

# Table of Contents

---

## Part I Planets

---

<b>1</b>	<b>Stars, Galaxies, and the Origin of Chemical Elements . . . .</b>	<b>3</b>
1.1	The History of the Universe . . . . .	3
1.2	Molecular Clouds . . . . .	6
1.3	The Pre-Main Sequence Evolution of Stars . . . . .	8
1.4	The Post-Main Sequence Evolution of Stars . . . . .	11
1.5	Element Composition and Dating . . . . .	13
1.5.1	Population I and Population II Stars . . . . .	13
1.5.2	Dating with Radiometric Clocks . . . . .	15
<b>2</b>	<b>Planet Formation . . . . .</b>	<b>19</b>
2.1	Accretion Disks and Planetesimal Formation . . . . .	19
2.2	Terrestrial Planets . . . . .	21
2.3	Jovian Planets and Kuiper Belt Objects . . . . .	24
2.4	The Migration of Jovian Planets . . . . .	25
2.5	The T-Tauri Stage . . . . .	26
2.6	Asteroids . . . . .	28
2.7	Comets . . . . .	31
2.8	Meteorites . . . . .	33
2.9	Early History of the Solar System . . . . .	34
<b>3</b>	<b>The Earth . . . . .</b>	<b>39</b>
3.1	Planetological History of the Early Earth . . . . .	39
3.2	Formation of the Moon . . . . .	40
3.3	Ocean-Vaporizing Impacts . . . . .	42
3.4	The End of the Heavy Bombardment . . . . .	44
3.5	The Environment on the Early Earth . . . . .	45
3.6	Seismology and the Earth's Interior Structure . . . . .	49
3.7	Volcanism and the Composition of Rocks . . . . .	52
3.8	The Earth's Core and Mantle . . . . .	56
3.9	The Earth's Magnetic Field and Sea-Floor Spreading . . . . .	58
3.10	Convection, Hot Spots and Plate Tectonics . . . . .	60
3.11	Mountain Building and the Evolution of Continents . . . . .	66
3.12	Plate Tectonics on Mars and Venus? . . . . .	71

<b>4</b>	<b>The Search for Extrasolar Planets</b>	73
4.1	The Recently Discovered Planets	73
4.2	Direct Search Methods for Planets	76
4.3	Indirect Search Methods	76
4.4	Circumstellar Disks	79
4.5	New Search Strategies	80
<b>5</b>	<b>Planets Suitable for Life</b>	87
5.1	Habitable Zones	87
5.1.1	The Solar Habitable Zone	88
5.1.2	Habitable Zones Around Other Stars	90
5.2	Planetary Mass and the Evaporation of the Atmosphere	91
5.3	The Lifetimes of the Stars	94
5.4	Tidal Effects on Planets	95
5.5	The Increase in Solar Luminosity and the Continuously Habitable Zone	97
5.6	Instabilities of the Planetary Atmosphere	98
5.6.1	The Greenhouse Effect	99
5.6.2	The Carbonate Silicate Cycle	99
5.6.3	The Runaway Greenhouse Effect	100
5.6.4	Irreversible Glaciation	101
5.7	Axis Variations of the Planets	103
5.8	Biogenic Effects on Planetary Atmospheres	105
5.9	Proterozoic Glaciations and Snowball Earth	107
5.10	The Requirements for Continuous Habitability	109
5.11	The Drake Formula	109
5.12	The Number of Habitable Planets	111

---

## Part II Life

---

<b>6</b>	<b>Life and its Origin on Earth</b>	117
6.1	What is Life?	117
6.2	The Special Role of Organic Chemistry	118
6.3	The Elements of Biochemistry	118
6.3.1	Proteins, Carbohydrates, Lipids, and Nucleic Acids	119
6.3.2	The Genetic Code	124
6.3.3	ATP, the Energy Currency of the Biochemical World	124
6.3.4	Synthesizing RNA, DNA, and Proteins	125
6.4	Cells and Organelles	127
6.5	Sequencing and the Classification of Organisms	129
6.5.1	Classification by Sequencing	129
6.5.2	The Molecular Clock	129
6.5.3	The Evolutionary Tree of Bacteria	130
6.5.4	The Timetable of the Evolution of Life	131

6.5.5	Sequencing and the Complete Genome . . . . .	133
6.6	Geological Traces of Life . . . . .	135
6.7	The Stage for the Appearance of Life . . . . .	136
6.7.1	The Origin of the Genetic Code . . . . .	137
6.7.2	The Urey–Miller Experiments . . . . .	138
6.7.3	The Search for the Last Universal Common Ancestor . . . . .	139
6.7.4	Summary: The Boundary Conditions . . . . .	142
6.8	Abiotic Chemical Evolution and the Theories of How Life Formed . . . . .	143
<b>7</b>	<b>Evolution . . . . .</b>	<b>149</b>
7.1	Darwin’s Theory . . . . .	149
7.2	The Development of Eukaryotes and Endosymbiosis . . . . .	151
7.3	Oxygen as an Environmental Catastrophe . . . . .	153
7.4	The Cell Nucleus and Mitosis . . . . .	154
7.5	Sexuality and Meiosis . . . . .	155
7.6	Genetic Evolution . . . . .	157
7.7	Multicellularity, the Formation of Organs, and Programmed Cell Death . . . . .	159
7.8	Problems of Life on Land . . . . .	162
7.8.1	Conquest of the Land by Plants . . . . .	163
7.8.2	New Organs of Land Plants . . . . .	166
7.8.3	Conquest of the Land by Animals . . . . .	171
7.9	The Great K/T Boundary Event . . . . .	173
7.10	The Tertiary and the Evolution of Mammals . . . . .	177
7.11	Primate Evolution . . . . .	178
7.12	DNA Hybridization . . . . .	187
7.13	Brain Evolution and Tool Use . . . . .	188
7.14	Stone Tool Culture . . . . .	190
7.15	Diet and Social Life . . . . .	192
7.16	The Logic of the Human Body Plan . . . . .	193
7.17	Evolution, Chance, and Information . . . . .	196
7.18	Cultural Evolution . . . . .	199
<b>8</b>	<b>The Search for Extraterrestrial Life . . . . .</b>	<b>201</b>
8.1	Life in the Solar System . . . . .	201
8.2	Europa’s Ocean . . . . .	202
8.3	Life on Mars . . . . .	204
8.3.1	Early Searches . . . . .	204
8.3.2	The Viking Experiments . . . . .	206
8.3.3	Mars Meteorites . . . . .	208
8.4	The Early Atmosphere of Mars . . . . .	210
8.5	Future Mars Missions . . . . .	212
8.6	Life Outside the Solar System . . . . .	214
8.7	UFOs . . . . .	216

---

**Part III Intelligence**


---

<b>9</b>	<b>The Future of Mankind</b>	221
9.1	Predicting Mankind's Future	221
9.2	Settlement of the Solar System	222
9.2.1	The Space Station	223
9.2.2	Moon and Mars Projects	225
9.2.3	Space Travel	228
9.2.4	Near-Earth Asteroids and the Mining of the Solar System	230
9.2.5	Space Habitats	231
9.2.6	Cultural Impact of Space Colonization	234
9.3	Interstellar Travel	236
9.4	Mastering the Biological World	237
9.4.1	Creating Life in the Laboratory	238
9.4.2	The Decoding of the Human Genome	239
9.4.3	Understanding Intelligence	239
9.5	Androids and Miniaturization	240
9.6	Connected Societies	241
9.7	Fear of the Future	242
9.8	The Dangers for Mankind	242
9.8.1	Bacterial or Viral Infection	243
9.8.2	Episodes of Extreme Volcanism	244
9.8.3	Irreversible Glaciation and the Runaway Greenhouse Effect	245
9.8.4	Comet or Asteroid Impact	246
9.8.5	Supernova Explosions and Gamma Ray Bursts	248
9.8.6	Irreversible Environmental Damage	250
9.8.7	Uncontrollable Inventions	250
9.8.8	War, Terrorism, and Irrationality	251
9.9	Survival Strategies	252
<b>10</b>	<b>Extraterrestrial Intelligent Life</b>	255
10.1	Does Extraterrestrial Intelligent Life Exist?	255
10.2	What is the Hypothetical Nature of the Extraterrestrials?	257
10.3	The Drake Formula, the Number of Extraterrestrial Societies	260
10.4	The Lifetime of an Extraterrestrial Civilization	262
10.5	Distances to the Extraterrestrial Societies	263
10.6	SETI, the Search for Extraterrestrial Intelligent Life	265
10.6.1	Radio and Optical Searches for Extraterrestrial Civilizations	266
10.6.2	Possible Contact in the not too Distant Future	270
10.7	The Fermi Paradox: Where are the Extraterrestrials?	272

10.7.1 They do not Exist . . . . .	273
10.7.2 Technically, a Visit is not Possible . . . . .	274
10.7.3 They are Nearby, but have not been Detected . . . . .	275
10.7.4 They are not Interested in Us . . . . .	275
10.8 The Zoo Hypothesis . . . . .	276
<b>References . . . . .</b>	<b>279</b>
<b>Author Index . . . . .</b>	<b>297</b>
<b>Subject Index . . . . .</b>	<b>303</b>

Intelligent Life in the Universe

Principles and Requirements Behind Its Emergence

Ulmschneider, P.

2006, XIV, 310 p. 156 illus., 37 illus. in color., Hardcover

ISBN: 978-3-540-32836-0