

Contents

1	General Introduction	1
1.1	The Origin of Beeswax	2
1.2	Nests and Nesting	2
1.3	Self-Organization of Nest Contents	3
1.4	Interspecific Utilisation of Beeswax	3
1.5	Communication of Vibrations and Scents	4
1.6	Wax Secretion, Comb Construction and the Queen	4
1.7	The Significance of Brood	5
1.8	The Role of Pollen in Comb Construction	6
1.9	Nectar Flows and Comb-Building	6
1.10	Construction of Combs	7
1.11	Energetics of Honey/Beeswax Conversion	8
1.12	Construction of Cells	9
1.13	Conversion of Scale Wax into Combs	10
1.14	Material Properties of Scale and Comb Wax	10
1.15	The Wax Gland Complex	11
1.16	The Chemistry of Beeswax	12
1.17	Synthesis of Beeswax	12
1.18	Material Properties of Honeybee Silk	13
	References	14
2	Nesting: Sites, Space and Density in Comb-Building	17
2.1	Introduction	17
2.2	Nesting Sites	18
2.2.1	The Dwarf Honeybees	18
2.2.2	The Cavity-Nesting Honeybees	19
2.2.3	The Giant Honeybees	20
2.3	Nest Cavities	22
2.4	Colony Space and Density	24
2.4.1	Arrangement of Space	24
2.4.2	Density Versus Space	26

2.4.3	Reduction of Nest Size	28
2.4.4	Other Qualities of "Space"	30
2.5	Seasonality, Space and Density	32
	References	34
3	Self-Organization of Nest Contents	41
3.1	Introduction	41
3.2	Pattern Formation in Combs	43
3.2.1	Reaction–Diffusion Systems Pattern Formation	43
3.2.2	Template Effects?	46
3.2.3	Recent Models	47
3.3	Developmental Cycles of <i>Apis florea</i> Nests	50
	References	54
4	Intraspecific and Interspecific Comb-Building	57
4.1	Introduction	57
4.2	Intraspecific Comb Wax Salvage	58
4.3	Interspecific Wax Salvage	60
4.4	Interspecific Wax Discrimination	62
4.5	Comb-Building in Mixed-Species Colonies	66
4.5.1	Organisation of Mixed-Species Colonies and Wax Foundation.	66
4.5.2	Cell-Size and Wax Discrimination	67
4.5.3	Cell-Size Modification of Foundation Sheets	67
4.5.4	Freely-Built Combs.	69
4.5.5	Utilisation of the Newly Built Combs.	73
4.5.6	General Comb-Building.	73
4.5.7	Comb-Building in Mixed-Species Colonies	74
	References	75
5	Communication by Vibrations and Scents in the Comb	79
5.1	Introduction	79
5.2	Vibrations	81
5.2.1	Queen Honeybees.	82
5.2.2	Worker Vibrations	85
5.3	Scents	93
5.3.1	Waggle Dance Scent-marking: Probable Cause?	94
5.3.2	Comb and Scents	95
5.3.3	Capping Brood Cells.	97
	References	101
6	Wax Secretion, Comb Construction and the Queen	105
6.1	Introduction	105
6.2	The Queen: A Necessary Stimulus for Comb-Building?	107

6.3	Comb-Building Experiments by Whiffler and Hepburn (1991a)	108
6.3.1	Queenright and Queenless Colonies	108
6.3.2	Free-Running and Confined Queens	110
6.3.3	Division Board Experiments	110
6.3.4	General Conclusions from the Experiments of Whiffler and Hepburn (1991a, b)	114
6.4	Comb-Building Experiments of Ledoux et al. (2001)	116
6.5	Perception of Queenrightness	117
6.6	Comb-Building Experiments of Maisonnasse et al. (2010).	122
6.7	The Construction of Queen Cells	123
	References	127
7	The Significance of Brood	131
7.1	Introduction	131
7.2	Parthenogenesis	132
7.3	Oviposition by Queens	133
7.4	The Meaning of Brood	134
7.5	Efficacy of Open Brood	137
7.6	Drone Brood	140
7.7	Brood-Rearing and Honey Storage	141
	References	142
8	The Role of Pollen in Honeybee Colonies	145
8.1	Pollen and Brood	145
8.2	Pollen and Wax Production	149
8.3	Physical Presence and Regulation of Pollen in the Colony	153
8.4	Pollen Pheromones	157
8.5	Pattern and Function of Pollen Cells	160
8.6	Cell Allocation	162
	References	170
9	Nectar Flows and Comb-Building	175
9.1	Introduction	175
9.2	Temperate Zone Spring as a Stimulus	177
9.3	Tropical Areas: Environmental-Based Construction	179
9.4	Nectar, the Unqualified Stimulus for Comb Construction	183
9.4.1	Hoarding Assays	185
9.4.2	The Honey Stomach	189
9.5	Decision-Making and Regulation of Comb-Building	189
9.6	Who are the Comb Builders?	192
9.7	Nectar Intake and Comb Fullness	197
9.8	Termination of the Stimulus	199
	References	203

10	Construction of Combs	207
10.1	Introduction	207
10.2	Parallelism Between Combs	208
10.3	Festoons and Torsion	209
10.4	Festoons and Comb Growth	213
10.5	Evidence of a Sense of Equilibrium	215
10.6	Application of the Sense of Equilibrium	217
10.7	The Orientation of Combs	219
10.8	Behavioural Aspects of Comb Construction	220
	References	220
11	Energetics of Honey/Beeswax Conversion	223
11.1	Introduction	223
11.2	Cumulative Ratios	225
11.3	Measures of Conversion Efficiency	230
11.4	Temperature and Wax Production	235
	References	235
12	Construction of Cells	237
12.1	Introduction	237
12.2	Manipulation of Wax Scales	238
12.3	Comb Operations	238
12.4	Inception of the Nest	241
12.5	Recognition of Cell Patterns	248
12.6	Assessment of Cell Size	250
12.7	The Cell Base: Changing from Rhombus to Hemisphere	254
	References	256
13	Conversion of Wax Scales into Comb Wax	259
13.1	Introduction	259
13.2	Wax Scales	261
13.3	Chemical Differences Between Scale and Comb Wax	261
13.4	Maturation of Newly Constructed Combs	262
13.5	Wax Scales	266
13.6	Unnatural Building Materials	267
	References	269
14	Material Properties of Scale and Comb Wax	273
14.1	Introduction	273
14.2	Temperature Effects	274
14.3	Crystal Changes	277
14.4	Tensile Properties	280
14.5	Crystal Texture	285
14.6	Wax Proteins	285

14.7	α -Helical Silk	287
14.8	Optical Studies	288
14.9	X-ray Diffraction Studies	289
14.10	Crystallites of Beeswax	291
14.11	Origins of Crystallites in Beeswax	295
	References	296
15	The Wax Gland Complex	301
15.1	Introduction	301
15.2	Source of Secretion	305
15.2.1	The Cuticle	305
15.2.2	The Epidermis	307
15.2.3	Fat Body and Oenocytes	309
15.2.4	Synchronising Cellular Activity	311
15.2.5	Ultrastructure of the Organelles of Wax Gland Cells	313
	References	317
16	The Chemistry of Beeswax	319
16.1	Introduction	319
16.2	Chemical Composition	320
16.3	Chemometrics	323
16.3.1	Chemometric Classification of Beeswaxes	325
16.3.2	Discrimination and Classification of Beeswaxes	330
16.4	The Proteins of Beeswax	334
16.5	Plant-Derived Aromatic Volatiles and Colourants in Beeswax	335
	References	337
17	Synthesis of Beeswax	341
17.1	Introduction: Proof of Beeswax Synthesis	341
17.1.1	François Huber (1814)	342
17.1.2	The Chemists: Dumas and Edwards (1843)	343
17.2	Routes of Synthesis	344
17.3	Biochemical Investigations on Beeswax Synthesis	344
17.3.1	Hypothetical Scheme for Beeswax Synthesis	344
17.3.2	Monoester Synthesis	347
17.3.3	Cuticular and Comb Waxes	348
17.4	Cellular Basis of Synthesis	351
17.4.1	Chemical Composition and the Ages of Worker Bees	353
17.5	Secretion of Beeswax	355
	References	362

18	Material Properties of Honeybee Silk	367
18.1	Introduction	367
18.2	Honeybee Silk: An α -Helical Protein	369
18.3	Behaviour of Silk at Different Temperatures	371
18.4	Relative Crystallinity	372
18.5	Solvent Effects on Silk	373
18.6	Honeybee Silk: An α -Helical Silk and a Coiled-Coil Protein	375
18.7	Molecular Dynamics of α -Helical Proteins	377
18.8	Genetic Basis of Honeybee α -Helical Fibroin	379
	References	380
	Index	383

Honeybee Nests

Composition, Structure, Function

Hepburn, H.R.; Pirk, C.W.W.; Duangphakdee, O.

2014, XVI, 389 p. 171 illus., 100 illus. in color.,

Hardcover

ISBN: 978-3-642-54327-2