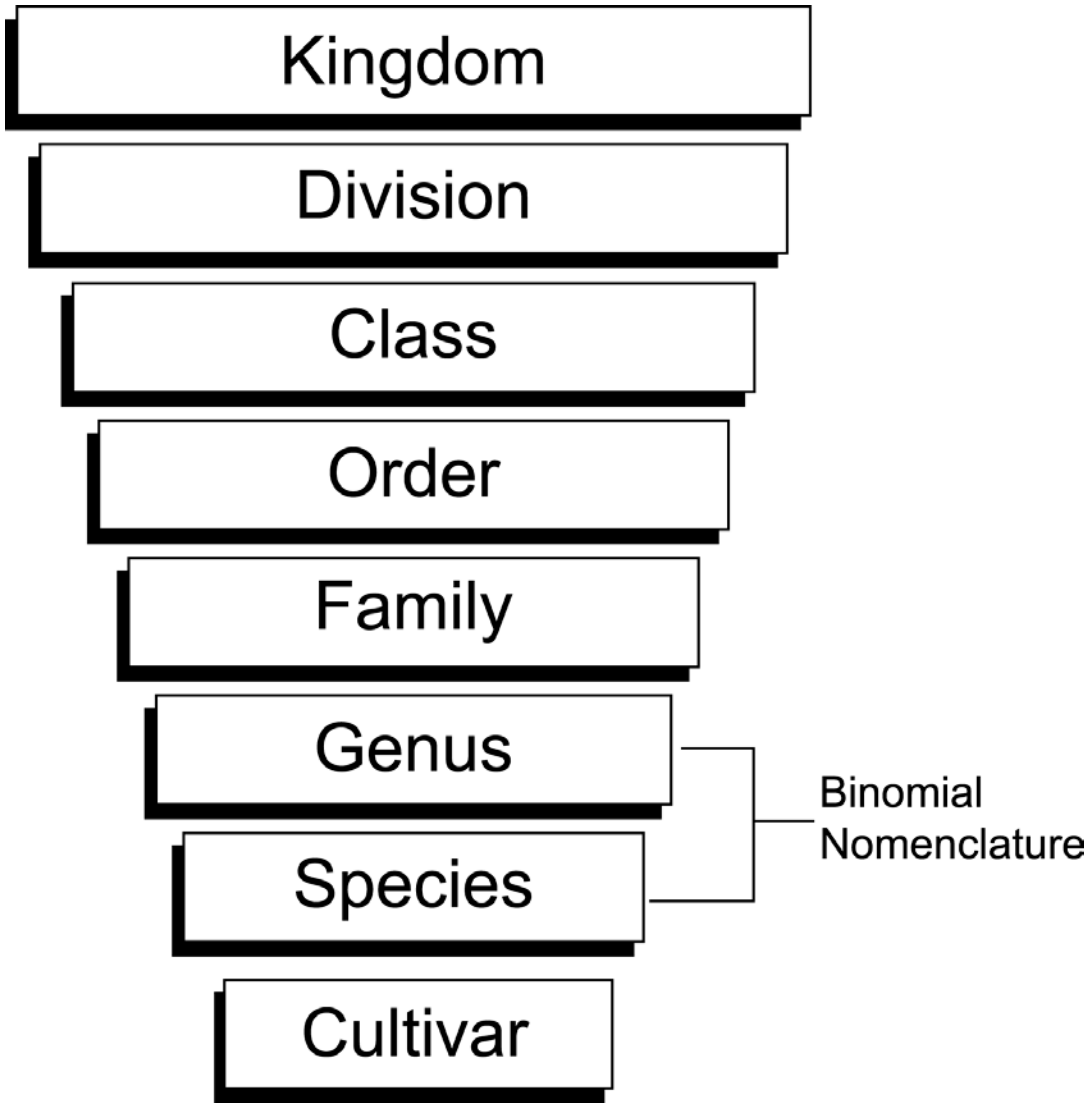
TM 3.13

Stem Growth



TM 3.14

Major Classification Categories



UNIT III: PLANT SCIENCE BASICS

AS 3.6

Lesson 3: Plant Classification and Nomenclature Name______________

Plant Pictionary: Part I

Objective: Identify and gather representations of plant characteristics used for classification.

Directions: Divide the class into two groups. Depending on class size, each group either works on half of the characteristics used to classify plants or on all of them. Each group should find at least two examples of each characteristic. Use magazines, seed catalogs, the Internet, or any other available resources.

Groups can create large flashcards or PowerPoint presentations. If flashcards are used, write on the back of the photo or sketch the characteristic (e.g., stem type, woody, or single trunk) and the common name of the plant (e.g., cedar). If the group is collecting examples on the computer, compose a key at the end with the same information.

Group 1 show its flashcards or presentation to Group 2. Group 2 identifies the characteristics used for classification. Do the same with Group 2’s presentation.

UNIT III: PLANT SCIENCE BASICS

AS 3.7

Lesson 3: Plant Classification and Nomenclature

Name_______________

Plant Pictionary: Part II

Objective: Use plant characteristics to identify plants' binomial nomenclature.

Directions Using the flashcards or presentations from AS 3.2 Leaf Poster, find the scientific name of the plants. Horticulture textbooks, encyclopedia, seed catalogs, and the Internet may be helpful.

Bonus Question: What is the binomial nomenclature for the seed you planted in Unit I?

GREENHOUSE OPERATION AND MANAGEMENT

Unit IV : Plant Growth

Lesson 1: Environmental Effects

Competency/Objective:

Describe environment necessary for optimal plant growth.

Study Questions

1. **What environmental factors affect plant growth?**
2. **What is the effect of light in the greenhouse?**
3. **How does light intensity affect plants?**
4. **How does light duration affect plant growth?**
5. **How does light quality affect plant growth?**
6. **How does temperature affect plant growth?**
7. **What gaseous elements within the greenhouse affect plant growth?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Master

   TM 4.1 Radiant Light Spectrum

3. Activity Sheets

   AS 4.1 Foot-Candle Demonstration
   AS 4.2 Effect of Light on Plants
   AS 4.3 Photoperiod in Plants
   AS 4.4 Greenhouse Air Pollutants

4. A current copy of Hummert's Helpful Hints

5. Carolina Biological Supply <http://www.carolina.com/general/company/Srv.asp>

6. NASCO catalogs <http://www.enasco.com/prod/Home>

TEACHING PROCEDURES

A. Introduction

This unit introduces students to basic concepts of plant growth: environmental effects, growing media and containers, irrigation, nutrients, and fertilizer. This lesson explains various environmental elements influencing plant growth. Students examine light intensity, duration, and quality, as well as temperature, air quality, and gaseous elements within the greenhouse.

B. Motivation

Students use the plants they have been tending since Unit I to illustrate the importance of light duration. Bring out the plants to initiate a conversation on the subject of light. Can the students recognize which plants have had too little light?

C. Assignment of Study Questions

In preparation for AS 4.6 in Lesson 3: Irrigation in this unit, take one plant from each student and organize them into three groups labeled D, E, and F. For at least 3 weeks, have students water plants in each group using a specific measuring cup. Use a measuring cup that is <u>larger</u> than needed for Group D plants so plants receive too much water. The measuring cup for Group E has the <u>correct</u> amount. Use a measuring cup that is <u>smaller</u> than necessary for Group F so that the plants receive very little water.

To prepare for AS 4.9 in Lesson 5: Fertilizer, split another batch of plants into groups G, H, and I. Have several forms of fertilizer available: slow release, water-soluble concentrate, and granular. Ask students to give plants in each group the following amounts of fertilizer: Group G - no fertilizer, Group H - too much, and Group I - the appropriate amount. As the plants grow, students should characterize how the plants in each group react to fertilizer during three stages of development: seedling/cutting, vegetative, and flowering. Be sure that students identify the type of fertilizer used on each pot.

At the end of Lesson 5, the class will complete a unit activity that relates to all of the activity sheets in Unit IV. Be sure that students keep each activity sheet in each lesson.

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement student responses and information with additional materials when needed.

1. What environmental factors affect plant growth?

Ask the students to name the three major environmental factors they have to monitor and control within a greenhouse. These are the basic factors directly related to successful plant growth. Be sure to mention that water is also important. It is discussed in Lesson 3 of this unit.

A. Light
B. Temperature
C. Air quality

2. What is the effect of light in the greenhouse?

Building on knowledge from Plant Processes (Unit III, Lesson 2), encourage students to discuss why light is important for plant growth. Why might artificial light be necessary? Ask students what characteristics of light are important for a greenhouse.

A. Light is necessary in order for photosynthesis to occur.
B. Different light sources are available for greenhouse crops.
   1. Solar
   2. Artificial (high-intensity discharge or fluorescent lamps)
      a. On a winter day
      b. On cloudy days
      c. To extend length of day
C. Light has various characteristics.
   1. Intensity (brightness)
   2. Duration (length of day)
   3. Quality (spectrum of color)

3. How does light intensity affect plants?

Based on their knowledge of photosynthesis, ask students to identify the benefits of adequate light intensity on greenhouse plants. Ask them to brainstorm what kind of crops might be low-, medium-, and high-intensity plants. To demonstrate the concept of foot-candles, have students perform AS 4.1 Because candles are lit, be sure to supervise carefully. Then to demonstrate the effect of light on plants, have students complete AS 4.2.

A. Measurement of light intensity
   1. Light intensity measured in foot-candles (f.c.)
   2. One foot-candle: the amount of light striking a surface 1 foot from a standard wax candle
   3. Noon on a sunny day: 10,000 f.c.
B. Different plants - different light intensity requirements

1. Low-light intensity plants: 500-1,250 f.c. - e.g., for tropical foliage plants, impatiens, African violets, ferns
2. Medium-light intensity plants: 1,250-2,500 f.c.
3. High-light intensity plants: more than 2,500 f.c. - e.g., for lilies, roses, geraniums

C. Adequate light intensity
  1. Photosynthesis process
  2. Provides for healthy plant growth, such as
     a. Thicker stems
     b. Increased height
     c. Greater leaf area
     d. Shorter internodes
     e. More roots
     f. More flowers
     g. Larger flowers
     h. Increased pigment

D. Inadequate light intensity
  1. Reduces rate of photosynthesis
  2. Can stunt plant growth
     a. Long internodes, weak stems
     b. Delayed or no flowering
     c. Reduced pigment
     d. Less leaf area
  3. Too little exposure on one side of plant
     a. Plants bend in direction of light (phototropism).
     b. Plants develop stems curved in direction of light.
     c. Roots turn away from the light.

E. Excessive light intensity
  1. Goes beyond plant's need for photosynthesis
  2. High temperature - accelerating plant respiration process and deleting plant food supply
  3. Can stunt plant growth
     a. Reduce pigment
     b. Cause smaller leaves and flowers
     c. Burn leaves and flowers
     d. Bleach leaves

4. How does light duration affect plant growth?

The length of time a plant receives light affects it on many levels. Discuss how light variations occur both naturally and through human intervention. Split the class into small groups and have them complete AS 4.3.

A. Rate of growth is affected by the amount of light received.
  1. Photosynthesis only in presence of light
  2. Light duration
     a. Varies with latitude and season
     b. Can be increased with artificial lights

c. Can be decreased with dark cloths

B. Photoperiodism is the plant's response to light duration.
   1. Flower bud initiation
   2. Bulb formation
   3. Tuber formation
   4. Bract coloration
   5. Plantlet formation

C. Different plants have different photoperiod requirements.
   1. Short-day plants
      a. Need short days to flower
      b. Example: poinsettia
   2. Long-day plants
      a. Need long days to flower
      b. Example: asters
   3. Indeterminate plants (also called day-neutral plants)
      a. Flowering not affected by day length
      b. Example: African violet

5. How does light quality affect plant growth?

Demonstrate the light spectrum for the students by using the suggested activity in Section F. Ask students why the quality of light might be important when artificial light is used.

A. Light quality
   1. Wavelength (or color) of light
   2. Measured in nanometers (nm)
   3. Not all wavelengths used during photosynthesis

B. Wavelengths
   1. Ultraviolet (UV) light
      a. UV light has very short wavelength (less than 400 nm).
      b. UV light is invisible.
      c. High levels reduce photosynthesis and cause sunscald.
      d. Growth is stunted if plants are exposed to high levels of UV light.
      e. Some greenhouse coverings screen out different amounts of UV light.
   2. White or visible light (combination of violet, blue, green, yellow, orange, and red)
      a. Blue light
         i. Wavelength: 492 nm
         ii. Very high photosynthetic activity
         iii. Very evident phototropism
         iv. Plant's response: shorter, dark, hard tissues in plants
      b. Green light
         i. Wavelength: 535 nm
         ii. Very low photosynthetic activity
      c. Red light
         i. Wavelength: 647-760 nm
         ii. Very high photosynthetic activity

iii. Plant's response: soft growth, long internodes, seed germination, photoperiodic response in long-day plants

3. Far-red light
   a. Wavelength: 760-780 nm
   b. Plant's response
      i. Promotes flowering of short-day plants
      ii. Inhibits flowering of long-day plants
4. Infrared light
   a. Wavelength: 780+ nm
   b. Invisible
   c. Heat effect on plants
   d. Plant's response
      i. Causes photosynthesis process to stop
      ii. Overheating a cause of stomata closing

6. How does temperature affect plant growth?

Ask students to discuss why temperature is important to plant growth. Is the same temperature necessary for all segments of a single plant's growth?

A. Temperature levels
   1. Minimum temperature level (below which growth does not occur)
   2. Maximum temperature level (above which growth does not occur)
   3. Optimum temperature level (at which growth is the greatest)

B. Seed germination
   1. Greatly affected by temperature
   2. Typically, optimum air temperature: 60-70^{o}F
   3. Can increase rate of germination with bottom heating

C. Photosynthesis
   1. Minimum temperature variable with plant species
   2. Maximum temperature: 95^{o}F
      a. Rate increases as temperature increases until it reaches 95^{o}F.
      b. At temperatures above 95^{o}F, rate drops quickly then stops (enzymes are deactivated).
   3. Optimum temperature in most plants: 50-75^{o}F

D. Other plant processes
   1. Respiration
      a. Higher temperatures increase respiration, depleting food needed to fuel cellular metabolism.
      b. Low temperatures (32-34^{o}F) slow respiration, keeping plants, cut flowers, fruits, and vegetables fresh for extended periods.
   2. Transpiration
      a. The rate of transpiration increases as leaf temperature rises.
      b. Leaf temperature can be affected by several factors, as listed below.
         i. Warm or cold air currents and drafts
         ii. Radiational cold (from sides of greenhouse on cold nights)
         iii. Condensation (moisture on leaves that is colder than the air)

E. Vegetative and flowering growth (varies with different plants)
   1. Lower than optimum temperature
      a. Delayed flowering
      b. Slowed growth
      c. Intensified color in leaves and flowers
   2. Higher than optimum temperature
      a. Earlier and smaller flowers
      b. Fewer leaves
      c. Reduced stem diameter
      d. Reduced flower color
      e. Inhibited or delayed flowering
      f. Shorter life

7. What gaseous elements within the greenhouse affect plant growth?

Air quality is an important issue in the growth cycle of greenhouse plants. Encourage students to discuss both positive and negative gases that may be present. Have students complete AS 4.4.

A. Gases that are essential for plant growth
   1. Oxygen
      a. Required for plant respiration
      b. Adequate amounts occurring naturally
   2. Carbon dioxide
      a. Required for photosynthesis
      b. Promotes plant growth and flowering
      c. Adequate amounts occurring naturally (produced by plant respiration and organic matter decay)
      d. CO_2 levels in the greenhouse environment
         i. Often limited (particularly when greenhouse fans are off)
         ii. Can be increased with use of a CO_2 generator (Refer to Unit II, Lesson 2.)
   3. Water vapors (humidity)
      a. Optimum relative humidity level is 45-85%.
      b. High levels (over 85%) promote fungal diseases.
      c. Low levels increase transpiration and stunt plant growth.
         i. Shorter plants
         ii. Fewer new shoots
         iii. Less leaf growth
         iv. Smaller flowers
         v. Stiff, upright stems
      d. There are two methods to increase relative humidity.
         i. Humidifiers
         ii. Water trays under benches
B. Air pollutants that can be detrimental to plant growth
   1. Natural gas
   2. Ethylene
   3. Fluoride

4. Ammonia
5. Chlorine
6. Nitrogen dioxide
7. Sulfur dioxide
8. Mercury
9. Herbicides
10. Wood preservatives (pentachlorophenol, creosote, and some paints)
11. Peroxyacetyl nitrate
12. Ozone

F. Other Activity and Strategy

To demonstrate light quality (see study question 5), use a prism or a clear, plastic disc that comes as a spacer for CD-Rewritable discs to refract sunlight onto a light surface. Reiterate that white light is not just white but a spectrum of color. Humans can discern violet, blue, green, yellow, orange, and red. These colors are important because each color of light has a specific effect on plants.

G. Conclusion

The primary environmental elements that affect plant growth are light, temperature, and air quality. (Water is also critical and is discussed in Lesson 3.) These elements must be monitored and possibly adjusted in all the plants, especially the ones the students are tending.

H. Answers to Activity Sheet

Instructor's discretion

I. Answers to Assessment

1. B
2. D
3. D
4. B
5. Extreme heat - any one of the following:
   A. Earlier and smaller flowers
   B. Fewer leaves
   C. Reduced stem diameter
   D. Reduced flower color
   E. Shorter life
   Extreme cold - any one of the following:
   A. Delayed flowering
   B. Slowed growth
   C. Intensified color in leaves and flowers
6. A. Blue light - shorter, dark, hard plant tissues
   B. Red light - long internodes, seed germination, and soft growth

7. Any two of the following: Not all plants have similar photoperiod requirements.
   A. Flower bud initiation
   B. Bulb formation
   C. Tuber formation
   D. Bract coloration
   E. Plantlet formation

UNIT IV: PLANT GROWTH

Name____________________

Lesson 1: Environmental Effects

Date_____________________

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. Long internodes and weak stems are signs of what type of light intensity?

   A. Adequate light intensity
   B. Inadequate light intensity
   C. Excessive light intensity
   D. Random light intensity

2. In what condition can artificial light can be used to promote growth in a greenhouse?

   A. On a windy day
   B. On a summer day
   C. To promote one's business
   D. To extend length of day

3. What three factors in a greenhouse must be closely monitored to maintain healthy plant growth and production?

   A. Light, wavelengths, and temperature
   B. Air quality, temperature, and photoperiodism
   C. Inflorescence, light, and temperature
   D. Temperature, air quality, and light

4. What is the optimum level of relative humidity in a greenhouse?

   A. 20-60%
   B. 45-85%
   C. 50-75%
   D. 75-95%

Short Answer Questions: Write the answers in the space provided.

5. What is one consequence of extreme heat and one consequence of extreme cold on greenhouse plants?

   A. Extreme heat:

   B. Extreme cold:

6. Which two colors of visible light have the greatest effect on plant growth? Describe how plants respond to each light.

Color	Plant' s Response
A.	A.
B.	B.

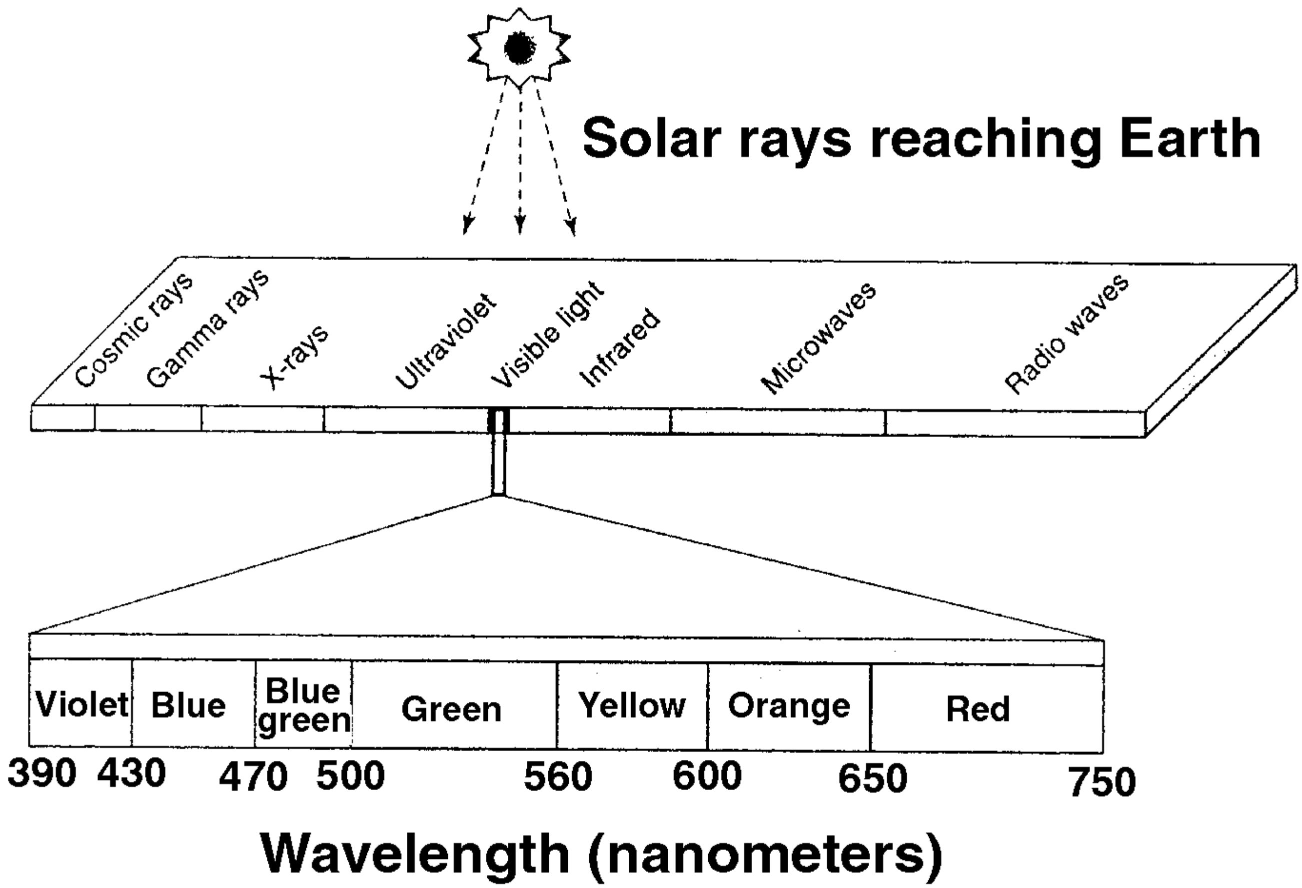
7. What are two events that occur during photoperiodism? Do all plants have the same light duration requirements? Why or why not?

   A

   B.

TM 4.1

Radiant Light Spectrum



Adapted from Acquaah, George. *Horticulture: Principles and Practices.* Upper Saddle River, NJ: Prentice Hall, 1999.

UNIT IV: PLANT GROWTH

AS 4.1

Lesson 1: Environmental Effects

Name___________________

Foot-Candle Demonstration

Objective: Demonstrate how a foot-candle measures light.

Directions*:* Follow the procedures listed below and answer the questions.

Materials:

16 standard-size candles
Ruler
Sturdy piece of light-colored cardboard
Matches

Procedures:

1. Set one candle on a flat surface.
2. Measure a distance of 1 foot. Place the cardboard parallel to the candle.
3. Light the candle and turn off the overhead light.
4. The light hitting the board represents 1 foot-candle of intensity.
5. Add a second candle.
6. Observe the intensity of the light. Record your findings.
7. Double the number of candles to four.
8. Observe the intensity of the light. Record your findings.
9. Double the number of candles to 16.
10. Observe the intensity of the light. Record your findings.

1. How did the intensity of light change when the second candle was lit?

2. How did the intensity of light change when four candles were lit?

3. How did the intensity of light change when 16 candles were lit?

UNIT IV: PLANT GROWTH

AS 4.2

Lesson 1: Environmental Effects

Name____________________

Effects of Light on Plants

Objective: Identify the effects of light in greenhouse plants.

Directions: Use the plants that were sown in Unit I, Lesson 1. These plants were assigned to three groups: Group A, Group B, and Group C. Your own plant belongs to one of these three groups. Since the seeds were planted at the beginning of Unit I, the three groups of plants have been exposed to various amounts of light as follows:

- Group A plants received 4 hours of light per day and then were put in a closet or under a cardboard box.
- Group B plants received natural light during normal daylight hours. (Plant was left on a window sill.)
- Group C plants received 17 hours of light per day with additional artificial light (identify type of artificial light).

Observe the groups of plant closely and answer the following questions. Some questions may require further research using various resource materials.

1. What type of plant did you grow?

2. What is the recommended amount of light for that plant?

3. Describe plants in Group A, Group B, and Group C in detail. Be sure to focus on the influence of light.

   Group A

   Group B

   Group C

4. What group is your plant in? How does it look? How much light do you think it received: too much, too little, or the proper amount of light? Why? Be specific.

5. What other factors could affect your plant's growth?

UNIT IV: PLANT GROWTH

AS 4.3

Lesson 1: Environmental Effects

Name___________________

Photoperiod in Plants

Objective: Describe photoperiodism and its relation to plants.

Directions: Work in small groups of three or four students. Use the Internet, books, magazines, and science and horticulture textbooks to answer the following questions. When answering the questions listed below, do not use examples given in the text. Relate your findings to the class in a poster, collage, oral presentation, or any other format that answers the questions.

1. List three to five long-day plants.

2. List three to five short-day plants.

3. List three to five plants day-neutral plants.

UNIT IV : PLANT GROWTH

AS 4.4

Lesson 1: Environmental Effects

Name___________________

Greenhouse Air Pollutants

Objective: Investigate the origin of air pollutants that could occur in greenhouses and point out ways to correct the problem.

Directions: Work in small groups of three or four students. Answer the following questions for three of the pollutants listed in Unit IV, Table 4.2, of the Student Reference. Use the Internet, books, magazines, science and horticulture textbooks to answer the following questions. Relate your findings to the class in a PowerPoint presentation, poster, oral presentation, or any other format that shares information with the class.

Pollutant #1___________________

Pollutant # 2___________________

Pollutant #3 ___________________

1. How could these pollutants enter a greenhouse? Are they naturally occurring substances? Are they a by-product of the greenhouse structure?

2. Do these pollutants affect all organic matter in a greenhouse? What signs do susceptible plants display? Do the pollutants have an effect on humans?

3. How would greenhouse professionals manage the presence of these air pollutants? Give at least two examples.

   A.

   B.

GREENHOUSE OPERATION AND MANAGEMENT
Unit IV: Plant Growth

Lesson 2: Growing Media and Containers

Competency/Objective:

Distinguish components of growing media, their uses, and basic types and sizes of containers.

Study Questions

1. **What is the importance of growing media?**
2. **How is field soil pasteurized?**
3. **Why is soilless media preferred for growing greenhouse crops?**
4. **What are the ingredients in soilless mixes and soil amendments?**
5. **What are some considerations in selecting growing containers?**
6. **What are the basic types of containers?**
7. **What are the most common materials for growing containers?**

References/Supplies/Materials

1. G*reenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 4.2 Composition of Soil-Based Growing Medium
   TM 4.3 Soil Texture Triangle
   TM 4.4 pH Scale
   TM 4.5 Peat Containers
   TM 4.6 Identifying Cell Packs
   TM 4.7 Container Shapes

3. Activity Sheets

   AS 4.5 Growing Media and Containers
   AS 4.6 Materials Update
   AS 4.7 Container Shopping

4. *Soil Science*. University of Missouri-Columbia: Instructional Materials Laboratory, 1995 (catalog numbers 10-5050-I, 10-5050-S).

5. *How Water Moves Through Soil* (Video). Available from University of Missouri-Columbia: Instructional Materials Laboratory (catalog number 10-5600-V).

TEACHING PROCEDURES

A. Review

The previous lesson described elements required to promote successful plant growth. This lesson continues with a discussion of what the plant is grown in, both the media inside and the container.

B. Motivation

To identify the ingredients of an ideal growing media, use the previously planted seeds to start a discussion of the differences in soil, amended soil, and soilless media. Point out container shapes, sizes, and material.

C. Assignment of Study Questions

Students should continue to water their plants.

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. Instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What is the importance of growing media?

Ask the students to brainstorm about the functions and qualities of growing media. Why is the selection of the growing media a vital aspect of plant growth?

A. Material in which the roots of plants grow
B. Functions
   1. Support the plant upright
   2. Hold mineral nutrients
   3. Hold water
   4. Allow for exchange of gases (oxygen, CO_2, nitrogen)

C. Important considerations
   1. Water-holding capacity
   2. Drainage
   3. Porosity - pore space between solid particles
      a. The total amount of pore space determines how well the growing medium can retain air and water.
      b. The levels of available oxygen are a function of porosity.
         i. Inadequate pore space means that a shortage of oxygen develops when too much water is supplied.
         ii. The size and distribution of individual pores determine the rate of gas exchange and drainage. These two factors influence the effectiveness of the growing medium.
         iii. The ideal medium has a mixture of large and small pore spaces.
   4. Effect of temperature on growing medium
      a. Affects activity of microorganisms
      b. Affects absorption rate of water and fertilizer
      c. Above 32^{o}F to slightly over 110^{o}F - microorganisms converting organic nitrogen fertilizers in soil to forms that can be readily absorbed
   5. Desirable features
      a. Loose and well aerated
      b. Suitable pH level and cation exchange capacity
      c. Good drainage, holding enough water for plant growth
      d. Free of unwanted seeds, weeds, insects, and pathogens
D. Physical characteristics of ideal field (mineral) soil (TM 4.2)
   1. Composition
      a. 50% solids
         i. 5% organic matter (decayed plant and animal residue)
         ii. 45% mineral matter
            (a) Sand - largest particle
            (b) Silt - formed by water breaking down minerals; smaller than sand
            (c) Clay - smallest particle; fills the gaps between the other particles
      b. 25% water
      c. 25% air (pore spaces - consist of oxygen, carbon, and hydrogen)
   2. Texture - size; distribution; proportion of sand, silt, and clay particles (TM 4.3)
      a. Water retention and air porosity are related to the soil's texture.
      b. Soil containing mostly sand (large particles) is composed of large pores.
      c. Soil with a majority of small, finely textured particles (clay) has small pores that resist the flow of water and therefore increase the soil's water-holding capacity.
      d. Equal amounts of all three particles in soil are called "loam."
      e. Pure loam is not found in the field.
      f. The combination of particles determines whether the soil texture is fine, medium, or coarse.
   3. Structure - arrangement of solid particles
      a. Affects water-holding capacity, porosity, soil's ability to transmit water into the plant (permeability), and the rate of water absorption into the roots (infiltration)
      b. Rearranging soil structure to achieve ideal composition for crop

E. Chemical characteristics
   1. pH - measurement of the level of alkalinity/acidity (TM 4.4)
      a. Ranges from 0 to 14
         i. 7 - neutral
         ii. Above 7 - alkaline (base)
         iii. Below 7 - acidic
      b. Determines whether the soil can receive nutrients (See Unit IV, Lesson 4.)
      c. pH range for most greenhouse crops from 5.5 to 6.5
   2. Cation exchange capacity - measurement of the capacity to hold nutrients
      a. Fertile soil attracts and retains essential nutrients, promoting plant growth.
      b. A cation is a positively charged ion in a solution.
      c. The soil's clay, silt, and organic particles have negative charges that attract and hold cations.
      d. A clay particle in soil has a large surface area, making the cation's absorption more efficient.

2. How is field soil pasteurized?

Have students look at the plants that were sown in field soil and soilless media. What differences do they see in the containers? Have them complete AS 4.5. If possible, demonstrate the steam pasteurization of soil; instructions are in the second suggested activity in Section F - Other Activities and Strategies.

A. Field (mineral) soil alone is not an acceptable growing medium for plants grown in containers.
   1. Generally heavy with poor drainage and aeration
   2. Variable quantity and quality of nutrients
   3. May contain weeds, insects, or disease
B. Field soil must be pasteurized and amended to achieve desired characteristics.
C. Pasteurization has two main purposes.
   1. Kills majority of weed seeds
   2. Kills bacteria and fungi that could cause plant disease (does not kill most organisms that are beneficial to plant growth)
D. There are three basic methods of pasteurization.
   1. Steam
      a. Soil must be mixed before steaming.
      b. Typical treatment is 140-160°F for 30 minutes.
      c. Planting can be done as soon as soil cools.
      d. This method should not be used when soil contains slow-release fertilizer.
   2. Chemical
      a. Not as effective as steam
      b. Fumes highly toxic to humans
      c. Must allow time before planting
      d. Commonly used chemicals
         i. Chloropicrin
         ii. Basamid (DMTT)

iii. Vapam
3. Electrical
   a. Not commonly used in commercial greenhouses
   b. Feasible only for small amounts of soil

3. Why is soilless media preferred for growing greenhouse crops?

Have the students reiterate positive aspects of soilless growing media over field soil. If possible, have both organic and nonorganic greenhouse managers visit. Give each manager one class period to speak and answer questions.

A. Contain no naturally occurring field (mineral) soil
B. Soilless mixes generally preferred for greenhouse crops
C. Benefits
   1. Lightweight
   2. Essentially inert
   3. Excellent drainage and porosity
   4. Consistent in composition
   5. Free of unwanted seeds, weeds, insects, and pathogens
   6. Can be custom mixed or purchased ready-to-use
   7. Do not require pasteurization

4. What are the ingredients in soilless mixes and soil amendments?

Bring in leftover soilless medium from the plants for the students to examine. What is the medium made of? What amendments are the most desirable? Do these amendments have any drawbacks? Have students complete AS 4.6.

A. Organic materials
   1. Benefits
      a. Improve physical structure of soil-based media
      b. Increase water-holding capacity
      c. Increase aeration and drainage
      d. Increase cation exchange
   2. Types
      a. Peat
         i. Peat moss, sphagnum moss, humus, etc.
         ii. Decomposed plant and animal residue
         iii. Can hold 15-20 times its weight in water
         iv. Ample quantities of pore space that hold air and water
      b. Wood residues
         i. Leaf mold, composted sawdust, bark, etc.
         ii. By-products of lumber industry
      c. Coir
         i. Coconut parts
         ii. By-product of coconut industry

iii. Excellent air porosity and water retention; medium absorbs moisture easily and drains quickly

B. Mineral (inorganic) materials
   1. Benefits
      a. Improve physical structure of soil-based media
      b. Increase aeration and drainage
   2. Types
      a. Sand (mountain rock origin)
         i. Sand provides good porosity and aeration by admitting large quantities of air into the growing medium.
         ii. It promotes drainage but cannot hold sufficient quantities of water for the emerging plant.
      b. Perlite (volcanic rock origin)
         i. Neutral pH
         ii. Holds three to four times its weight in water
         iii. Improves drainage and aeration
         iv. Ideal as a seed-germinating medium for rooting cuttings
      c. Vermiculite (mica origin)
         i. Absorbs fertilizer
         ii. Contains sources of magnesium and potassium
      d. Calcined clay
         i. Retains nutrients in medium
         ii. Adds volume to the medium and improves the soil structure

C. Other materials
   1. Polystyrene flakes - by-product of polystyrene processing
   2. Rock wool
      a. Spun from basalt, coke, and limestone
      b. Not biodegradable, which poses environmental concerns

5. What are some considerations in selecting growing containers?

Primary influences of container selection are based on both the plant itself and the intended market. Another concern is how long the plant is in the container, e.g., hanging basket of fuschia versus flats of bedding plant plugs in the retail market. How might the wholesale market be different?

A. Plant growth habit
   1. Plant height
   2. Plant width
   3. Plant shape
   4. Plant requirement for root space

B. Intended market
   1. Retail (generally larger pots)
   2. Wholesale (generally smaller pots)

6. What are the basic types of containers?

Both organic and synthetic materials are used in greenhouses. Encourage the students to discuss what these materials are and how each might be beneficial, e.g., growing seedlings versus potted plants. Have students complete AS 4.7.

A. Rooting containers
   1. Used for seeding or root cuttings
   2. Made from organic materials
      a. Peat pellets and strips (TM 4.5)
         i. Self-contained growing units
         ii. Expand when watered
      b. Peat pots
         i. Made from compressed peat moss
         ii. Must be filled with growing media
   3. Made from other materials
      a. Plastic flats
      b. Metal flats
      c. Plastic foam cubes
      d. Rock wool fibers
B. Bedding plant containers
   1. Cell packs (TM 4.6)
      a. Generally made of plastic
      b. Usually contain 36, 48, or 72 cells per flat
      c. Used for producing plug seedlings
   2. Plant packs
      a. Generally made of plastic
      b. Usually contain one to six cells per unit and six to eight units per flat
      c. Used for bedding and garden vegetable plants
   3. Individual pots
      a. Generally made of plastic
      b. Range in size (most common: 2-4 in.)
      c. Used to produce larger bedding plants
C. Foliage and flowering plant containers (can range in size from 2 to 12+ in.) (TM 4.7)
   1. Standard pot
      a. Equal in width and depth
      b. Best for plants that are not top heavy
   2. Azalea pot
      a. Height - 3/4 of its width
      b. Ideal for shorter plants with spreading foliage
      c. Wide base - stability for top-heavy plants
   3. Rose pot
      a. Height - 1 1/2 times its width
      b. Ideal for plants with large, deep root systems
   4. Bulb pan
      a. Width twice the depth

   b. Best for shallow-rooted plants
5. Hanging baskets
   a. Generally made of plastic
   b. Suitable for a variety of plants

7. What are the most common materials for growing containers?

Containers in commercial greenhouse are composed of organic and synthetic materials. Discuss the benefits and drawbacks of each. Are some materials better for certain types of plants or the growers?

A. Plastic (most commonly used)
   1. Types
      a. Round (more air circulation between pots)
      b. Square (more space efficient but less air circulates among pots, leading to diseased leaves)
   2. Advantages
      a. Lightweight to lift and ship
      b. New pots - sterile; used pots - can be chemically sterilized
      c. Less prone to fertilizer residue/algae buildup
      d. Less watering required
      e. Wide selection of sizes, shapes, and colors
      f. Inexpensive
   3. Disadvantages
      a. Nonporous (does not “breathe”)
         i. Less aeration for root system
         ii. Possibility that growing medium may become waterlogged
      b. Can crack and becomes brittle with age
      c. Disposal - environmental concern
B. Clay (used for centuries)
   1. Advantages
      a. Porous
         i. Excellent aeration and gas exchange
         ii. Excellent drainage prevents growing medium from becoming waterlogged
      b. Sturdy, less likely to tip
      c. Long lasting
      d. Can be steam sterilized
      e. Can be reused
   2. Disadvantages
      a. Plants drying out faster and requiring more frequent watering
      b. Prone to fertilizer residue/algae buildup
      c. Heavy to lift and ship
      d. Subject to breakage
      e. Relatively more expensive
C. Peat - peat moss pressed into sheets and formed into shapes
   1. Advantages

a. Can be transplanted along with plant (less trauma to plant when transplanted)
b. Roots penetrating container as plant grows

2. Disadvantages
   a. Does not last very long
   b. Dries out quickly and becomes difficult to rewet

F. Other Activities and Strategies

1. Invite a manager from an organic greenhouse and a traditional greenhouse manager on separate days to discuss issues of growing media and containers. A nearby university Extension office may be able to help you find an organic greenhouse grower. What kind of growing medium do they use, amended soil or a soilless mixture? Do they create their own soilless medium? What are the ingredients in it and why those particular items? Ask them to show the class what their growing medium looks like. Ask them to address concerns of chemical pasteurization (methyl bromide), vermiculite, rock wool, and polystyrene. With regards to containers, what type do they prefer and why? What are the costs involved in “being green”?

2. Steam Pasteurization of Soil - This smelly exercise requires an oven, soil, a meat or candy thermometer, ovenproof pan, some aluminum foil, and ventilation.

   A. Before using the soil, thoroughly sterilize the equipment. Wash containers and tools with soapy water to remove debris. Sterilize wood and plastic items by rinsing them in a solution of 1 part chlorine bleach and 10 parts water. Let dry before using.

   B. Place moist but not wet soil in an ovenproof pan. Cover with foil, sealing the edges. Insert the thermometer in the middle of the soil mass, making a small hole in the foil. Bake in a 250°F oven until the thermometer reads 160-180°F. Remove from oven and let cool.

   Note: The amount of time to sterilize the soil varies depending on soil volume and moisture content. Remember that dry soil does not pasteurize well.

3. Show the class any or all of the following videos, which are available from CATER (Career & Technical Education Resources), 2 London Hall, University of Missouri-Columbia: *How to Grow Plants in a Greenhouse: Bedding Plant Production*, Vol. I (AG V162); *How to Grow Plants in a Greenhouse: Foliage Plant Production*, Vol. II (AG V163); and *Growing Media for Landscape Plants* (AG V172).

G. Conclusion

The growing media’s water-holding capacity, porosity, drainage, and aeration foster healthy plant growth. Soilless medium is preferred over field soil. By amending the composition through the addition of organic and inorganic materials, soil-based media can be substantially improved. The selection of plant containers and the choice of materials depend on usage and the intended market.

H. Answers to Activity Sheets

AS 4.5 Growing Media and Containers

Instructor's discretion

AS 4.6 Materials Update

Instructor's discretion

AS 4.7 Container Shopping

Instructor's discretion

I. Answers to Assessment

1. A
2. C
3. B
4. D
5. B
6. Any two of the following for A-C:
   A. Rooting/seeding plants: peat pellets, peat strips, peat pots, plastic flats, metal flats, rock wool fiber, plastic foam cubes
   B. Foliage/flowering plants: standard, azalea, rose, bulb, and hanging pots
   C. Bedding plants: cell packs, plant packs, and individual pots
7. Any two of the following:
   A. Lightweight
   B. Essentially inert
   C. Excellent drainage and porosity
   D. Consistent in composition
   E. Free of unwanted seeds, weeds, insects, and pathogens
   F. Can be custom mixed or purchased ready-to-use
   G. Do not require pasteurization
8. Steam - cannot be used in conjunction with slow-release fertilizers
   Chemical - not as effective as steam, fumes are toxic to humans, growing media must aerate before planting can occur
   Electrical - can be used only on very small areas
9. E
10. C
11. A
12. F
13. D
14. B

UNIT IV: PLANT GROWTH

Name___________________

Lesson 2: Growing Media and Containers

Date____________________

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. What is the composition of an ideal field (mineral) soil?

   A. 50% solids, 25% water, and 25% air
   B. 15% organic matter, 40% water, 5% air, and 40% silt
   C. 45% mineral, 1% water, 1% air, and 53% sand
   D. 30% air, 30% mineral, 20% water, and 20% silt

2. What are three most popular container materials?

   A. Peat, vermiculite, and clay
   B. Plastic, metal, and perlite
   C. Clay, peat, and plastic
   D. Rock wool, peat, and plastic

3. What three features are essential for a good growing medium?

   A. Porosity, lightweight, and pasteurization
   B. Water-holding capacity, drainage, and porosity
   C. Drainage, silt, and sand
   D. Porosity, water-holding capacity, and loam

4. What are two disadvantages of using mineral (field soil)?

   A. Cation exchange capacity and CO_2 levels
   B. No need for pasteurization and is too heavy
   C. Superior aeration but not enough water
   D. Poor aeration and potential contaminants

5. When selecting a type of container, what are the two most important considerations?

   A. Growth media and pot size
   B. Plant growth and market
   C. Container material and plant growth
   D. Market and porosity

Short-Answer Questions: Write the answers in the space provided.

6. What are two examples of container types for the following types of greenhouse plants?

   A. Rooting/seeding plants

      1.

      2.

   B. Foliage/flowering plants

      1.

      2.

   C. Bedding plants

      1.

      2.

7. What are the two benefits of soilless media for growing plants?

   A.

   B.

8. What are the three methods of soil pasteurization? What is one drawback of each technique?

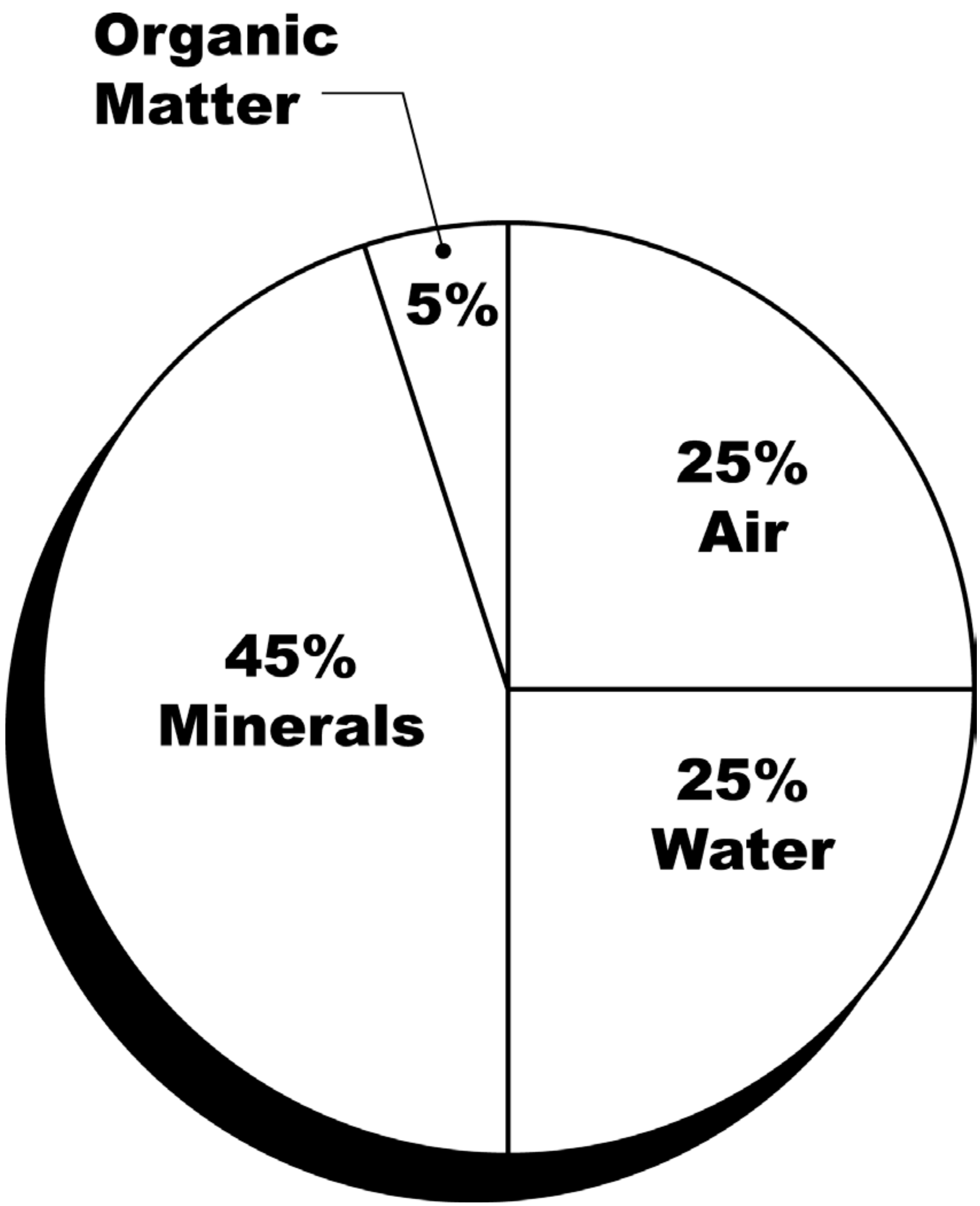
<u>Method</u>	<u>Drawback</u>
A.	A.
B.	B.
C.	C.

Match the ingredients in soilless mixes and soil amendments on the left with their origin on the right. Write the letter in the space provided.

____9. Rock wool	A. Mica
____10. Coir	B. Mountain rock
____11. Vermiculite	C. Coconut by-product
____12. Sphagnum peat moss	D. Volcanic rock
____13. Perlite	E. Spun basalt, coke, and limestone
____14. Sand	F. Decomposed plant and animal residue

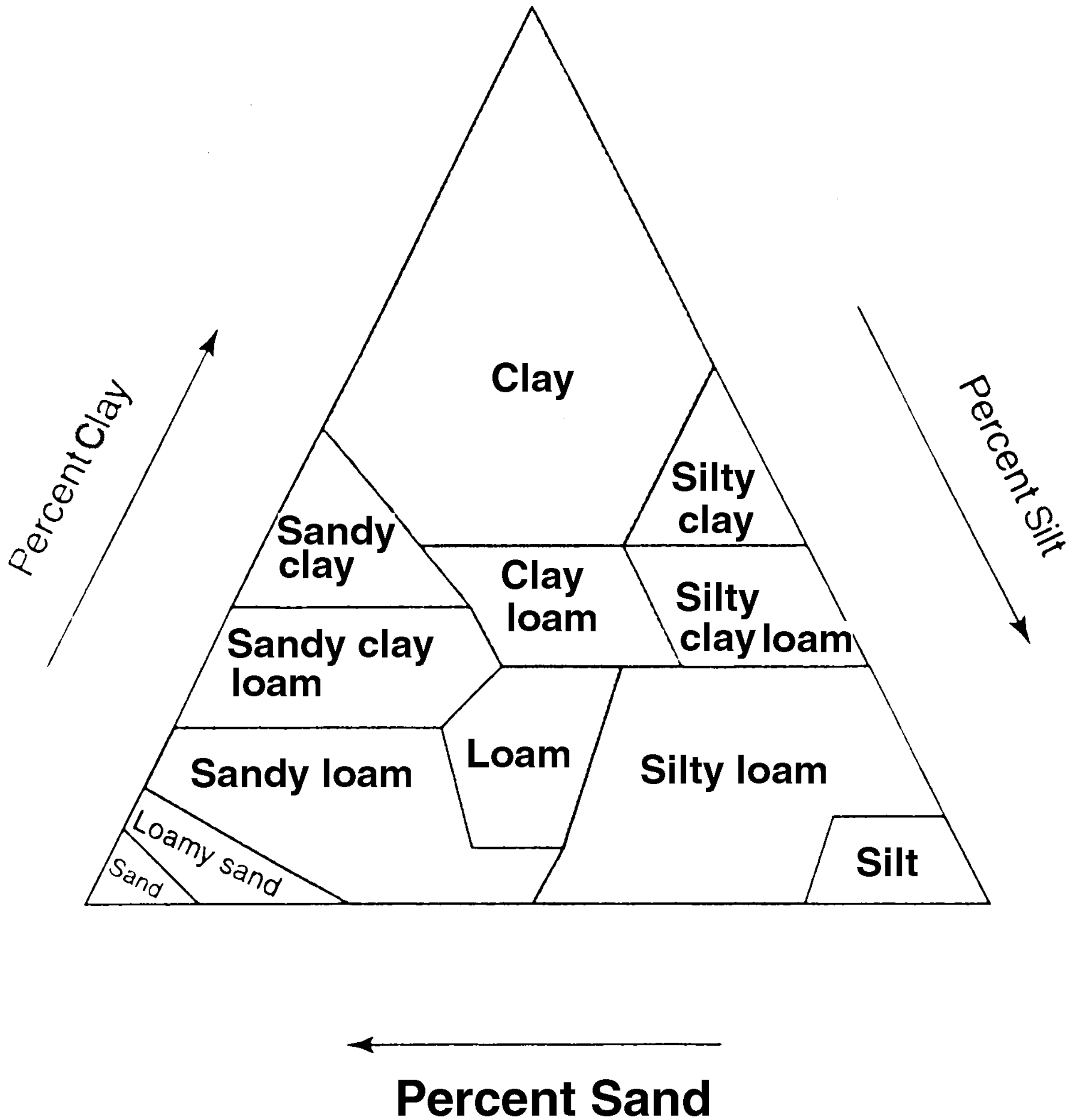
TM 4.2

Composition of Soil-Based Growing Media



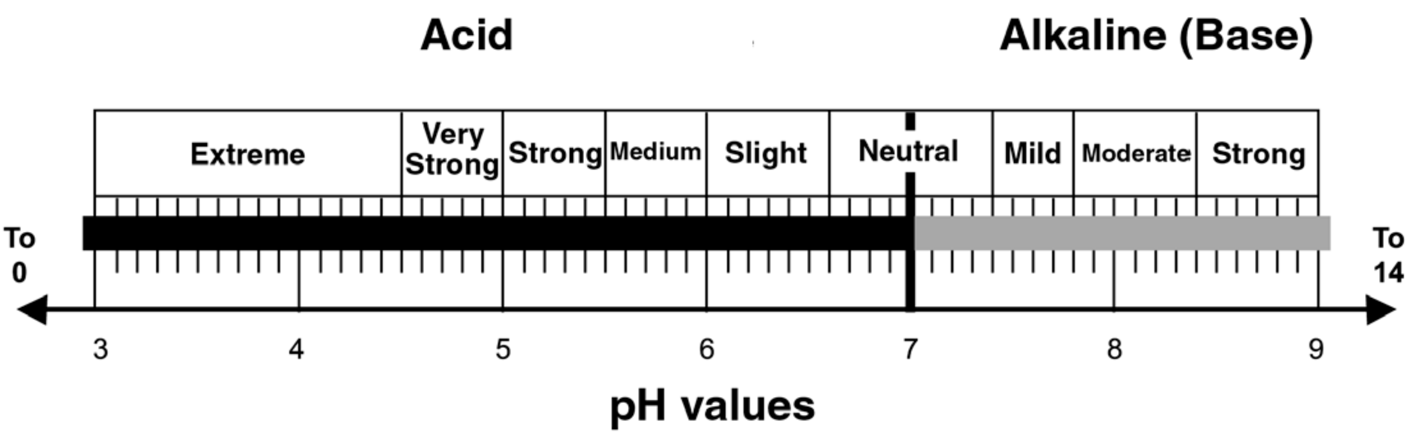
TM 4.3

Soil Texture Triangle



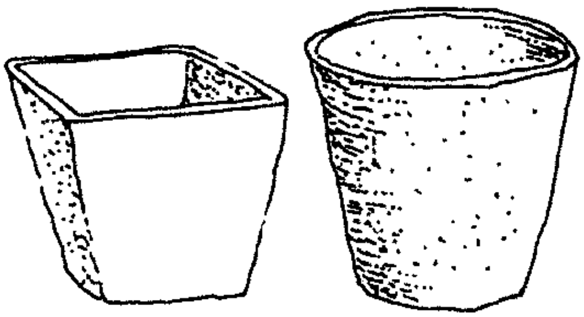
TM 4.4

pH Scale



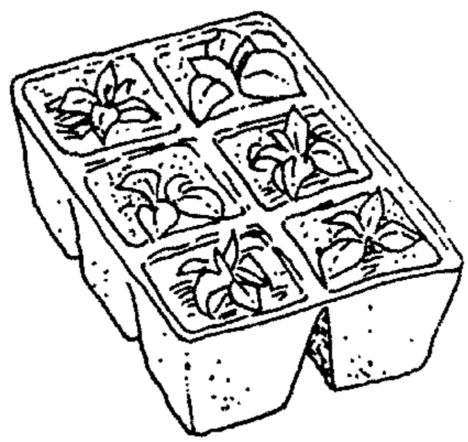
TM 4.5

Peat Containers



Peat Pots

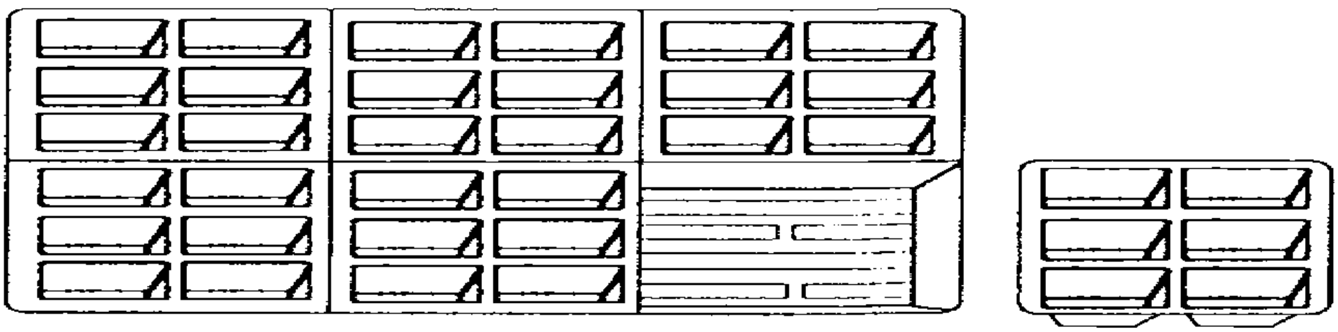
Peat Pellet



Peat Strip

TM 4.6

Identifying Cell Packs



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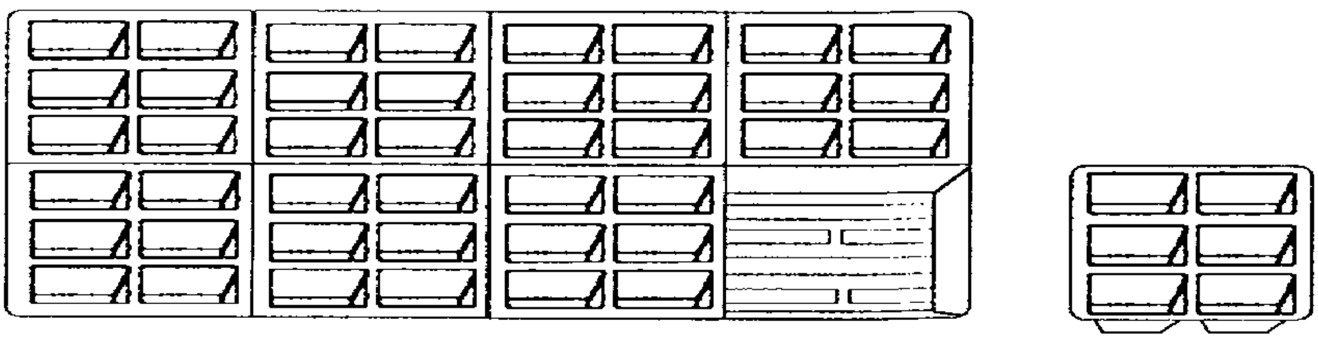

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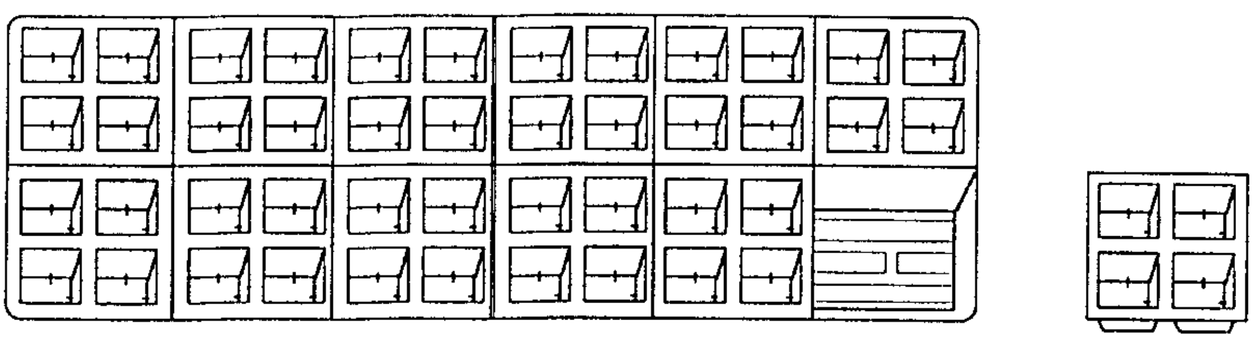

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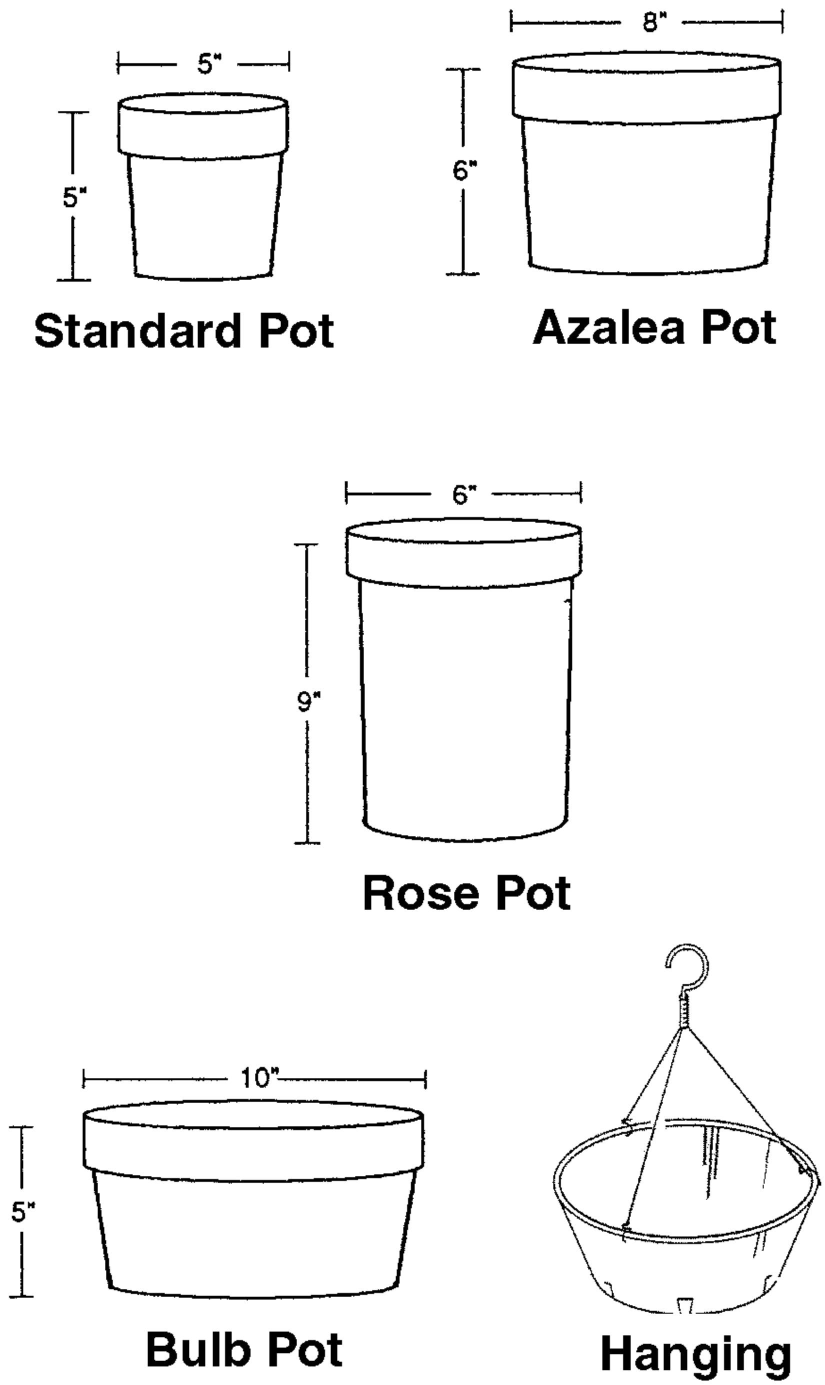
TM 4.7

Container Shapes



UNIT IV: PLANT GROWTH

AS 4.5

Lesson 2: Growing Media and Containers

Name___________________

Growing Media and Containers

Objective: Identify the differences in soil and soilless growing media and evaluate types of containers used.

Directions: Use seeds planted earlier in this unit to assess the effectiveness of growing media. Remember that at the beginning of Unit I when the seeds were planted, half of the class' plants were randomly planted in soil. Then answer the following questions.

1. How do the plants look? Describe in detail.

2. Turn a little bit of the growing media and record observations. Describe the differences in the soil and the soilless media.

3. What kind of container is used to grow the plants? What is the container made of (clay, plastic, etc.)? Could the type of container or material influence the growth of the plants? Explain.

4. If this plant were grown for retail sale, what container would be the best option? For wholesale?

UNIT IV: PLANT GROWTH

AS 4.6

Lesson 2: Growing Media and Containers

Name___________________

Materials Update

Objective: Evaluate the materials used in greenhouses.

Directions: Using the Internet and other sources, work in small groups to research one of the words listed below. Then answer the questions and present your findings to the class as a PowerPoint presentation.

- Bagasse
- Calcined clay
- Chloropicrin
- Hydrogel (Terrasorb)
- Methyl bromide
- Peat moss
- Perlite
- Rock wool
- Vermiculite

1. What is it?

2. What is its use?

3. What are the benefits of using it?

4. Are there negative aspects to its use?

5. Is there an alternative?

6. How cost-effective is the option?

UNIT IV: PLANT GROWTH

AS 4.7

Lesson 2: Growing Media and Containers

Name______________________

Container Shopping

Objective: Compile a list of appropriate containers and prices to fill a greenhouse.

Directions: Using the Internet and other sources, research the price and types of containers it would take to fill a greenhouse the size of your school's greenhouse.

1. How many containers will it take to fill the greenhouse?

2. What size pots: just one size or a variety? Which sizes?

3. Is it necessary to buy any rooting containers?

4. How many cell packs and hanging baskets will you use?

5. How are cell packs sized?

6. How are cell packs sold?

7. What materials are the containers made from?

8. Why did you choose that material?

9. What types of plants are you growing? Did this influence your choice? Why?

10. How much money will these containers cost?

GREENHOUSE OPERATION AND MANAGEMENT

Unit IV: Plant Growth

Lesson 3: Irrigation

Competency/Objective:

Explain factors involved in proper greenhouse irrigation.

Study Questions

1. **What factors affect the irrigation of greenhouse crops?**

2. **How often should crops be irrigated?**

3. **What are some basic irrigation guidelines?**

4. **How should water be delivered to plants?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 4.8 Interaction Between Growing Medium's Porosity and Depth
   TM 4.9 Capillary Action of Water in Growing Medium

3. Activity Sheets

   AS 4.8 Over-, Under-, and Proper Watering
   AS 4.9 Water Delivery Systems

TEACHING PROCEDURES

A. Review

   Light, temperature, and air quality are important factors in aiding plant growth as well as the composition of the growing media and the containers used. The most important factor affecting the health and growth of a greenhouse crop is water. Water delivers essential nutrients to the root system. This lesson provides guidelines for proper irrigation and describes several methods of delivering the water to the plants.

B. Motivation

1. Irrigation is more complicated than just spraying plants with a hose for a few minutes. Ask the students to brainstorm why water is so important for the plants. Use the plants they have been watering to illustrate the significance of water.

2. Saturate a sponge and lay it flat on a screen with space below it so that students can observe that water runs out of it. Turn the sponge up so it rests on its longest edge. (More water runs out of it than it did when it was flat.) Now turn it up so it rests on its narrowest edge. (Even more water runs out of the sponge.) Ask students if the position of the sponge has an effect on how fast it absorbs water. Ask them to predict why.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What factors affect the irrigation of greenhouse crops?

Water delivers valuable nutrients to plants. Students should note that public water might also have additives such as fluoride and salts that can damage plants. Some plants are more sensitive than others.

A. Irrigation is the most important greenhouse practice.
   1. Quality water is essential to plant growth.
   2. Proper irrigation practices are critical to crop success.
B. Water has a major role in plant growth.
   1. Dissolves nutrients and translocates them throughout the plant
   2. Supports plant structure when plant cells are filled
C. Several factors contribute to moisture stress in plant.
   1. Growing medium - very important factor
      a. The growing medium must provide adequate absorption, drainage, and retention.
      b. When medium's capillaries absorb and retain water, the force of gravity drains water from the plant container, creating a conflicting interaction. (TM 4.8)
         i. Medium's porosity and depth resolve this conflicting interaction.

ii. Large particles in the growing medium are porous and facilitate drainage after irrigation.
iii. The depth of the medium relates to the height of the plant's container.
(a) Water in tall containers pulls easily through the medium; drainage is complete.
(b) Water is retained in short containers because the medium's capillaries resist the force of gravity.

2. Air temperature
   a. Warmer air temperatures increase plant transpiration rate, relative humidity decreases, and water in plant cells is depleted.
   b. Air temperature must be monitored and regulated.

D. Irrigation considerations
1. Provide uniform watering.
2. Minimize amount of water/fertilizer runoff.
3. Minimize amount of water on foliage.
4. Consider integrating fertilizer injection system directly into irrigation system.

E. Plants vary in their sensitivity to the elements in some water supplies.
1. Fluoride
   a. Added to public water systems for tooth decay prevention
   b. Can cause tips of some plants to burn
2. Softened water
   a. Contains high levels of sodium
   b. Should not be used for plant irrigation

2. How often should crops be irrigated?

When do you water? Discuss the consequences of underwatering and overwatering using the plants the students have been watering. Have students complete AS 4.8.

A. Frequency depends on various factors.
1. Water-holding capacity of growing medium
2. Growing medium and container type
3. Internal environment (greenhouse humidity, temperature, light)
4. External environment (season)
5. Plant itself
   a. Species
   b. Size
   c. Stage of growth
   d. Soil depth

B. There are several ways to identify when plants need water.
1. Visual observations
   a. Plant starts to wilt.
   b. Growing medium becomes dry and lighter in color.
   c. Weight of pot is lighter.
2. Stick placed in growing medium and removed
   a. If stick is dry, water the plant.

b. If medium clings, do not water the plant.

C. There are several consequences of underwatering.
   1. Moisture stress from depriving plant of water
   2. Wilting because cells shrink
   3. Stomata close up
      a. Prevent further loss of moisture
      b. Restrict CO_2 from entering leaf
      c. Photosynthesis hindered
      d. Plant growth stunted
   4. No water or minerals to roots
      a. Leaves, stem, and emerging flowers are deprived of water and nutrients.
      b. Plant develops shorter internodes, smaller leaves, and harder and tougher plant tissue.

D. There are several consequences of overwatering.
   1. Especially detrimental for seedlings
   2. Affects root system
      a. Restricts exchange of gases; limits level of oxygen
      b. Damages root tissue
      c. Increases risk of disease invasion
   3. Wilting
   4. Leggy growth
   5. Slowed growth

3. What are some basic irrigation guidelines?

Have students discuss the important aspects of growing media related to water: porosity, drainage, and water-holding capacity. Ask students to define leaching, an important aspect of irrigation.

A. Use proper growing media. (See Unit IV, Lesson 2.)

B. Water only when indicated.

C. Water thoroughly each time.
   1. Purpose
      a. Leaches (flushes) soluble salts and excess nutrients from growing media
      b. Buildup of salts and nutrients damaging to root system
   2. Method
      a. Moisten entire area around roots; do not allow root system to dry out.
      b. Do not allow overflowing over top of pot.
      c. Water until water drains from bottom.
      d. Water early in day to allow water to evaporate from foliage and flowers.

D. Take steps to reduce risk of plant disease.
   1. Do not wet foliage or flowers.
   2. Keep end of hose off the floor to avoid pathogens that can contaminate plants.

4. How should water be delivered to plants?

The three basic styles of irrigation are overhead delivery, surface delivery, and subsurface delivery. Some plants respond better to specific methods. Ask students to discuss why this might be. Have the class complete AS 4.9 to augment information learned here.

A. Water delivery to plants in the greenhouse through both manual and automated systems (See Unit II, Lesson 2.)
B. Manual method - use of handheld hose and wand
    1. Widely used in small greenhouse operations
    2. Labor intensive
    3. Costly
    4. Difficult to water plants uniformly
C. Overhead delivery - foliage-type watering system (automated method)
    1. Sprinkler systems
        a. Spray stake/nozzle systems mounted near plants, spraying bedding plants from above and on the sides
        b. Disadvantages
            i. May leave salt residues on foliage if irrigation system contains nutrients
            ii. Increased risk of disease from wet foliage
            iii. May displace or puddle growing medium
            iv. Evaporation from using overhead sprinklers
            v. Increased risk of disease from wet foliage
    2. Boom irrigation system
        a. Water wand hanging above plants and traveling across greenhouse spraying water onto plants
        b. Spray stake/nozzle systems mounted near plants, spraying plants from above and from the sides.
        c. Custom built to greenhouse's dimensions
        d. Delivers fertilizer during irrigation (fertigation)
        e. Saves 40% in water compared to manual techniques
D. Surface delivery (automated method)
    1. Applies water under foliage
        a. Uniform amount of water is applied at base of plant.
        b. Leaves do not get wet; rate of evaporation from foliage and soil is reduced.
        c. Growing medium does not get waterlogged.
        d. Nutrients do not leach into the soil.
    2. Use of drip tubes - delivering water directly to the soil without wetting the foliage
        a. Drip emitters have small tubes with weights attached that are placed in individual pots. They slowly dispense drops of water directly to the medium.
        b. Ooze tubes have small holes in a double-layer tube and are placed next to rows of plants.
            i. Deliver low volume of water; conserve large amounts of water
            ii. Used in areas with limited resources of water and where water is expensive
        c. Water loops are actually ooze tubes that are wrapped around the stems of plants in individual pots.

E. Subsurface (subirrigation) delivery
   1. Delivers water directly to medium without wetting foliage; applies water under pot
   2. Capillary mat system (TM 4.9)
      a. Plant containers are placed on top of soaked, synthetic mat that rests on level bench.
      b. Bench is protected with a sheet of plastic.
      c. Dripping water runs off bench, preventing soluble salts from accumulating on mat.
      d. Plastic pots are best to use; clay pots lose moisture through sidewalls.
      e. A drip tube waters the mat uniformly.
      f. Plants are watered from above using a hose.
         i. This creates a column of water that extends from growing medium to the mat.
         ii. Capillary action pulls water upward from a saturated mat through a drainage hole into the growing medium.
         iii. Capillary action occurs because water rises to a given height in "tubes" (capillaries) with narrow diameters. (TM 4.9)
         iv. Pore spaces in growing medium function as capillary tubes and carry water from the mat to the roots.
   3. Ebb and flood system
      a. Flats of plants rest on specially constructed, raised, waterproof benches.
      b. Each bench must be absolutely level and have a trench for the nutrient solution and several pipes to carry a given number of gallons of water per minute. The amount of water depends on the size of the greenhouse operation.
      c. The irrigation solution (water and nutrients) is pumped from a central storage tank into the bench and spreads quickly and evenly over the growing medium.
      d. The solution remains on the bench for a few minutes and then drains back into the storage tank for recycling.
      e. Ebb and flood system never wets the foliage (which would promote disease) and it can be applied any time of the day or night. A computer can regulate the entire operation.
      f. Ebb and flood is a completely closed recirculating system that does not contaminate the groundwater.

F. Other Activity and Strategy

Have three similar-size pots of the same plant and water each one with tap, reverse osmosis (RO) filtered water, and spring water. Ask students if they see the effects of three types of water on the growth of plants in the classroom. Tap water is water filtered for contaminants and possibly augmented with fluoride. Filtered water is water that has been changed in one of three ways: distilled, deionized, or filtered through RO. These methods are used to eliminate soluble salts and other contaminants like hard metals. These methods can remove minerals and trace metals that plants need for nutrition. It is not an appropriate substitute for public water. Greenhouse growers find that filtered water, especially, is less expensive. RO is useful when applied with water containing essential nutrients. Spring water should be water derived from a natural source without having its mineral content changed. Thus, depending on its source, the water may be alkaline or acidic.

G. Conclusion

Water plays a vital role in the growth and development of greenhouse crops. There are several factors that affect irrigation: the medium's absorption, drainage, and retention as well as air temperature. Frequency of irrigation depends on several variables and the greenhouse owner can use different techniques to assess the need for watering. Overwatering and underwatering have severe consequences on the health of greenhouse crops. Irrigation may be delivered through manual or automatic systems.

H. Answers to Activity Sheets

AS 4.8 Over-, Under-, and Proper Watering

Instructor's discretion

AS 4.9 Water Delivery Systems

Instructor's discretion

I. Answers to Assessment

1. A
2. D
3. C
4. A. Moisten entire area around the roots.
   B. Do not let water overflow.
   C. Water until water drains from the bottom.
   D. Water early in the morning to allow water to evaporate from foliage and flowers.
5. A. Growing medium and container type
   B. Internal environment
   C. External environment (season)
   D. The plant itself
6. A. Water dissolves vital nutrients and translocates them through the plant.
   B. Water fills the plant cells allowing the plant to thrive

UNIT IV: PLANT GROWTH

Name____________________

Lesson 3: Irrigation

Date_____________________

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. What does it mean to "leach" a crop?

   A. Flush soluble salts and excess nutrients
   B. Augment soluble salts and excess nutrients
   C. Spray extra nutrients
   D. Restrict the amount of water

2. Displacement of growing medium, salt residue on foliage, and increased risk of disease characterize which water delivery system?

   A. Subsurface
   B. Surface
   C. Ebb and flood
   D. Overhead

3. What factors must the growing medium provide to prevent moisture stress?

   A. Air temperature, absorption, and frequency
   B. Transpiration, frequency, and drainage
   C. Retention, absorption, and drainage
   D. Absorption, transpiration, and frequency

Short-Answer Questions: Write the answers in the space provided.

4. What are the four steps involved in thoroughly watering a plant?

   A.

   B.

   C.

   D.

5. What four factors relate to frequency of irrigation?

   A.

   B.

   C.

   D.

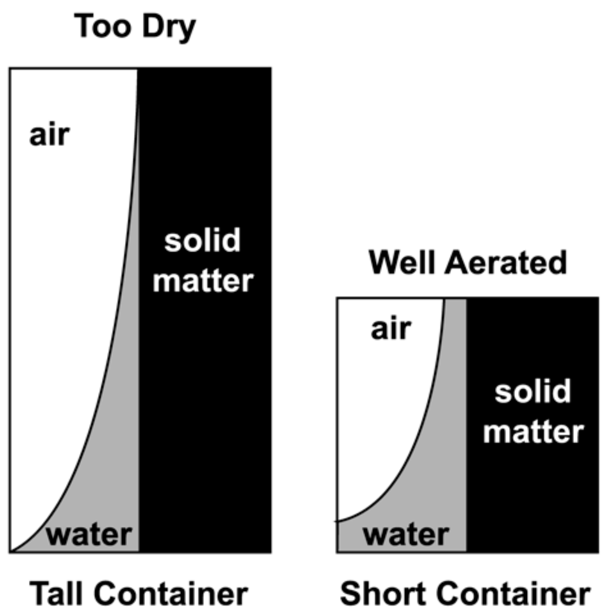
6. What are two reasons why water is an essential element in plant growth?

   A.

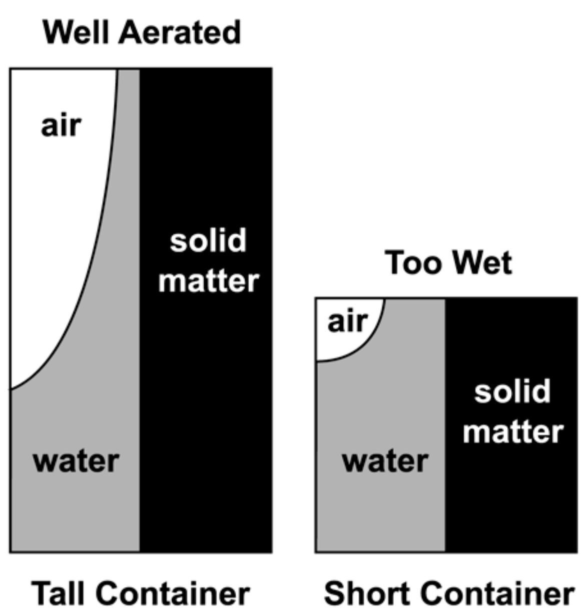
   B.

TM 4.8

Interaction Between Growing Medium's Porosity and Depth



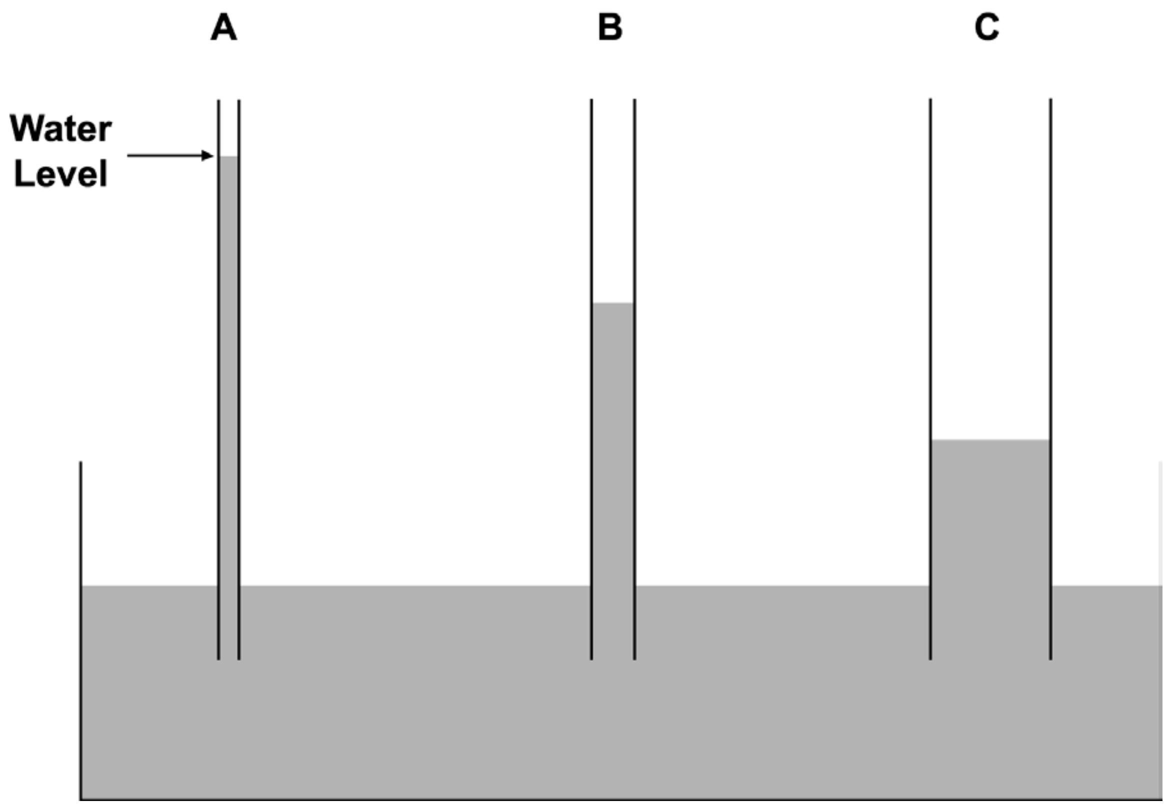
Highly Porous Medium



Less Porous Medium

TM 4.9

Capillary Action of Water in Growing Medium



UNIT IV: PLANT GROWTH

AS 4.8

Lesson 3: Irrigation

Name___________________

Over-, Under-, and Proper Watering

Objective: Identify the characteristics of overwatering, underwatering, and proper watering.

Directions: Using the Unit IV plants (labeled Group D, E, and F), evaluate how well the plants have grown. Also pay attention to the growing media.

1. Which group was underwatered? Overwatered? Watered properly?

2. Describe the conditions of each of the three groups of plants.

3. How does the growing media look? Use as much detail as possible.

4. What is the overall condition of the plants growing in the soil?

UNIT IV: PLANT GROWTH

AS 4.9

Lesson 3: Irrigation

Name ___________________

Water Delivery Systems

Objective: Compare specific types of water delivery systems to classmates.

Directions: Divide into small groups and investigate two water delivery systems listed below. Respond to the following questions. Present your findings to your peers by creating a PowerPoint presentation, poster, or some other visual aid.

- Hand watering
- Spaghetti tube irrigation
- Drip irrigation
- Ebb and flood
- Capillary mat system
- Overhead irrigation
- Perimeter irrigation
- Soaker hose system
- Misting system
- Any others?

1. What type of water delivery system is it?

2. What are the positive aspects of this system?

3. What are the limitations of this system?

4. With what type of plant does this system works best? Give examples.

5. How economical is this system?

6. Does this system present any potential environmental concerns?

GREENHOUSE OPERATION AND MANAGEMENT

Unit IV: Plant Growth

Lesson 4: Nutrients

Competency/Objective:

Identify nutrients essential for plant growth and development and signs of deficiency or toxicity.

Study Questions

1. **How do nutrients affect plant growth?**
2. **What nutrients are essential for plant growth?**
3. **How are nutritional deficiencies identified?**
4. **What are some common symptoms of macronutrient deficiencies?**
5. **What are some common micronutrient disorders?**
6. **What factors affect the availability of nutrients?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 4.10 Effect of Field Soil's pH on Nutrient Availability
   TM 4.11 Effect of Soilless Medium's pH on Nutrient Availability

3. Activity Sheet

   AS 4.10 Specific Nutrients

TEACHING PROCEDURES

A. Review

Building on the previous lessons concerning the elements needed to grow greenhouse plants, students now explore the nutrients needed for plant growth and development. This lesson examines signs of macronutrient deficiency and micronutrient toxicity.

B. Motivation

Ask students to name the types of nutrients needed for their own growth and development. Where does this nutrition come from? Just as humans, plants require specific nutrients are the building blocks for health and growth. How do plants obtain needed nutrition? Without these basic elements, greenhouse crops would be unable to flourish.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. Instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. How do nutrients affect plant growth?

The nutritional requirements of greenhouse plants differ from other crops. The greenhouse operator learns to manipulate plants by giving them the appropriate nutrients at the correct time in the development cycle to optimize growth rate and maximize profitability.

A. Nutrients are necessary for all plant growth and development.
   1. Plants need adequate levels of minerals to grow at an optimal rate.
   2. Both insufficient and excessive amounts of nutrients can have a negative impact on plant growth.
B. Greenhouse plants have higher supplemental nutritional requirements than other agricultural crops.
C. Fertilizers are applied as nutritional supplements to promote plant growth. (See Unit IV, Lesson 5.)

2. What nutrients are essential for plant growth?

There are 18 nutrients necessary for plant development. Six nutrients are needed in large quantities, nine in trace amounts, and three in very large amounts: carbon, hydrogen, and oxygen. The last three are absorbed through the air and water.

A. Macronutrients
   1. Primary (fertilizer nutrient)
      a. Nitrogen (N)
         i. Found in chlorophyll and enzymes
         ii. Essential to growth.
         iii. Helps the plant resist disease and sustain environmental extremes, such as drought and freezing
         iv. Is recycled within the plant
      b. Phosphorous (P)
         i. Stimulates root growth
         ii. Promotes early crop maturity
      c. Potassium (K) - contributing to growth of plant tissue
   2. Secondary
      a. Calcium (Ca)
         i. Increases the pH level, which corrects acidity in the growing medium
         ii. Key factor in cell development
         iii. Affects the roots' ability to absorb magnesium and potassium
      b. Magnesium (Mg) - helps produce chlorophyll, fats, and sugars
      c. Sulfur (S)
         i. Used in all plants
         ii. Is absorbed in some vegetables (e.g., cabbage and onions)
         iii. Part of the plant's vitamins and amino acids
         iv. Assists in producing protein

B. Micronutrients - trace elements; in varying quantities affect photosynthesis, protein synthesis, cell development, flowering, and other plant processes
   1. Boron (B)
   2. Chlorine (Cl)
   3. Copper (Cu)
   4. Iron (Fe)
   5. Manganese (Mn)
   6. Molybdenum (Mo)
   7. Nickel (Ni)
   8. Sodium (Na)
   9. Zinc (Zn)

C. Nonfertilizer nutrients - representing 89% of the plant's content by dry weight
   1. Carbon
   2. Hydrogen
   3. Oxygen

3. How are nutritional deficiencies identified?

Discuss the importance of having a monitoring system to ensure proper nutrition for greenhouse crops.

A. Establishing and consistently following a nutrient monitoring system
B. Monitoring methods
   1. Visual observation
      a. Signs of nutritional deficiencies vary greatly with species.
      b. Signs are often visible only in later stages and may be too late to save the plant.
   2. Analysis of foliage (leaf tissue testing)
   3. Analysis of growing medium
      a. Level of nutrients
      b. Level of elements that affect availability of nutrients
         i. pH
         ii. Soluble salts
         iii. Pests and disease
C. Visual diagnosis
   1. Not always clear
   2. General terms
      a. Chlorosis: gradual yellowing of tissues as green chlorophyll breaks down (interveinal chlorosis - yellowing between leaf veins)
      b. Necrosis: dead tissue, brown or black

4. What are some common symptoms of macronutrient deficiencies?

Six macronutrients play important roles in a plant’s development. If there is a paucity of the nutrient, growth is slowed. Each deficiency has visible signs the students can learn to spot.

A. Nitrogen (N) - lost through erosion and leaching
   1. Slow growth
   2. Spindly, fewer lateral shoots
   3. Chlorosis, beginning with older/lower leaves
B. Phosphorous (P)
   1. Stunted, spindly growth
   2. Deeper green leaves and stems
   3. Purplish veins and stems
C. Potassium (K)
   1. Slow growth
   2. Interveinal chlorosis beginning with older leaves
   3. Necrotic or scorched edges beginning with older leaves
D. Calcium (Ca)
   1. Yellow, brown, or black new leaf tips
   2. Dieback of growing points
   3. Roots - short, thick

E. Magnesium (Mg)
   1. Interveinal chlorosis of older leaves, usually beginning in center of leaf
   2. Necrosis of edges and marginal scorching
F. Sulfur (S)
   1. Chlorosis similar to nitrogen deficiency but not necessarily beginning with older leaves
   2. May turn orange or red
   3. Hardening of stems

5. What are some common micronutrient disorders?

Micronutrients are just as vital as macronutrients but the amount of nutrients needed is much less. This means that a little goes a long way and a little more may be toxic.

A. Micronutrient deficiency
   1. Plant develops symptoms that are often similar to macronutrient deficiency.
   2. Even minor deficiencies can affect plant growth.
B. Micronutrient toxicity
   1. Toxicity occurs when excessive amounts of one nutrient prevent other nutrients from providing available nourishment to the plant.
   2. Symptoms are difficult to recognize and can be mistaken for nutritional deficiency.

6. What factors affect the availability of nutrients?

The soil's pH and soluble salts can slow and even kill a greenhouse crop. Other factors that affect availability of nutrients are pests and diseases, which are addressed further in Unit VI.

A. pH level of field soil
   1. Optimal pH for field soil - 5.8-6.5
   2. Controls availability of nutrient uptake
   3. Correcting pH levels
      a. Add lime to soil that is too acidic (increases pH).
      b. Add sulfur to soil that is too alkaline (decreases pH).
   4. Effect of field soil's pH on nutrient availability (See TM 4.10.)
B. Soilless media - effect of pH on nutrient availability (See TM 4.11.)
C. Buildup of soluble salts in soil
   1. Harms some plants that are more sensitive than others, especially young plants
   2. Originates from low-quality irrigation water and fertilizer residues
   3. Insufficient amounts - cause of nutrient deficiency and slow plant growth
   4. Fertilizers - a form of salt that increases levels of soluble salt in the medium
   5. Excessive amounts damaging to root system
      a. Increase risk of disease
      b. Limit uptake ability
   6. Excessive amounts damaging to foliage
      a. Salts are translocated through the plant.
      b. Injury to plant tissue can range from mild chlorosis to leaf burn.
   7. Causes reduction in water intake into the plant, which induces wilting

8. Injury to foliage
9. Ways to avoid and correct buildup of soluble salts
   a. Use high-porosity growing media.
   b. Maintain adequate moisture level.
   c. Leach media by applying large amounts of water and allowing 15-20% to drain out of container.

D. Pests and diseases (See Unit VI, Lesson 1.)
   1. Damage roots
   2. Prevent plant from efficiently absorbing nutrients

F. Other Activity and Strategy

Have the class test the pH of water. Obtain pH test strips and several types of water: tap water, filtered water (preferably reverse osmosis), and spring water (bottled is fine). You may also augment filtered water with some bicarbonate of soda to change the pH. The optimal pH for irrigation water is 5.5-6.5 (acidic). Ask the students why. (Answer: Essential nutrients are soluble at that pH level.)

G. Conclusion

Greenhouse plants have higher nutritional needs. The greenhouse owner must monitor the plants to ensure that proper care is given. It is advisable to maintain a regular schedule and to test the soil and plants because relying on visual cues alone may be insufficient for saving a crop.

H. Answers to Activity Sheet

Instructor's discretion

I. Answers to Assessment

1. C
2. B
3. A
4. A
5. A. Add lime.
   B. Add sulfur.
6. A. Chlorosis beginning but not necessarily confined to older leaves
   B. Leaves turning orange or red
   C. Stems hardening
7. A. Slow growth
   B. Spindly plants with fewer lateral shoots
   C. Chlorosis beginning with older, lower leaves
8. A. Stunted, spindly growth
   B. Deeper green leaves and stems
   C. Purplish veins and stems
9. B
10. B

11. A
12. A
13. A
14. A
15. B

UNIT IV: PLANT GROWTH

Name___________________

Lesson 4: Nutrients

Date____________________

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. What is the effect of a buildup of soluble salts in the growing medium?

   A. Promotes excessive intake of water
   B. Prevents absorption of fertilizer
   C. Damages root system
   D. Increases development of foliage

2. Which nutrients are absorbed through air and water?

   A. Chlorine, iron, and magnesium
   B. Carbon, oxygen, and hydrogen
   C. Oxygen, nitrogen, and sodium
   D. Potassium, phosphorous, and nitrogen

3. When does micronutrient toxicity occur?

   A. Excessive amounts of one nutrient
   B. Insufficient amounts of trace elements present in growing medium
   C. Excessive amounts of macronutrients
   D. Buildup of soluble salts

4. What amount is indicated in an analysis of the growing medium?

   A. Nutrients
   B. Necrotic tissue
   C. Chlorosis
   D. Root development

Short-Answer Questions: Write the answers in the space provided.

5. A. How is the pH level of acid soil adjusted?

   B. How is the pH level of alkaline soil adjusted?

6. What are three symptoms of sulfur deficiency in plants?

A.

B.

C.

7. What are three symptoms of nitrogen deficiency in plants?

A.

B.

C.

8. What are three symptoms of phosphorous deficiency in plants?

A.

B.

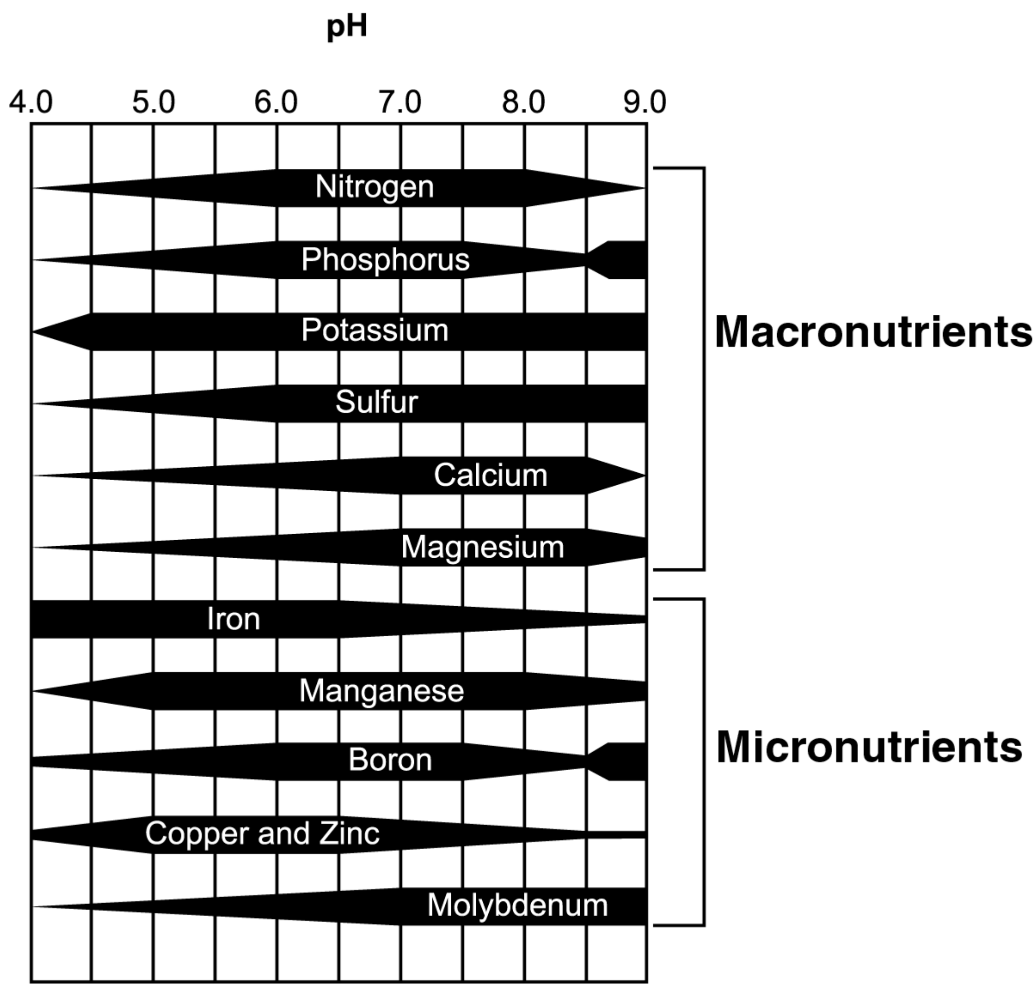
C.

Match the nutrient on the left with its classification on the right. Write the letter in the space provided.

9. ____Nickel	A. Macronutrient
10. ____Manganese	
11. ____Calcium	B. Micronutrient
12. ____Sulfur	
13. ____Potassium	
14. ____Magnesium	
15. ____Chlorine	

TM 4.10

Effect of Field Soil's pH on Nutrient Availability

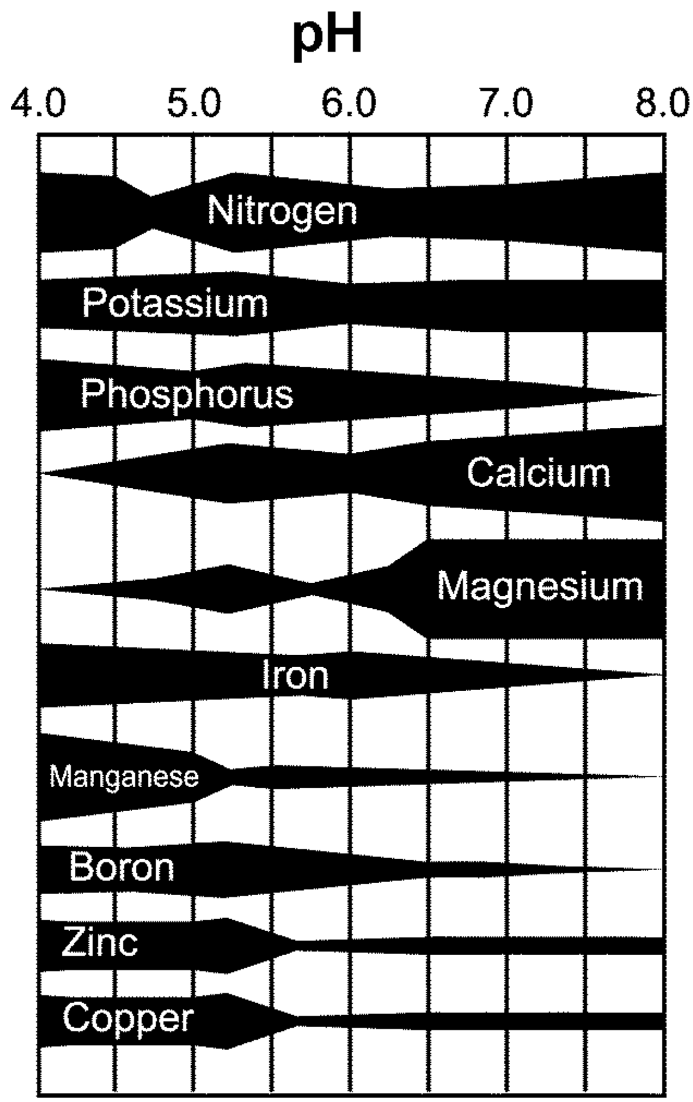


Widest part of bar indicates maximum availability.

Adapted from *Introduction to Horticulture*, 3rd ed., Danville, IL: Interstate Publishers, Inc., 2000.

TM 4.11

Effect of Soilless Medium's pH on Nutrient Availability



Widest part of bar indicates maximum availability.

Adapted from Nelson, Paul V., *Greenhouse Operation and Management*, 3rd ed., Reston, VA: Reston Publishing Company, Inc., 1985.

UNIT IV: PLANT GROWTH

AS 4.10

Lesson 4: Nutrients

Name___________________

Specific Nutrients

Objective: Identify nutrients needed for specific greenhouse crops.

Directions: Work in small groups. Each group examines nutritional requirements for a different crop. Select a crop from one of the following: potted flowering, bedding/garden plants, or foliage plants. Use the Internet, information from books, university Extension publications, or other sources to research the specific nutritional needs of the selected plant. You may bring an example of this plant to class, but this is not required in order to complete the activity. Present your findings to the class as a PowerPoint presentation or create a poster. Respond to the following questions.

1. What pH level of the growing medium does the plant prefer?

2. How do you achieve this pH level if the growing medium is not at the prescribed level?

3. Considering the pH required for optimal growth and development, what nutrients does this plant need?

4. What macronutrients does this plant require?

5. What micronutrients does it need?

6. What are the signs of nutritional deficiency for this plant? How can they be corrected?

GREENHOUSE OPERATION AND MANAGEMENT

Unit IV: Plant Growth

Lesson 5: Fertilizer

Competency/Objective:

Identify the need for fertilizer.

Study Questions

1. **What is the purpose of a fertilizer management plan?**
2. **What are the sources of fertilizer?**
3. **What forms of fertilizer are available?**
4. **What is a fertilizer analysis?**
5. **How is the correct amount of fertilizer calculated?**
6. **How are fertilizers applied?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 4.12 Hose-Siphoning Device Used to Apply Fertilizer
   TM 4.13 Dosmatic Injector

3. Activity Sheets

   AS 4.11 Healthy Plant
   AS 4.12 Calculating Fertilizer Dilution Ratios

TEACHING PROCEDURES

A. Review

Nutrients are the elements needed for plant growth and development. Fertilizers deliver nutrients. This lesson reinforces the need for a fertilizer management schedule to optimize plant health, and it explains sources, forms, and applications of fertilizer.

B. Motivation

Requirements for fertilizer vary with the type of plant and the stage of development. Use the last series of plants that students planted at the beginning of Unit I to demonstrate the effect of different amounts of fertilizer in the seedlings.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting of information needed to answer and discuss the study questions. The instructor may choose to work on one question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What is the purpose of a fertilizer management plan?

Limited root volume and heavy leaching contribute to greenhouse plants' need for additional nutrients. Supplements are geared to optimize growth, thus making the greenhouse more profitable.

A. Prevent and correct nutritional deficiencies
   1. Greenhouse plants have the highest supplemental nutritional requirements in all agriculture.
   2. Growing media do not always supply necessary nutrients.
B. Increase overall condition of plants, making them more resistant to disease
C. Improve appearance
D. Optimize growth more efficiently
E. Increase profits of greenhouse operation
F. Match fertilizer to plant's nutritional needs at different stages of development

2. What are the sources of fertilizer?

There are two sources of fertilizer: organic and inorganic. Organic is bulky and imprecise in its nutrient quantity. Inorganic fertilizer is a synthesized concentrate of mineral salts.

A. Organic fertilizer
   1. Made from once-living sources
      a. Natural (animal manure)
      b. Processed (bone meal, fish emulsion)
   2. Relatively low amounts of nutrients
   3. Releases nutrients slowly

B. Inorganic fertilizer
   1. Made from nonliving sources (synthetic)
   2. More concentrated amounts of nutrients; excessive use can injure roots
   3. Releases nutrients rapidly

3. What forms of fertilizer are available?

Ask students to describe the types and forms of fertilizer they have used on their own crops.

A. Slow-release fertilizer
   1. Organic or inorganic
   2. Less risk of burn
   3. Releases nutrients over long period of time
   4. Breaks down by water and bacteria

B. Granular
   1. Mixed into growing medium or applied to top of medium
   2. Available in stakes or sticks and placed in soil
   3. Measured by weight

C. Liquid or dry
   1. Must be mixed with water
   2. Can be injected into irrigation system (fertigation)
   3. Measured by parts per million (ppm)

4. What is a fertilizer analysis?

Nitrogen, phosphorous, and potassium are macronutrients needed in large quantities. A complete fertilizer refers to a ratio of these three elements. All labels list the percentages of macronutrients always in the same order: N-P-K. Other macronutrients or micronutrients may be included in fertilizer.

A. A “complete” fertilizer contains at least three basic macronutrients.
   1. Nitrogen (N)
   2. Phosphorous (P)
   3. Potassium (K)

B. An analysis of these elements is found on the fertilizer label.

1. The percent of each element is listed in this order: N-P-K.
2. For example, a label reading 20-17-16 indicates the fertilizer contains 20% nitrogen, 17% phosphorous, and 16% potassium.

C. Other nutrients may also be included.

5. How is the correct amount of fertilizer calculated?

Each fertilizer mix has its own dilution ratio. Each mix must be carefully calculated to ensure the proper level of nutrient is delivered to the plants. The label provides this information. Have students complete AS 4.12.

A. Concentrated dry or liquid fertilizer must be mixed with water at a specific ratio.
B. Check dilution ratio of fertilizer.
C. Calculate the amount of fertilizer needed to make the correct concentration.
D. Calibrate fertigation equipment to deliver proper dilution ratio.
E. Concentration rates are calibrated in ppm, as calculated by the following formula:

$$\frac{\text{desired ppm}}{\text{75 X percent of active ingredient}} = \frac{\text{\# oz}}{\text{100 gallons water}}$$

1. Multiply the percent of active ingredient in the fertilizer by 75 (a constant).
2. Divide this number by the ppm needed. This number represents the number of ounces of fertilizer per 100 gallons of water necessary to produce the proper concentration.
3. To mix smaller amounts of fertilizer, use a proportion.
4. First determine the correct number of ounces per 100 gallons, as shown above. Then use the following formula:

$$\frac{\text{\# oz}}{\text{100 gallons of water}} = \frac{\textbf{?}}{\text{calibration ratio}}$$

5. To find the unknown number of ounces (**?**), divide by the total calibration ratio.
   a. The calibration ratio is the <u>total</u> number of gallons and fertilizer used to create a concentrated solution.
   b. For example, if the calibration ratio is 1:13, the total number of gallons is 14. This makes the denominator 14.
6. Cross-multiply to solve for **?**.
7. **?** is the number of ounces of fertilizer added to 1 gallon of water in order to create a solution with the correct ppm.

6. How are fertilizers applied?

Environmental factors within the greenhouse and specific methods of application are explored. See TMs 4.12 and 4.13.

A. Carefully follow fertilizer label directions.

B. Growing medium must be moist when applying any fertilizer.
C. Dry and liquid fertilizers are dissolved in water.
D. A hose siphon injects the fertilizer.
   1. Connects between water outlet and hose with a tube extending down into container of concentrate
   2. Easy and inexpensive method
   3. Must be calibrated (usually 1:12 to 1:16)
E. A constant feed system is generally considered the best way of supplying nutrients.
   1. Every irrigation
   2. Every other irrigation

F. Other Activity and Strategy

Show the class a video available from CATER (Career & Technical Education Resources), 2 London Hall, University of Missouri-Columbia: *Fertilizing Landscape Plants* (AG V175).

G. Conclusion

Fertilizers are the method of delivering valuable nutrients to greenhouse crops. Plants and their growing cycle demand varying levels of nutrients; therefore, a fertilizer management program is required.

H. Answers to Activity Sheet

AS 4.11 Healthy Plant

Instructor's discretion

As 4.12 Calculating Fertilizer Dilution Ratios

1. 4.3 oz
2. 2.2 oz
3. 1.7 oz

I. Answers to Assessment

1. A constant feed system
2. Student may choose any four of the following:
   A. Prevent and correct nutritional deficiencies
   B. Increase overall condition of crops
   C. Improve appearance
   D. Optimize growth and development of plants
   E. Increase profitability
   F. Match fertilizer to plant's nutritional needs
3. A. Liquid or dry
   B. Granular

C. Slow release

4. A. Desired ppm
   B. Percent of active ingredient
   C. Calibration ratio
5. B
6. C
7. D

UNIT IV: PLANT GROWTH

Name____________________

Lesson 5: Fertilizer

Date_____________________

ASSESSMENT

Short-Answer Questions: Write the answers in the space provided.

1. What is the best method of applying fertilizer?

2. What are four reasons for having a fertilizer management plan?

   A.

   B.

   C.

   D.

3. What are three forms of fertilizer?

   A.

   B.

   C.

4. What three pieces of information are needed to calculate the appropriate amount of fertilizer? The information can be found on the fertilizer label.

   A.

   B.

   C.

Multiple Choice: Circle the letter of the best answer.

5. What is a N-P-K fertilizer?

   A. Incomplete
   B. Complete
   C. A macrofertilizer
   D. A microferilizer

6. What are two types of fertilizer?

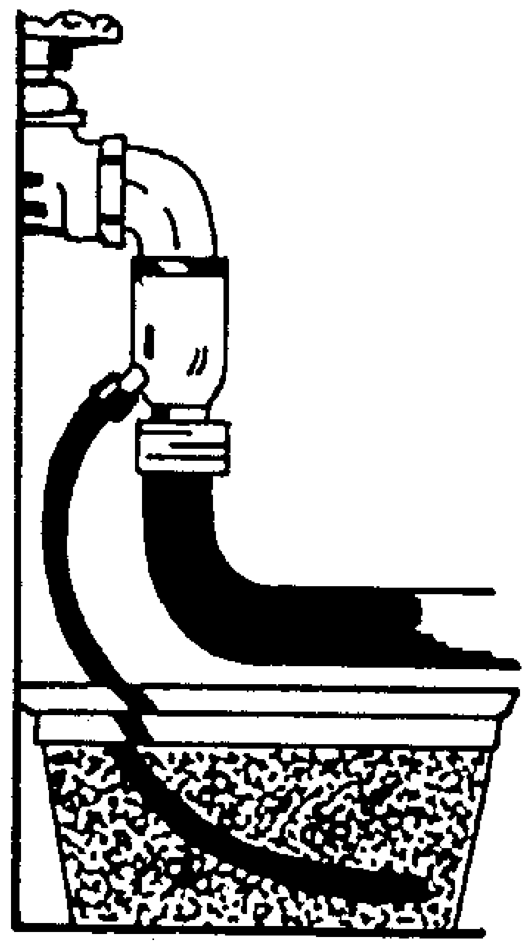
   A. Organic and macrofertilizer
   B. Inorganic and macrofertilizer
   C. Organic and inorganic
   D. Macrofertilizer and microfertilizer

7. What must be mixed with concentrated dry or liquid fertilizer at a specific ratio in order to provide the necessary nutrients to the greenhouse crop?

   A. Nitrogen
   B. Growing medium
   C. Phosphorous
   D. Water

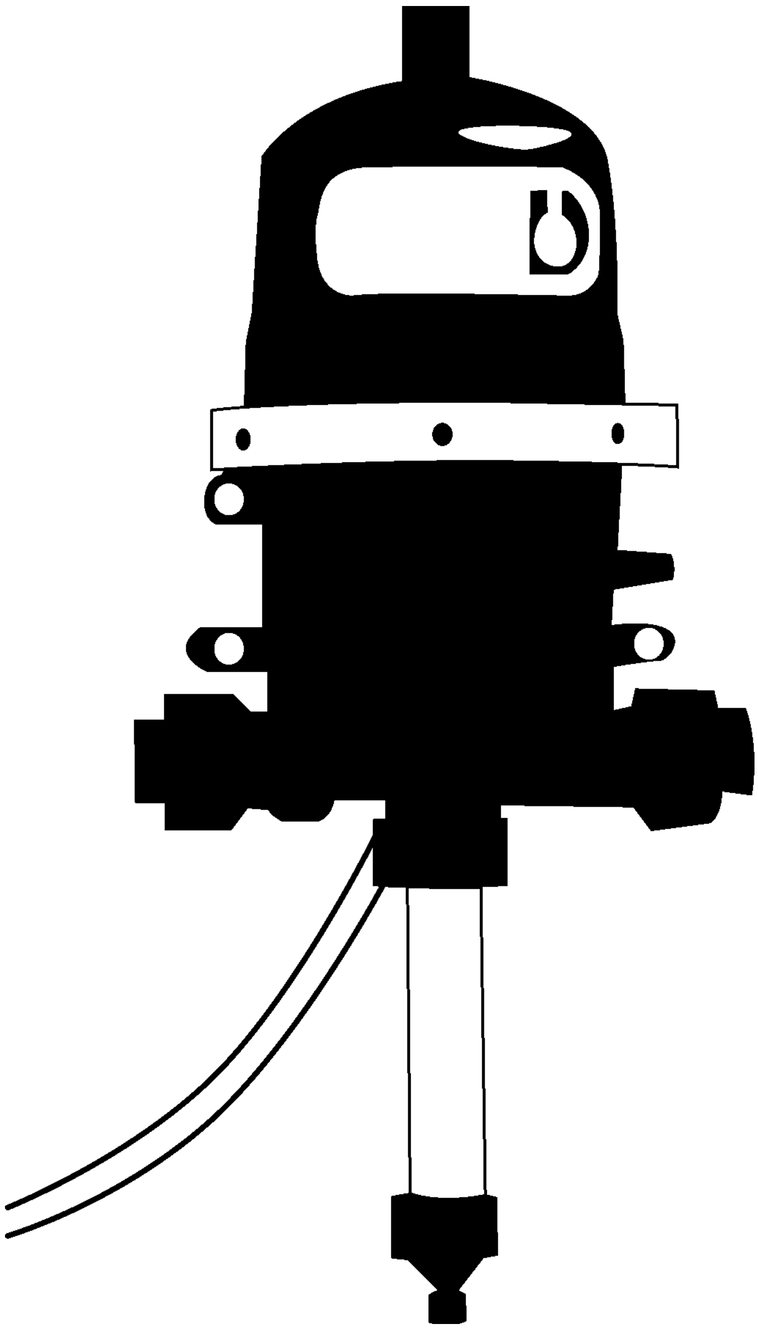
TM 4.12

Hose-Siphoning Device Used to Apply Fertilizer



TM 4.13

Dosmatic Injector



UNIT IV: PLANT GROWTH

AS 4.11

Lesson 5: Fertilizer

Name____________________

Healthy Plant

Objective: Identify the proper nutrients and fertilizer needed for different plants at each stage of its development.

Directions: Use textbooks, the Internet, university Extension publications, or other reference material to research the fertilizer needs of the three groups of plants (labeled Group G, H, and I) that you fertilized at the beginning of this unit.

1. Is a slow-release fertilizer better than a water-soluble concentrate or would a granular fertilizer be a better option? Observe how fertilizer affects the plants at three different stages of development: seedling/cutting, vegetative, and flowering and record your findings in the following table.

Group	**At Seeding/Cutting Stage**	**Vegetative Stage**	**Flowering Stage**
G			
H			
I			

2. Was organic or inorganic fertilizer used? Why? Record your response, including a justification for your selection, in the following table.

Group	Organic Fertilizer	Inorganic Fertilizer
G		
H		
I		

3. What is the appropriate fertilizer ratio for these plants? What fertilizer ingredients are these plants sensitive to?

Group	Fertilizer Ratio	Sensitivity to Specific Ingredients
G		
H		
I		

4. Do these plants require specific macronutrients and micronutrients? Are there macronutrients and micronutrients that these plants should not receive?

Group	Macronutrients		Micronutrients	
	Needed	*Should Not Receive*	*Needed*	*Should Not Receive*
G				
H				
I				

UNIT IV: PLANT GROWTH

AS 4.12

Lesson 5: Fertilizer

Name___________________

Calculating Fertilizer Dilution Ratios

Objective: Calculate the fertilizer dilution ratio.

Directions: To solve the following problems, use the ppm (parts per million) formula to calculate the fertilizer dilution ratio. Show all your work in the space provided.

The calibration ratio is the total number of gallons and fertilizer used to create a concentrated solution. Hint: If the calibration ratio is 17:1 then the total number of gallons is 18. Cross-multiply to solve for the number of ounces per gallon.

$$\frac{\text{desired ppm}}{75 \times \text{percent of active ingredient}} = \frac{\text{\# oz}}{\text{100 gallons water}}$$

To find the number of ounces of fertilizer per gallon of water, set up the following proportion:

$$\frac{\text{\# oz}}{\text{100 gallons of water}} = \frac{?}{\text{calibration ratio}}$$

1. Your poinsettias require extra nitrogen (N). The fertilizer is 15-16-17 with a calibration ratio of 13:1. How many ounces per 100 gallons of water yield a solution with 350 ppm N? How many ounces of 15-16-17 do you add to 1 gallon of concentrated solution?

2. Bedding plants require more nitrogen. The fertilizer lists 17-16-15 with a calibration ratio of 17:1. How many ounces per 100 gallons of water yield 150 ppm N in the solution? How many ounces of fertilizer give the appropriate 150 ppm concentration in 1 gallon of water?

3. The poinsettias are almost ready for sale and need just a little bit of extra nitrogen. The fertilizer is 20-20-20 with a calibration ratio of 12:1. How many ounces per 100 gallons of water yield a solution of 200 ppm N? If you only needed 1 gallon, how many ounces would be appropriate?

UNIT IV ACTIVITY

Plant Growth

Name___________________

Plant Portfolio

Objective: Create a portfolio that incorporates information learned in the five lessons in Unit IV.

Directions: Use information from completed activity sheets, photographs, sketches, university Extension publications, Internet, and other sources to create a portfolio of the plant you grew at the beginning of Unit I. Supply information as indicated below.

Basic Information

- Plant (common name and bionomial)
- Visual representation of the plant
- Origin of plant and classification
- Optional: a brief paragraph on the history of the plant.

Specific Greenhouse Needs

- How much light does it need?
- What is its photoperiod?
- How sensitive is it to temperature?
- How sensitive is it to air quality?
- What type of growing media is required?
- What type of container should it be planted in? What type of material is this container made of?
- How much water is needed?
- Is the plant susceptible to soluble salts or fluoride?
- What irrigation delivery system is preferred? Why?
- What soil pH delivers the appropriate nutrients?
- What nutrients are required and at what stage of development?
- What type of fertilizer should be used - organic or inorganic? Why?
- Is this plant a viable choice for a greenhouse crop? Why?
- If so, at what level: wholesale or retail?

GREENHOUSE OPERATION AND MANAGEMENT

Unit V: Plant Propagation

Lesson 1: Sexual Propagation

Competency/Objective:

Demonstrate the correct method for sexual propagation in the greenhouse environment.

Study Questions

1. **What is sexual propagation?**
2. **What are some basic considerations for sexual propagation?**
3. **What are the environmental conditions to germinate seeds?**
4. **What is dormancy and how is it overcome?**
5. **What are the basic stages of the germination process?**
6. **What are the steps for planting seeds?**
7. **How do monocots and dicots differ in germination?**
8. **How should seedlings be cared for after germination?**
9. **When and how are seedlings transplanted?**
10. **How should seedlings be cared for after transplanting?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 5.1 Steps in Seed Germination of a Monocot
   TM 5.2 Steps in Seed Germination of a Dicot

3. Activity Sheet

   AS 5.1 Transplanting a Seedling

4. Plug trays/seedling tray, growing media, 606 cell pack containers, plastic labels, small trowel, fork, or knife

TEACHING PROCEDURES

IMPORTANT NOTE: Each student needs to have a seedling for AS 5.1, as noted in Suggested Time Frame for Teaching (p. xxxv). Begin sowing fast-growing plants before teaching this lesson.

A. Introduction

   A brief review of Lesson 1 from Unit III on plant parts, structures, and functions might be a helpful refresher for students. This unit addresses plant propagation: sexual propagation in Lesson 1 and asexual propagation in Lesson 2.

B. Motivation

   Ask student if they observed any differences in their treatment of the seeds sown at the beginning of Unit I. How have various environmental factors - light, water, air, and temperature - affected the growth of the plants?

C. Assignment of Study Questions

D. Supervised Study

   Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

   Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

   1. What is sexual propagation?

   Using seeds to start new plants is referred to as sexual propagation.

   A. It is a method by which new plants are produced from seeds.
   B. Environmental conditions must be ideal for germination to occur.

2. What are some basic considerations for sexual propagation?

The quality of seeds and proper storage of seeds are important factors. The other two elements students should know well are containers and growing media.

A. Seed selection
   1. Select high-quality seeds that are free of the following:
      a. Disease and insects
      b. Broken seeds
      c. Weed or other seeds
   2. Hybrid seeds offer advantages but cost more.
      a. More resistant to disease
      b. Generally more vigorous; produce higher yield
B. Seed storage
   1. Keep seeds dry and cool.
   2. Store seeds in paper packets in sealed glass jars.
C. Containers
   1. Should be clean and sturdy
   2. Size and material according to type of seeding
      a. Direct seeding
      b. Indirect seeding
D. Growing media
   1. Clean, free of debris and disease
   2. Loose
   3. Fine texture
E. Legal considerations
   1. Federal law - the Plant Variety Protection (PVP) Act of 1970
      a. Encourages scientists and breeders to continue biotechnological experiments
      b. Provides plant breeders with exclusive marketing rights within the United States
      c. Grants a certificate of protection for 18 years; is analogous to a patent
      d. Contact information:
         Commissioner, Plant Variety Protection Office
         Agricultural Marketing Service
         National Agricultural Library Bldg., Room 0, 10301
         Baltimore Blvd., Beltsville, MD 20705-2351
   2. PVP amendments in 1994
      a. The amended PVP restricts how much seed a grower can save. The law states that the grower may save no more seed than the planting area can accommodate.
      b. The grower cannot sell saved seed if plans change.
   3. State law - Missouri Plant Law
      a. This requires all who sell, give away, or transport nursery stock in the state of Missouri to submit to inspection.
      b. The purpose of the inspection is for the state entomologist to examine the plants for insects and diseases.
      c. Fees for greenhouse inspections are based on the facility’s square foot area under glass.

d. Contact information:
State Entomologist
Missouri Department of Agriculture
P.O. Box 630
Jefferson City, MO 65102-0630
Phone: (573) 751-5507
Fax: (573) 751-0005

3. What are the environmental conditions to germinate seeds?

Ask the students to name four important environmental factors. As a hint, mention that they were covered in Unit IV. Why do they think these factors are vital to plant propagation?

A. Moisture
  1. Water absorption - first step in germination
  2. Growing medium
    a. Should be moist
    b. Misted with fine spray after seeds are sown
    c. Covered to retain moisture

B. Temperature
  1 Different seeds germinate at different temperatures.
    a. Warm weather crops
    b. Cool weather plant
  2. General range is 68-86°F.
  3. Soil temperature should remain constant.
  4. Heating elements can be used to warm soil.

C. Light
  1. Some seeds require light to germinate.
    a. Should be sown shallowly
    b. Should not be covered
    c. Example: lettuce
  2. Many seeds require no light to germinate. (In some cases, light may <u>inhibit</u> germination.)
    a. Should be sown more deeply
    b. May be placed in a dark area
    c. Example: geraniums

D. Air
  1. Germination is an aerobic process (requiring oxygen).
  2. Medium must be well aerated.

4. What is dormancy and how is it overcome?

Seeds wait for the ideal environmental conditions before germinating. This resting state is called dormancy. The length of dormancy varies among plants. For example, some varieties of maple have seeds whose dormancy period lasts only a few weeks, whereas some lotus plant seeds germinate after 2,000 years of dormancy. Some hard seeds need some coaxing to germinate. The three methods for overcoming dormancy are described here.

A. Dormancy
   1. Resting stage of seed
   2. Prevents seed from germinating until environmental conditions are ideal
B. Methods of overcoming dormancy
   1. Scarification of hard seed coatings
      a. Mechanical - rubbing with sandpaper or nicking a portion of seed coating
      b. Chemical - carefully soaking in sulfuric acid to soften seed coating
   2. Exposure to cold (stratification) for several weeks
   3. Exposure to heat to weaken seed coating

5. What are the basic stages of the germination process?

Four stages signal the germination of plants. Ask students to recall the emergence of their plants from the previous unit and the structures of plants learned in Unit III. What is the first phase?

A. Water absorption
B. Enzymatic breakdown
C. Production of new cells; formation of new tissue
D. Emergence of seedling

6. What are the steps for planting seeds?

Ask students to recount how they planted the seeds used for Unit IV and what if anything they would do differently.

A. Prepare growing medium
   1. Fill container up to 3/4 in. from the top with moistened germination mixture. Ensure that container has drainage holes.
   2. Level off and tap to settle.
   3. Make shallow holes or rows according to directions on seed packet.
B. Set seeds
   1. Place seeds in the holes or rows.
   2 Label with plant type, variety, and date of planting.
   3. Cover with dry medium (generally, with an amount twice the seeds' diameter).
C. Observe daily
   1. Watch for signs of too much or too little moisture.
   2. Watch for germination.

7. How do monocots and dicots differ in germination?

TMs 5.1 and 5.2 are good illustrations of the differences in monocot and dicot germination. Ask students what they notice while examining the images. What are the differences between the two types of plants?

A. Monocot (See TM 5.1.)
   1. Hypogeous germination (Cotyledon remains underground.)
   2. Stages
      a. Seed swells as moisture is absorbed.
      b. Seed coat ruptures.
      c. Radicle grows down.
      d. First internode and epicotyl grow up.
      e. After epicotyl emerges, new leaves form and food production starts.
      f. New root system grows just beneath the soil above the first internode.

B. Dicot (See TM 5.2.)
   1 Epigeous germination (Cotyledon emerges aboveground.)
   2. Stages
      a. Seed swells as moisture is absorbed.
      b. Seed coat splits.
      c. The radicle emerges and grows down.
      d. The hypocotyl elongates, forms an arch, and pulls the cotyledon upward.
      e. When the hypocotyl reaches light, elongation ceases, and the hypocotyl straightens up and pulls the cotyledons out of the soil.
      f. The cotyledons open, turn green, and provide food until the true leaves develop.
      g. The first true leaves unfold from the epicotyl, exposing the growth bud.
      h. The cotyledons die, dry up, and fall off.

8. How should seedlings be cared for after germination?

This question addresses fundamental concerns for the greenhouse operator: environment, irrigation, fertilization, and disease prevention.

A. Environment
   1. Remove cover once seeds have germinated.
   2. Move to area that receives bright light.
   3. Growing temperature is 10°F cooler than temperature for germination period.

B. Watering
   1. Keep moist but not soggy.
   2. Allow drying between watering but do not allow seedlings to wilt at any time.

C. Fertilizing
   1. Fertilize promptly and regularly with a complete fertilizer.
      a. 20-20-20 is usually appropriate.
      b. Apply 1/4 of the recommended strength a few days after germination.
   2. Too much fertilizer can damage seedlings.

D. Disease prevention and treatment
   1. Prevent disease.
      a. Use soilless mix or pasteurized medium and sterilized containers.
      b. Provide sufficient air circulation.
      c. Allow medium to dry out slightly between waterings.
   2. Treat diseases such as damping-off (a fungal disease that attacks at ground line).
      a. Limited infection - Dig out and discard infected plants and soil.

b. Widespread infection - Drench entire soil area with fungicide.

9. When and how are seedlings transplanted?

Seedlings are fragile. When transplanting the seedlings, timing, methods, and handling are vital to their survival. Have students complete AS 5.1.

A. Timing
   1. Seedlings can be transplanted after they develop the first set of true leaves.
   2. Do not delay transplanting.
      a. Health of the plant suffers.
      b. Seedlings become overcrowded and spindly.

B. Method
   1. Water seedlings.
   2. Carefully lift the small plants with a small trowel, fork, or knife.
      a. Leave some growing medium around roots.
      b. Do not allow roots to dry out.
   3. Fill container with moist growing medium.
   4. Make a hole in the medium.
   5. Insert seedlings slightly deeper than they were in the previous pot.
   6. Gently pat growing medium around base of seedling.
   7. Water the plant.

C. Handling
   1. Seedlings are fragile and must be handled gently.
   2. Handle by leaves, not stems.

10. How should seedlings be cared for after transplanting?

Ask students to consider what kinds of precautions a greenhouse owner should take to ensure successful transplanting of seedlings.

A. Keep in indoor environment.
B. Keep in shade or under fluorescent lighting for a few days.
C. Keep away from intense heat.

F. Other Activity and Strategy

Show the class a video available from CATER (Career & Technical Education Resources), 2 London Hall, University of Missouri-Columbia: *Plant Propagation*, Volume I (AG V46),

G. Conclusion

There are proper procedures and methods involved in sexual propagation. Germinating seeds is affected by several factors and the process varies with monocots and dicots. Caring for seedlings is crucial after germination and transplanting.

H. Answers to Activity Sheet

Instructor's discretion

I. Answers to Assessment

1. D
2. A
3. D
4. A. Resistant to disease
   B. Produce higher yield.
5. Germination in dicot plants wherein the cotyledon grows aboveground.
6. Plants produced from seeds
7. A. Environment
   B. Water
   C. Fertilizer
   D. Disease prevention and treatment
8. After developing the first set of true leaves
9. A. Keep indoors
   B. Keep in shade or under fluorescent lighting
   C. Keep away from intense heat
10. A. Prepare the growing medium
    B. Set the seeds
    C. Watch daily
11. To ensure nursery stock is without insect and disease infestations.

UNIT V: PLANT PROPAGATION

Name____________________

Lesson 1: Sexual Propagation

Date____________________

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. What is the second stage in germination?

   A. Emergence of seedling
   B. Absorption of water
   C. Production of new cells
   D. Enzymatic breakdown

2. What are temperature, water, air, and light?

   A. Environmental factors in germination
   B. Consideration for sexual propagation
   C. Factors in timing of transplantation
   D. Methods to overcome dormancy

3. What are three methods to overcome dormancy?

   A. Chemical, mechanical, and aerbic process
   B. Mechanical, heat, and enzymatic breakdown
   C. Stratification, scarification, and water absorption
   D. Heat, stratification, and scarification

Short-Answer Questions: Write the answers in the space provided.

4. What are two advantages of using hybrid seeds?

   A.

   B.

5. What is epigeous germination?

6. What is sexual propagation?

7. What are four factors to observe in caring for seedlings after germination?

   A.

   B.

   C.

   D.

8. When can seedlings be transplanted?

9. What are three ways to care for seedlings after transplanting?

   A.

   B.

   C.

10. What are three steps in planting seeds?

    A.

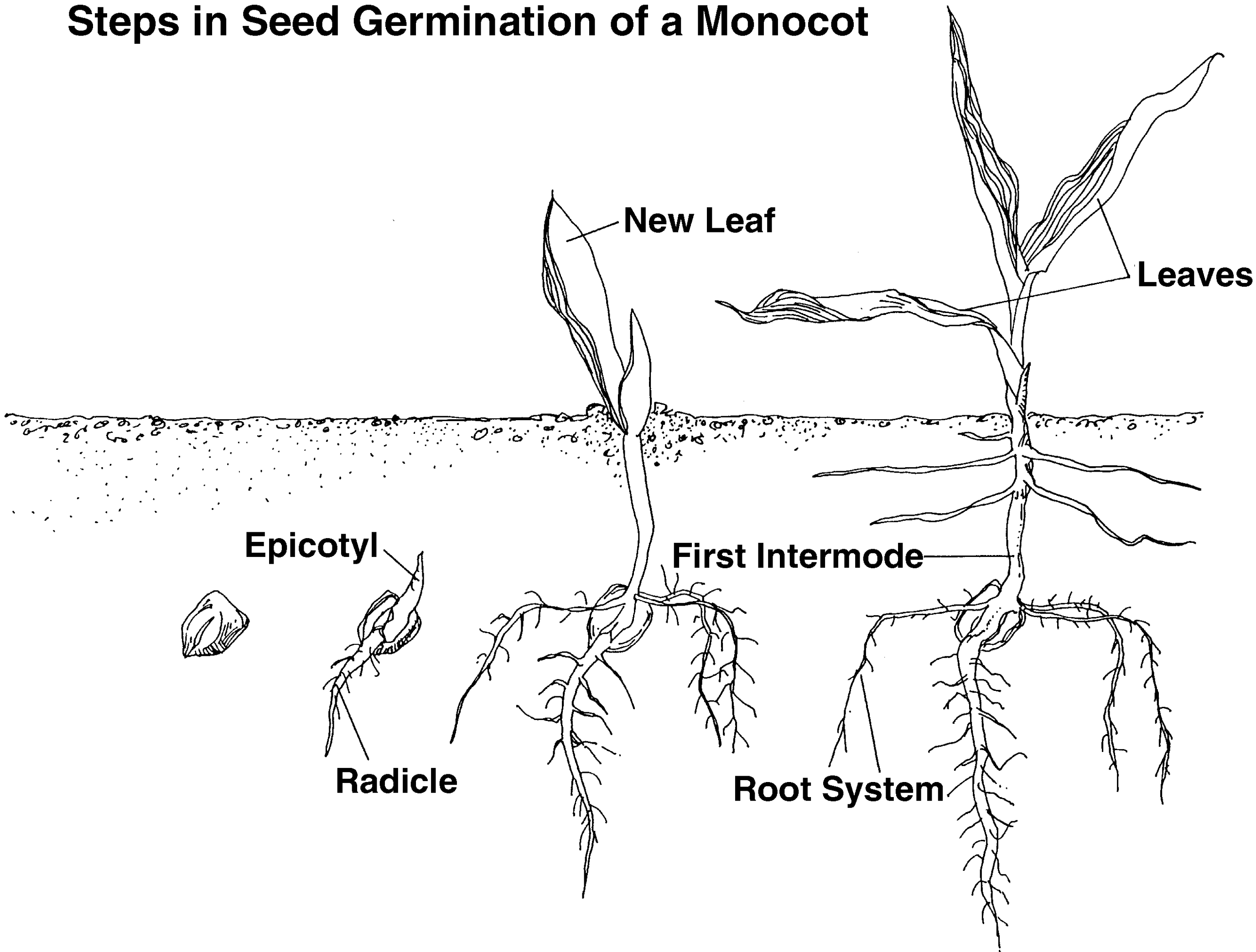
    B.

    C.

11. What is the purpose of the Missouri Plant Law?

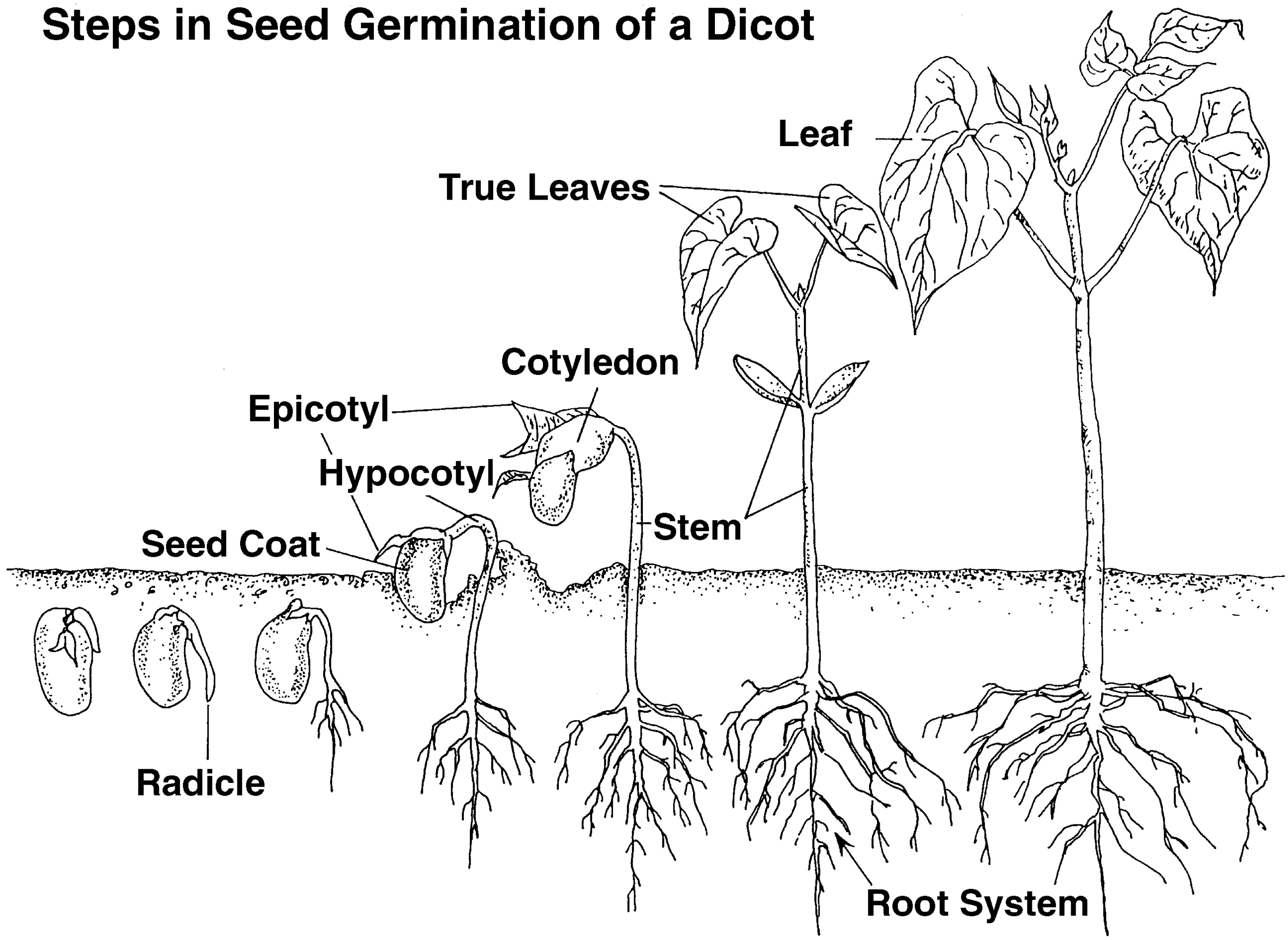
TM 5.1

Steps in Seed Germination of a Monocot



TM 5.2

Steps in Seed Germination of a Dicot



UNIT V: PLANT PROPAGATION

AS 5.1

Lesson 1: Sexual Propagation

Name____________________

Transplanting a Seedling

Objective: Demonstrate proper procedures in transplanting a seedling.

Directions: Transplant a seedling. Record all the steps involved. Identify the type of seedling by recording its binomial nomenclature and common name. Record the date the plants were transplanted and note the seedling's progress.

Materials

Growing medium
Pen and paper
Plastic labels
Plug trays/seedling tray
606 cell pack
Small trowel, fork, or knife
Water

Procedures

1. Water seedling.
2. Carefully lift seedling with small trowel, fork, or knife.
3. Fill plant container with moist growing medium.
4. Insert a hole in the growing medium.
5. Insert seedling slightly deeper than it was in previous pot.
6. Pat growing medium around base of seedling.
7. Water seedling.

GREENHOUSE OPERATION AND MANAGEMENT

Unit V: Plant Propagation

Lesson 2: Asexual Propagation

Competency/Objective:

Differentiate between various types of asexual propagation procedures.

Study Questions

1. **What is asexual propagation?**
2. **What are general considerations for asexual propagation?**
3. **How are plants propagated by budding?**
4. **How are plants propagated by cuttings?**
5. **How are plants propagated by division?**
6. **How are plants propagated by grafting?**
7. **How are plants propagated by layering?**
8. **How are plants propagated by tissue culture?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 5.3 Cutting Locations
   TM 5.4 Cuttings
   TM 5.5 Division
   TM 5.6 Grafting
   TM 5.7 Layering

3. Activity Sheets

   AS 5.2 Asexual Propagation

AS 5.3 Budding and Tissue Culture

TEACHING PROCEDURES

A. Review

This lesson continues to discuss propagation by describing six alternative methods of propagation. The content of Lesson 2 reinforces students' knowledge of plants because these techniques rely upon an understanding of which plant parts are cut and why.

B. Motivation

Ask students to justify why a greenhouse grower would want to use propagation methods that did not rely on using seeds. What are the advantages?

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What is asexual propagation?

Asexual propagation is plant reproduction without seeds. In other words, asexual propagation uses parts of one plant to create another. It is faster than sexual propagation and because the new plant is a clone, the characteristics of the new plant are the same as the parent or original plant.

A. Asexual propagation uses leaves, stems, or roots of a parent plant to reproduce a new plant.
B. It is a popular means of reproducing plants.
   1. Faster than sexual propagation
   2. Produces characteristics identical to parent plant (cloning)

2. What are general considerations for asexual propagation?

Tools, sanitation, greenhouse environment, and proper labeling are examined. Ask students why they think sanitation is a bigger factor in asexual propagation than in sexual propagation.

A. Tools
   1. Sharp knife
      a. To cut parts from plants
      b. To divide plants
      c. To make wounds in plant materials
   2. Dibble (stick) to make holes in growing medium
   3. Duster to apply rooting compound
B. Sanitation
   1. Keep tools clean and sterile.
      a. Disinfect before use.
      b. Disinfect knives after each cutting.
   2. Place cuttings in sterile container until planted.
   3. Sterilize rooting solution after each use.
   4. Discard any excess plant debris.
C. Growing medium
D. Lighting
E. Temperature
F. Labeling
   1. Labels enable grower to keep track of all plants.
   2. Labels should contain detailed information.
      a. Plant's name and variety
      b. Date propagated
      c. Any special treatment
G. Legal issues
   1. Federal law - Plant Patent Act of 1930
      a. This law covers asexually reproduced plants except for tubers.
      b. It precludes others from asexually propagating or selling the plant without prior permission from the patent holder.
      c. Licensing agreements allow growers to grow and sell the specified variety.
      d. Patent expires after 20 years.
      e. Amendments to the Plant Patent Act were passed in 1998.
         i. Explicitly protects the owner of a plant patent against unauthorized sale of plant parts that would be used to propagate the plant
         ii. Expands protections on par with those for sexually propagated plants covered by the Plant Variety Protection Act
      f. Contact information:
         Assistant Commissioner for Patents, Washington, DC 20231
   2. State law - Missouri Plant Law
      a. This law requires all in the state of Missouri who sell, give away, or transport nursery stock (woody stem plants, perennials, bulbs, roots, crowns, corms, rhizomes, and tubers) to submit to inspection.
      b. The purpose of the inspection is for the state entomologist to examine the plants for insects and diseases.
      c. Inspections occur twice a year.
      d. Fees for greenhouse inspections are based on the facility's square foot area under glass.

   e. Contact information:
      State Entomologist
      Missouri Department of Agriculture
      P. O. Box 630
      Jefferson City, MO 65102-0630
      Phone: (573) 751-5507
      Fax: (573) 751-0005

3. How are plants propagated by budding?

As one of the techniques of asexual propagation, budding is a specialized form of grafting (discussed below).

A. A single bud from one plant is inserted into the bark or another variety.
B. It is similar to grafting but uses only a single bud as the scion.
C. A commercial plant propagator usually performs specialized grafting techniques.

4. How are plants propagated by cuttings?

Cuttings taken from the stem or leaves of a parent plant are used in this form of propagation. See TMs 5.3 and 5.4.

A. Cuttings of parent plant rooted to form new plants
B. Types of cuttings
   1. Stem cuttings
      a. Taken from section or tip of stem
      b. Softwood, herbaceous, semihardwood, hardwood, conifer
   2. Leaf cuttings
      a. Piece or entire leaf
      b. Leaf vein
      c. Leaf bud
   3. Stem cuttings
C. Steps
   1. Begin with clean cutting tools, containers, and growing medium.
   2. Make cuts according to the type of cutting used.
   3. Treat base of cutting with a rooting hormone.
   4. Plant the cutting in moist soilless growing medium.
   5. Place in high-humidity environment to reduce moisture loss.
      a. Enclosed in a plastic bag
      b. On misting bench
   6. Provide appropriate amounts of sunlight.
   7. Keep temperature between 65 and 75°F.
D. Root growth can be encouraged with rooting hormones.
   1. Purpose
      a. Increases percentage of cuttings that root
      b. Helps plants root more quickly and uniformly

    c. Stimulates formation of more vigorous roots
  2. Methods of application
    a. Dust with rooting powder.
      i. Apply small amount to base of cutting.
      ii. Excessive amounts can cause stem to rot.
    b. Dip or spray hormone solutions. Dip base of cutting into solution for short period of time.
    c. Be aware that pathogenic organisms can be spread from diseased cuttings to healthy cuttings via the solution. Discard any leftover solution after dipping.

5. How are plants propagated by division?

The term "division" refers to splitting plant parts to grow new plants. Corms, bulbs, rhizomes, tubers, and crowns are excellent examples of division. If possible, bring in one of the above to show the class. (See TM 5.5.)

A. Division is the separation of clumps of a plant into small groups, each having roots, stems, buds, and leaves or the potential to develop these parts.
B. Division is a natural means of reproducing for some plants (e.g., tulips, daffodils).

6. How are plants propagated by grafting?

This procedure involves melding two different plants together. It is most often used for trees and roses. (See TM 5.6.)

A. Buds, twigs, or shoots (known as scions) are taken from one plant and inserted into the stems or roots of a similar plant (known as the rootstock), matching cambiums in the process.
B. There are two types of grafting.
  1. Whip (or tongue) grafts join small scion to similar sized rootstock.
  2. Cleft and bark grafts join small scion to large rootstock.
C. Grafting is used most often for trees and roses.

7. How are plants propagated by layering?

Layering is a method of propagating that does not split the new plant from the parent until the roots are established. There are six different types of layering. Two of these types are illustrated in TM 5.7. After students have investigated all of the propagation methods (except tissue culture), have them complete AS 5.2.

A. Layering is the process of establishing new roots on the stem while the stem remains attached to the parent plant.
B. Layering is a technique commonly used to propagate many houseplants.
C. It involves wounding a piece of plant stem and burying it.
D. There are several types of layering.
  1. Simple: A portion of the stem is wounded, treated, and buried; the tip is left exposed.
  2. Air: A portion of the stem is removed and rooting is induced at the wounded area.

3. Tip: Terminal tip is wounded, treated, and buried.
4. Serpentine or compound: Stem is covered and exposed.
5. Mound: Stem is cut back and buried while dormant.
6. Trench: Entire plant, except for tip, is bent and buried.

8. How are plants propagated by tissue culture?

This is a technical way of cloning plants by using very little plant material but very specific and sterile conditions. Orchids and lilies are two crops grown in this manner. Have students complete AS 5.3.

A. Also referred to as micropropagation
B. Highly technical method
   1. Use one or more cells from the tissue of a plant to produce a new plant.
   2. Pieces of plants are grown in sterile conditions in artificial media.
   3. This allows mass production of plants in a short period of time.

F. Other Activity and Strategy

Show the class videos from CATER (Career & Technical Education Resources), 2 London Hall, University of Missouri-Columbia: *Plant Propagation* (AG V47) and *Plant Tissue Culture Part II* (AG V170).

G. Conclusion

Asexual propagation involves several methods and procedures. Each technique provides various alternatives for reproducing plants.

H. Answers to Activity Sheets

AS 5.2 Asexual Propagation

Instructor's discretion

AS 5.3 Budding and Tissue Culture

Instructor's discretion

I. Answers to Assessment

1. E
2. D
3. F
4. B
5. A
6. C

7. A. Quicker method of propagation
   B. Produces characteristics identical to parent plant
8. A. Simple: Portion of stem is wounded, treated, and buried
   B. Air: Portion of stem is removed and rooting is induced at wound
   C. Tip: Tip is wounded, treated, and buried.
   D. Serpentine or compound: Stem is covered and exposed in several places.
   E. Mound: Stem is cut back and buried when dormant.
   F. Trench: Entire plant except for tip is bent and buried.
9. Joins scion to a larger rootstock
10. Students may list any two of the following:
    A. Use one or more cells to produce new plant.
    B. Grow in sterile conditions in artificial media.
    C. Mass production in short period of time.
11. Budding is a form of grafting that uses only buds as a scion.
12. Students may list any four of the following:
    A. Sharp knife
    B. Dibble stick
    C. Sterile equipment
    D. Proper growing medium
    E. Duster
    F. Labels
13. Root hormone
14. Tubers
15. Based on square feet under glass in the greenhouse

UNIT V: PLANT PROPAGATION

Name____________________

Lesson 2: Asexual Propagation

Date_____________________

ASSESSMENT

Match the statement on the left with the propagation method on the right. Write the letter in the space provided.

___1.	Bury pieces of plant while still attached to parent plant	A.	Tissue culture
___2.	Attaching a piece of one plant to another	B.	Budding
___3.	Planting a piece of stem or leaf	C.	Division
___4.	Attaching a bud to another plant	D.	Grafting
___5.	Growing plants from cells	E.	Layering
___6.	Separating plant parts	F.	Cutting

Short-Answer Questions: Write the answers in the space provided.

7. What are two advantages to asexual propagation?

   A.

   B.

8. What are six types of layering? Describe two of them.

   A.

   B.

   C.

   D.

   E.

   F.

9. What is a cleft and bark graft?

10. What are two features of micropropagation?

    A.

    B.

11. What is the difference between budding and grafting?

12. What are four tools a greenhouse owner needs to asexually propagate plants?

    A.

    B.

    C.

    D.

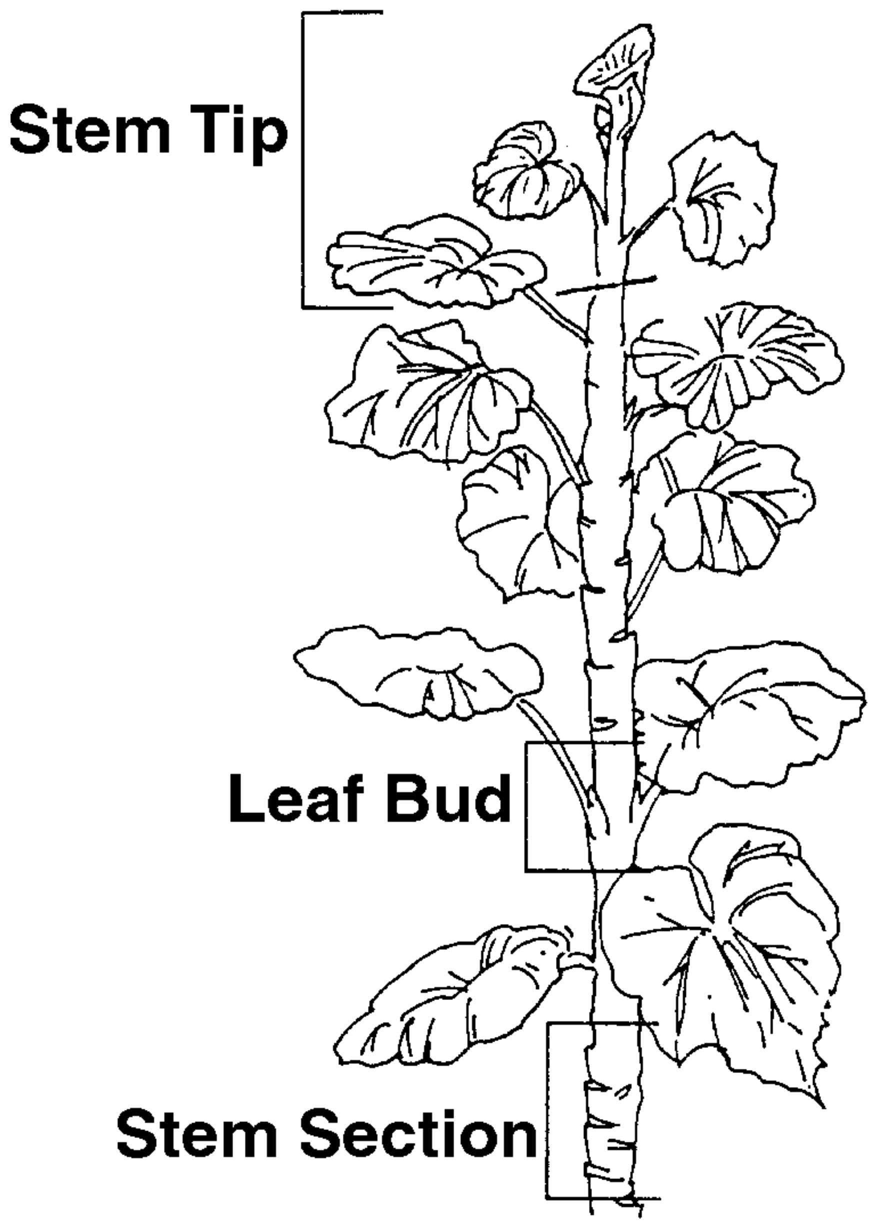
13. How is root growth encouraged when using cuttings?

14. What type of asexually reproduced plant is **not** covered by the Plant Patent Act?

15. How is the inspection fee for greenhouses determined under the Missouri Plant Law?

TM 5.3

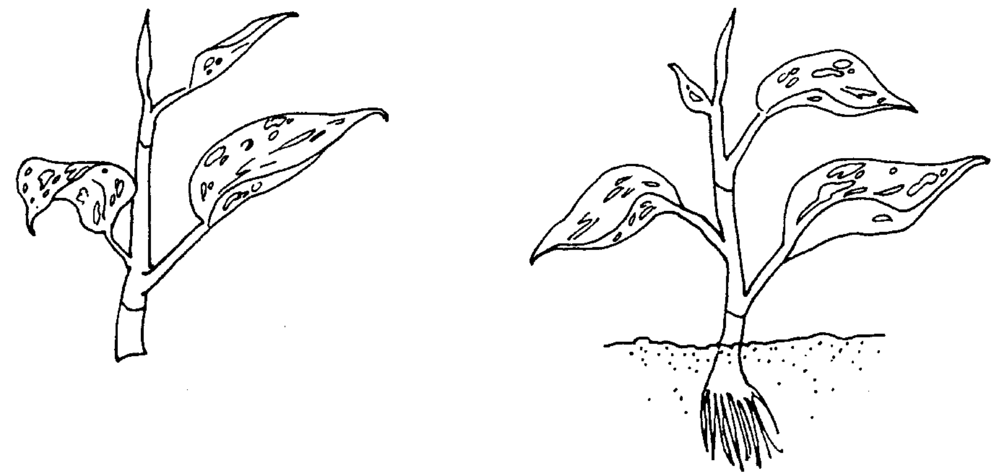
Cutting Locations



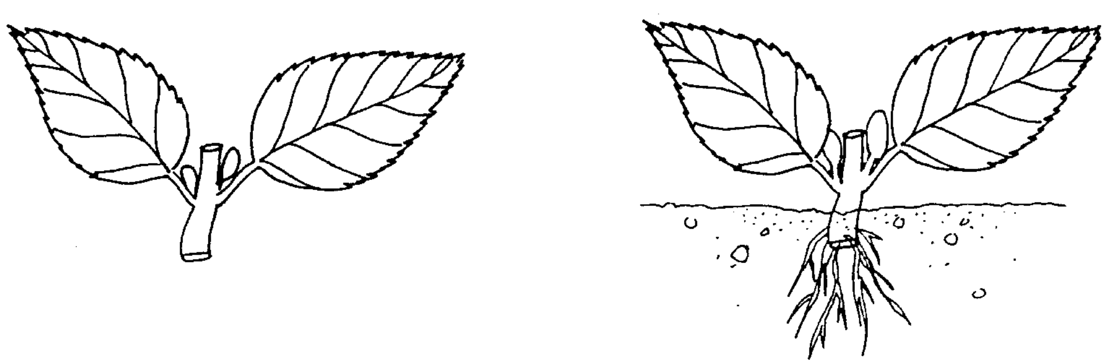
TM 5.4

Cuttings

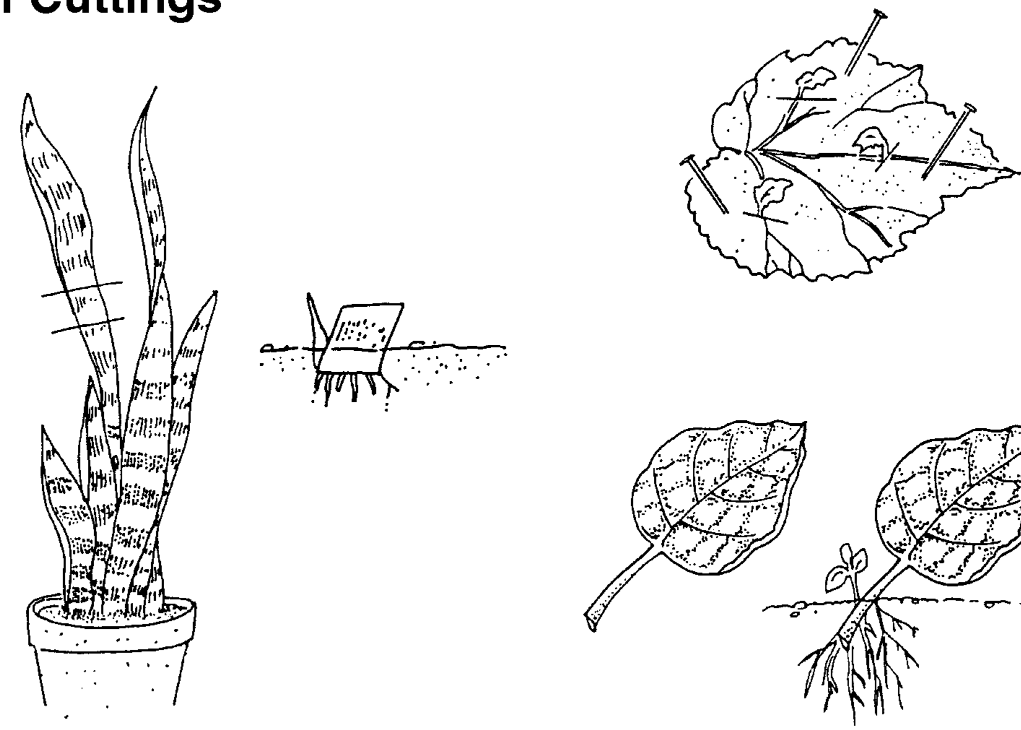
Stem Tip Cutting



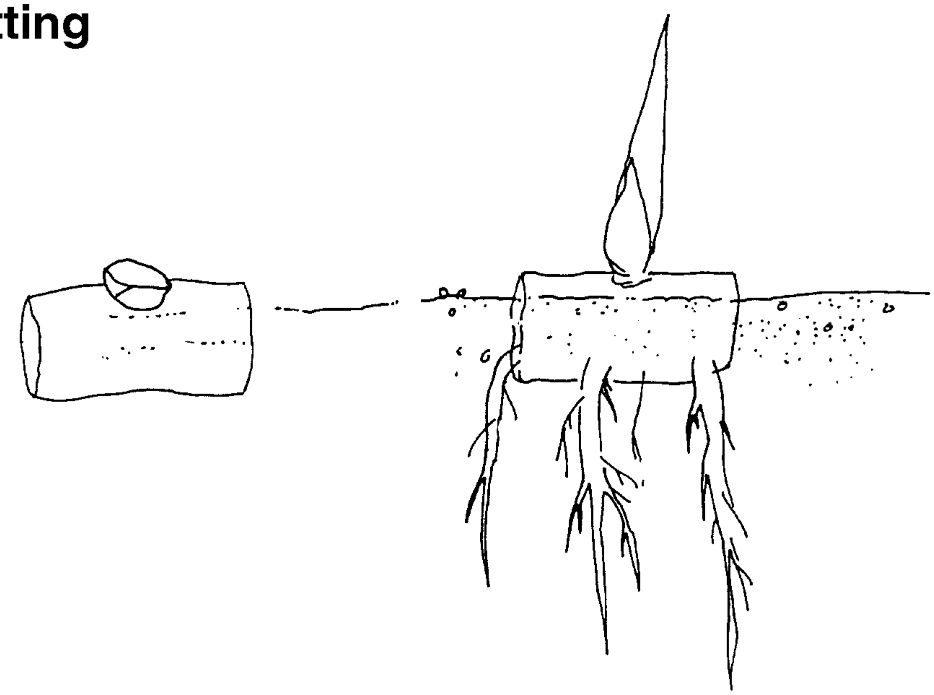
Leaf and Bud Cutting



Leaf Cuttings

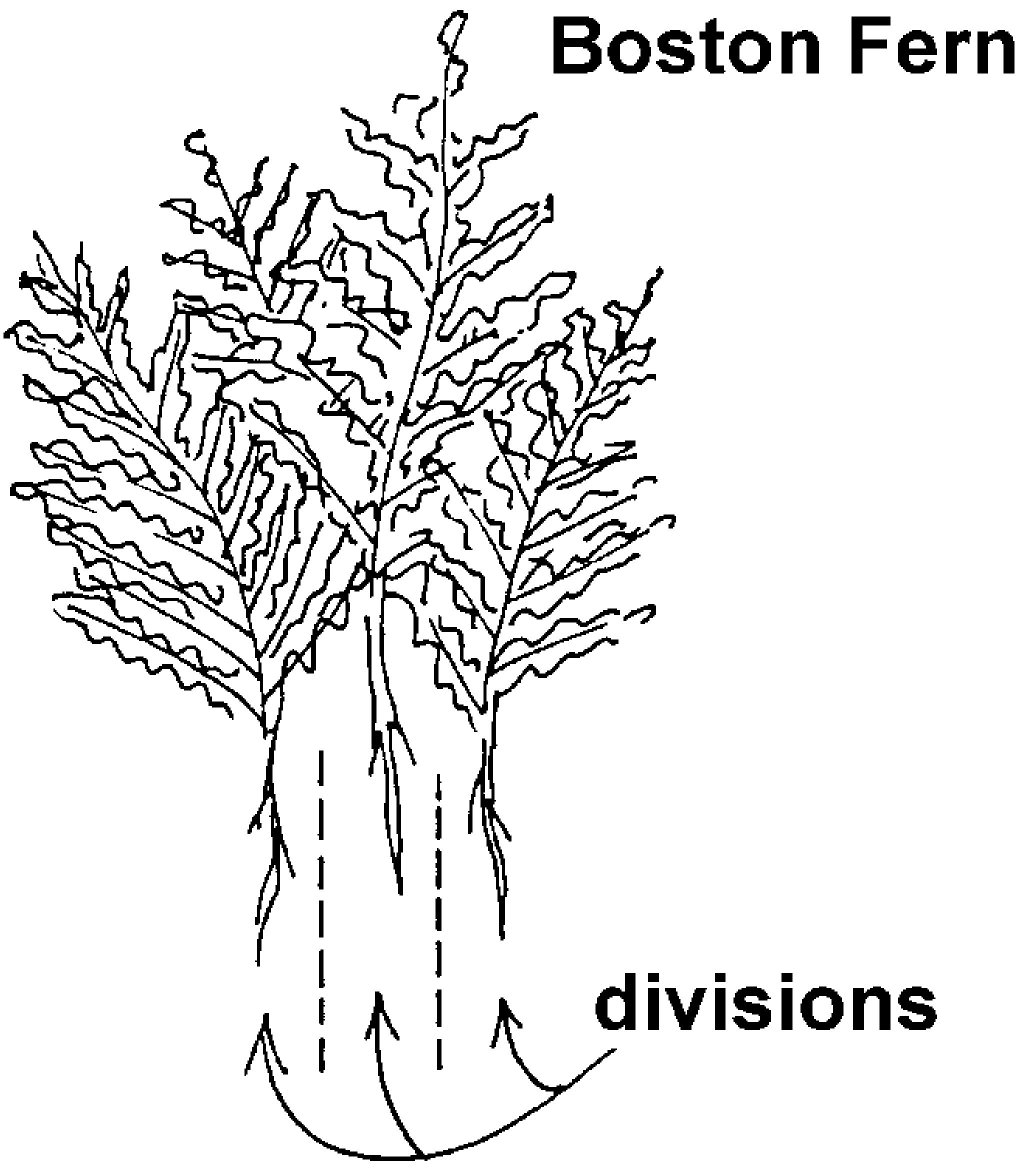


Stem Cutting



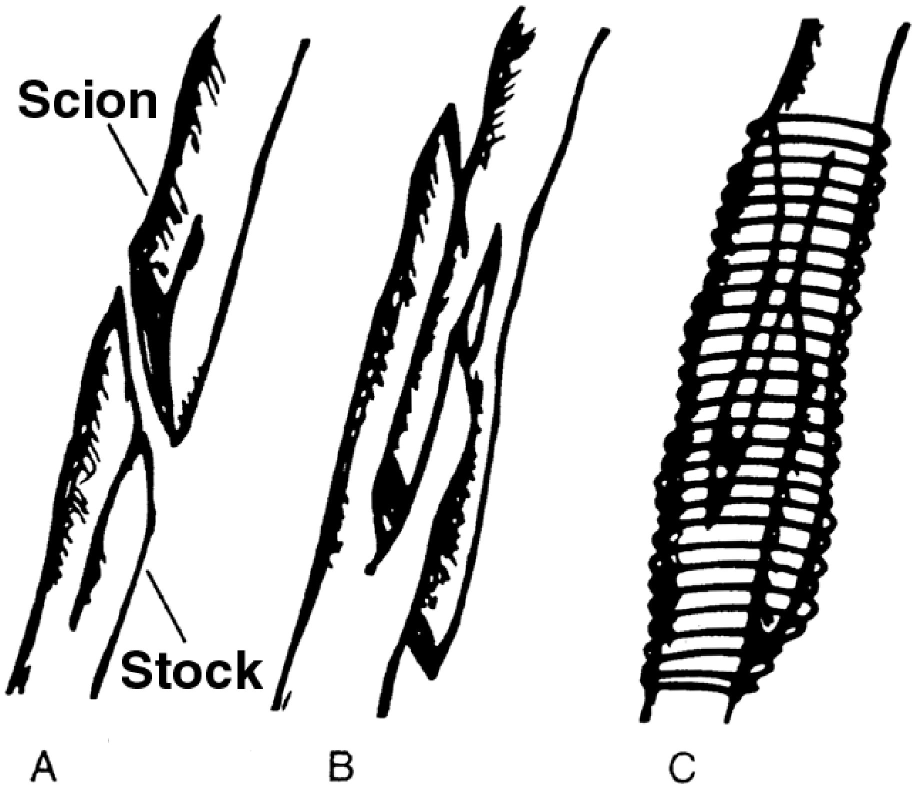
TM 5.5

Division



TM 5.6

Grafting



A - Stock and scion are prepared.

B - The two parts are unified.

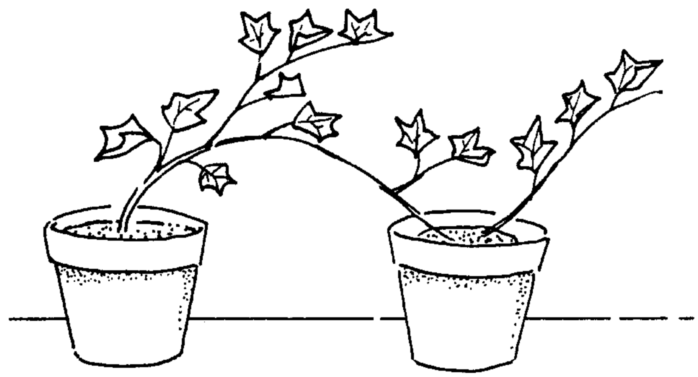
C. - The graft is wrapped with waxed string.

Adapted from Boodley, James W. *The Commercial Greenhouse*, 2nd ed. Albany, NY: Delmar Publishers, 1996.

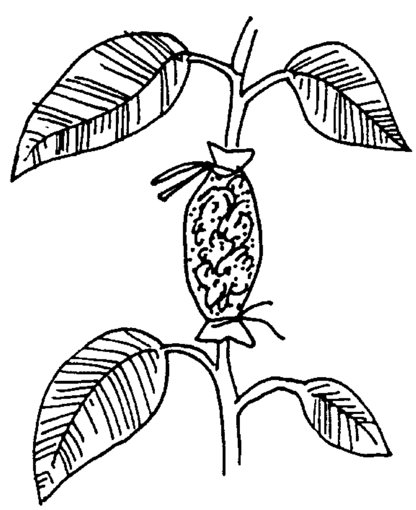
TM 5.7

Layering

Simple Layering



Air Layering



UNIT V: PLANT PROPAGATION

AS 5.2

Lesson 2: Asexual Propagation

Name__________________

Asexual Propagation

Objective: Demonstrate a method of asexual propagation.

Directions: Select a plant to propagate. Gather the growing medium, root hormone, a bulb duster, sharp knives, and dibble sticks. Label the plant and the method of propagation.

1. What is the common name of the plant?

2. What is its binomial nomenclature?

3. What is the preferred method of propagation for this plant?

4. What method of asexual propagation did you use?

5. What are the steps involved?

6. How long does it take for the plant to propagate?

UNIT V: PLANT PROPAGATION

AS 5.3

Lesson 2: Asexual Propagation

Name__________________

Budding and Tissue Culture

Objective: Differentiate between budding and tissue culture.

Directions: Answer the following questions about budding and tissue culture.

1. What is budding?

2. What steps are involved?

3. Budding is used on what type of plants? List at least three plants and give both the common name and binomial nomenclature.

Common Name	Binomial Nomenclature
A.	A.
B.	B.
C.	C.

4. Is this the only method applicable for this plant?

5. How cost-effective is it?

6. What is tissue culture?

7. What steps are involved?

8. What equipment is needed?

9. Any there other special considerations or needs for this method of propagation?

10. Tissue culture is used on what type of plants? List at least three plants and give both the common name and binomial nomenclature.

Common Name	Binomial Nomenclature
A.	A.
B.	B.
C.	C.

11. Is this the only method used for this plant?

12. How cost-effective is it?

13. What equipment is needed?

14. Does this method of propagation require any other special considerations or needs?

GREENHOUSE MANAGEMENT AND OPERATION

Unit VI: Plant Health

Lesson 1: Greenhouse Pests and Diseases

Competency/Objective:

Identify pests and diseases in the greenhouse and factors that contribute to their presence.

Study Questions

1. **What is a pest?**

2. **What are the most common insect and arachnid pests?**

3. **How do other pests affect greenhouse crops?**

4. **How do diseases affect greenhouse plants?**

5. **What are the most common diseases that affect greenhouse plants?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 6.1 Types of Mouth Parts
   TM 6.2 Gradual Metamorphosis
   TM 6.3 Complete Metamorphosis
   TM 6.4 Aphid
   TM 6.5 Fungus Gnat
   TM 6.6 Mealybug
   TM 6.7 Scale
   TM 6.8 Thrips
   TM 6.9 Whitefly
   TM 6.10 Spider Mites
   TM 6.11 Other Pests

3. Activity Sheets

   AS 6.1 Path of Destruction Part I: Insects and Arachnids
   AS 6.2 Path of Destruction Part II: Other Pests and Diseases

4. Entomology Identification Slides, University of Missouri-Columbia: Instructional Materials Laboratory, 1996 (catalog number 10-6110-X).

5. "Greenhouse Crop Pests and Their Natural Enemies." (Slides and Script). Ohio, 1992. Available from University of Missouri-Columbia: Instructional Materials Laboratory (catalog number 10-6290-X).

6. "Pest Management and Identification." University of California-Davis. <http://www.ipm.ucdavis.edu/PMG/crops-agriculture.html>

7. UC IPM Online. <http://www.ipm.ucdavis.edu/>

TEACHING PROCEDURES

A. Introduction

A greenhouse is an artificial environment constructed to maximize prolific and speedy growth of plants. The optimal conditions of a greenhouse also attract unwanted living organisms that can devastate a crop. This unit describes types of pests, methods of control, and pesticide use and safety. Lesson 1 introduces students to the most prevalent pests and diseases that may inhabit a greenhouse.

B. Motivation

Ask students why greenhouses can be susceptible to pests and diseases. Challenge the class to defend why greenhouse owners should be able to identify various pests and diseases. Have students describe the types of pests that have ruined their own garden or crops.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study question.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What is a pest?

A pest is generally defined as a living organism that encroaches on the health and survival of another living thing, greenhouse crops in this instance. There are the seven types of interlopers most common in greenhouses.

A. A pest can be defined as anything (usually a living organism) that causes plant injury or loss.
B. The seven major pests are as follows.
   1. Insects
   2. Arachnids (mites, spiders, millipedes, centipedes)
   3. Nematodes
   4. Rodents and other mammals
   5. Mollusks
   6. Weeds
   7. Disease

2. What are the most common insect and arachnid pests?

Aphids, fungus gnats, mealybugs, scale, thrips, whiteflies, and mites are the most common pests. The pests' physical characteristics indicate the part of the plant the pest prefers and the type of damage it causes. These characteristics also help students identify the pest. Have students complete AS 6.1.

A. May attack various plant parts (e.g., vascular system, leaves, roots)
   1. Interfere with plant function
   2. Reduce rate of development
B. Characteristics (See TM 6.1.)
   1. Knowing the types of mouth parts helps identify the pest.
      a. Chewing
      b. Piercing-sucking
      c. Rasping-lapping
   2. Identifying the life cycle helps the greenhouse owner know when to prevent or treat plants from invasion.
      a. Gradual metamorphosis (See TM 6.2.)
      b. Complete metamorphosis (See TM 6.3.)
      c. No metamorphosis
C. Aphids (See TM 6.4.)
   1. Green peach aphids - common greenhouse pest
   2. Spread bacteria and viral disease
   3. Insect - characteristics
      a. Adult size: 1/25 -1/8 in. (1-3 mm)
      b. Piercing-sucking mouth parts
   4. Plant symptoms
      a. New shoots stunted and distorted
      b. Tiny yellow spots on foliage
      c. Honeydew - food source for black sooty mold

D. Fungus gnats (See TM 6.5.)
   1. Larvae, not adults, inflicting damage to plants
   2. Can be confused with shore flies
   3. Insect characteristics
      a. Larvae size: 1/4 in. (6 mm); adult size: 1/8 in. (3 mm)
      b. Larvae - chewing mouth parts
   4. Plant symptoms
      a. Stunted growth, lack of vigor
      b. Wilted leaves
      c. Leaf drop
      d. Yellow foliage
E. Mealybugs (See TM 6.6.)
   1. Insect - characteristics
      a. Adult size: 1/8-3/8 in. (3-4 mm)
      b. Piercing-sucking mouth parts
   2. Plant symptoms
      a. Loss of vigor
      b. Yellow, deformed foliage
      c. Leaf drop
      d. Give off honeydew
F. Scale (See TM 6.7.)
   1. Insect - characteristics
      a. Adult size: 5/16 in. (8 mm)
      b. Piercing-sucking mouth parts
      c. Round, hard shell with waxy, rubbery coating
   2. Plant symptoms
      a. Lack of vigor; stunted growth
      b. Yellowing leaves
      c. Leaf drop
      d. Give off honeydew
G. Thrips (See TM 6.8.)
   1. Spread disease among plants
   2. Insect - characteristics
      a. Adult size: 1/25 in. (1 mm)
      b. Rasping-lapping mouth parts
   3. Plant symptoms
      a. Malformed new growth and flowers
      b. Streaking and browning of flower petals
      c. Leaf and flower drop
H. Whiteflies (See TM 6.9.)
   1. Spread disease among plants
   2. Insect - characteristics
      a. Adult size: 1/16 in. (2 mm)
      b. Piercing-sucking mouth parts
   3. Plant symptom: tiny yellow spots on foliage called honeydew
I. Mites (See TM 6.10.)

1. Difficult to control
2. Cause severe economic damage
3. Arachnid - characteristics
   a. Less than 1/50 in. long (0.50 mm)
   b. Piercing-sucking mouth parts
4. Plant symptoms
   a. Tiny, yellow spots/bronze-colored foliage
   b. Curled leaves
   c. Tiny webs that brown leaves (spider mites)

3. How do other pests affect greenhouse crops?

Insects and arachnids are not the only pests that attack greenhouse crops. Invertebrates like nematodes, snails, and slugs, mammals such as rodents and birds, as well as weeds may also attack plants. Ask students to predict the type of damage these pests might inflict. See TM 6.11. Have students complete AS 6.2.

A. Nematodes
   1. Wormlike invertebrates
   2. Plant parasite that lives in soil
   3. Usually harmless to plants but may penetrate root cells, giving fungi and bacteria an opportunity to enter
B. Rodents, birds, and other animals
   1. May eat plant parts
   2. May dig up soil
C. Snails and slugs
   1. Nocturnal
   2. Feed on leaves and young stems, leaving slimy trail behind
D. Weeds (defined as any unwanted plant growing out of place)
   1. Create competition with cultivated plants for space, light, water, and nutrients
   2. May harbor pests and disease that can spread to cultivated plants

4. How do diseases affect greenhouse plants?

Diseases in greenhouses can be separated into two varieties: those with cultural causes and those with parasitic causes. Ask the students to differentiate between viruses, bacteria, and fungi. How are these diseases spread?

A. Types of disease
   1. Cultural - caused by chemicals, nutrient deficiencies, damage to plant parts, and inadequate environmental conditions
   2. Parasitic - caused by microorganisms
B. Organisms that cause disease
   1. Viruses
      a. Most difficult type of disease to control and treat
      b. May cause stunted growth or death

c. Usually attack plants' vascular system
d. Spread by equipment, sucking insects, asexual propagation
2. Bacteria - entering plant through openings in plant epidermis
3. Fungi
a. Most common source of plant disease
b. Fungal spore growth on and in plants
c. Spread via air, insects, and water
C. Sources of disease
1. Infected soil
2. Debris from previous crops
3. Water
4. Air
5. Plant tissue from cuttings and other plants

5. What are the most common diseases that affect greenhouse plants?

Seedlings, foliage, and roots are the parts of plants that are the most vulnerable to common greenhouse diseases. Greenhouse owners must be attentive to humidity and excess water, which can create an environment that is conducive to disease.

A. Damping-off
1. Caused by *Phytophthora* or *Rhizoctonia* fungi
2. Common with seedlings
3. Fungi originating in soil or on seed
4. Plant symptoms
a. Preemergence: Seed is destroyed before germination.
b. Postemergence: Seedling is destroyed at soil level.
B. Botrytis blight (gray mold)
1. Caused by fungi
2. Costly disease of greenhouse crops
3. Requires a cool, humid environment to grow
4. Plant symptoms
a. Gray spots appear on foliage.
b. Tissue under spots turns soft, brown, then rotted.
C. Leaf spot and other foliar diseases
1. Caused by bacteria or fungi
2. If caused by fungi, can be treated; if caused by bacteria, must discard plant
3. Grows in humid environments
4. Plant symptoms
a. Discolored leaves
b. Distorted leaves
D. Root rot disease
1. Caused by bacteria or by *Pythium* and *Phytophthora* fungi
2. Most common cause of houseplant death
3. Overwatering: allowing fungi and bacteria to enter root system; decreasing uptake of water and dissolved nutrients by root hairs

4. Plant symptoms
   a. Roots are brown or black and few in number.
   b. Roots are slimy and have a foul odor.
   c. Foliage exhibits yellow, wilted leaves and leaf drop.

F. Other Activity and Strategy

Invite an entomologist to discuss various greenhouse pests and to assess whether some are more likely to be found in your location. In addition, ask the scientist to describe any pests not described in this lesson that might live in your area. Request large color photos of the pests, if possible, and a unit of measure to demonstrate how small the pests are.

G. Conclusion

Common pests and diseases can attack plants in greenhouses. Several environmental factors can make the greenhouse susceptible to pests. Each pest and disease affects crops in different ways.

H. Answers to Activity Sheets

AS 6.1 Path of Destruction Part I: Insects and Arachnids

Instructor's discretion

AS 6.2 Path of Destruction Part II: Other Pests and Diseases

Instructor's discretion

I. Answers to Assessment

1. Students may list any three of the following:
   A. Damping-off; origin - fungi
   B. Botrytis blight (gray mold); origin - fungi
   C. Foliar diseases, e.g., leaf spot; origin - bacteria or fungi
   D. Root rot; origin - bacteria or fungi
2. A. Insects,
   B. Arachnids
   C. Mollusks
   D. Nematodes
3. Students may list any four of the following:
   A. Infected soil
   B. Debris from previous crop
   C. Water
   D. Air
   E. Infected plant tissue
4. Penetrates root cells, giving fungi and bacteria an entrance to plants.
5. A

6. A
7. B
8. D
9. C
10. B

UNIT VI: PLANT HEALTH

Name____________________

Lesson 1: Greenhouse Pests and Diseases

Date_____________________

ASSESSMENT

Short-Answer Questions: Write the answers in the space provided.

1. What are three common diseases in the greenhouse setting and where do they come from?

Disease	Origin
A.	A.
B.	B.
C.	C.

2. Rodents, birds, weeds, and disease can attack greenhouse crops. What are four other pests?

   A.

   B.

   C.

   D.

3. What are four sources of disease within the greenhouse environment?

   A.

   B.

   C.

   D.

4. What damage can a nematode cause?

Multiple Choice: Circle the letter of the best answer.

5. What symptoms are evident on a plant from an insect with a piercing-sucking mouth part?

   A. Yellow foliage and honeydew
   B. Honeydew and curled leaves
   C. Tiny webs and bronze colored foliage
   D. Leaf drop and stunted growth

6. What damage does an insect with rasping-lapping mouth parts leave on a plant?

   A. Streaking and browning of flower petals
   B. Honeydew and yellow spots on foliage
   C. Curled leaves and tiny webs
   D. Lack of vigor and leaf drop

7. Which pest is difficult to control and causes economic damage?

   A. Thrips
   B. Mites
   C. Aphids
   D. Mealybugs

8. Which disease causes economic hardship for the greenhouse owner?

   A. Root rot
   B. Damping-off
   C. Leaf spot
   D. Botrytis

9. What is the most common source of disease in plants?

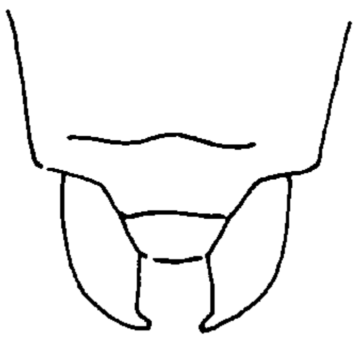
   A. Parasites
   B. Viruses
   C. Fungi
   D. Bacteria

10. What type of pest has chewing mouth parts?

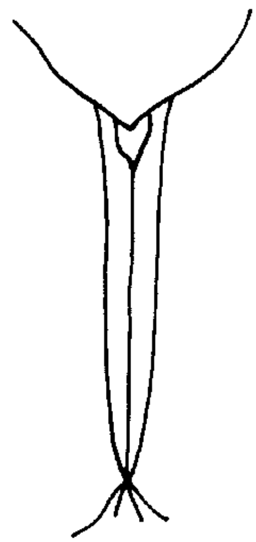
    A. Fungus gnat adult
    B. Fungus gnat larvae
    C. Mealybug adult
    D. Mealybug larva

TM 6.1

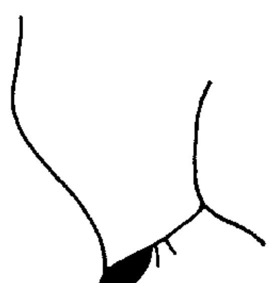
Types of Mouth Parts



Chewing



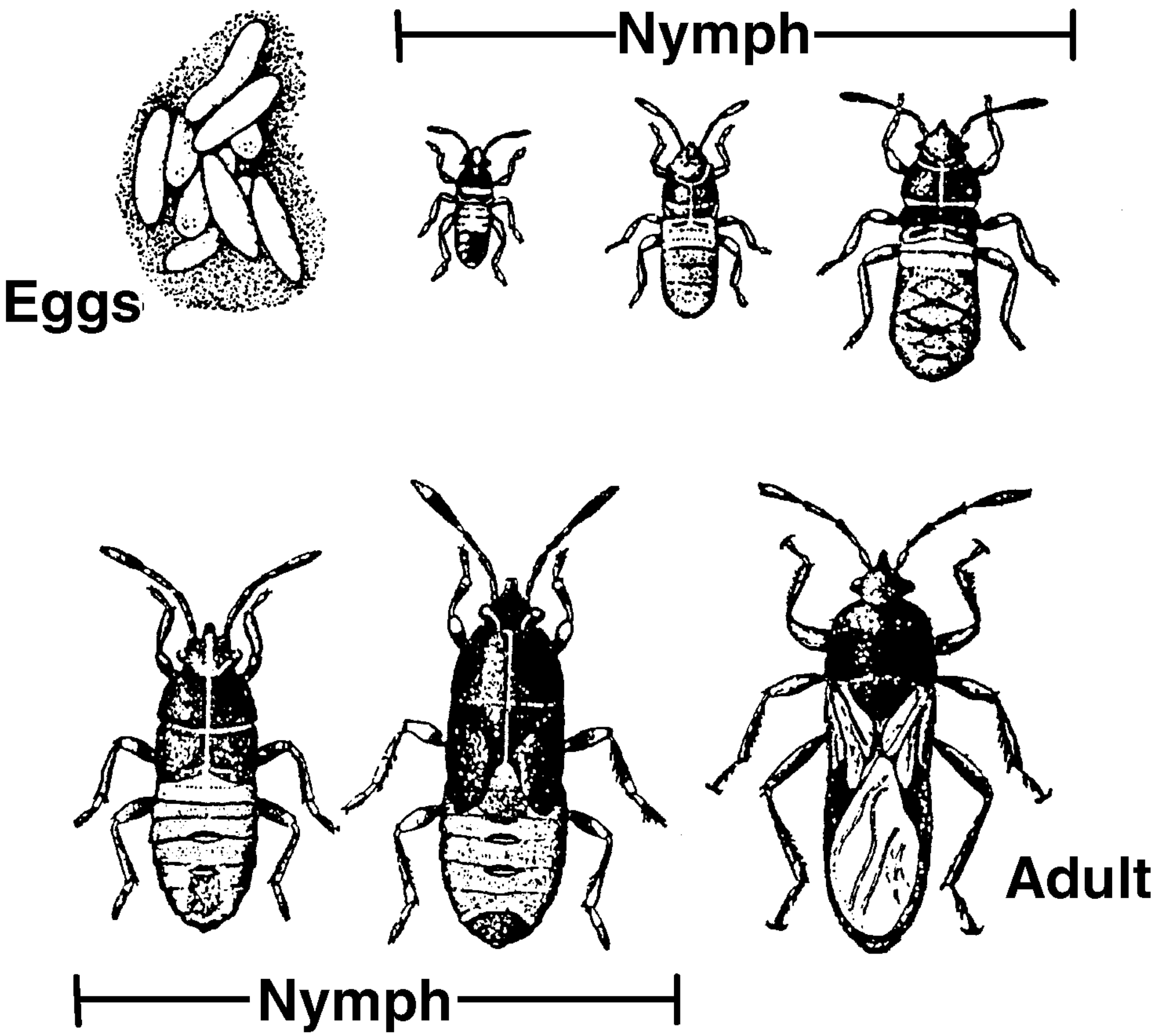
Piercing-
Sucking



Rasping-
Lapping

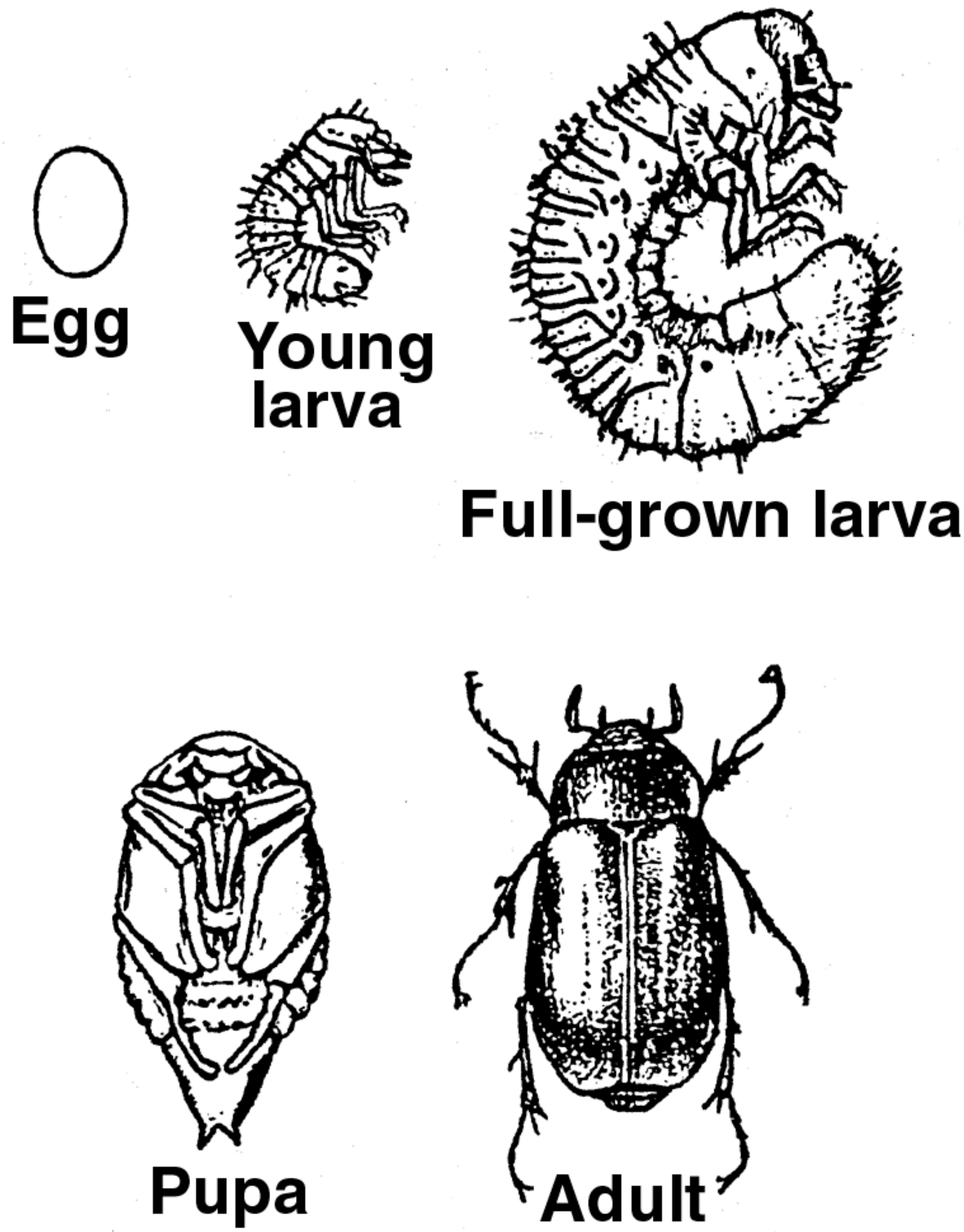
TM 6.2

Gradual Metamorphosis



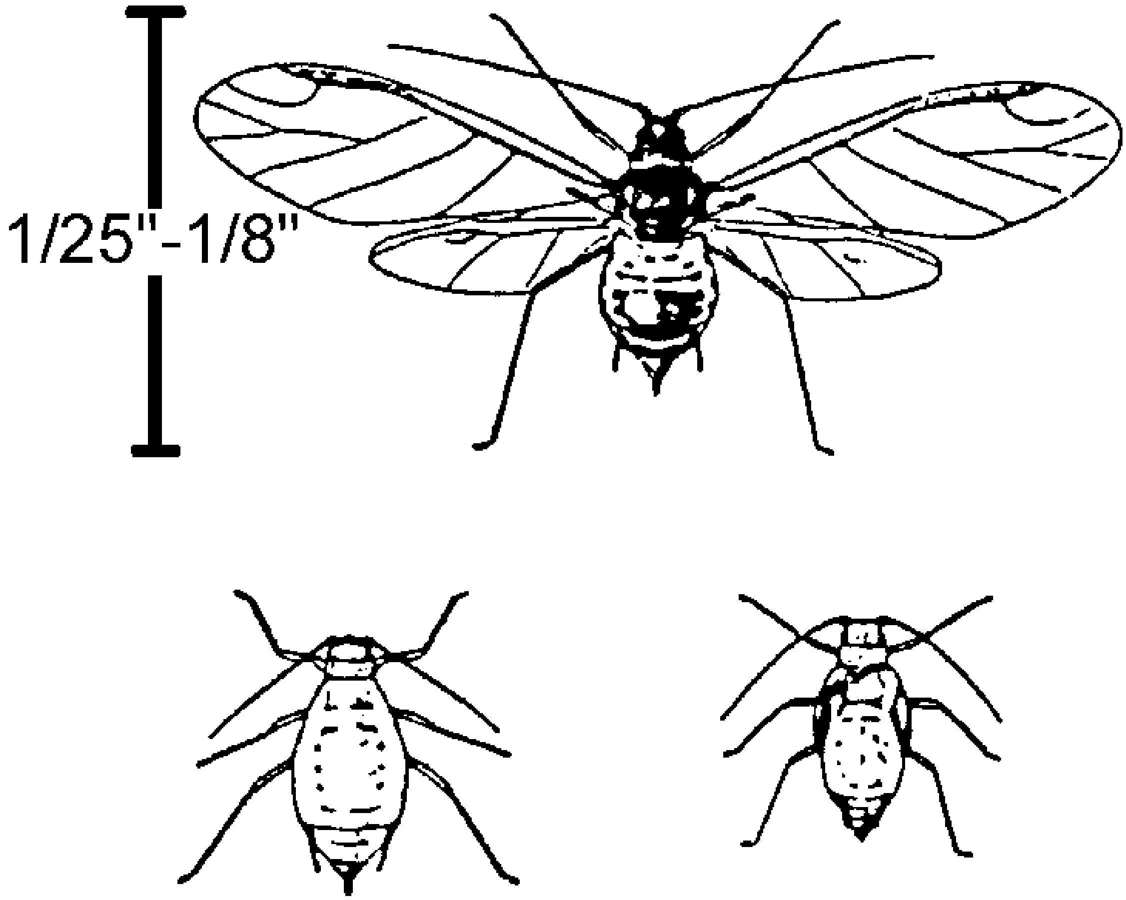
TM 6.3

Complete Metamorphosis



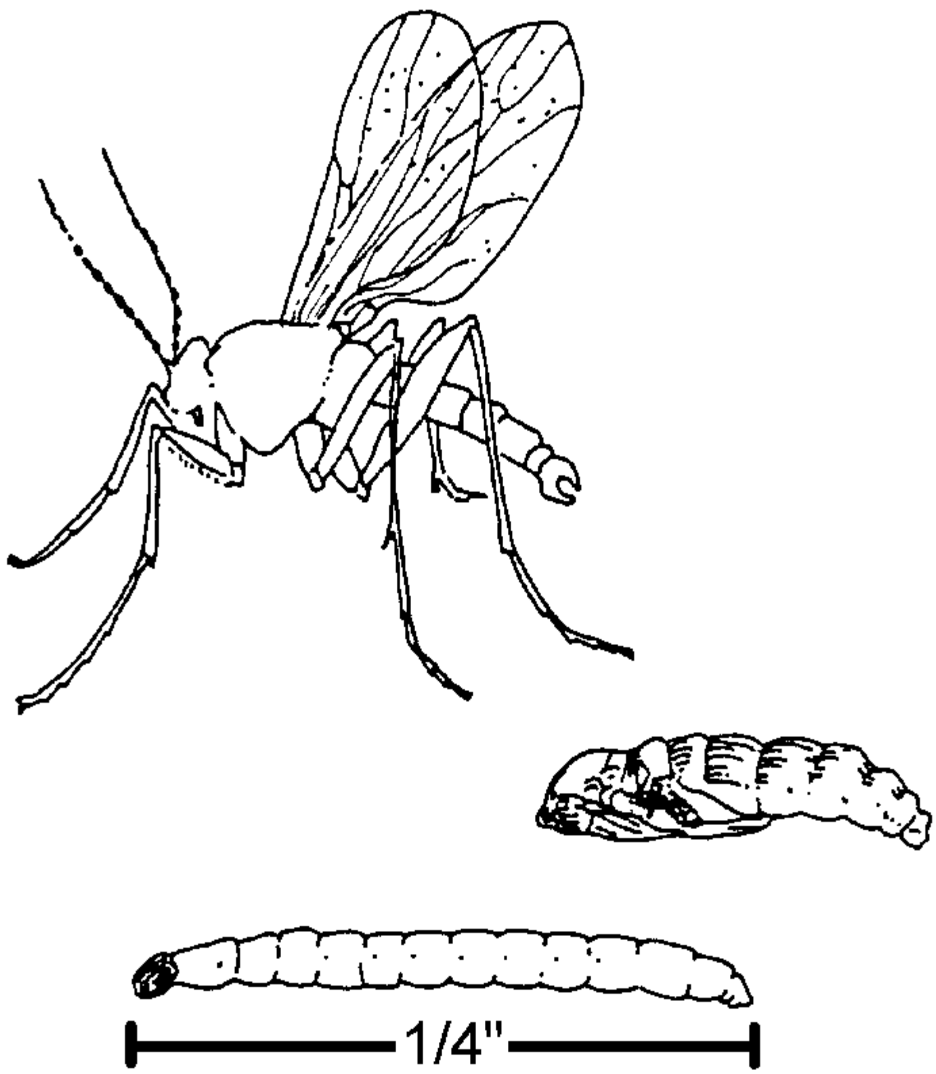
TM 6.4

Aphid



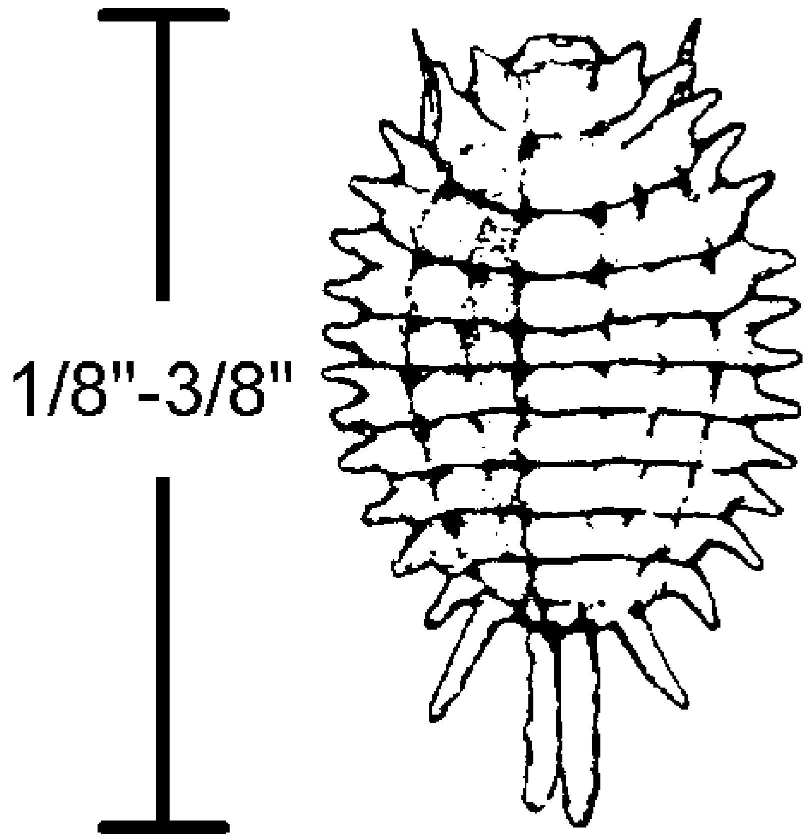
TM 6.5

Fungus Gnat



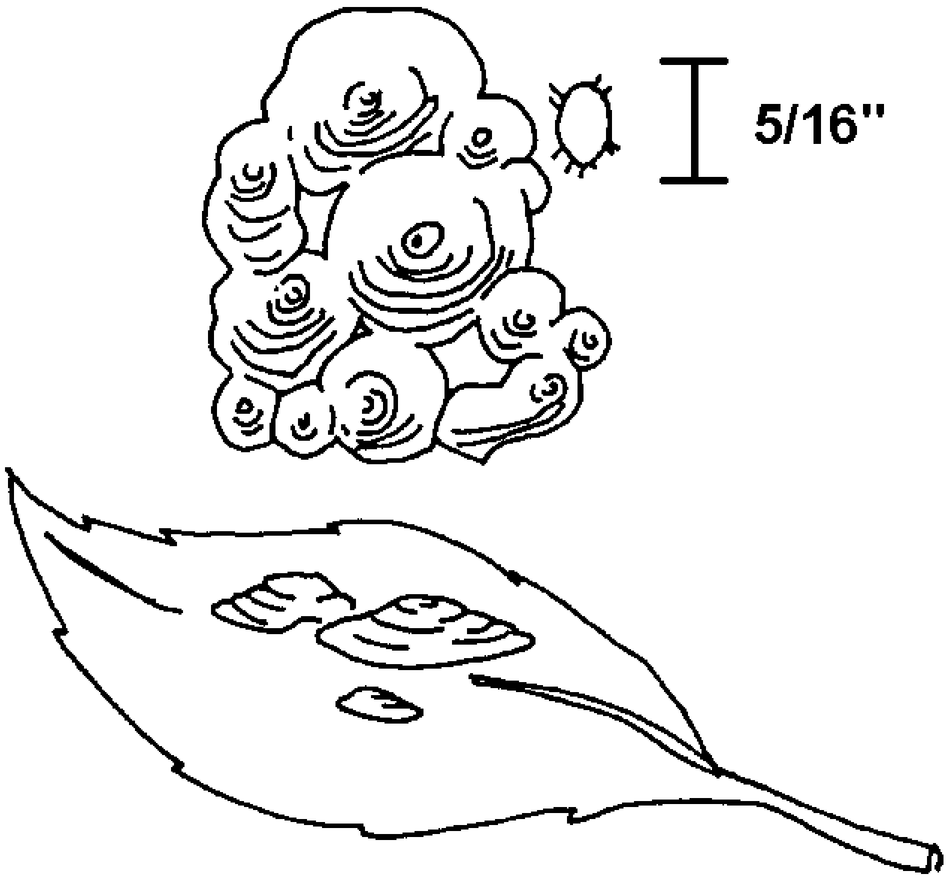
TM 6.6

Mealybug



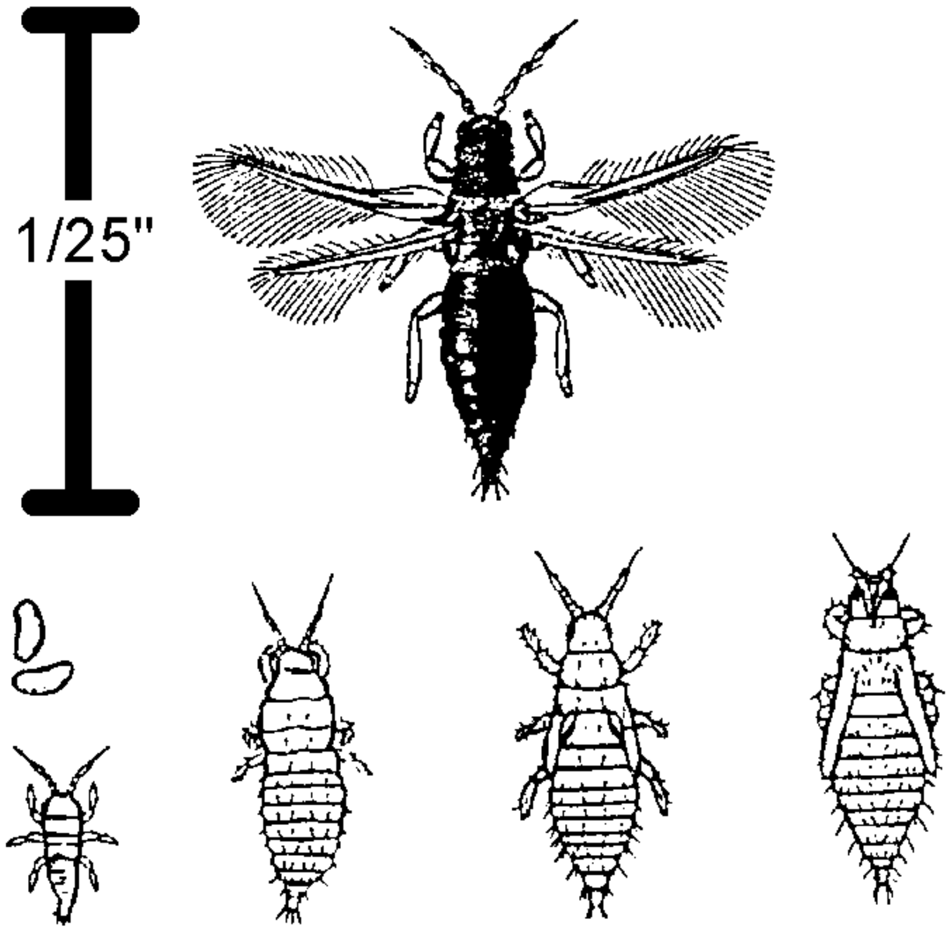
TM 6.7

Scale

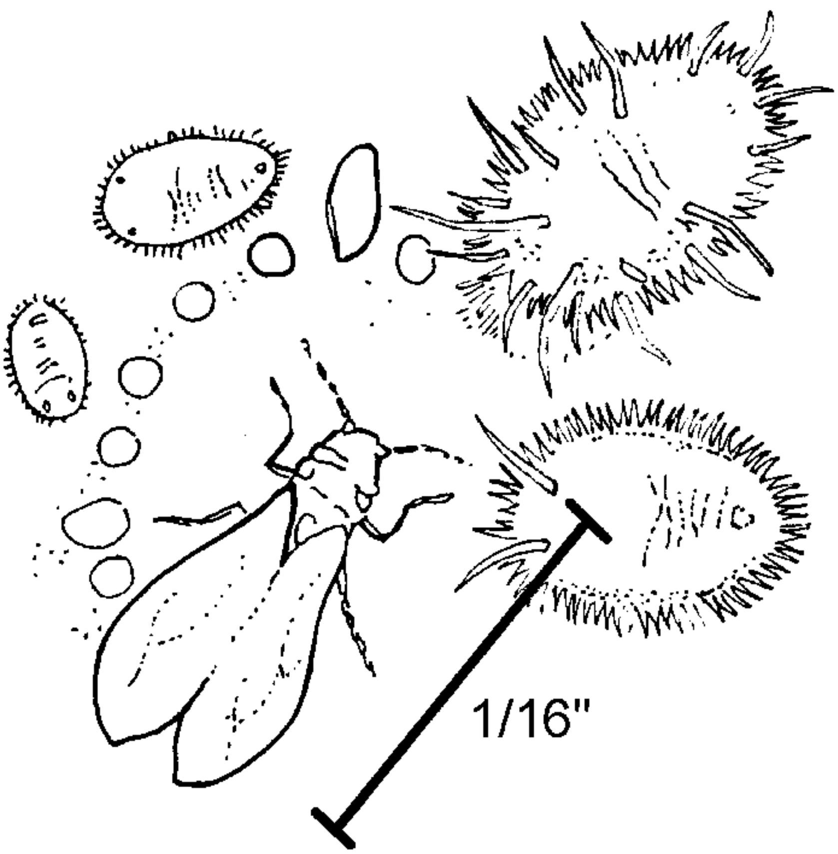


TM 6.8

Thrips

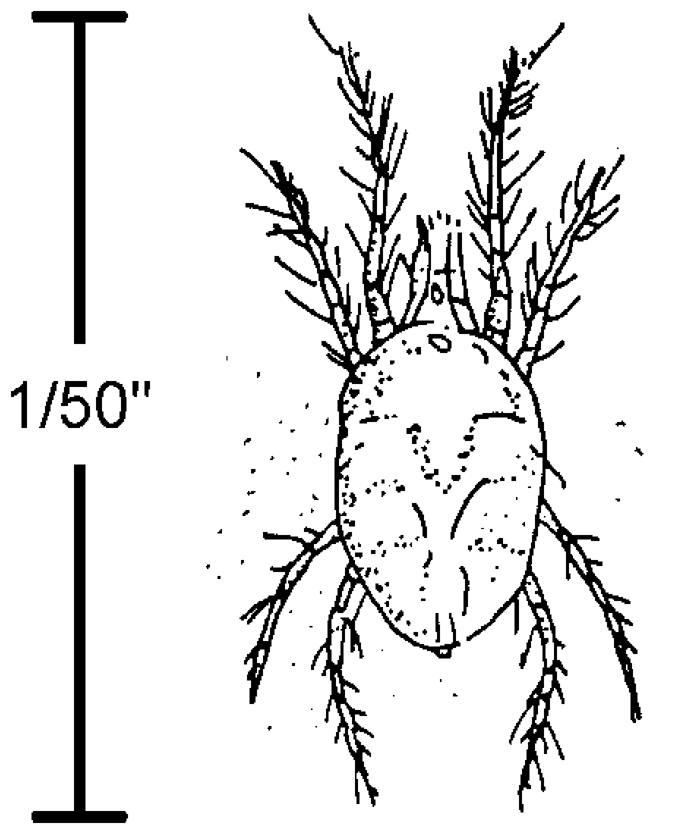


Whitefly



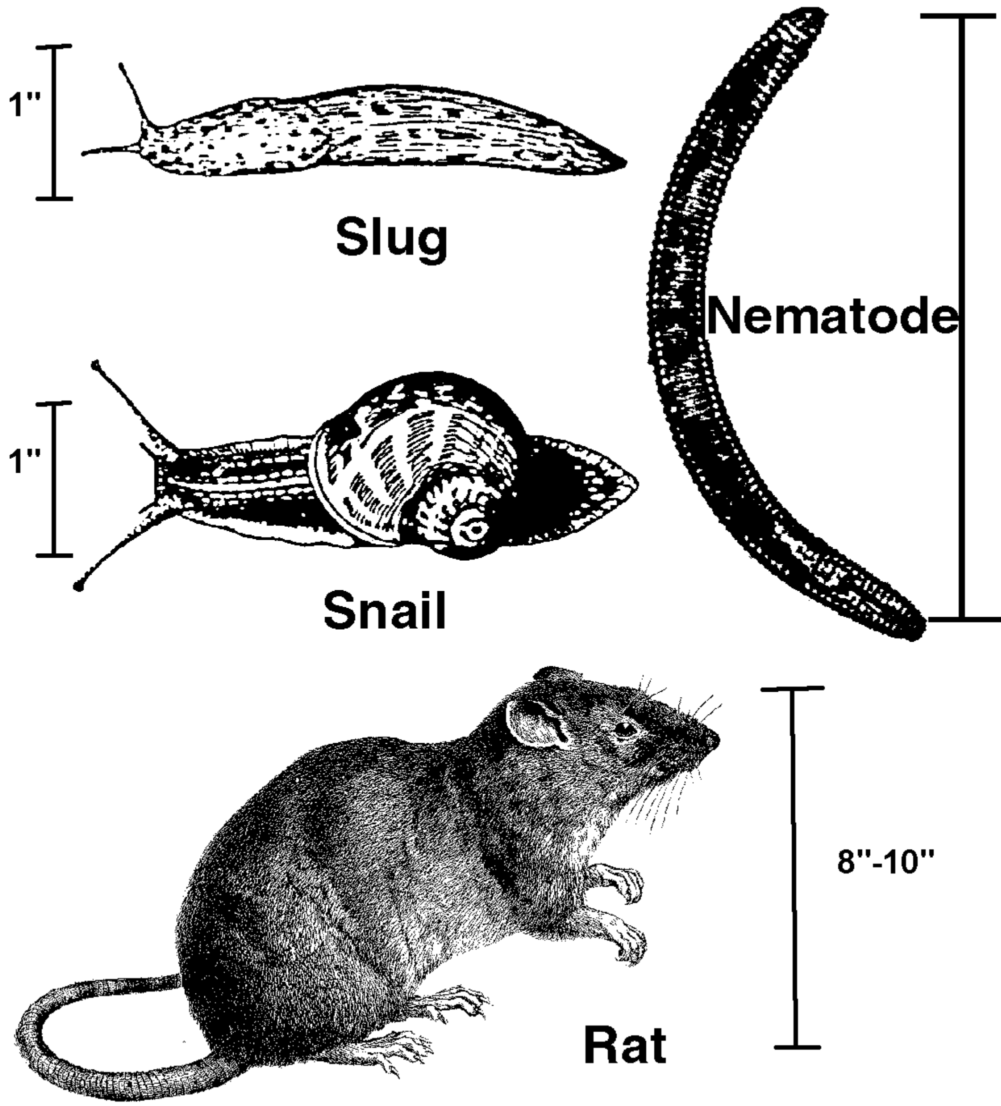
TM 6.10

Spider Mite



TM 6.11

Other Pests



UNIT VI: PLANT HEALTH

AS 6.1

Lesson 1: Greenhouse Pests and Diseases

Name ______________________

Path of Destruction Part I: Insects and Arachnids

Objective: Compile illustrations of the devastation caused by insects and arachnids on greenhouse-grown plants.

Directions: In small groups, gather photographs, pictures, or create color illustrations of damage from aphids, mites, whiteflies, thrips, scale, mealybugs, and fungus gnats. You may create a poster or PowerPoint presentation. Please provide the following information for each illustration.

1. What are the common names of the pests?

2. Are these pests arachnids, insects, or mollusks?

3. What type of mouth parts do they have?

4. Write a description of the damage each pest inflicts.

UNIT VI: PLANT HEALTH

AS 6.2

Lesson 1: Greenhouse Pests and Diseases

Name ___________________

Path of Destruction Part II: Other Pests and Diseases

Objective: Compile illustrations of the devastation caused by other pests and diseases on greenhouse-grown plants.

Directions: In small groups, gather photographs, pictures, or create color illustrations of damage from nematodes, rodents, snails, slugs, damping off, Botrytis blight, foliar diseases, and root rot. You may create a poster or PowerPoint presentation. Provide the following information for each illustration.

1. What name or names are the pests or diseases known by?

2. Are the pests nematodes, mammals, mollusks, or diseases?

3. Write a description of the damage each pest or disease inflicts.

4. What are some precautions that can be taken to avoid introducing the pests and diseases into a greenhouse?

GREENHOUSE OPERATION AND MANAGEMENT
Unit VI: Plant Health

Lesson 2: Pest Control

Competency/Objective:

Differentiate between various pest management methods.

Study Questions

1. **How can greenhouse owners protect plants from pests?**
2. **What are biological pest management methods?**
3. **What are chemical pest management methods?**
4. **What are cultural pest management methods?**
5. **What are mechanical pest management methods?**
6. **What is an integrated pest management (IPM) system?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Activity Sheets

   AS 6.3 Applied Pest Management
   AS 6.4 Integrated Pest Management

3. "Pest Management and Identification." University of California-Davis. <http://www.ipm.ucdavis.edu/PMG/crops-agriculture.html>

4. UC IPM Online. <http://www.ipm.ucdavis.edu/>

TEACHING PROCEDURES

A. Review

   In the previous lesson, students identified common pests and diseases in the greenhouse setting. This lesson introduces five pest management programs: biological, chemical, cultural, mechanical, and integrated. Pest control programs aim to protect plants from pests and to promote plants' resistance to pests.

B. Motivation

Have students relate how they control pests that attack their gardens or crops. Are some methods better than others? What are unique features of various pest control techniques? The greenhouse owner has options in managing or removing pests and diseases that directly relate to the financial well-being of the operation.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study question.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. How can greenhouse owners protect plants from pests?

As the class reviews the principles of basic pest control, ask students to consider which of the four control measures are proactive. If someone wants to grow organic greenhouse crops, what are the best methods?

A. Basic pest control principles
   1. Preventing pest introduction
   2. Reducing or eliminating pest population
   3. Protecting plant from pests already present
   4. Increasing plant resistance to pests
B. Basic methods of control
   1. Biological
   2. Chemical
   3. Cultural
   4. Mechanical

2. What are biological pest management methods?

Predators, parasites, and pathogens can naturally control pests in a greenhouse. This process of management is environmentally sound but has its drawbacks. Biological control is best used when the pest population is small.

A. Controlling pests by introducing living organisms that are predators of pests
B. Examples:
   1. Releasing ladybugs to control certain insect pests
   2. Introducing the bacterium *Bacillus thuringinensis* to kill certain worms
   3. Planting trap plants to lure pests away from cultivated plants

3. What are chemical pest management methods?

Chemicals are a quick and cost-effective way to eradicate pests. But pesticides can be hazardous to humans when they apply the chemicals, to greenhouse workers after application, and to the environment during disposal. In addition, some pests build up tolerance and become resistant to the product.

A. Chemicals are used for various reasons.
   1. Protect plants from pests
   2. Treat plants affected by pests
   3. Destroy pests
B. Pesticides are the most commonly used pest management chemicals.
   1. Pesticides that kill unwanted plants - herbicides
   2. Pesticides that kill unwanted, nonplant pests
      a. Acaricide (spiders and ticks)
      b. Aviacides (birds)
      c. Bactericide (bacteria)
      d. Fungicides (fungi)
      e. Insecticides (insects)
      f. Miticides (mites, ticks)
      g. Molluscides (snails, slugs)
      h. Nematicides (nematodes)
C. Chemicals used to control pests can be deadly and must be used with extreme caution.

4. What are cultural pest management methods?

Cultural pest management refers to controlling pests through cultivation.

A. Using various greenhouse management techniques to control pests
B. Examples:
   1. Mulching and pruning plants
   2. Pasteurizing growing media
   3. Purchasing quality seeds
   4. Using disease-resistant varieties of seeds

5. What are mechanical pest management methods?

Time-consuming and labor intensive, mechanical pest management is not practical for large operations. But a significant advantage is that it has a minimal impact on the environment because no chemicals are used. Have students complete AS 6.3.

A. Using physical means of preventing, removing, or destroying pests
B. Examples:
   1. Weeding and mulching
   2. Handpicking large bugs from plants
   3. Hanging flytraps
   4. Maintaining sanitation

6. What is an integrated pest management (IPM) system?

Ask students to infer what "integrated" pest management entails. Lead students to the discovery that IPM is a complex system that requires planning, monitoring, acting, and evaluating. Ask students to complete AS 6.4.

A. IPM is a comprehensive approach, using a combination of methods.
   1. Biological
   2. Chemical
   3. Cultural
   4. Mechanical
B. IPM is an integrated system whose goals are to reduce the following:
   1. Number and impact of pests (not necessarily to eradicate all of them)
   2. Economic loss due to pests
   3. Reliance on pesticides
   4. Safety hazards to humans, animals, plants, and the environment
C. IPM requires decision making and planning.
   1. Knowledge of pests' life cycle, mouth types, and other characteristics
   2. Identification of pests that damage plants and the plants' symptoms
   3. Establish level of damage that is unacceptable
   4. Implementation of IPM strategies
   5. Early detection
   6. Safe eradication measures
   7. Monitoring
   8. Evaluation
D. IPM incorporates best management practices (BMPs).
   1. Combine scientific methods and practical knowledge
   2. Maintain cost-efficient operation and crop quality while protecting environment
   3. BMP practices that control pests
      a. Test growing media
      b. Determine correct time and application of fertilizers
      c. Ensure proper drainage
      d. Manage irrigation systems

e. Use controlled-release fertilizers
f. Use natural (biological) pest controls
g. Use cultural pest controls

F. Other Activities and Strategies

1. Show the class the following videos, which are available from CATER (Career & Technical Education Resources), 2 London Hall, University of Missouri-Columbia: *Integrated Pest Management* (AG V109) and *Integrated Pest Management in Greenhouses* (AG V111).

2. Invite a representative from the local university Extension office to discuss IPM.

G. Conclusion

There are numerous pests and diseases in greenhouses. Environmental factors make the greenhouse susceptible to the pests. Different methods of managing pests are available to the greenhouse owner.

H. Answers to Activity Sheets

AS 6.3 Applied Pest Management

Instructor's discretion

AS 6.4 Integrated Pest Management

Instructor's discretion

I. Answers to Assessment

1. C
2. D
3. A
4. B
5. A. Prevent pest introduction
   B. Reduce pest population
   C. Protect plants from pests
   D. Increase plant resistance to pests
6. A. Reduce pests
   B. Reduce economic loss
   C. Reduce reliance on pesticides
   D. Reduce safety hazards
7. Any four of the following:
   A. Knowledge of pest biology
   B. Identification of plant symptoms
   C. Establishing level of damage that is not acceptable
   D. Implementation of IPM strategies begins

E. Early detection
F. Safe eradication
G. Monitoring
H. Evaluation

UNIT VI: PLANT HEALTH

Name____________________

Lesson 2: Pest Control

Date_____________________

ASSESSMENT

Match the pesticide management method on the left with its definition on the right. Write the letter in the space provided.

___1. Chemical — A. Physical elimination of pests

___2. Cultural — B. Use living organisms to eliminate pests

___3. Mechanical — C. Use organic and inorganic compounds to eliminate pests

___4. Biological — D. Use greenhouse cultivation techniques to eliminate pests

Short-Answer Questions: Write the answers in the space provided.

5. What are the four principles of pest control?

   A.

   B.

   C.

   D.

6. What are the four goals of integrated pest management (IPM)?

   A.

   B.

   C.

   D.

7. What are four examples of decision making and planning that are necessary for a good IPM plan?

    A.

    B.

    C.

    D.

UNIT VI: PLANT HEALTH

AS 6.3

Lesson 2: Pest Control

Name________________

Applied Pest Management

Objective: Design a pest management system.

Directions: Choose one of the following pest management systems - biological, chemical, cultural, or mechanical - and one type of greenhouse crop - floriculture, olericulture, ornamental, or organic. Create a method of controlling greenhouse pests. Be as specific as possible. Work in small groups and present results to the class. Note: Chemical management of an organic greenhouse is not a valid choice.

Pest Management System __________________________ Crop _________________

1. How does this pest management system effectively treat the selected crop?

2. Why did you select this management system?

3. Are there any disadvantages to using this system?

4. What steps are advocated in implementing this pest management system?

5. What types of pests threaten your selected crop most frequently?

UNIT VI: PLANT HEALTH

AS 6.4

Lesson 2: Pest Control

Name__________________

Integrated Pest Management

Objective: Devise an integrated pest management system for a greenhouse crop.

Directions: Building on information from AS 6.3, create an integrated method for controlling greenhouse pests. Work in small groups. Be as specific as possible about the steps to follow to produce this plan. If you are interested in an integrated management system in an organic setting, apply best management practices to the problem. Present your findings to the class.

Crop __________________

1. Where should the integrated pest management system be used: in a regular commercial greenhouse setting or an organic environment? Why?

2. Outline the plan in detail. Justify your choices.

3. What advantages does IPM offer that other methods do not?

4. Why is your crop suited to an IPM system to eliminate pests?

GREENHOUSE OPERATION AND MANAGEMENT
Unit VI: Plant Health

Lesson 3: Pesticide Use and Safety

Competency/Objective:

Explain safe usage and application of pesticides.

Study Questions

1. **What information is found on a pesticide label?**
2. **What are pesticide toxicity levels?**
3. **In what forms are pesticides available and how should they be applied?**
4. **What is the mode of action for different types of pesticides?**
5. **What basic pesticide safety issues must be understood?**
6. **What are general procedures for pesticide storage and disposal?**
7. **What personal protection measures are essential when applying pesticides?**
8. **What are the appropriate steps to take in case of accidental pesticide poisoning?**
9. **Where can greenhouse owners find up-to-date pesticide information and recommendations?**
10. **What certifications are required to use pesticides?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 6.12 Sample Pesticide Label
   TM 6.13 Types of Sprayers Used to Apply Pesticides
   TM 6.14 Sample Pesticide Application Log

3. Activity Sheets

   AS 6.5 Pesticide Dilution Ratios
   AS 6.6 Pesticide Update

4. *Pesticide Safety*. University of Missouri-Columbia: Instructional Materials Laboratory, RAS 1997 (catalog numbers 10-6050-I and 10-6050-S).

5. *Applying Pesticides Correctly: Missouri Core Manual*. University of Missouri Extension, 1994 (catalog number 10-6060-S).

6. Fishel, Fred. “Integrated Pest Management in Missouri’s Urban Environment” Integrated Pest Management - MU Guide. University of Missouri-Columbia Extension. <http://muextension.missouri.edu/xplor/agguides/pests/ipm1004.htm>

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8. “Geiger Company Supplemental Catalog.” <http://www.geigerco.com/labels_msds/2001_cat.pdf> accessed 5/9/02.

9. “Pesticides - Certified Applicators and Operator (Commercial, Non-Commercial and Public).” Missouri Department of Agriculture. Pest Management. <http://www.mda.state.mo.us/d7c.htm> accessed 5/9/02.

TEACHING PROCEDURES

A. Review

   Many pests and diseases are common in greenhouses. Students learned to recognize these pests in Lessons 1 and 2. Lesson 3 discusses pesticide labels, usage, toxicity, and application methods.

B. Motivation

   Ask students to identify common pesticides that they have used for their own crops. What hazards do they pose? How should authorized personnel apply pesticides?

C. Assignment of Study Questions

D. Supervised Study

   Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study question.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What information is found on a pesticide label?

A pesticide label contains important information relating to the product's chemicals. Details about the ingredients and their use, warning statements, and EPA registration are provided. See TM 6.12.

A. Pesticide labels are extremely important.
B. The label is the law.
   1. Indicates legal use, storage, and disposal methods
   2. Controls sale and distribution
C. Label directions contain essential information.
   1. Ingredients (including chemical names)
   2. Type of pesticide and what it is designed to control
   3. Amount of contents
   4. Signal words (Caution, Warning, Danger)
   5. Routes of entry (user's body parts that must be protected)
   6. Specific action (action taken to prevent poisoning)
      a. Type of clothing and equipment that should be worn
      b. Hazards (environmental, physical, chemical)
      c. Specific toxicity (to certain plant or animal life)
      d. Recommended first aid in case of accidental poisoning
      e. EPA classification
      f. Directions for proper use
      g. Storage and disposal directions
      h. Safe reentry time (time before entering area without protective clothing and gear)
D. Read all label information and strictly adhere to all label directions.

2. What are pesticide toxicity levels?

Pesticide toxicity levels have specific definitions for caution, warning, and danger. Ask students how they think toxic pesticides might come into contact with humans.

A. Pesticide toxicity levels are measured by an LD_{50} test.
B. The LD_{50} level is a lethal dose of a pesticide that is necessary to kill 50% of test animals within 2 weeks.
   1. Expressed in milligrams of per kilogram of test animal's body weight
   2. The lower the LD_{50} number, the greater the pesticide toxicity and less needed to kill
C. There are three kinds of toxicity.
   1. Oral (ingested)
   2. Inhaled (breathed)
   3. Dermal (absorbed through skin)

D. Pesticide labels use signal words based on toxicity levels.
   1. Caution
      a. Slightly toxic
      b. Oral LD_{50} rating: 500-5,000
   2. Warning
      a. Moderately toxic
      b. Oral LD_{50} rating: 50-500
   3. Danger or Danger Poison
      a. Highly toxic
      b. Oral LD_{50} rating: 0-50
      c. Letters printed in red and accompanied by a skull and crossbones drawing

3. In what forms are pesticides available and how should they be applied?

Pesticides are either liquid or dry. However, within those two categories, pesticides are found in many forms. For example, aerosol is a liquid form of a pesticide; granular is a dry form of a pesticide. Appropriate application of these chemicals should be directed at different plant parts at specific times in the plant's life cycle. Liquid or dry pesticides are diluted with water in specific ratios. AS 6.5 allows the student to practice calculating pesticide dilution formulas.

A. Forms of pesticides
   1. Liquid
      a. Aerosols
         i. Denoted by A on label
         ii. Pressured cans or aerosol bombs
      b. Emulsifiable concentrates
         i. Denoted by EC on label
         ii. Mixed with water in spray tank
      c. Encapsulated
         i. Pesticide sealed in microcapsules
         ii. Time release
         iii. Mixed with water
      d. Flowable
         i. Denoted by F or L on label
         ii. Mixed with water
   2. Dry
      a. Bait
         i. Denoted by B on label
         ii. Pesticide-laden substance that lures pests
      b. Dust
         i. Denoted by D on label
         ii. Pesticide and inert ingredients ground into dust
         iii. Applied dry
      c. Granular
         i. Denoted by G on label
         ii. Same composition as dust but larger particles

iii. Applied dry
d. Soluble powder
 i. Denoted by S or SP on label
 ii. Dissolved in water
e. Wettable powder
 i. Denoted by W or WP on label
 ii. Mixed with water in spray tank
 iii. Must be constantly agitated to keep mixed
f. Dry flowable
 i. Dry granules of pesticide
 ii. Less dust than powders

B. Application methods
 1. Seed treatment
 2. Growing media treatment
 3. Plant wound treatment
 4. Foliar treatment
 5. Postharvest treatment
C. Equipment (See TM 6.13.)
 1. Sprayers (handheld, hose end, pump, backpack, wheelbarrow)
 2. Aerosol generators and foggers
D. Pesticide application log (See TM 6.14.)
 1. Identifies where to apply pesticide, active ingredients, and EPA registration number
 2. Identifies date of application and safe reentry date
 3. Enumerates Personal Protection Equipment needed

4. What is the mode of action for different types of pesticides?

How does the pesticide kill the pest? Does the pest die upon contact? Is its life cycle disrupted? Discuss this based on knowledge of the pest's life cycle.

A. Biologics - contain living organisms (viruses, bacteria, fungi) that cause the pest to become diseased and die
B. Contact pesticides - kill immediately when sprayed directly on pest
C. Fumigants - poison gases that are breathed or absorbed
D. Growth regulators - adversely affect development
E. Herbicides (two types)
 1. Nonselective - kills all plants
 2. Selective - kills only target weeds
F. Pheromones
 1. Natural chemicals attract pest
 2. Lure pest into trap
G. Protectants - prevent pest from entering or damaging plant
H. Stomach poison pesticides - kill when eaten or swallowed
I. Systemics
 1. Absorbed by plant; translocated to all parts via vascular system
 2. Kill pest when feeding on plant

5. **What basic pesticide safety issues must be understood?**

   Why are there so many regulations surrounding the use of chemicals on plants? AS 6.6 allows students to research this question.

   A. Chemical pesticides are powerful substances that must be handled with extreme caution.
      1. Can be deadly to humans and animals
      2. Can contaminate water and food
      3. Can pollute the environment
   B. Adhere to all laws and guidelines that govern the use of pesticides. (See study question 10.)
      1. Federal
      2. State
      3. Local
   C. Take all safety measures to protect yourself and those around you.
   D. Worker Protection Standard was issued by the U.S. Environmental Protection Agency (EPA).
      1. Information provided on exposure to pesticides
         a. Pesticide safety training
         b. Safety poster on pesticides
         c. Access to labeling information for handlers and early-entry workers
         d. Access to specific information on pesticides used on-site.
      2. Protection against exposure provided
         a. Prohibits handlers from contaminating others with pesticides
         b. Notifies workers of treatment areas to avoid inadvertent exposure
         c. Requires monitoring during handling tasks to ensure safety of handlers
      3. Means to alleviate exposure available
         a. Provides decontamination sites
         b. Provides emergency assistance to worker or handler poisoned or injured by a pesticide

6. **What are general procedures for pesticide storage and disposal?**

   Dovetailing on the discussion of the last question, inquire again why there are so many safety procedures. What are potential consequences of not following guidelines on the label?

   A. Pesticide storage
      1. Read and follow label for storage instructions.
      2. Be aware of general pesticide storage safety guidelines.
         a. Store in original containers.
            i. Make sure labels are visible.
            ii. Indicate the date of purchase.
         b. Do not store near food, medicine, or other supplies.
         c. Keep away from flammable materials.
         d. Routinely check for leaks or damage.
         e. Keep cleanup materials close by.
         f. Properly dispose of old or unwanted products.

B. Pesticide and pesticide container disposal
   1. Read and follow label's precautions and instructions regarding proper disposal.
   2. Be aware of general pesticide disposal guidelines.
      a. Do not dispose of pesticides down drains, into sewers, or down waterways.
      b. Follow guidelines for pesticides and pesticide container disposal as mandated by the U.S. Department of Agriculture (USDA) and the EPA.
      c. Contact the state Department of Natural Resources for specific pesticide laws and guidelines.

7. What personal protection measures are essential when applying pesticides?

Ask students to justify why personal protection is important when using pesticides. If possible, invite an agriculture Extension agent to the classroom to discuss safety and pesticides.

A. Obtain proper education and permits for pesticide use.
B. Wear the recommended Personal Protective Equipment (PPE), which may consist of any or all of the following items.
   1. Goggles
   2. Respirator
   3. Long sleeves rolled over long rubber gloves
   4. Hat
   5. Rubber boots
   6. Overalls or coveralls secured with a band over boots
C. Follow general application safety guidelines.
   1. Select the safest, least toxic substance possible.
   2. Use only approved products and use only for intended purpose.
   3. Use the proper equipment and clothing.
   4. Review label carefully.
      a. Know and follow proper application procedures.
      b. Know what to do in case of an accident.
   5. Mix only the amount needed.
   6. Do not eat, drink, or chew anything during or after application until hands are thoroughly washed with cleanser and water.
   7. Be aware of the environment in which application takes place.
      a. Need adequate ventilation
      b. Clear area of people, animals, and items
   8. Apply with extreme caution.
   9. Clean all equipment and clothing.
   10. Thoroughly wash skin with cleanser and water.

8. What are the appropriate steps to take in case of accidental pesticide poisoning?

It is important to have the pesticide container nearby during application in case of an accident. The label provides important information to medical personnel.

A. Observe victim for symptoms.

1. Symptoms vary depending on the following:
   a. Type and amount of pesticide
   b. Length of exposure
   c. Time interval between exposures
   d. Victim’s general state of health
2. The are two basic categories of pesticide poisoning.
   a. External irritants
      i. Pesticide comes in contact with external tissues.
      ii. Symptoms may include stinging of eyes, ears, throat, nose, mouth, or other external tissues.
   b. Internal poisons
      i. Pesticide is taken into the body through mouth or skin.
      ii. This may result in injury to internal body organs.

B. Know and follow first aid procedures.
1. Act as quickly as possible.
2. Remove victim from contaminated area.
3. Remove contaminated clothing from the victim.
4. Generously flood affected area with water.
5. Contact a doctor or the poison control center.
6. Administer first aid as directed by doctor or poison control center.

9. Where can greenhouse owners find up-to-date pesticide information and recommendations?

Ask students where they think timely data could be found about pesticides and recommendations for use.

A. University Extension offices
B. Department of Agriculture (federal and state)
C. Pesticide suppliers

10. What certifications are required to use pesticides?

The state of Missouri requires that anyone who applies pesticides in a commercial setting must have a license. The training includes information on protective equipment and personal safety. The following applies to those working in the state of Missouri. Information on reciprocity with surrounding states is also included.

A. Types of certified applicators and operators
1. Certified Commercial Applicators
2. Certified Noncommercial Applicators
3. Certified Public Operators (government employees)
4. Certified Private Applicator Licenses
5. Pesticide Technician Licenses
6. Pesticide Dealer Licenses

B. Process for obtaining certification

1. For Certified Commercial Applicators, Certified Noncommercial Applicators, and Certified Public Operators (government employees):
   a. Must pass state pesticide certification examinations, General Standards of Competence (CORE) examination, and at least one of the category examinations
   b. Must submit a completed Certified Applicator and Pesticide Dealer Application to the Bureau of Pesticide Control to reserve time for taking the certification examinations
   c. Can purchase study manuals from the University of Missouri Extension Publications office by mailing in a completed manual order form or by calling 800-292-0969
   d. After passing the required exams and depending on the type of license for which the applicant is applying, need to check with the Bureau of Pesticide Control for further details
2. For Certified Private Applicators:
   a. Complete Certified Private Applicator Training Program (sponsored by University of Missouri Cooperative Extension Service)
   b. Complete Private Applicator Certification Training Verification Form

C. Certification expiration and recertification
1. Certified Commercial Applicator licenses expire annually. The license may be renewed by submitting the license fee and the signed renewal card before expiration. (As of 2002, the fee is $50; contact the Bureau of Pesticide Control for changes.)
2. Certified Noncommercial Applicator licenses expire annually. The license may be renewed by submitting the license fee and the signed renewal card before expiration. (As of 2002, the fee is $25; contact the Bureau of Pesticide Control for changes.)
3. Certified Public Operator licenses expire every 3 years and may be renewed by submitting the signed renewal card (no license fee is charged).
4. Certified Private Applicator licenses expire 5 years from issue date. License and certification may be renewed by completing recertification training at the local county Extension office.
5. All Certified Applicators and Operators are required by state law to renew their certification every 3 years.
   a. This may be accomplished by attending an approved recertification program or by reexamination.
   b. The University of Missouri Cooperative Extension Service provides recertification training annually during January. Other groups, businesses, and associations also sponsor recertification training programs.
   c. The Missouri Department of Agriculture Bureau of Pesticide Control must approve all recertification training programs before awarding recertification credit to those who attend.
   d. Guidelines for pesticide recertification training programs may be obtained by contacting the Bureau of Pesticide Control.

D. Contact information:
Missouri Department of Agriculture Bureau of Pesticide Control
Plant Industries Division
The Bureau of Pesticide Control
P.O. Box 630
Jefferson City, MO 65102
Phone: 573-751-5504

Fax: 573-751-0005

E. Reciprocal states
   1. Reciprocity allows an applicant to apply for a Missouri license based on applicant's certification in another state without having to take and pass the Missouri certification examinations.
   2. The Missouri Department of Agriculture has entered into formal reciprocal agreements with the following states:
      a. Agricultural Aviation Board of Mississippi - Categories 1A, 2, 5, and 6
      b. Arkansas - all categories except for ornamental and turf pest control and the structural pest control categories
      c. Illinois - all categories administered by the Illinois Department of Agriculture (no agreement with the Illinois Department of Public Health)
      d. Iowa - all categories
      e. Kansas - all categories
      f. Louisiana - all categories except for the structural pest control categories
      g. Nebraska - all categories

F. Other Activities and Strategies

1. Have students obtain applications for state certification for Commercial Applicator. If they were actually taking the exam, what information would they need to know? Where is the nearest test site? When is the next test date?

2. Invite an agriculture Extension agent to discuss pesticide safety. Topics that may be of interest include least toxic pesticide controls, biopesticides, and insect growth regulators.

3. Show the class any of the following videos, available from CATER (Career & Technical Education Resources), 2 London Hall, University of Missouri-Columbia: *Pesticide Safety in the Greenhouse* (AG V90), *Part I: Minimal Risk for Pesticide Applicator* (AG V233), *Part II: Minimal Risk to the Environment* (AG V234).

G. Conclusion

Understanding the contents of a pesticide label, applying the chemicals, and knowing what safety precautions to take are critical factors in managing pesticides in the greenhouse.

H. Answers to Activity Sheets

AS 6.5 Pesticide Dilution Ratios

1. 1.1 lb
2. 35%
3. 2.4 lb
4. 7 gal.
5. 20%
6. 5.2 gal.

AS 6.6 Pesticide Update

Instructor's discretion

I. Answers to Assessment

1. A
2. A
3. D
4. D
5. C
6. D
7. E
8. B
9. G
10. C
11. F
12. A
13. A. External irritants
    B. Internal poisons
14. A. Human and animal fatality
    B. Contaminated water and food
    C. Polluted environment
15. A. Caution - slight toxicity
    B. Warning - slightly toxic
    C. Danger or Danger - Poison - highly toxic
16. The student may list any four of the following:
    A. Goggles
    B. Respirator
    C. Long sleeves rolled over long rubber gloves
    D. Hat
    E. Rubber boots
    F. Overalls
    G. Coveralls secured with band over boots
17. A. The Environmental Protection Agency B. Federal government
18. A. Information on pesticide exposure
    B. Protection against exposure
    C. Means to mitigate exposure

UNIT VI: PLANT HEALTH

Name___________________

Lesson 3: Pesticide Use and Safety

Date____________________

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. How often must all Certified Applicators and Operators renew their certification?

   A. Every 3 years
   B. 5 years for issue date
   C. Annually
   D. Every 2 years

2. Who mandates the disposal of pesticides?

   A. USDA and the EPA
   B. USDA and the State Department of Agriculture
   C. State Department of Natural Resources and Conservation and USDA
   D. State Department of Agriculture and the EPA

3. What information does a pesticide label contain?

   A. LD_{50} test animal, storage directions, and intended use
   B. Restrictions, ingredient statement, and price
   C. Poison control center's telephone number, hazards, and toxicity to other plants and animals
   D. EPA classification, first aid recommendations, and signal words

4. Who can provide a greenhouse operator with the most current information and recommendations on pesticides?

   A. University Extension offices, the EPA, and Department of Natural Resources
   B. Department of Agriculture (federal and state), Department of Conservation, and university Extension office
   C. Pesticide retailers, the EPA, and Department of Agriculture (federal and state)
   D. University Extension office, pesticide retailers, and Department of Agriculture (federal and state)

5. What type of pesticide is made up of aerosols, emulsifiable concentrates, and flowable forms?

A. Dry
B. Gel
C. Liquid
D. Semisolid

Match the type of pesticide on the left with the method of damage done to pests on the right. Write the letter in the space provided.

______6. Biologics	A. Kills when swallowed
______7. Contact	B. Kills when inhaled
______8. Fumigant	C. Lures pests to traps
______9. Growth hormones	D. Living organisms kill pests
______10. Pheromones	E. Kills pests directly
______11. Protectants	F. Prevents pests' entry
______12. Stomach	G. Disrupts pests' development

Short-Answer Questions: Write the answers in the space provided.

13. What are the two basic categories of pesticide poisoning?

A.

B.

14. What are three consequences of improper pesticide use?

A.

B.

C.

15. What are the three signal words that may appear on a pesticide? What is the toxicity level of each signal word?

Signal Word	Toxicity Level
A.	A.
B.	B.
C.	C.

16. Each label recommends Personal Protective Equipment. What are four items that might be required when applying pesticide?

    A.

    B.

    C.

    D.

17. A. What agency issued the Worker Protection Standard?

    B. Is it a local, state or federal entity?

18. What are the three main elements of the Worker Protection Standard?

    A.

    B.

    C.

Sample Pesticide Label

TM 6.12

7. RESTRICTED USE PESTICIDE
(GROUND AND SURFACE WATER CONCERNS)
FOR RETAIL SALE AND USE ONLY BY CERTIFIED APPLICATORS OR PERSONS UNDER THEIR DIRECT SUPERVISION, AND ONLY FOR THOSE USES COVERED BY THE CERTIFIED APPLICATOR'S CERTIFICATION.

8. Bug-B-Ded Incecticide
14. 6EC

9. Active Ingredient:
Killazine (2, 4, 6 diamizine) 37.4%
Inert ingredients: 62.6%
Total: 100.0%
1 gal. contains 6.0 lb. killazine
10. 2.5 GALLONS
U.S. Standard Measure
11. EPA Reg. No 100-358
12. EPA Est. 34704-MI-1
3. Statement of Practical Treatment
If swallowed, DO NOT induce vomiting. Call a physician or Poison Control Center immediately.
If in eyes, flush with plenty of water.
If on skin, wash with plenty of soap and water.
NOTE TO PHYSICIAN: vomiting should only be induced under professional supervision.

17. Directions for Use
It is a violation of federal law to use this product in a manner inconsistent with its labeling.

Agricultural Use Requirements
Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR part 170.
Do not enter or allow worker entry into treated areas during the restricted-entry interval (REI) of 4 hours.
PPE is required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water is:
• Coveralls • Waterproof gloves • Shoes plus socks

Cool-season turf: Chinch bugs, fleas and mole crickets: apply 1 ounce of product per 1000 square feet.
Warm-season turf: White grubs: apply 2 ounces product per 1000 sq. ft. and water in with supplemental irrigation. Allow at least 10 days before making a second application.

1. Keep out of the reach of children
2. CAUTION
4. Harmful if swallowed or absorbed through the skin. Causes minor skin irritation.

5. Personal Protective Equipment (PPE):
Applicators and other handlers must wear:
• Long sleeved shirts
• Chemical resistant gloves
• Shoes plus socks
6. Environmental Hazards
This product is toxic to fish. Do not apply directly to water or to areas where surface water is present.
15. Physical or Chemical Hazards
Do not use or store near heat or open flame.
18. Storage and Disposal
Storage: Do not contaminate water, food, or feed by storage or disposal. Store at temperatures above 32°F.
Pesticide Disposal: Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility.
Container Disposal: Triple rinse (or equivalent). Then puncture container and dispose of in a sanitary landfill or incinerate.
16. Limited Warranty and Disclaimer:
The manufacturer warrants that this product conforms to the chemical description on the label; that this product is reasonably fit for the purposes set forth in the directions; that the directions, warnings, and other statements on this label are based upon responsible experts' evaluation of reasonable tests of effectiveness, of toxicity to laboratory animals, and to plants, and of residues on food crops and upon reports of field experience.

13. BUGS-R-US Inc.
1468 North-South Expressway
P.O. Box 5600
Research Triangle Park, NC 123451.

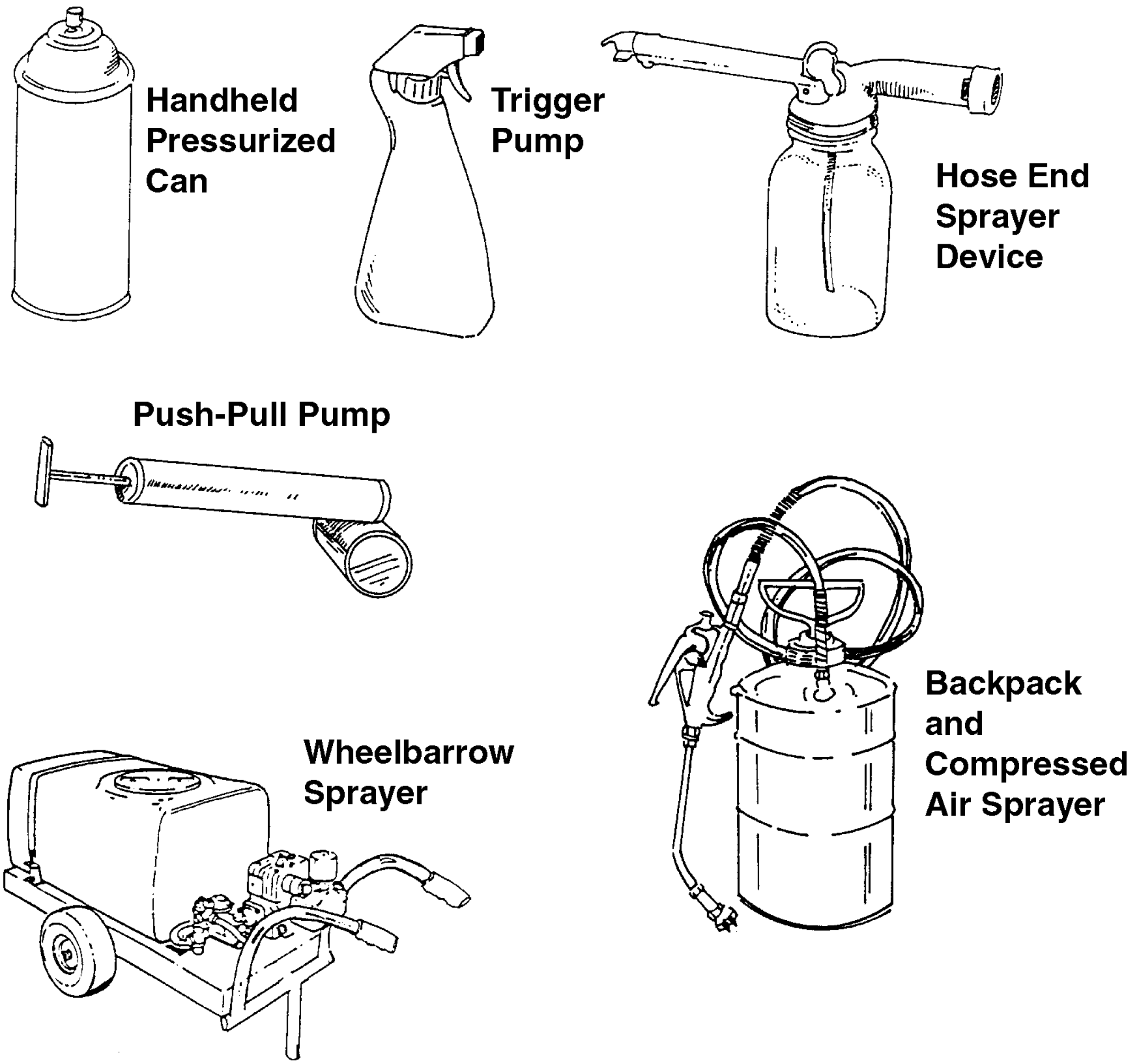
Key to Numbering

1. Child hazard warning.
2. Signal word.
3. Statement of practical treatment
4. Hazards to humans and domestic animals
5. Personal protective equipment
6. Environmental hazards
7. Use classifications
8. Brand (trade) name
9. Ingredient statement
10. Net contents
11. EPA registration number
12. EPA establishment number
13. Name and address of manufacturer
14. Formulation
15. Physical or chemical hazards
16. Limited warranty and disclaimer
17. Directions for use
18. Storage and disposal

From Fred Fishel and Paul Andre. "Understanding the Pesticide Label." Agricultural publication G1911 - Reprinted December 1, 2001. University of Missouri-Columbia. <http://muextension.missouri.edu/xplor/agguides/agengin/g01911.htm> accessed 4/1/02.

TM 6.13

Types of Sprayers Used to Apply Pesticides



TM 6.14

Sample Pesticide Application Log

Procedure	Application #1	Application #2
Area Treated: Location & Description		
Product Name		
EPA Registration Number		
Active Ingredient: Common or Chemical Name		
Date of Application: Month/Day/Time		
Entry Restricted Until: Month/Day/time		
Requirement to Post When Area Is Treated? Yes/No		
Requirement to Give Oral Notification? Yes/No		
PPE Requirements for Handlers		
Early Entry PPE Required for Workers		
Other Label Requirements to Protect Workers and Others		

UNIT VI: PLANT HEALTH

AS 6.5

Lesson 3: Pesticide Use and Safety

Name________________________

Pesticide Dilution Ratios

Objective: Compute pesticide dilution ratios.

Directions: Use each of the following formulas for dilution ratios to answer the questions. Show all of your work.

Note: 8.3 lb/gal. equals the weight of water.

- To find the number of gallons of emulsifiable concentrate needed to produce a spray of a given percentage of active ingredient:

$$\frac{\textbf{gallons of spray wanted X percent of active ingredient wanted X 8.3 lb/gal.}}{\textbf{pounds active ingredient per gallon of concentrate X 100}}$$

- To find the number of pounds of wettable powder needed to produce a spray of a given percentage of active ingredient:

$$\frac{\textbf{gallons of spray wanted X percent of active ingredient wanted X 8.3 lb/gal.}}{\textbf{percent active ingredient in insecticide product}}$$

- To find the percentage of active ingredient in a mixed product:

$$\frac{\textbf{pounds of insecticide used X percent of active ingredient}}{\textbf{gallons of mixture X 8.3 lb/gal.}}$$

1. How many pounds of cyromazine 75% wettable powder are needed for 200 gal. of spray solution with .05% cyromazine?

2. Six pounds of bendiocarb in a 50% wettable powder are mixed in 100 gal. of water. What is the percentage of active ingredient in the mixed spray?

3. How many pounds of cyfluthrin 85% wettable powder are needed for 100 gal. solution with 0.25% cyfluthrin?

4. How many gallons of naled 25% emulsifiable concentrate (1.75 lb naled per gallon) are needed to make 100 gal. of spray with 1.5% naled?

5. Two and a half pounds of carbaryl in a 65% wettable powder are mixed in 100 gal. of water. What is the percentage of active ingredient in the spray mixture?

6. How many gallons of naled 35% emulsifiable concentrate (3 lb naled per gallon) are needed to make 250 gal. of spray with 0.75% naled?

UNIT VI: PLANT HEALTH

AS 6.6

Lesson 3: Pesticide Use and Safety

Name__________________

Pesticide Update

Objective: Summarize new information on issues surrounding pesticides in greenhouses.

Directions: Use at least one of the reliable sources listed in the Student Reference. Web sites are acceptable if the information is from a government source, university Extension, or professional journal.

1. What is the name of the source you accessed (e.g., EPA web site)?

2. What are the names of the new chemicals that have been approved for greenhouse use?

3. What is the use of the chemicals (e.g., fungicide for vegetable crops)?

4. Have any chemicals been banned?

5. Which ones?

6. What is the phaseout period?

7. Why the ban?

8. Are there any new biopesticides? Explain.

9. What is the status of the Food Quality Protection Act of 1996? What are the potential ramifications to greenhouse operators? Has it been amended? If so, how? Has it been repealed?

10. Is there any other new legislation, either national or state, that affects greenhouse operators?

GREENHOUSE OPERATION AND MANAGEMENT

Unit VII: Greenhouse Business Management

Lesson 1: Commercial Greenhouse Crops

Objective:

Plan a commercial greenhouse crop.

Study Questions:

1. Why are certain commercial crops selected for a greenhouse operation?

2. How does a growing schedule expedite the production of commercial crops?

3. What are the costs of producing commercial crops?

4. How is the quality of commercial crops evaluated?

5. What do commercial plants need after harvest and during marketing?

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 7.1 Missouri's Commercial Floriculture Crops
   TM 7.2 Missouri's Popular Floriculture Crops

3. Activity Sheets

   AS 7.1 Selecting Commercial Crops and Devising a Growing Schedule
   AS 7.2 Cost Analysis of a Commercial Crop
   AS 7.3 Plant Care After Harvest and During Marketing

TEACHING PROCEDURES

A. Introduction

Unit VII focuses on two broad aspects of greenhouse business management: planning a commercial crop and developing a marketing plan. Lesson 1 describes factors in crop selection, growing schedule, cost analysis, crop evaluation, and caring for the crops postharvest and during marketing.

B. Motivation

Be sure that the plants grown in Unit IV are prominently displayed in the classroom. Ask students to discuss why they selected a certain type of plant to grow. Ask them to analyze the factors that influenced their choice. If they wanted to sell their plant, how would they care for it? A greenhouse owner resolves similar questions on a larger scale.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. Instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. Why are certain commercial crops selected for a greenhouse operation?

Refer to TM 7.1 to remind the class of the wholesale value of Missouri commercial crops. Ask students to use the data as they consider which floriculture crop(s) would be the most successful for a commercial greenhouse operation. Have them justify their choices. If a crop is not as profitable as others, should the greenhouse owner still grow it? How does demand from customers dictate the selection of commercial crops? During the discussion of specific types of commercial crops, refer to TM 7.2.

A. In response to market analysis
   1. Determine what types of crops to grow.
      a. Visit local nurseries, landscaping outlets, retail and wholesale operations.
      b. Determine if producing new crops is profitable.
   2. Identify types, sizes, and amounts of plants that customers want.
      a. Read trade journals (e.g., *Greenhouse Manager*, *Greenhouse Grower*, and *Grower Talks*).

   b. Read popular magazines (e.g., *Midwest Living*, *Better Homes and Gardens*, and *House Beautiful*).

B. To determine sales potential of cut flowers
   1. Available in various retail outlets (floral shops, malls, grocery stores)
   2. Some cut flowers sold on special occasions (e.g., roses on Valentine's Day)

C. To determine sales potential of foliage
   1. Numerous species and varieties
   2. Several species produced year-round (e.g., foliar hanging baskets)

D. To determine sales potential of potted flowering plants
   1. Some plants (e.g., poinsettias, Easter lilies) are produced at specific times.
   2. Many plants are produced throughout the year (e.g., chrysanthemums).

E. To determine sales potential of bedding/garden plants
   1. Complement personal and commercial landscaping
   2. Produced for spring sales; some also available during summer and fall (e.g., impatiens, petunias)
   3. Represent nearly 59% of Missouri's floriculture crops in 1999

2. How does a growing schedule expedite the production of commercial crops?

Ask students if having a growing schedule is important. Have them explain whether a greenhouse owner should create such a plan. What would happen if the owner wanted to cultivate multiple varieties of plants but had no growing schedule? Then ask them to list the information that could be included in a crop schedule.

A. Identifies when to plant each crop

B. Outlines specific times for various cultural practices for each crop, for example:
   1. Planting
   2. Fertilization
   3. Irrigation
   4. Application of pesticides (See TM 6.14 - Sample Pesticide Application Log in Unit VI, Lesson 3.)
   5. Propagation
   6. Aeration
   7. Drainage
   8. Day-length treatment
   9. Harvest
   10. Postharvest

C. Identifies environmental conditions required, for example:
   1. Temperature
   2. Amount of light exposure
   3. Moisture/humidity levels
   4. Growing media
   5. Nutrients
   6. Foliar analysis
   7. Presence of diseases and pests

D. Records management procedures
   1. Order/reorder supplies
   2. Ship crops
   3. Billing
E. Develops crop rotation plan
   1. Plan efficient year-round use of bench space.
   2. Space plants very close together when they are first transplanted.
   3. As plants develop, allow more space between pots.
   4. Determine number and spacing of plants on benches.
   5. Calculate production time and space required per crop (measured in square foot weeks).
      a. Determine how many square inches there are per flat. (Multiply the dimensions of the flat.)
      b. Convert square inches to square feet by dividing the total number of square inches in the flat by 144 (the total number of square inches per square foot). The result is the amount of bench space per flat in square feet.
      c. Multiply the amount of bench space in square feet by the number of weeks required to grow the plant.
      d. The result is the amount of bench space required as measured in square foot weeks.

      Example: One coleus flat is 12 x 24 in. and it takes 6 weeks to grow.

      12 in. x 24 in. = 288 sq in.

      (1 sq ft = 12 X 12 sq in. [144 sq in.])

      Convert square inches into square feet. Divide the total number of square inches in the coleus flat (288) by 144 sq in. (1 sq ft).

      288/144 = 2 sq ft (amount of bench space per flat)

      2 sq ft X 6 weeks = 12 sq ft weeks (amount of bench space required in square foot weeks)

F. Identifies who is responsible for performing each task throughout growing cycle

3. What are the costs of producing commercial crops?

Draw upon students' SAE experiences in the greenhouse industry or other agriculture-related enterprises by asking them to identify types of expenses in those jobs. Explain that just like other businesses, greenhouse operations have expenses that are categorized into two groups. And all business operations must generate a cost analysis to assess profit and loss. AS 7.2 gives the students an opportunity to generate their own cost analysis.

A. Fixed (ownership) costs are paid regularly, regardless of amount of sales.
   1. Major categories: depreciation, interest, repairs and shelter, taxes, and insurance
   2. Greenhouse operations

a. Depreciation of greenhouse structure and equipment
b. Interest on land and building(s)
c. Repair expenses to maintain greenhouse structures, equipment, etc.
d. Taxes on property
e. Insurance for employees and greenhouse structure

B. Variable (operating) costs change with production level and amount of use.
1. Major categories: labor (salaries), fertilizer, chemicals, seed, gasoline and oil, inventory, supplies, advertising, utilities, telephone, principal payment
2. Greenhouse operations
a. Labor (seasonal and full-time employees)
b. Fertilizer, rooting and growing media, chemicals
c. Seeds and plants
d. Fuel for heating greenhouse
e. Inventory of growing and packing supplies (containers and labels)
f. Advertising and display expenses
g. Utilities, water, and telephone

C. Cost analysis calculates profit and loss of the operation and indicates the net return. A cost analysis statement lists the following information:
1. Amount of all variable expenses designated directly to specific crop
2. Income received from all crops
3. For fixed expenses: average weekly cost per square foot of bench space (used and vacant benches)

Formula: Total fixed costs/52 (number of weeks per year)/square foot bench space = average cost per week per square foot

Example: Total fixed costs = $15,000; total bench space = 20,000 sq ft

$15,000/52 = $288.46 per week

$288.46/20,000 sq ft = $0.014 per week per square foot

4. How is the quality of commercial crops evaluated?

The greenhouse owner must assess the quality of commercial crops before selling them to customers. Ask students to describe the characteristics of a plant they would consider buying.

A. Adequate nutrients and fertilization for optimal growth
B. Sufficient water, aeration, and drainage
C. Absence of yellow, broken, or dying leaves
D. Free of insect damage
E. Neat and clean plant container
F. Informative care tag provided for customer
G. Appealing packaging of plant and container

5. **What do commercial plants need after harvest and during marketing?**

   After crops are harvested and ready for sale, they must be maintained under favorable environmental conditions and handled with care.

   A. Postharvest
      1. Maintaining moisture in plants
         a. Keep relative humidity at optimal level for crops.
         b. Offset depletion of water during refrigeration and humidify storage area.
      2. Regulating respiration rate
         a. High temperatures raise respiration rate.
         b. Store plants at recommended cool temperatures.
      3. Handling crops carefully
         a. Do not touch plants more than necessary.
         b. Put plants in protective containers that are appropriately filled.
         c. Ensure plants' safety when loading onto trucks/vans for shipping.
   B. Marketing
      1. Keep storage and display areas cool.
      2. Provide correct amounts of light and shade.
      3. Provide small amounts of fertilizer.
      4. Water only as needed.
      5. Elevate plants.
      6. Maintain cleanliness to prevent damage from ethylene production.

F. Other Activities and Strategies

1. Bring in various seed catalogs and have students plan a flower or vegetable garden. Ask them to justify their choices and compile a list of cultural and environmental procedures that each plant would require.

2. Show one or more videos from the *Landscape Design Series* available from CATER (Career & Technical Education Resources), University of Missouri-Columbia: *Volume I: Principles of Landscape Design* (AG V148), *Volume II: The Landscape Design Process* (AG V149), and *Volume III: Landscape Design Presentation* (AG V150).

3. Show other videos relating to commercial crops available from CATER: *A Professional's Guide to Success with Bedding Plants* (AG V160), *Planting Techniques Part II: Herbaceous Plants and Ground Covers* (AG V174), *Landscaping with Container Plants* (AG V176), and *Seasons of Beauty: Desert Plants for Your Landscape* (AG V245).

G. Conclusion

In selecting commercial crops for a greenhouse operation, the owner considers which types of plants are profitable to sell. Consumer demand is a major influence. A growing schedule is designed to systematically organize all stages of the production cycle. Greenhouse operations have fixed and variable expenses. The owner develops a cost analysis to determine profit and loss. In order to sell the plants, they must be appealing to the customer and in good condition. After harvest and during marketing, the crops need special care.

H. Answers to Activity Sheets

AS 7.1 Selecting Commercial Crops and Devising a Growing Schedule

Answers will vary.

AS 7.2 Cost Analysis of a Commercial Crop

Answers will vary.

AS 7.3 Plant Care After Harvest and During Marketing

Answers will vary.

I. Answers to Assessment

1. Students may list any two of the following:
   A. Determine what types of crops to grow.
   B. Visit local nurseries, landscaping outlets, retail and wholesale operations.
   C. Determine if producing crops is profitable.
   D. Identify types, sizes, and amounts of plants that customers want.
   E. Read trade journals (*Greenhouse Manager*, *Greenhouse Grower*, and *Grower Talks*)
   F. Read popular magazines (e.g., *Midwest Living*, *Better Homes and Gardens*, and *House Beautiful*)
   G. Determine sales potential of cut flowers, foliage, potted flowering plants, and bedding/garden plants
2. A. Complement personal and commercial landscaping
   B. Produced for spring sales; some also available during summer and fall
   C. Represent nearly 59% of total horticultural sales (1999)
3. Students may list any four of the following:
   A. Planting
   B. Fertilization
   C. Irrigation
   D. Application of pesticides
   E. Propagation
   F. Aeration
   G. Drainage
   H. Day-length treatment
   I. Harvest
   J. Postharvest
4. A. Plan efficient use of bench space
   B. Determine number and spacing of plants on benches

5. Students may list any four of the following for each type of cost:

    Fixed Costs

    A. Depreciation of greenhouse structure and equipment
    B. Interest on land and building(s)
    C. Repair expenses to maintain greenhouse structures, equipment, etc.
    D. Taxes on property
    E. Insurance for employees and greenhouse structure

    Variable Costs

    A. Labor (seasonal and full-time employees)
    B. Fertilizer and growing media
    C. Seeds and plants
    D. Fuel for heating greenhouse
    E. Inventory of growing supplies
    F. Advertising expenses
    G. Utilities and telephone
6. A. The amount of all variable expenses, designated directly to each crop
    B. The income received from all crops
    C. For fixed expenses, the average weekly cost per square foot of bench space (used and vacant benches)
7. Students may list any four of the following:
    A. Adequate nutrients and fertilization for optimal growth
    B. Sufficient water, aeration, and drainage
    C. Absence of yellow, broken, or dying leaves
    D. Free of insect damage
    E. Neat and clean plant container
    F. Informative care tag provided for customer
    G. Appealing packaging of plant and container
8. Students may list any two of the following:
    A. Maintaining moisture in plants
    B. Keep relative humidity at optimal level for crops.
    C. To offset depletion of water during refrigeration, humidify storage area.
    D. Regulating respiration rate
    E. Store plants at recommended cool temperatures.
    F. Handling crops carefully
    G. Do not touch plants more than necessary.
    H. Put plants in protective containers that are appropriately filled.
    I. Ensure plants' safety when loading onto trucks/vans for shipping
9. Students may list any two of the following:
    A. Keep storage and display areas cool.
    B. Provide correct amounts of light and shade.
    C. Apply small amounts of fertilizer.
    D. Water only as needed.
    E. Elevate plants
    F. Maintain cleanliness to prevent exposure to ethylene gas (typically from automobile fumes).

UNIT VII: GREENHOUSE BUSINESS MANAGEMENT

Name ________________________

Lesson 1: Commercial Greenhouse Crops

Date ________________________

ASSESSMENT

Short-Answer Questions: Write your answers in the space provided.

1. What are two ways to decide which crops should be selected?

   A.

   B.

2. What are three reasons that bedding/garden plants are often selected as commercial crops in Missouri?

   A.

   B.

   C.

3. What are four cultural practices included in a growing schedule?

   A.

   B.

   C.

   D.

4. What are two reasons for having a crop rotation plan?

   A.

   B.

5. What are four examples of fixed and variable costs in greenhouse operations?

Fixed Costs	Variable Costs
A.	A.
B.	B.
C.	C.
D.	D.

6. What are three sources of information that a cost analysis provides?

   A.

   B.

   C.

7. When a greenhouse owner evaluates the commercial crop, what are four characteristics he or she looks for?

   A.

   B.

   C.

   D.

8. After harvest, what are two conditions that plants require?

   A.

   B.

9. What are two necessary conditions for plants that are ready for marketing?

   A.

   B.

TM 7.1

Missouri's Commercial Floriculture Crops

Crop	Wholesale Value*	Percent of Total
Cut Flowers	$ 281,000	0.8
Foliage Plants	2,192,000	6.4
Potted Flowering Plants	11,711,000	34.2
Bedding and Garden Plants	20,085,000	58.6
TOTAL	**$34,269,000**	**100%**

*Crops grossing $100,000 or more in 1999; *Missouri Farm Facts*, 2000

TM 7.2

Missouri’s Popular Floriculture Crops

CUT FLOWERS*

Chrysanthemums
Daffodils/narcissus
Gladioli
Iris
Roses
Snapdragons
Tulips
Zinnias

FOLIAGE PLANTS**

Potted Foliage
Foliar Hanging Baskets

POTTED FLOWERING PLANTS**

African violets
Azaleas
Chrysanthemums
Easter lilies
Poinsettias
Potted cyclamens
Potted kalanchoes

BEDDING/GARDEN PLANTS**

Geraniums
Hardy/garden chrysanthemums
Impatiens (also New Guinea impatiens)
Petunias
Vegetable flats

* Examples taken from *1997 Census of Agriculture*, Volume 3, Special Studies Part 2. “Census of Horticultural Specialties (1998).” U.S. Department of Agriculture, National Agricultural Statistics Service.

**Crops grossing $100,000 or more in 1999; *Missouri Farm Facts*, 2000

Unit VII: GREENHOUSE BUSINESS MANAGEMENT

AS 7.1

Lesson 1: Commercial Greenhouse Crops

Name________________________

Selecting Commercial Crops and Devising a Growing Schedule

Objective: Select commercial crops for a greenhouse operation. Justify your choices and create a growing schedule that outlines when to perform key cultural, environmental, and management practices.

Directions: Work with a partner or on your own. Access the Internet, trade journals, university Extension publications, federal and state documents, etc., to obtain information about various greenhouse crops. Base your selections on the information presented in the following scenario.

You are in charge of a retail greenhouse in Missouri that has been in business for 4 years. Your staff includes a grower, three growing assistants, a production specialist, a greenhouse service technician, and a marketing manager. You want to start cultivating three to four new crops. The greenhouse has 14,000 sq ft of bench space. Since your operation began, a wholesale garden center and a landscaping business started and their sales are booming. Your community is growing as well. The housing market is flourishing and employment, representing diverse sectors, is at an all-time high.

Commercial Crop Selected	Justification
1.	
2.	
3.	
4.	

Growing Schedule

Create additional rows and columns as needed. Provide a different growing schedule for each crop. In addition to listing activities performed after planting, indicate when events should be done *before* planting by enclosing the week number within parentheses, e.g., "Order supplies (12)" in the "Week After Planting" column. Enter specific dates, e.g., 3/11-3/15 in the "Actual Week" column.

Note: If you have access to a spreadsheet, create a template for this crop schedule and enter the information online.

(Crop Name)

____

Step	Cultural, Environmental, and Management Practices	Week After Planting	Actual Week	Staff Member Responsible for Task	Date Completed
1.					
2.					
3.					
4.					
5.					

Unit VII Greenhouse Business Management

AS 7.2

Lesson 1: Commercial Greenhouse Crops

Name____________________

Cost Analysis of a Commercial Crop

Objective: Generate a cost analysis for a greenhouse crop.

Directions: Work with a partner or on your own. Use the Internet, commercial catalogs, and other sources to finish filling out the blanks below and then answer the following questions. You may choose one of the crops from the previous activity sheet. Use the following scenario. Show all of your work.

The greenhouse has 5,000 sq ft of bench space. The production time for the crop is 20 weeks. Assume your crop consists of 750 cuttings grown in 6-inch pots. Your utilities for the year are $2,225 and labor costs are $1,480 for the year.

Crop: _________________

Fixed Costs*

Depreciation: $2,000

Interest on Investment: $40,000 X 6% opportunity cost =______________

Repairs & Maintenance: $600

Taxes: $40,000 X 32% (commercial rate) X $5.20/$100 assessed value = ______

Insurance: $550

Total fixed costs: $_________________

Average cost per week per square foot = total fixed costs/52 weeks per year/square foot bench space

Average cost per week per square foot = ________________________________

*Estimates for the purpose of this exercise only

Variable / Operating Costs

Rooted Cuttings:	
Royalty/Cutting:	
Transportation/Cutting:	
Soilless Media:	
Containers:	
Fertilizer:	
Fungicides: *	
Insecticides: *	
Care Tags:	
Commission:	
Advertising/Mailing/Paper/Copying:	
Subtotals:	
Death Loss or Unsalable: (5% of subtotal)	
Totals:	

*May be optional for your crop

1. What are the total costs for the crop?
2. What is the total cost per plant?
3. What is the net profit for the plant?
4. At what sale price could you sell the plants and still make a profit?

Unit VII Greenhouse Business Management

AS 7.3

Lesson 1: Commercial Greenhouse Crops

Name___________________

Plant Care After Harvest and During Marketing

Objective: Outline the specific care requirements after harvest and during marketing for two types of plants.

Directions: The table below lists the four floriculture crops produced in Missouri, including popular plants per crop. Select two different crops. For each crop, select one representative plant. (For example, you could select cut flowers and foliage as two different crops. Then you could select daffodils as a representative plant of the cut flower crop and potted foliage as a representative of the foliage crop.) Write the two crop names and the two plant names at the top of the After Harvest Care and Marketing Care tables. List the care requirements in the rows provided. If necessary, add more rows.

Floriculture Crops in Missouri			
Cut Flower Crop	**Foliage Crop**	**Potted Flowering Crop**	**Bedding/Garden Crop**
Chrysanthemums	Potted foliage	African violets	Geraniums
Daffodils	Hanging baskets	Azaleas	Hardy chrysanthemums
Narcissus		Chrysanthemums	Impatiens
Gladioli		Easter lilies	New Guinea impatiens
Iris		Poinsettias	Petunias
Roses		Potted cyclamens	Vegetable flats
Snapdragons		Potted kalanchoes	

Crop #1: **Plant #1:**	**Crop #2:** **Plant #2:**
AFTER HARVEST CARE	AFTER HARVEST CARE
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.
7.	7.
8.	8.
9.	9.
10.	10.

Crop #1: **Plant #1:**	**Crop #2:** **Plant #2:**
DURING MARKETING CARE	DURING MARKETING CARE
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.
7.	7.
8.	8.
9.	9.
10.	10.

GREENHOUSE OPERATION AND MANAGEMENT

Unit VII: Greenhouse Business Management

Lesson 2: Marketing Plan

Objective:

Develop a basic marketing plan.

Study Questions:

1. How is the customer base identified?

2. How does a greenhouse business attract customers?

3. How does record keeping help manage a greenhouse business?

References / Supplies / Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Assignment Sheet

   AS 7.4 Creating a Marketing Plan

TEACHING PROCEDURES

A. Review

   After planning commercial crops, the greenhouse owner must develop a marketing plan that promotes sales and ensures a profit. Lesson 2 addresses the basics of a marketing plan. It describes how to determine the customer base, attract customers, and keep records relating to key aspects of the greenhouse operation.

B. Motivation

   Engage students in a discussion about farmers' markets or local greenhouses that sell flowers, vegetables, or bedding plants. What crops sold the best? What time of year were they sold? Were the prices reasonable and the quality of the plants acceptable? Where would they prefer to shop? Why are these factors important to the salesperson?

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. Instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. How is the customer base identified?

Select a local agriculture-related business (feed store, nursery, farm equipment dealership, etc.) and ask students to infer what type of customers would be interested in that enterprise. After deciding which types of commercial crops are suited to the greenhouse operation, the owner's first step in developing a marketing plan is to identify the types of customers who would be interested in buying those plants.

A. Determine if selling to wholesale or retail customers
   1. Wholesalers sell in bulk directly to businesses that will sell the crops, such as landscapers, nurseries, vegetable growers, florists, garden centers, chain stores, grocery stores, etc. The wholesalers' customers have the following characteristics:
      a. Do not need special greenhouse sales personnel, displays, advertising, or customer parking lot from the wholesaler
      b. Usually buy entire crop at one time
      c. Purchase assorted crops and supplies year-long
      d. Pay less per crop
   2. Retailers sell to the general public in shopping areas, grocery stores, floral shops, malls, etc. The retailers' customers have the following characteristics:
      a. A large customer base that purchases a relatively small amount of plants
      b. Buys from shopping centers, grocery stores, etc., but may also purchase plants from discounted wholesale outlets
      c. Pay more per crop
      d. Require informed sales personnel, attractive displays, and parking lots
      e. Like to browse throughout greenhouse

B. Conduct market research
   1. What are the demographics of the area?
      a. Income level
      b. Population of community
      c. Age ranges
      d. Employment sectors
      e. Level of unemployment

    f. Characteristics of residential areas
2. Who is the competition?
    a. Determine if market can support multiple greenhouse operations.
    b. Determine if competitors offer same or different products and services.
    c. Identify location of competitors.

2. How does a greenhouse business attract customers?

Like all commercial enterprises, a greenhouse business must attract customers in order to stay economically viable. Ask students to name a few products they typically purchase (or want to buy) and then encourage them to analyze what triggered their interest in the merchandise. Have them focus on how the product is packaged, advertised, displayed, etc. The greenhouse owner's marketing plan must include techniques for attracting customers. Have students complete AS 7.4.

A. Advertising
    1. Direct mail
    2. Web sites on Internet
    3. Media (television, radio, magazines, newspapers)
    4. Provide company logo and information about types of services in visually appealing manner
B. Displays in greenhouse
    1. Located within easy reach
    2. Creatively presented
    3. Encourage browsing in store
    4. Promote specific crops for holidays, seasons, and special occasions
C. Competitive pricing
    1. Determine reasonable profit margin based on what customers are willing to pay and competitors' prices
    2. Provide coupons in weekly advertising supplements

3. How does record keeping help manage a greenhouse business?

An integral aspect of managing a greenhouse business is keeping accurate records. The purposes of record keeping are multifaceted. One of the most significant functions is to provide documentation for specific events indicated on the growing schedule. By having written or computer-generated reports available, the greenhouse owner can make intelligent marketing decisions that affect the production and promotion of his or her crops.

A. Maintains financial records
    1. Tracks and categorizes fixed and variable costs
    2. Records income realized from crops, including
        a. Number of plants sold and price per plant
        b. Grade of products
        c. When each product was sold
        d. Amount of good, unwanted plants and poor-quality, unwanted plants
        e. Amount of all sales

3. Indicates sales trends
4. Compares amount of sales from previous time periods

B. Records employee information (time sheets, salaries, hiring/firing dates, etc.)
C. Records expenses incurred in maintaining all mechanical systems in greenhouse (e.g., irrigation, electrical, and heating)
D. Keeps an up-to-date inventory of all supplies
E. Maintains record of customers
   1. Name, address, phone number
   2. Credit/payment history
   3. Special requests or purchases
F. Records environmental practices, including
   1. Temperature
   2. Nutritional level of growing media
   3. Amount of water
   4. Amount of light
   5. Effect of overall condition of plant (e.g., condition of foliage)
   6. Computer software
      a. Predicts temperature and energy use
      b. Calculates concentrations of nutrients
      c. Manages pest control
G. Records cultural practices, including
   1. Dates of planting each crop
   2. Spacing intervals between each plant
   3. Nutrients and fertilizer provided
   4. Amount of daylight required per plant
   5. Amount, type, and application date of pest control measures (See TM 6.14 -"Sample Pesticide Application Log" in Unit VI, Lesson 3.)
   6. Harvest
   7. Computer software - manages pest control

F. Other Activity and Strategy

Contact a volunteer from the Horticultural Speakers Bureau to speak to the class about gardening (314/577-9442; <ridgwaydb.mobot.org/mobot/edu/mstrgard.htm>).

G. Conclusion

After selecting suitable commercial crops for a greenhouse operation, the greenhouse owner develops a marketing plan. The first consideration is whether to sell crops as a wholesaler or retailer. Once this is resolved, the owner identifies the customer base by analyzing the market. This involves researching the demographics of the area and examining potential competitors. Several advertising techniques can help attract customers. By maintaining careful records, the greenhouse owner ensures that critical components of the business are managed efficiently and correctly. Record keeping also helps the greenhouse owner make informed marketing decisions.

H. Answers to Activity Sheet

Instructor's discretion

I. Answers to Assessment

1. B
2. A
3. A
4. B
5. A
6. B
7. A
8. B
9. A. What are the demographics of the area?
   B. Who is the competition?
10. Students may list any two of the following for <u>one</u> of the following questions:
    (What are the demographics of the area?)
    A. Income level
    B. Population of community
    C. Age ranges
    D. Employment sectors
    E. Level of unemployment
    F. Characteristics of residential areas
    (Who is the competition?)
    A. Determine if market can support multiple greenhouse operations
    B. Determine if competitors offer same or different products
    C. Identify location of competitors
11. A. Advertising (direct mail; web sites on Internet; media [television, radio, magazines, newspapers]; provide company logo, information, and types of services in visually appealing manner)
    B. Displays in greenhouse (located within easy reach; creatively presented; encourage browsing in store; promote specific crops for holidays, seasons, and special occasions)
    C. Competitive pricing (determine reasonable profit margin based on what customers are willing to pay and competitors' prices, provide coupons in weekly advertising supplements)
12. Students may list any five of the following:
    A. Maintains financial records
       1. Tracks and categorizes fixed and variable costs
       2. Records income realized from crops, including
       3. Indicates sales trends
       4. Compares amount of sales from previous time periods
    B. Records employee information (time sheets, salaries, hiring/firing dates, etc.)
    C. Records expenses incurred in maintaining all mechanical systems in greenhouse (e.g., irrigation, electrical, and heating)
    D. Keeps an up-to-date inventory of all supplies
    E. Maintains record of customers

F. Records environmental practices
G. Records cultural practices, including
H. Keeps all records up-to-date and available to greenhouse personnel

UNIT VII: GREENHOUSE BUSINESS MANAGEMENT

Name__________________

Lesson 2: Marketing Plan

Date________________________________

ASSESSMENT

Matching: The left-hand column lists descriptions relating to the characteristics of wholesalers' customers and retailers' customers. Write A for wholesalers' customers and B for retailers' customers in the space provided.

1. ____ Buy plants in shopping areas	A. Wholesalers' customers
2. ____ Purchase assorted crops and supplies year-long	B. Retailers' customers
3. ____ Purchase entire crop at one time	
4. ____ Require parking lots	
5. ____ Pay less per crop	
6. ____ Like to browse in store	
7. ____ Do not need sales personnel, displays, or advertising	
8. ____ Pay more per crop	

Short-Answer Questions: Write your answers in the space provided.

9. What two basic questions are asked while conducting market research?

   A.

   B.

10. Using **one** of the questions listed above, what are two specific pieces of information of interest to a greenhouse owner?

   A.

   B.

11. What are three techniques for attracting customers?

A.

B.

C.

12. What are five ways records help manage greenhouse operations?

A.

B.

C.

D.

E.

UNIT VII: GREENHOUSE BUSINESS MANAGEMENT **AS 7.4**

Lesson 2: Marketing Plan

Name________________________________

Creating a Marketing Plan

Objective: Create a marketing plan that promotes a greenhouse business and selected crops.

Directions: Refer to the scenario described in AS 7.1 in Lesson 7.1, the list of commercial crops selected, and the growing schedules prepared for each new crop. Devise a marketing plan for your greenhouse operation and focus on the three to four new crops you decided to cultivate. Work in small cooperative groups.

Ensure that your marketing plan responds to the following questions:

A. Who are your targeted customers?
B. What techniques are useful for attracting customers?
C. Which records of cultural, environmental, or management practices affect marketing decisions?

Present your marketing plan to the class. Suggested approaches are listed below.

A. Give a PowerPoint presentation.
B. Present plan as a TV or radio commercial.
C. Make an oral presentation using visual aids.
D. Create a web site.

UNIT VII ACTIVITY

Greenhouse Business Management

Name____________________

Designing a Garden

Objective: Plan the design, costs, and growth schedule of a garden.

Directions: Develop a plan for creating one of the projects listed below or devise your own garden. Access one or more of web sites listed below, search the Internet for other sites, consult trade journals and popular magazines, visit local nurseries and greenhouses, and/or talk to professional growers. Be sure to address the following:

- Select suitable plants for your garden.
- Ensure that a local greenhouse or nursery sells them.
- Calculate how much it would cost to create this type of garden.
- Supply a statement of expenses.
- Calculate how much bench space (measured in square feet weeks) is required to plant your garden.
    - Determine how many square inches there are per flat. (Multiply the dimensions of the flat.)
    - Convert square inches to square feet by dividing the total number of square inches in the flat by 144 (the total number of square inches per square foot). The result is the amount of bench space per flat in square feet.
    - Multiply the amount of bench space in square feet by the number of weeks required to grow the plant.
    - The result is the amount of bench space required as measured in square foot weeks.
- Develop a growing schedule for the plants.
- Present your gardening project to the class as a marketing plan; address the students as the targeted customers.
- Devise techniques for interesting them in your garden.

Suggested Web Sites

- Brooklyn, New York, Botanical Garden <http://www.bbg.org>
- Chicago Botanic Garden <http://www.chicago-botanic.org>
- Garden Clubs of Missouri <http://www.gardenclubsofmissouri.org>
- GardenWeb <http://www.gardenweb.com>
- Gateway Greening Inc. (not-for-profit) <http://www.st-louis.missouri.org/gateway-greening>
- HGTV - Home and Garden Television <http://www.hgtv.com/HGTV/searchResults>
- Missouri Botanical Garden <http://www.mobot.org/gardeninghelp>
- Missouri Prairie Foundation <http://www.moprairie.org>

- Missouri Wildflowers Nursery <http://www.mowildflowers.net>
- National Gardening Association <http://www.garden.org>
- Plant a Row for the Hungry (Garden Writers Association of America) <http://www.gwaa.org>
- Powell Gardens, near Kansas City <http://www.powellgardens.org>
- University of Missouri-Columbia, Xplor Horticulture Publications <http://muextension.missouri.edu/xplor/agguides/hort/index.htm>
- Urban Wildlife Sanctuary Program <http://www.wildneighbors.org>
- Wild Ones Natural Landscapers <http://www.for-wild.org>

Gardening Projects

1. Herb garden
2. Landscaping for the yard
3. Flower garden with perennials and/or annuals
4. Organic vegetable garden
5. Garden that attracts hummingbirds and butterflies
6. Desert garden
7. Garden of Missouri native plants
8. Garden of prairie plants
9. Winter garden
10. Topiary garden
11. “Water” garden (pond or water fall, water plants)
12. Japanese-style garden
13. Potted plant garden
14. Shade-loving plant garden
15. Rose garden
16. Bulb garden
17. Vegetable garden for the needy

18. Wildflower garden

19. Formal garden

20. Ground cover garden

21. English

22. Garden based on a color theme

23. Night garden

24. Garden of exotic plants

25. Garden for all seasons