

INTRODUCTION	1
About This Book	1
Foolish Assumptions	2
Icons Used in This Book	3
Beyond the Book	3
Where to Go from Here	3
PART 1: THE WORLD OF THE CELL	5
CHAPTER 1: Exploring the World of the Cell	7
Cells and Viruses: Discovering the Inhabitants of the Microscopic World	7
You: On the cellular level	8
Them: Bacteria and viruses	9
The Life of a Cell: How Cells Get What They Need to Survive and Reproduce	10
Sexual Reproduction: Shuffling the Genetic Deck for the Next Generation	10
DNA to Protein: Following the Instructions in the Genetic Code	11
DNA Technology: Tackling the World's Problems	11
CHAPTER 2: Take a Tour inside the Cell	13
Admiring the Unity and Diversity of Cells	13
Finding Common Ground: Structures in All Cells	14
Customs: Plasma membrane	15
A happenin' place: The cytoplasm	16
The library: DNA-containing region	17
Workbenches: Ribosomes	17
Your Body, Your Cells: Eukaryotic Cells	18
Home office: The nucleus	20
Post office: The endomembrane system	22
The fireplace: Mitochondria	24
In the kitchen: Chloroplasts	26
Scaffolding and railroad tracks: The cytoskeleton	27
Rebar and concrete: Cell walls and extracellular matrices	30
Tiny but Mighty: Prokaryotic Cells	32
Castle walls: The cell wall	33
Ooze, slime, and grappling hooks: Capsules, pili, and fimbriae	33
Outboard motors: Bacterial flagella	33

CHAPTER 3: Dead or Alive: Viruses	35
Viruses: Hijackers of the Cellular World	35
Just the basics: The structure of viruses	36
Knock, knock, virus calling: How viruses get into cells	37
War on a Microcosmic Scale: Viruses of Bacteria	39
Seek and destroy: The lytic cycle	40
I think I'll take a little nap: The lysogenic cycle	41
I've Got a Cold: Viruses of Eukaryotes	41
Same story, different players	42
Come in and take your coat off	44
There's more than one way to copy a virus	45
Leaving it all behind	47
Putting it all together	47
HIV and AIDS: Viruses in the real world	48
PART 2: MOLECULES: THE STUFF OF LIFE	51
CHAPTER 4: Better Living through Chemistry	53
Life Really Matters	53
It's Elemental: Atoms That Make Up Living Things	54
Exploring subatomic particles	56
Defining elements	56
Comparing isotopes	57
Let's Bond: How Atoms Are Attracted to Each Other	59
Feeling fulfilled by arranging your electrons just right	60
Holding on: Electronegativity	63
Give and take: Oxidation and reduction	64
Opposites attract: Ionic bonds	65
Sharing is caring: Covalent bonds	65
A molecule by any other picture	66
Don't hog the toys! Polar covalent bonds	67
Molecular Velcro: Hydrogen bonds	67
Molecular cliques: Hydrophobic interactions	69
Blue Planet: The Ocean inside Your Cells	69
Splitting water	70
Measuring pH	70
Changing pH	71
Maintaining pH	71
Chain, Chain, Chain: Building and Breaking Polymers	72
Identifying the parts and the whole	72
Getting together and breaking up again	73
Dressing for success: Functional groups determine molecular properties	73

CHAPTER 5:	Carbohydrates: How Sweet They Are	77
	CH ₂ O: Structure of Carbohydrates	77
	Keeping it simple: Monosaccharides	78
	Making it complex: Polysaccharides	82
	Sticky and Sweet: Functions of Carbohydrates	84
CHAPTER 6:	Proteins: Workers in the Cellular Factory	87
	Get into Shape: Levels of Protein Structure	87
	Get in line: Primary structure	89
	The long and winding road: Secondary structure	91
	3D: Tertiary structure	92
	Sometimes one is not enough: Quarternary structure	94
	Jacks of All Trades: The Many Functions of Proteins	95
	Get 'Er Done: Enzymes Make Things Happen	95
	Made for each other: Enzymes and substrates	96
	Helping hands: Cofactors and Coenzymes	97
	Listening to others: Inhibiting enzymes	97
	Gatekeepers: Membrane Proteins	100
	I'm in Charge: DNA-Binding Proteins	101
CHAPTER 7:	DNA and RNA: Instructions for Life	103
	It's Puzzling: Structure of Nucleic Acids	103
	Navigating nucleotides	104
	Naming the nucleotide bases	105
	Recognizing nucleotides	107
	Making DNA and RNA	107
	The double helix of DNA	109
	Shaping up RNA molecules	110
	Breaking the Code: The Function of DNA and RNA	110
CHAPTER 8:	Lipids: Waterproof and Energy Rich	113
	Hydrocarbons: Structure of Lipids	113
	Saturating fatty acids	114
	Forming fats and oils	115
	Looking at other types of lipids	116
	You Say Fat Like It's a Bad Thing: Functions of Lipids	119
PART 3:	THE WORKING CELL	121
CHAPTER 9:	Hello, Neighbor: How Cells Communicate	123
	Shipping and Receiving: Transport across Membranes	123
	Getting past the bouncer	124
	Which way should I go?	124
	Crossing the border	125
	Going with the flow	126
	It's an uphill battle	127

Chatting through Cellular Connections	129
Shaking hands through cell-cell attachments	129
Sticking together through thick and thin	131
Jumping the cell-cell gap	131
Sending and Receiving Signals	132
Satellite dishes: Receptors	133
Relaying the message: Signal transduction	133
Amplifying the signal	135
Calming down: Deactivating the signal	137

CHAPTER 10: **Metabolism: Transferring Energy and Matter** 139

Rewinding Up Your Metabolism	139
Stayin' Alive: Cellular Work and the Laws of Thermodynamics	141
The first law of thermodynamics	141
The second law of thermodynamics	143
Going to work in the cellular factory	147
One Step at a Time: Metabolic Pathways	151
Taking baby steps during chemical reactions	152
Helping hands from enzymes	153
Giving and taking electrons in redox reactions	155
Shuttling electrons with electron carriers	156
Getting what you need at the cellular level	158

CHAPTER 11: **Cellular Respiration: Every Breath You Take** 159

Cellular Respiration: An Overview	159
Controlling the burn	161
Transferring energy to ATP	162
Moving electrons to oxygen	162
Taking things one step at a time	163
Gimme a Break: Glycolysis	164
Everybody's doing it	165
Fine print: The steps of glycolysis	165
Making ATP by substrate-level phosphorylation	167
Living by glycolysis alone: Fermentation	168
The Wheel of Fire: Krebs Cycle	170
Linking glycolysis and Krebs	171
Fine print: The steps of the Krebs cycle	173
More is better: Taking advantage of the Krebs cycle	174
Taking It to the Bank: Chemiosmosis and Oxidative Phosphorylation	174
Transferring electrons along an electron transport chain	175
Transferring energy from food to ATP	177
The steps of the chemiosmotic theory of oxidative phosphorylation	177
Doing the math: How many ATP can you make from the energy in a glucose molecule?	179

Breaking Down Complex Carbohydrates, Proteins, and Fats	180
Finding an on-ramp to the superhighway	180
Feeding complex carbohydrates into the system	181
Burning fat	181
Breaking down proteins	183
It's a Two-Way Street: Connections between Metabolic Pathways . . .	183
Reversing the flow of matter and energy	184
Packing on the fat	185
Building muscle	185
Cellular respiration in the real world	186

CHAPTER 12: **Photosynthesis: Makin' Food**

in the Kitchen of Life	187
Photosynthesis: An Overview	187
Getting what plants need	188
Examining the role of soil	190
Basking in the Sun	190
Capturing the Sun's energy with pigments	191
Yin and yang: The light reactions and the Calvin cycle	192
Shine on Me: The Light Reactions	194
Transferring light energy to chemical energy	194
The steps of photophosphorylation	196
The Circle of Life: Calvin Cycle	198
The steps of the Calvin cycle	199
Got Food? Photosynthesis in the Real World	201

CHAPTER 13: **Splitsville: The Cell Cycle, Cell Division, and Cancer**

.	203
Reproducing the Cell	203
Drifting Apart: Binary Fission	204
Red Light, Green Light: The Cell Cycle	205
Pausing during Gap 1	206
The S phase and Gap 2	206
The Dance of the Chromosomes: Mitosis	207
Breaking Up Is Hard to Do: Cytokinesis	209
Keeping It under Control	211
Cancer: The Enemy Within	212
Defining cancer	212
Causes of cancer	215
Fighting back	217

PART 4: GENETICS: FROM ONE GENERATION TO THE NEXT 219

CHAPTER 14: Meiosis: Getting Ready for Baby 221

Let's Talk about Sex, Baby: Reproduction	221
Riding the life cycle	222
Counting chromosomes	223
Homologous Chromosomes	224
Going Separate Ways: Meiosis	225
Following the plan	226
An overview of meiosis	226
Shuffling the Genetic Deck: Crossing Over	229
Why Two Divisions Are Better than One	230
It Was All a Mistake: Nondisjunction	231

CHAPTER 15: Genetics: Talkin' 'Bout the Generations 233

Pass the Peas, Please: Mendel and Segregation of Single Gene Traits	233
Living like a monk	234
Speaking the lingo	235
Round pea meets wrinkled pea	236
The odds are 3:1	237
Making a prediction	238
Testing an idea	240
Remembering meiosis	241
Playing by the rules	241
Tracing a trait: Pedigrees	243
I Can Go My Own Way: Independent Assortment	245
Round yellow pea meets wrinkled green pea	245
Puzzling over the Punnett	247
Remembering meiosis	248
It's News to Mendel: Inheritance beyond Simple Dominance	249
Almost Inseparable: Linked Genes	253
Traveling together because of linkage	254
Slipping away through recombination	255
Building a map of a chromosome	255
Mama's Boy: Sex-Linked Inheritance	257
Explaining the differences	257
Analyzing the pedigree	258

PART 5: MOLECULAR GENETICS: HOW CELLS READ THE BOOK OF LIFE 261

CHAPTER 16: DNA Replication: Doubling Your Genetic Stuff 263

DNA Replication: An Overview	263
Everybody Lend a Hand: Enzymes Involved in DNA Replication	264

It Takes a Village: Events at the Replication Fork	265
Start at the very beginning: Origins of replication	265
Learning to unwind with helicase	266
Putting down some primer	266
Rolling down the line	268
Replacing some tiles	268
Tying up loose ends	268
Finishing the job	269
Keeping It Together: Leading and Lagging Strands	269

CHAPTER 17: **Transcription and Translation:**

What's in a Gene?	273
File It under Genes: The Blueprints for RNA and Proteins	273
Defining a gene	274
Going with the flow	274
Make a Copy, Please: Transcription	275
Locating the file	275
Hiring a worker	276
Marking the end	278
Finishing Touches: RNA Processing in Eukaryotes	278
Making a Protein: Translation	280
Reading the code	280
The decoder: tRNA	283
Master craftsman: The ribosome	284
The steps of translation	285
Don't Drink and Drive: Mutation	288
Everybody makes mistakes	288
Dealing with the consequences	289

CHAPTER 18: **Control of Gene Expression: It's How You Play Your Cards That Counts**

Controlling the Situation: Gene Regulation and Information Flow	291
Becoming a specialist	292
Keeping house	293
I Can Be Flexible: Gene Expression in Bacteria	294
Organizing bacterial genes	295
Taking E. coli to dinner	295
Looking at lac	296
Feeling repressed	296
Game on: Inducing the lac operon	297
Game over: Repressing the lac operon	298
Advancing to the next level: Catabolite repression of the lac operon	298

The Master Plan: Gene Expression in Eukaryotes	301
Seizing the opportunity	301
Unpacking the plan	302
Controlling transcription	304
Controlling events between transcription and translation	306
Controlling translation and beyond	307
Learning from Experience: Epigenetics	308

PART 6: MOLECULAR BIOLOGY: HARNESSING THE POWER OF DNA.....311

CHAPTER 19: The Book of You: Reading Your Genes	313
Copying a gene with PCR	313
Sorting molecules using gel electrophoresis.....	316
Reading a gene with DNA sequencing	318
I Read the Whole Thing: Sequencing Genomes	323
Unleashing the power of genomics	324
Reading the book of life with shotgun sequencing	324
Looking within the human genome	326
Beyond Genomics: Systems Biology and Epigenomes	327
Comparing gene expression with DNA microarrays	328
Mapping the epigenome	330

CHAPTER 20: Rewriting the Code of Life: Recombinant DNA Technology and Genome Editing	331
Piecing It Together: Recombinant DNA Technology.....	332
Cutting DNA with restriction enzymes	332
Making cDNA with reverse transcriptase.....	333
Cloning genes into a library	334
Finding a gene with DNA probes.....	336
Changing the Plan: Using Recombinant DNA Technology to Solve Problems.....	337
Making useful proteins through genetic engineering	338
Searching for disease genes	339
Building a "better" plant with genetic engineering.....	341
Fixing a broken gene with gene therapy	342
Hitting the Bull's-Eye with Genome Editing	344
Get off my lawn! CRISPR in nature	344
Changing the plan: CRISPR in the lab	346

PART 7: THE PART OF TENS.....349

CHAPTER 21: Ten Important Rules for Cells to Live By	351
The Cell Theory	351
The First Law of Thermodynamics	352

The Second Law of Thermodynamics.	353
The Theory of Evolution by Natural Selection.	354
The Law of Conservation of Matter	356
Nucleic Acids Pair in Antiparallel Strands	357
Central Dogma.	358
Protein Shape Is Essential to Their Function.	358
Law of Segregation	360
Law of Independent Assortment.	360

CHAPTER 22: Ten Ways to Improve Your Grade. 361

Monitor Your Learning	361
Study Smarter	362
Actively Participate in Class	363
Schedule Your Study Time	363
Give Your Brain a Well-Rounded Workout during Study Sessions. . .	364
Get Creative with Memory Tricks	365
Recognize the Difference between Levels of Understanding.	365
Remember the Supporting Material.	366
Use Your First Test as a Diagnostic Tool	366
Get Help Sooner Rather than Later	367

INDEX. 369