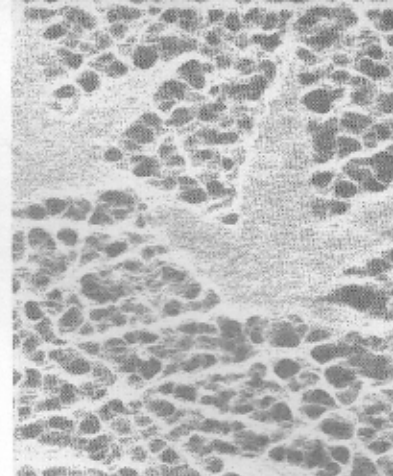


Contents overview



- 1 Introduction 1
- 2 Introduction to the principles of chemistry 15

I Plant Structure 49

- 3 Cell structure 50
- 4 Cell division: mitosis and meiosis 84
- 5 Tissues and the primary growth of stems 103
- 6 Leaves 137
- 7 Roots 159
- 8 Structure of woody flowering plants 181
- 9 Flowers and reproduction 205

II Plant Physiology and Development 237

- 10 Photosynthesis 239
- 11 Respiration 272
- 12 Transport processes 297
- 13 Soils and mineral nutrition 326
- 14 Development and morphogenesis 348
- 15 Genes and the genetic basis of metabolism and development 381

III Genetics and Evolution 417

- 16 Genetics 418
- 17 Population genetics and evolution 452
- 18 Classification and systematics 478
- 19 Kingdom Monera: prokaryotes 502
- 20 Kingdom Mycetozoa: fungi 534
- 21 Algae 573
- 22 Nonvascular plants: mosses, liverworts and hornworts 617
- 23 Vascular plants without seeds 642
- 24 Seed plants I: gymnosperms 677
- 25 Seed plants II: angiosperms 708

IV Ecology 739

- 26 Population and ecosystems 740
- 27 Biomes 772

Glossary G-1

Index I-1

Contents

1 Introduction to plants and botany 1

Concepts 1

Plants 1

Scientific method 3

Areas where the scientific method is inappropriate 5

Origin and evolution of plants 5

Diversity of plant adaptations 10

Plants versus the study of plants 11

2 Introduction to the principles of chemistry 15

Concepts 15

Atoms and molecules 16

Chemical bonds 16

Water 19

Carbon compounds 21

Mechanisms of chemical reactions 24

Second-order reactions 24

Catalysts 25

First-order reactions 25

Reaction equilibria 25

Organic molecules and polymeric construction 26

Functional groups 26

Polymeric construction 27

Carbohydrates 28

Monosaccharides 28

Polysaccharides 29

Amino acids and proteins 31

Levels of organization in protein structure 34

Nucleic acids 35

Lipids 38

Polymers of fatty acid 38

Cofactors and carriers 41

Energy-carrying cofactors 41

Electron carriers 43

Enzymes 44

Substrate specificity 44

Rate of enzyme action 44

Control of enzyme activity 45



Clematis.

I Plant structure 49

3 Cell structure 50

Concepts 50

Membranes 54

Composition of membranes 54

Properties of membranes 56

Basic cell types 59

Plant cells 60

Protoplasm 60

Plasma membrane 60

Nucleus 60

Central vacuole 62

Cytoplasm 63

Mitochondria 63

Plastids 64

Ribosomes 66

Endoplasmic reticulum 68

Dictyosomes 69

Microbodies 70

Hyaloplasm 71

Microtubules 71

Microfilaments 74

Storage products 75

Cell wall 75

Fungal cells 77

Associations of cells 80

Box 3.1 The metric system and geometric aspects of cells 78

4 Growth and division of the cell 84

Concepts 84

Growth phase of the cell cycle 86

G₁ Phase 86

S Phase 86

G₂ Phase 90

Division phase of the cell cycle 90

Mitosis 90

Cytokinesis 93

Meiosis 94

Meiosis I 96

Meiosis II 98

Unusual types of cell division 98

Cell division of prokaryotes 99

Division of chloroplasts and mitochondria 100

5 Tissues and the primary growth of stems 103

Concepts 103

External organization of stems 107

Internal organization of stems 113

Basic types of cells and tissues 113

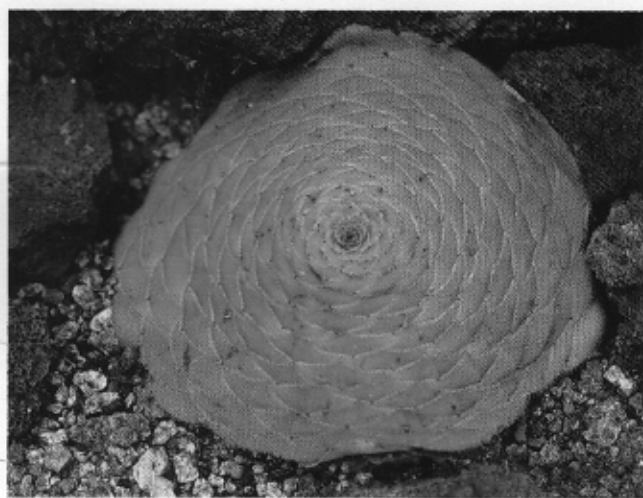
Vascular tissues 118

The Arrangement of primary tissues 126

Stem growth and differentiation 131

Plants and people: Fibers 135

Box 5.1 How much can a plant lose and still be a plant? 108



Aeonium tabuliforme.

6 Leaves 137

Concepts 137

External structure of foliage leaves 138

Internal structure of foliage leaves 145

Epidermis 145

Mesophyll 146

Vascular tissues 148

The petiole 149

Initiation and development of leaves 150

Dicots 150

Monocots 152

Morphology and anatomy of other leaf types 153

Succulent leaves 153

Sclerophyllous foliage leaves 153

Bud scales 154

Spines 155

Tendrils 155

Leaves with Kranz anatomy 156

Insect traps 156

Plants and people: Leaves, food, and death 157

7 Roots 159

Concepts 159

External structure of roots 160

Organization of root systems 160

Structure of individual roots 164

Internal structure of the root 166

Root cap 166

Root apical meristem 167

Zone of elongation 167

Zone of maturation/root hair zone 169

Mature portions of the root 171

Origin and development of lateral roots 172

Other types of roots and root modifications 173

Storage roots 173

Prop roots 174

Contractile roots 175

Mycorrhizae 175

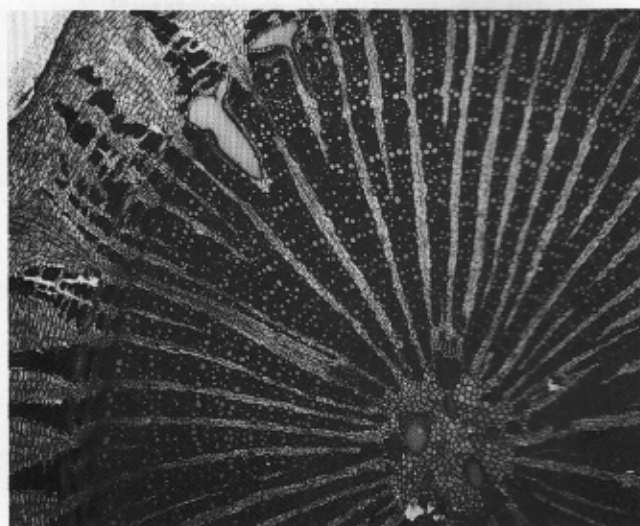
Root nodules and nitrogen fixation 177

Haustorial roots of parasitic flowering plants 178

Plants and people: Roots and world politics 179

8 Structure of woody plants 181

- Concepts 181
- Vascular cambium 184
 - Initiation of the vascular cambium 184
 - Fusiform initials 187
 - Ray initials 188
 - Arrangement of cambial cells 188
- Secondary xylem 188
 - Types of wood cells 188
 - Annual rings 191
 - Heartwood and sapwood 192
- Secondary phloem 194
- Outer bark 195
 - Cork and the cork cambium 195
 - Lenticels and oxygen diffusion 197
 - Initiation of cork cambium 198
- Secondary growth in roots 199
- Anomalous forms of growth 200
 - Anomalous secondary growth 200
 - Multiple vascular cambia 200
- Plants and people: Dendrochronology—tree ring analysis 203
- Box 8.1 Geometry, structure, and function 183



Parthenium argentatum: cross-section of trunk

9 Flowers and reproduction 205

- Concepts 205
- Asexual reproduction 207
- Sexual reproduction 207
 - The plant life cycle 208
 - Flower structure 210
 - The gametophytes 214
 - Fertilization 217
 - Embryo and seed development 218
 - Fruit development 220

Flower structure and cross-pollination 221

- Cross pollination 221
- Stamen and style maturation times 221
- Stigma and pollen incompatibility 222
- Monoecious and dioecious species 222
- Animal-pollinated flowers 223
- Wind-pollinated flowers 224
- Ovary position 225
- Inflorescences and pollination 226
- Fruit types and seed dispersal 229
 - True fruits and accessory fruits 229
 - Classification of fruit types 230
- Agamospermy 233
- Plants and People: Flowers, fruits, seeds, and civilization 234

II Plant physiology and development 237

10 Energy metabolism: photosynthesis 239

- Concepts 239
- Energy and reducing power 240
 - Energy carriers 240
 - Reducing power 242
 - Other electron carriers 245
- Photosynthesis 247
 - The light-dependent reactions 248
 - The stroma reactions 256
 - Anabolic metabolism 259
- Environmental and internal factors 259
 - Light 259
 - Leaf structure 262
 - Water 263
 - C₄ metabolism 264
 - Crassulacean acid metabolism 267
- Plants and people: Photosynthesis, air, and life 269

11 Energy metabolism: respiration 272

- Concepts 272
- Types of respiration 274
 - Anaerobic respiration 275
 - Aerobic respiration 280
 - Heat-generating respiration 287
 - Pentose phosphate pathway 289
 - Respiration of lipids 290
 - Photorespiration 291
- Environmental and internal factors 291
 - Temperature 292
 - Lack of oxygen 292
 - Internal regulation 292
- Total energy yield of respiration 293
- Respiratory quotient 294
- Plants and people: Plants, babies, and heat 295



Rhipsalis.

12 Transport processes 297

Concepts 297

Diffusion, osmosis, and active transport 299

Water potential 300

Cells and water movement 301

Short distance intercellular transport 308

Guard cells 310

Motor cells 311

Transfer cells 311

Long distance transport: phloem 311

Long distance transport: xylem 315

Properties of water 315

Water transport through xylem 317

Control of water transport by guard cells 323

13 Soils and mineral nutrition 326

Concepts 326

Essential elements 327

Criteria for essentiality 330

Mineral deficiency diseases 331

Causes of deficiency diseases 331

Symptoms of deficiency diseases 334

Mobile and immobile elements 334

Soils and mineral availability 335

Cation exchange 337

Soil acidity 339

The endodermis and selective absorption of substances 340

Mycorrhizae and the absorption of phosphorus 340

Nitrogen metabolism 340

Nitrogen fixation 341

Nitrogen reduction 343

Nitrogen assimilation 344

Plants and people: From fertility gods to fertilizers 345

14 Development and morphogenesis 348

Concepts 348

Sensing environmental stimuli 351

Light 351

Gravity 351

Touch 352

Temperature 353

Water 353

Responding to environmental stimuli 354

Tropic responses 354

Nastic responses 355

Morphogenic responses 355

Taxis 357

Communication within the plant 357

Perception and transduction 357

Chemical messengers 359

Activation and inhibition of shoots by auxin 366

Cell elongation 367

Apical dominance 367

Differentiation of vascular tissues 368

Interactions of hormones in shoots 369

Hormones as signals of environmental factors 369

Leaf abscission 369

Tropisms 370

Flowering 372

Ripeness to flower 372

Photoperiodic induction to flowering 373

Endogenous rhythms and flowering 377

Salty mangrove (*Avicennia germinans*).
(Robert and Linda Mitchell)



15 *Genes and the genetic basis of metabolism and development* 381

Concepts 381

Storing genetic information 384

Protecting the genes 384

The genetic code 385

The structure of genes 388

Transcription 390

Protein synthesis 393

Ribosomes 393

tRNA 394

mRNA translation 394

Control of protein levels 397

Analysis of genes and recombinant DNA techniques 399

Nucleic acid hybridization 399

Restriction endonucleases 401

Identifying DNA fragments 401

DNA cloning 404

DNA sequencing 406

Genetic engineering of plants 407

Viruses 409

Virus structure 409

Virus metabolism 410

Formation of new virus particles 413

Origin of viruses 413

Plant diseases caused by viruses 414

III *Genetics and evolution* 417

16 *Genetics* 418

Concepts 418

Replication of DNA 421

Mutations 423

Causes of mutations 423

Effects of mutations 427

Somatic mutations 428

DNA repair processes 429

Monohybrid crosses 430

Monohybrid crosses with incomplete dominance 430

Crossing heterozygotes with themselves 432

Monohybrid crosses with complete dominance 434

Test crosses 436

Multiple alleles 438

Dihybrid crosses 438

Genes on separate chromosomes: independent assortment 439

Genes on the same chromosome: linkage 441

Multiple genes for one character 444

Other aspects of inheritance 444

Maternal inheritance 444

Lethal alleles 447

Multiple sets of chromosomes 448

Wolf Lake Fire, Yellowstone. (© Jeff Henry/Peter Arnold, Inc.)

17 *Population genetics and evolution* 452

Concepts 452

Population genetics 455

Factors that cause the gene pool to change 455

Situations in which natural selection does not operate 460

Multiple selection pressures 461

Rates of evolution 461

Speciation 462

Phyletic Speciation 464

Divergent Speciation 465

Convergent Evolution 468

Evolution and the origin of life 470

Conditions on Earth prior to the origin of life 470

Chemicals produced chemosynthetically 472

The formation of polymers 473

Aggregation and organization 473

Early metabolism 474

Oxygen 475

The presence of life 475

Plants and people: Zoos, botanical gardens, and genetic drift 469

18 *Classification and systematics* 478

Concepts 478

Types of classification systems 480

Historical aspects of plant classification 482

Ancient period 482

The Renaissance period 482

The modern period: evolution and classification 484

Levels of taxonomic categories 485

Types of evidence used for taxonomic analysis 488

Homology and analogy 488

Taxonomic studies 491

Exploration and discovery 491

Preliminary studies of new plants 493

Biosystematic and experimental studies 498

The major lines of evolution 499

Box 18.1 Identifying unknown plants 494

19 Kingdom Monera: prokaryotes 502

Concepts 502

Structure of the prokaryotic cell 505

Protoplasm 505

Cell wall 508

Flagella 510

Cell division and reproduction 512

Cell division 512

Exchange of genetic material 512

Metabolism 514

Acquisition of energy 514

Sources of carbon and reducing power 519

Classification of prokaryotes 519

Division Archaeobacteria 523

Division Eubacteria 525

Gliding bacteria 526

Nitrogen-fixing bacteria 526

Nitrifying bacteria 527

Denitrifying bacteria 528

Mycoplasmas 528

Division cyanobacteria 529

■ Box 19.1 The "misclassification" of the blue-green algae 530

20 Kingdom Mycetae: fungi 534

Concepts 534

General characteristics of fungi 536

Nutrition 536

Body 539

Spores 547

Heterokaryosis and parasexuality 550

Metabolism 552

Division Myxomycota (slime molds) 553

Division Eumycota (true fungi) 555

Subdivision Mastigomycotina 555

Subdivision Zygomycotina 557

Subdivision Ascomycotina 558

Subdivision Basidiomycotina 562

Subdivision Deuteromycotina or fungi imperfecti 564

Associations of fungi with other organisms 565

Lichens 565

Fungus-plant associations 567

Fungi as disease agents of plants 567

Brown rot of stone fruits 567

Rusts and smuts 568

Sirex/Amylostereum disease in pinus 570

21 Algae and the origin of eukaryotic cells 573

Concepts 573

Origin of eukaryotic cells 576

DNA structure 576

Nuclear structure 577

Nuclear division 577

Organelles 578

Origin of eukaryotes: the endosymbiont theory 578

Division Euglenophyta: euglenoids 586

Division Pyrrophyta: dinoflagellates 586

Division Chrysophyta 588

Class Bacillariophyceae: diatoms 589

Class Chrysophyceae: golden brown algae 590

Class Xanthophyceae: yellow-green algae 590

Division Chlorophyta: green algae 591

Body construction in the green algae 592

Life cycles of the green algae 596

Representative genera of the green algae 599

Division Phaeophyta: brown algae 604

Division Rhodophyta: red algae 611

22 Nonvascular plants: mosses, liverworts and hornworts 617

Concepts 617

Classification of nonvascular plants 620

Division Bryophyta: mosses 621

The gametophyte generation 621

The sporophyte generation 627

Metabolism and ecology 628

Division Hepatophyta: liverworts 630

Gametophytes 630

Sporophytes 633

Division Anthocerotophyta: hornworts 634

Gametophytes 636

Sporophytes 638

Origin and evolution of nonvascular plants 639



Liverworts (*Marchantia* sp.). (Runk/
Schoenberger from Grant Heilman)

23 Vascular plants without seeds 642

Concepts 642

Early vascular plants 645

Rhyniophytes 645

Zosterophyllophytes 650

Psilotum 653

Division Psilotophyta 653

The microphyll line of evolution 655

Morphology 655

Heterospory 657

Extant genera 661

The megaphyll line of evolution 663

Division Trimerophytophyta 663

Origin of Megaphylls 663

Division Arthropophyta 664

Division Pteridophyta 667

Box 23.1 Form genera 675

24 Seed plants I: gymnosperms 677

Concepts 677

Division Progymnospermophyta:

progymnosperms 680

Aneurophytales 682

Archeopteridales 682

Evolution of seeds 683

Division Coniferophyta: conifers 685

Coniferales 685

Origin and evolution of conifers 695

Taxales 696

Division Pteridospermophyta: seed ferns 697

Division Cycadophyta: cycads 699

Division Cycadeoidophyta: cycadeoids 702

Division Ginkgophyta: maidenhair tree 703

Division Gnetophyta 704

Plants and people: Economic importance of
conifers 706

25 Seed plants II: angiosperms 708

Concepts 708

Origin and early evolution of the angiosperms 712

Classification of flowering plants 716

Class Liliopsida 717

Class Magnoliopsida 725

IV Ecology 739

26 Populations and ecosystems 740

Concepts 740

Plants in relation to their habitats 741

Abiotic components of the habitat 742

Biotic components of the habitat 749

The structure of populations 755

Geographic distribution 755

Age distribution: demography 758

 r and K selection 760

The structure of ecosystems 763

Physiognomic structure 763

Temporal structure 763

Species composition 766

Trophic levels 768

27 Biomes 772

Concepts 772

World climate 774

Effects of Earth's tilt 774

Atmospheric distribution of heat 774

Oceanic distribution of heat 778

Continental drift 779

Present position of the world's continents 779

Measuring ancient continental positions and
climates 780

Past positions of the world's continents 781

The world biomes at present 783

Moist temperate biomes 784

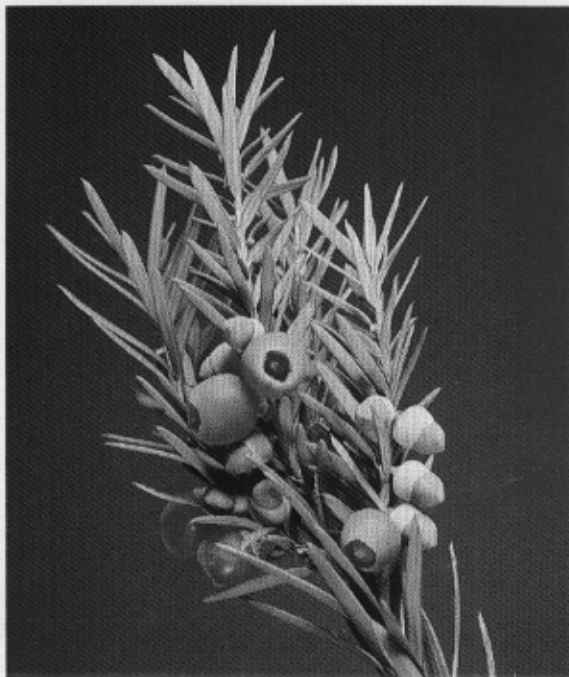
Dry temperate biomes 789

Polar biomes 795

Tropical biomes 797

Glossary G-1

Index I-1



Japanese yew (*Taxus cuspidata*).
(Photography by Grant Heilman)