Brief Contents

PARTI

Introducing Life in the Universe

- 1 A Universe of Life? 1
- 2 The Science of Life in the Universe 14
- 3 The Universal Context of Life 45

PART II

Life on Earth

- 4 The Habitability of Earth 97
- 5 The Nature of Life on Earth 139
- 6 The Origin and Evolution of Life on Earth 177

PART III

Life in the Solar System

- 7 Searching for Life in Our Solar System 219
- 8 Mars 243
- 9 Life on Jovian Moons 279
- 10 The Nature and Evolution of Habitability 312

PARTIV

Life Among the Stars

- 11 Exoplanets: Their Nature and Potential Habitability 349
- 12 The Search for Extraterrestrial Intelligence 397
- 13 Interstellar Travel and the Fermi Paradox 431

Epilogue: Contact—Implications for the Search and Discovery 465

Answers to
Quick Quiz Questions AQ-1

Appendixes

- A Useful Numbers A-1
- B Useful Formulas A-2
- C A Few Mathematical Skills A-3
- D The Periodic Table of the Elements A-9
- E The Solar System A-10
- F List of Learning Objectives A-13

Glossary G-1 Credits C-1

Index I-1

Detailed Contents

Preface viii About the Authors xv How to Succeed in Your Astrobiology Course xvii

PARTI

Introducing Life in the Universe

1	ΔΙ	H	ni	ve	rse	of	li	fe?	1
				V	136		Same I	101	

- 1.1 The Possibility of Life Beyond Earth 2
- 1.2 The Scientific Context of the Search 4
- 1.3 Places to Search 7
- 1.4 The Science of Astrobiology 10 Exercises and Problems 12 MOVIE MADNESS Cinema Aliens 9

2 The Science of Life in the Universe 14

- 2.1 The Ancient Debate About Life Beyond Earth 15
- 2.2 The Copernican Revolution 22
- 2.3 The Nature of Modern Science 29
- 2.4 THE PROCESS OF SCIENCE IN ACTION The Fact and Theory of Gravity 36 Exercises and Problems 41 DO THE MATH 2.1 Kepler's Third Law 26 SPECIAL TOPIC 2.1: Geocentrism

and the Church 28

MOVIE MADNESS Gravity 36

3 The Universal Context of Life 45

- 3.1 The Universe and Life 46
- 3.2 The Structure, Scale, and History of the Universe 47
- 3.3 A Universe of Matter and Energy 64
- 3.4 Our Solar System 72
- 3.5 THE PROCESS OF SCIENCE IN ACTION Ongoing Development of the Nebular Theory 86 Exercises and Problems 92

KEY ASTRONOMICAL DEFINITIONS

DO THE MATH 3.1 How Far Is a Light-Year? 51

11.4 The Habitabil

SPECIAL TOPIC 3.1 HOW DO We Know That the Universe Is Expanding? 56 MOVIE MADNESS Interstellar 64

MOVIE MADNESS AFFRAGEDORAFED STORE STROME

6.6 THE PROCESS OF SURBERN ACTIONS ANTIBICIALLINE 210

for the Sebreholtmak Thosabeam NESS

PART II

Life on Earth

4 The Habitability of Earth

- 4.1 Geology and Life 98
- 4.2 Reconstructing the History of Earth and Life 99
- 4.3 The Hadean Earth and the Dawn of Life 110
- 4.4 Geology and Habitability 114
- 4.5 Climate Regulation and Change 124
- 4.6 THE PROCESS OF SCIENCE IN ACTION Formation of the Moon 130 Exercises and Problems 135

DO THE MATH 4.1 Radiometric Dating 106 KEY GEOLOGICAL DEFINITIONS 111

MOVIE MADNESS Ice Age: Dawn of the Dinosaurs 116

5 The Nature of Life on Earth 139

- 5.1 Defining Life
- 5.2 Cells: The Basic Units of Life 148
- 5.3 Metabolism: The Chemistry of Life 155
- 5.4 DNA and Heredity 158
- 5.5 Life at the Extreme 164
- 5.6 THE PROCESS OF SCIENCE IN ACTION Evolution as Science 169 Exercises and Problems 174

KEY BIOLOGICAL DEFINITIONS 143

SPECIAL TOPIC 5.1 Charles Darwin and the Theory of Evolution 147

DO THE MATH 5.1 The Dominant Form of Life on Earth 154

MOVIE MADNESS War of the Worlds 165

6 The Origin and Evolution of Life on Earth 177

- 6.1 Searching for Life's Origins
- 6.2 The Origin of Life 182

6.3	The Evolution of Life 190	9	Life on Jovian Moons 279
6.4	Impacts and Extinctions 198	9.1	The Moons of the Outer Solar System 280
6.5	Human Evolution 206	9.2	Life on Jupiter's Galilean Moons 288
6.6	THE PROCESS OF SCIENCE IN ACTION Artificial Life 210	9.3	Life Elsewhere in the Solar System 296
	Exercises and Problems 216	9.4	THE PROCESS OF SCIENCE IN ACTION
	DO THE MATH 6.1 Bacteria in a Bottle I:		Chemical Energy for Life 304
	Lessons for Early Life 188		Exercises and Problems 309
	MOVIE MADNESS Armageddon 206 DO THE MATH 6.2 Bacteria in a Bottle II:		DO THE MATH 9.1 The Strength of the Tidal Force 286
	Lessons for the Human Race 210		MOVIE MADNESS 2010: The Year We
			Make Contact 295
ART	111		traterrestrial Intelligence 397
ife	in the Solar System	10	The Nature and Evolution of Habitability 312
7	Searching for Life	10.1	The Concept of a Habitable Zone 313
	in Our Solar System 219	10.2	Venus: An Example in Potential Habitability 315
	Environmental Requirements for Life 220	10.3	Surface Habitability Factors and the Habitable
1.2	A Biological Tour of the Inner Solar System 225		Zone 321
7.3	A Biological Tour of		The Future of Life on Earth 326
	the Outer Solar System 229	10.5	THE PROCESS OF SCIENCE IN ACTION Global Warming: Science, Consequences, and Solutions 330
7.4	THE PROCESS OF SCIENCE IN ACTION Spacecraft Exploration of the Solar System 234		Exercises and Problems 345
	Exercises and Problems 240		DO THE MATH 10.1 Chances of Being in the Zone 323
	MOVIE MADNESS 2001: A Space Odyssey 231		SPECIAL TOPIC 10.1 How Long Is
	DO THE MATH 7.1 Newton's Version of Kepler's Third Law 234		5 Billion Years? 329
	Acpier 5 min a Larr Lo		MOVIE MADNESS Wall-E 330
8	Mars 243		
8.1	Fantasies of Martian Civilization 244	PART	
8.2	A Modern Portrait of Mars 246	Life	Among the Stars
8.3	The Climate History of Mars 262	11	Exoplanets: Their Nature and
8.4	Searching for Life on Mars 266	11	Potential Habitability 349
8.5	THE PROCESS OF SCIENCE IN ACTION Martian Meteorites 272	11.1	Distant Suns 350
	Exercises and Problems 276		Discovering Exoplanets 358
	DO THE MATH 8.1 The Surface Area—to—Volume		The Number and Nature of Exoplanets 374
	Ratio 265		The Habitability of Exoplanets 380
	MOVIE MADNESS The Martian 267	11.5	THE PROCESS OF SCIENCE IN ACTION Classifying Stars 387
			Exercises and Problems 393
			DO THE MATH 11.1 Finding Orbital Distances for
			Exoplanets 371
			DO THE MATH 11.2 Finding Masses of Exoplanets 372
			DO THE MATH 11.3 Finding Sizes of Exoplanets 37

SPECIAL TOPIC 11.1 The Names of Exoplanets				
MOVIE MADNESS Star Wars	383			

12 The Search for Extraterrestrial Intelligence 397

- 12.1 The Drake Equation 398
- 12.2 The Question of Intelligence 402
- 12.3 Searching for Intelligence 406
- 12.4 THE PROCESS OF SCIENCE IN ACTION
 UFOs and Aliens on Earth 420
 Exercises and Problems 428

special topic 12.1 Frank Drake and His Equation 401

DO THE MATH 12.1 The Distance Between Signaling Societies 402

MOVIE MADNESS Contact 413

13 Interstellar Travel and the Fermi Paradox 431

- 13.1 The Challenge of Interstellar Travel 432
- 13.2 Spacecraft for Interstellar Travel 437
- 13.3 The Fermi Paradox 447
- 13.4 THE PROCESS OF SCIENCE IN ACTION
 Einstein's Special Theory of Relativity 455
 Exercises and Problems 461

 DO THE MATH 13.1 The Rocket Equation 437

 DO THE MATH 13.2 Time Dilation 443

 MOVIE MADNESS Star Trek 447

And perdirect sciences converges the dutered seeming

2. Public lascination with UFOs and agen visita-

The transfer of the spinsted and the straightful of the

Cincluding: What is life? Hery did life pegin

Epilogue: Contact—Implications for the Search and Discovery 465

Exercises and Problems 472

MOVIE MADNESS E.T. 468

Answers to Quick Quiz Questions AQ-1

Appendixes

- A Useful Numbers A-1
- B Useful Formulas A-2
- C A Few Mathematical Skills A-3
- D The Periodic Table of the Elements A-9
- E The Solar System A-10
- F List of Learning Objectives A-13

er stars - first obtained in the 1920s - has xiven add- \

Glossary G-1 Credits C-1 Index I-1