Tak	oles an	d Figures	XV
Pre	face		xvii
Hot	w to U	se This Book	XX
Par	tI I	ntroduction	1
1	Арри	roaching the Topic	3
	1.1	Four Basic Questions	5
	1.2	Working Backwards for a Moment	6
	1.3	Questions, Questions, Questions	8
	1.4	An Unlikely Story	11
	1.5	Back to Reality	13
2	Look	king beyond Earth	15
	2.1	Are We Alone in the Universe?	15
	2.2	What We Know about Exoplanets	18
	2.3	Exobeings and Their Planetary Environment	21
	2.4	Exobeings and Humans on Earth	23
	2.5	From Knowns to Unknowns	24
	2.6	Sources of Energy and Biological Evolution	25
	2.7	The Brains of Exobeings	27
	2.8	Emergence and Consciousness	29
3	Striv	ing to Understand	31
	3.1	What Is Scientific Speculation?	32
	3.2	What Counts as Proof?	34
	3.3	What Do Scientists Know and Not Know?	36
	3.4	How Accurate Are Facts?	37
	3.5	What We Still Cannot Explain	38
	3.6	Problems and Mysteries	39

Cambridge University Press & Assessment
978-1-009-22641-7 — Life and Language Beyond Earth
Raymond Hickey
Table of Contents
More Information



	3.7	The Nature of Exceptions	40
	3.8	What About 'Weird Life'?	40
	3.9	How Different Could They Be from Us?	42
	3.10	Two Other Questions	44
Par	tII T	he Universe We Live In	45
4	Tryin	ng to Grasp Size	47
	4.1	Astronomy and History	48
	4.2	How Has the Universe Developed?	50
	4.3	Estimating the Size of the Universe	53
	4.4	The Observable Universe	54
5	Star I	Formation and Planets	58
	5.1	Red Dwarfs	59
	5.2	Brown Dwarfs	60
	5.3	The Life of a Star	61
	5.4	Where Do the Elements Come From?	63
	5.5	Peering into the Future	64
6	The L	ikelihood of Life	69
	6.1	Basic Preconditions	70
	6.2	Favouring Factors	76
	6.3	Key Developments and Events	79
	6.4	Mass Extinctions in Earth's History	83
	6.5	Strikes from Beyond	84
7	Possi	ble Conditions on an Exoplanet	87
	7.1	The Fine-Tuning Problem	88
	7.2	Small-Scale and Large-Scale Structures	91
	7.3	The Underlying Basis of Structure	92
	7.4	Emergent Properties	93
	7.5	Unintended Side Effects	95
	7.6	Things Which Only Happened Once	97
	7.7	What Are the Alternatives?	98

vii

8	How	and Where to Look for Exolife	100
	8.1	Recent Finds in Our Cosmic Neighbourhood	101
	8.2	Improved Technology	102
	8.3	Methods for Finding Exoplanets	106
	8.4	A Planet in the Habitable Zone	108
	8.5	What About Rogue Planets?	109
	8.6	Rare Earth Hypothesis	110
	8.7	The Copernican Principle	112
	8.8	Earth Similarity Index and Planetary Habitability Index	112
	8.9	Classifying Exoplanets	114
	8.10	When is an Exoplanet 'Earth-like'?	115
	8.11	Potential for Life on Moons	118
	8.12	A Lunar Trio	119
	8.13	Microbial Life on a Moon: What Could It Tell Us?	125
	8.14	Where Are We at Present?	126
9	The L	imits of Exploration	128
	9.1	Getting Around the Universe	129
	9.2	Sending Out Probes	132
	9.3	Getting Here After We Are Gone	132
	9.4	A Feeling for Distance	133
10	Asses	ssing Probabilities	135
	10.1	Considering the Fermi Paradox	135
	10.2	Looking at the Drake Equation	138
Par	t III O	ur Story on Earth	141
11		low Path of Evolution	143
11	11.1	Just What Is Life?	145 145
	11.1		145 147
	11.2	Energy Regime of the Body Finding Out How Life Works	$\frac{147}{147}$
	11.3 11.4	5	
			149 150
	11.5	Energy Gradients	150
	11.6	Life Getting Under Way	151



	11.7	Functional Principle and Realisation	154
	11.8	The Rise of Predators	155
	11.9	Different Kinds of Evolution	157
	11.10	Genes and Phenotypes	159
	11.11	Control from Above or Below?	160
	11.12	'Design' from Below	162
12	How I	Does the Whole Work?	164
	12.1	Devices and Organisms	165
	12.2	Evolution and Design	166
	12.3	Do the Parts Know the Whole?	167
	12.4	A Question of Scale	168
	12.5	When Do Cells Become an Organism?	169
	12.6	Sexual Reproduction	170
	12.7	Variety is the Spice of Life	174
	12.8	A Quirk in Meiosis	174
	12.9	Genetic Mutation	175
	12.10	Divergent Evolution	176
	12.11	Convergent Evolution	177
	12.12	Analogous and Homologous Structures	180
	12.13	Epilogue: Profusion in Nature	181
13	The R	oad to <i>Homo sapiens</i>	183
	13.1	The Pitfall of Compressing the Past	184
	13.2	Palaeoanthropology: Reaching Back in Time	185
	13.3	Rummaging Around in Caves	187
	13.4	The Out of Africa Hypothesis	188
	13.5	'The March of Progress'	190
	13.6	The Context of the Genus Homo	192
	13.7	Divisions within the Genus Homo	194
	13.8	The Progression of Consciousness	199
	13.9	Defining Homo sapiens Anatomically	200
	13.10	Energy Intake	202
	13.11	Narrow Range of Values	204
	13.12	Brain Size	205
	13.13	Evolution of Our Anatomy and Physiology	208
	13.14	Defining Homo sapiens Culturally	213

Contents	
CONTENIS	

ix

	13.15	Tool Making, Cognition and Communication	214
	13.16	Making Flint Tools	215
	13.17	The Management of Fire	216
	13.18	The Advent of Cooking	217
	13.19	Wearing Clothes	221
	13.20	Setbacks in Our Evolution	223
	13.21	Hominins: The Big Picture Once More	225
	13.22	A Unique Species and the Great Cognitive Gap	226
14	The R	ise of Human Societies	228
	14.1	In the Beginning Was the Group	229
	14.2	Humans, the Great Extenders	229
	14.3	The Origins of the Leader	230
	14.4	Societies on Exoplanets	232
	14.5	The Question of Violence	233
	14.6	Evidence for Social Organisation	236
	14.7	The Advent of Farming	237
	14.8	Culture and Human Evolution	239
	14.9	Cultural Buffering	239
	14.10	Would Exosocieties Have Money?	241
	14.11	And Would They Have Art?	241
	14.12	The View from Science Fiction	245
Par	t IV Tł	ne Runaway Brain	249
15	The B	rain-to-Body Relationship	251
	15.1	Wallace's Puzzle	252
	15.2	Are Brains Necessary for Life?	255
	15.3	Structure of the Human Brain	256
	15.4	Characteristics of the Human Brain	260
	15.5	Windows on the World: The Human Senses	264
	15.6	The Cost of Our Brain	269
16	How I	Brains Develop	270
	16.1	Embryogenesis and the Brain	271
	16.2	The Proliferation of Neurons	273
	16.3	Childhood and Puberty	274
	16.4	Lifespan and Aging	276



17	Our C	Cognition	280
	17.1	The Limits of Cognition	281
	17.2	Theory of Mind and the Notion of Self	283
	17.3	Internalisation of the World We Perceive	286
	17.4	The Tiger in the Bush: Our Love of Patterns	287
18	Conse	ciousness	290
	18.1	The Role of Emotions	292
	18.2	The Origin of Emotions	293
	18.3	The Hard Problem	294
	18.4	The Sense of Self Again	297
	18.5	Size of the Brain and Consciousness	304
	18.6	Where Is Consciousness?	305
	18.7	Consciousness and Attention	306
	18.8	The Conscious and Unconscious Brain: A Division	
		of Labour	307
	18.9	The Quantum Brain?	308
	18.10	Memory	309
	18.11	Neuroplasticity	312
	18.12	Consciousness: An Attempted Summary	313
	18.13	A Final Remark	315
19	Artifi	cial Intelligence	316
	19.1	The Singularity: A Modern Frankenstein?	318
	19.2	A Conscious Computer?	321
	19.3	Sentio ergo sum Again	324
	19.4	The Mental Lives of Exobeings	325
Par	tV La	anguage, Our Greatest Gift	327
20	Looki	ng at Language	329
	20.1	What Is Language?	330
	20.2	The Purpose of Language	331
	20.3	Definitions of Language	333
	20.4	Design Features of Language	333
	20.5	Structural Notions in Linguistics	338

21	Talki	ng about Languaga	343
21		ng about Language	
	21.1	1 0	344
	21.2	8	346
	21.3	0.00	348
	21.4	0 0	350
	21.5	0.00,	352
	21.6		354
	21.7	What Are Speaker Intuitions?	357
22	The V	iew from Linguistics	359
	22.1	The Complexity Envelope of Language	360
	22.2	Levels of Language: Modular Organisation	362
	22.3	Language Typology	367
	22.4	Language Production	368
	22.5	The Human Tongue and Throat	369
	22.6	What We Hear	371
	22.7	Vowels and Consonants	372
	22.8	Convergent Evolution and Language Production	377
23	The L	anguage Faculty and Languages	378
	23.1	The Nature of Language Acquisition	378
	23.2	The Question of Modality: Sound or Gestures?	380
	23.3	Sign Language	382
	23.4	Communication by Touch?	384
	23.5	Receptive Modality	384
	23.6	Language and Writing	387
	23.7	Linguistic Diversity on Earth and Beyond	390
	23.8	Was There One Original Language?	393
	23.9	Language Change	396
24	T	uage and the Brain	399
	Lang	0	
	Lang 24.1	0	399
	0	Language Areas in the Brain	399 403
	24.1	Language Areas in the Brain The Binding Problem in Language	



25	Acqui	iring Language	410
	25.1	Are We Predestined for Speech?	411
	25.2	The Absence of Exposure to Language	414
	25.3	Characteristics of Language Acquisition	415
	25.4	Stages of Language Acquisition	416
	25.5	Abduction and Ambiguity in Language	418
	25.6	Localisation of Language and Early Childhood	419
	25.7	Language Transmission	419
	25.8	The Logical Problem of Acquisition	420
	25.9	The Evidence of Pidgins and Creoles	420
	25.10	Is There a Gene for Language?	421
	25.11	Constructed Languages	422
26	Huma	ans and Animals	425
	26.1	How Intelligent Are Animals?	426
Par	t VI Li	fe and Language, Here and Beyond	433
27	Preco	nditions for Life	435
	27.1	What Can the Range of a Search Be?	437
	27.2	The Panspermia Hypothesis	438
	27.3	What Can Be Assumed about Exolife Forms?	438
	0 - 4		
	27.4	Habitat Independence and Flexibility	441
	27.4 27.5	Habitat Independence and Flexibility To Recap: The Likelihood of Life	441 441
		· · ·	
	27.5	To Recap: The Likelihood of Life	441
	27.5 27.6	To Recap: The Likelihood of Life The Role of Serendipity	441 444
28	27.5 27.6 27.7 27.8	To Recap: The Likelihood of Life The Role of Serendipity Being Out of Sync	441 444 445
28	27.5 27.6 27.7 27.8	To Recap: The Likelihood of Life The Role of Serendipity Being Out of Sync Post-Human/Post-Biological?	441 444 445 446
28	27.5 27.6 27.7 27.8 What 28.1	To Recap: The Likelihood of Life The Role of Serendipity Being Out of Sync Post-Human/Post-Biological? Might Exolife Be Like?	441 444 445 446 448
28	27.5 27.6 27.7 27.8 What 28.1 28.2	To Recap: The Likelihood of Life The Role of Serendipity Being Out of Sync Post-Human/Post-Biological? Might Exolife Be Like? Lifespan for Exobeings	441 444 445 446 448 450
28	27.5 27.6 27.7 27.8 What 28.1 28.2 28.3	To Recap: The Likelihood of Life The Role of Serendipity Being Out of Sync Post-Human/Post-Biological? Might Exolife Be Like? Lifespan for Exobeings What Would Their Average Size Be?	441 444 445 446 448 450 452
28	27.5 27.6 27.7 27.8 What 28.1 28.2 28.3	To Recap: The Likelihood of Life The Role of Serendipity Being Out of Sync Post-Human/Post-Biological? Might Exolife Be Like? Lifespan for Exobeings What Would Their Average Size Be? Alternative Ecologies and Behaviours	441 444 445 446 448 450 452 453
28	 27.5 27.6 27.7 27.8 What 28.1 28.2 28.3 28.4 	To Recap: The Likelihood of Life The Role of Serendipity Being Out of Sync Post-Human/Post-Biological? Might Exolife Be Like? Lifespan for Exobeings What Would Their Average Size Be? Alternative Ecologies and Behaviours Feeling Like an Exobeing	441 444 445 446 448 450 452 453 457

Contents

xiii

	28.8	How Would They Count?	466
	28.9	Would They Have a Sense of Time?	467
29	Looki	ing for Signs of Life	472
	29.1	Biosignatures and Technosignatures	472
	29.2	The Nature of a Signal	475
	29.3	METI: Trying to Get in Touch	477
	29.4	Would They Want to Know Us?	478
30	The Is	ssue of First Contact	479
	30.1	Some Scenarios	479
	30.2	How to Contact Them: Language-Independent	
		Messages	483
	30.3	A Messenger from Beyond?	485
	30.4	Communicating without Meeting Them	487
	30.5	And If We Find One, What Then?	489
	30.6	Predicting Reactions	491
31	Language Beyond Earth		493
	31.1	Research on Evolution	495
	31.2	When Did It All Start?	496
	31.3	Where and Why Did It Start?	498
	31.4	Primary and Secondary Functions in Biology	500
32	How	Human Language Arose	503
	32.1	Looking for a Beginning	503
	32.2	Some Early Triggers	505
	32.3	From Proto-Language to Language	515
	32.4	The Evolving Levels of Language	523
	32.5	Sounds and Sound Systems	524
	32.6	What Is Morphology?	532
	32.7	Syntax: The Grammar of Sentences	535
	32.8	A Possible Parallel: The Immune System	545
	32.9	Language and Thought	549
	32.10	The Evolution of the Language Faculty	554
	32.11	Language, Evolution and Innateness	557



Contents

Bibliography

Index

	32.12	Language and the Physical Brain	560
	32.13	Language and Memory	562
33	The L	565	
	33.1	What Might Their Language Be Like?	566
	33.2	Could We Understand Them?	568
	33.3	Could They Understand Us?	570
34	Look	ing Forward: The Basic Questions Again	574
35	Some	e Final Thoughts	581
App	oendix	A: A Possible Roadmap to Exobeings	587
Арр	590		
Glo	593		
Tim	616		
Figi	624		
Refe	626		

632

661