Contents

	Preface xi
1	CELLS AND DIFFUSION 1
•	Cell Structure 1 Generalized Plant Cell / Leaf Cells / Cells of Vascular Tissue / Root Cells
	Diffusion 10 Fick's First Law / Continuity Equation and Fick's Second Law / Time-Distance Relation for Diffusion
1	Membrane Structure 20 Membrane Models / Organelle Membranes
	Membrane Permeability 26 Concentration Difference Across a Membrane / Permeability Coefficient / Diffusion and Cellular Concentration
	Cell Walls 34 Chemistry and Morphology / Diffusion Across Cell Walls / Stress-Strain Relations of Cell Wall
	Problems 44
	References 45
2	WATER 49
	Physical Properties 50 Hydrogen Bonding / Surface Tension / Capillary Rise / Capillary Rise in the Xylem / Tensile Strength / Electrical Properties
	 Chemical Potential 61 Free Energy and Chemical Potential / Analysis of Chemical Potential / Standard State / Hydrostatic Pressure / Water Activity and Osmotic Pressure / The Van't Hoff Relation / Matric Potential / Water Potential Central Vacuole and Chloroplasts 79 Water Relations of the Central Vacuole / Boyle-Van't Hoff Relation / Osmotic Responses of Chloroplasts
	Responses of emotoplasts

v

Water Potential and Plant Cells 86

Incipient Plasmolysis / Chemical Potential and Water Potential of Water Vapor / Plant-Air Interface / Pressure in the Cell Wall Water / Water Flux / Kinetics of Volume Changes

Problems 101

References 102

3 SOLUTES 105

Chemical Potential of Ions 106

Electrical Potential / Electroneutrality and Membrane Capacitance / Activity Coefficients of Ions / Nernst Potential / Example of E_{NK}

.

Fluxes and Diffusion Potentials 116

Flux and Mobility / Diffusion Potential in a Solution / Membrane Fluxes / Membrane Diffusion Potential—Goldman Equation / Application of the Goldman Equation / Donnan Potential

Active Transport 136

Electrogenicity / Boltzmann Energy Distribution and Q_{10} , a Temperature Coefficient / Activation Energy and Arrhenius Plots / Ussing-Teorell Equation / Example of Active Transport / Energy for Active Transport / Carriers, Solute Uptake, and the Michaelis-Menten Formalism / Facilitated Diffusion

Principles of Irreversible Thermodynamics 160

Fluxes, Forces, and Onsager Coefficients / Water and Solute Flow / Volume Flux Density, L_P , and a j Values of Reflection Coefficients

Solute Movement Across Membranes 172

The Influence of Reflection Coefficients on Incipient Plasmolysis / Extension of the Boyle Van't Hoff Relation ; Reflection Coefficients of Chloroplasts

Problems 179

References 181

4 LIGHT 185

Wavelength and Energy 187

Lightwaves / Energy of Light / Illumination, Photon Flux Density, and Irradiance / Sunlight / Planck's and Wien's Formulae

···· ---- ···

Absorption of Light by Molecules 198

Role of Electrons in Absorption Event / Electron Spin and State Multiplicity / Molecular Orbitals / Photoisomerization / Light Absorption by Chlorophyll

De-excitation 209

Fluorescence, Phosphorescence, and Radiationless Transitions / Competing Pathways for De-excitation / Lifetimes / Quantum Yields

Absorption Spectra and Action Spectra 216

Vibrational Sublevels in an Energy Level Diagram / The Franck-Condon Principle / Absorption Bands and Absorption Coefficients / Conjugation / Action Spectra / Absorption and Action Spectra of Phytochrome

Problems 235

References 237

5 PHOTOCHEMISTRY OF PHOTOSYNTHESIS 239

Chlorophyll—Chemistry and Spectra 242

Types and Structures / Absorption and Fluorescence Emission Spectra / Absorption in vivo -Polarized Light

Other Photosynthetic Pigments 250

Carotenoids / Phycobilins

Excitation Transfers Among Photosynthetic Pigments 257

Resonance Transfer of Excitation / Transfers of Excitation Between Photosynthetic Pigments / Excitation Trapping

Groupings of Photosynthetic Pigments 266

Photosynthetic Units / Excitation Processing / Photosynthetic Action Spectra and Enhancement Effects / Two Photosystems Plus Light-Harvesting Antenna

Electron Flow 273

 $Electron \ Flow \ Model \ / \ Components \ of \ the \ Electron \ Transfer \ Pathway \ / \ Types \ of \ Electron \ Flow \ / \ Photophosphorylation \ / \ Vectorial \ Aspects \ of \ Electron \ Flow \$

Problems 287

References 288

6 BIOENERGETICS 291

Gibbs Free Energy 292

Chemical Reactions and Equilibrium Constants / Interconversion of Chemical and Electrical Energy / Redox Potentials

Biological Energy Currencies 302

ATP—Structure and Reactions / Gibbs Free Energy Change for ATP Formation / NADP-NADPH_2 Redox Couple

Chloroplast Bioenergetics 311

Redox Couples $\H/$ H' Chemical Potential Differences Caused by Electron Flow / Evidence for Chemiosmotic Hypothesis

Mitochondrial Bioenergetics 322

Electron Flow Components-Redox Potentials / Oxidative Phosphorylation

Energy Flow in the Biosphere 330

Incident Light—Stefan-Boltzmann Law / Absorbed Light and Photosynthetic Efficiency / Food Chains and Material Cycles

Problems 335

References 336

7 TEMPERATURE—ENERGY BUDGETS 339

Energy Budget—Radiation 340

Solar Irradiation / Absorbed Infrared Irradiation / Emitted Infrared Radiation / Values for *a*, a_{lK} , and $e_{I\!R}$ / Net Radiation / Examples for Radiation Terms

___...

Wind—Heat Conduction and Convection 355

Wind—General Comments / Air Boundary Layers / Boundary Layers for Bluff Bodies / Heat Conduction/Convection Equations / Dimensionless Numbers / Examples of Heat Conduction/Convection

Latent Heat—Transpiration 368

Heat Flux Density Accompanying Transpiration / Heat Flux Density for Dew or Frost Formation / Examples of Frost and Dew Formation

Soil 372

Thermal Properties / Soil Energy Balance / Variations in Soil Temperature

Further Examples of Energy Budgets 376

Leal'Shape and Orientation / Shaded Leaves Within Plant Communities / Heat Storage / Time Constants

Problems 383

References 384

8 LEAVES AND FLUXES 387

Resistances and Conductances—Transpiration 389 Boundary Layer Adjacent to Leaf / Stomata / Stomatal Conductance and Resistance / Cuticle / Intercellular Air Spaces / Fick's First Law and Conductances or Resistances

Water Vapor Fluxes Accompanying Transpiration 403

Conductance and Resistance Network / Values of Conductances / Effective Lengths and Resistance / Leaf Water Vapor Concentrations and Mole Fractions / Examples of Water Vapor Levels in a Leaf / Fluxes of Water Vapor / Control of Transpiration

CO 2 Conductances and Resistances 416

Resistance and Conductance Network / Mesophyll Area / Resistance Formulation for Cell Components / Cell Wall Resistance / Plasmalemma Resistance / Cytosol Resistance / Mesophyll Resistance / Chloroplast Resistance

CO₂ Fluxes Accompanying Photosynthesis 429

Photosynthesis / Respiration and Photorespiration / Comprehensive CO₂ Resistance Network / Compensation Points / Fluxes of CO₂ / Range in Photosynthetic Rates / CO_2 Conductances

Water Use Efficiency 444

Values of WUE / Elevational Effects on WUE / Stomatal Control of WUE / C, Versus C₄ Plants

Problems 455

References 456

9 PLANTS AND FLUXES 461

Gas Fluxes Above the Leaf Canopy 462

Wind Speed Profiles / Flux Densities / Eddy Diffusion Coefficients / Resistance of Air Above the Canopy / Transpiration and Photosynthesis / Values for Fluxes and Concentrations / Condensation

Gas Fluxes Within Plant Communities 471

Eddy Diffusion Coefficient and Resistance / Water Vapor / PAR Attenuation / Values of Foliar Absorption Coefficients / Light Compensation Point / CO, Concentrations and Fluxes / CO₂ at Night

Soil 481

Soil Water Potential / Darcy's Law / Soil Hydraulic Conductivity Coefficient / Fluxes for Cylindrical Symmetry / Fluxes for Spherical Symmetry

Water Movement in the Xylem and Phloem 491

 Root Tissues / The Xylem / Poiseuille's Law / Applications of Poiseuille's Law / The Phloem / Phloem Contents and Speed of Movement / Mechanism of Phloem Flow / Values for Components of the Phloem Water Potential

 The Soil-Plant-Atmosphere Continuum 506

 Values of Water Potential Components / Resistances and Areas / Capacitance and Time Constants / Diurnal Changes

 Problems 518

 References 520

APPENDIXES 525

I Symbols and Abbreviations 527

II Numerical Values of Constants and Coefficients 533

HI Conversion Factors 539

IV Logarithms and Trigonometric Functions 547

V Calculus 549

VI Gibbs Free Energy and Chemical Potential 567

VII Further Comments on Irreversible Thermodynamics 577

VIII Description of Plant Growth 583

ANSWERS TO PROBLEMS 587

INDEX 595