

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	A Brief History of Planktic Foraminifer Research.	3
	References	7
<b>2</b>	<b>Classification and Taxonomy of Extant Planktic Foraminifers</b>	<b>11</b>
2.1	Classification and Taxonomy	12
2.1.1	Molecular Genetics	13
2.2	Bilamellar Spinose Species	16
2.2.1	<i>Beella digitata</i> (Brady 1879) (Plate 2.1)	18
2.2.2	<i>Bolliella adamsi</i> Banner and Blow 1959 (Plate 2.2)	18
2.2.3	<i>Globigerina bulloides</i> d'Orbigny 1826 (Plate 2.3)	20
2.2.4	<i>Globigerina falconensis</i> Blow 1959 (Plate 2.4)	23
2.2.5	<i>Globigerinella calida</i> (Parker 1962) (Plate 2.5)	25
2.2.6	<i>Globigerinella siphonifera</i> (d'Orbigny 1839) (Plate 2.6)	25
2.2.7	<i>Globigerinoides conglobatus</i> (Brady 1879) (Plate 2.7)	30
2.2.8	<i>Globigerinoides ruber</i> (d'Orbigny 1839) (Plate 2.8)	32
2.2.9	<i>Globigerinoides sacculifer</i> (Brady 1877) (Plates 2.9 and 2.10)	36
2.2.10	<i>Globoturborotalita rubescens</i> Hofker 1956 (Plate 2.11)	41
2.2.11	<i>Globoturborotalita tenella</i> (Parker 1958) (Plate 2.11)	41
2.2.12	<i>Orbulina universa</i> d'Orbigny 1839 (Plate 2.12)	41
2.2.13	<i>Orcadia riedeli</i> (Rögl and Bolli 1973) (Plate 2.13)	46
2.2.14	<i>Sphaeroidinella dehiscens</i> (Parker and Jones 1865) (Plate 2.14)	46

2.2.15	<i>Turborotalita clarkei</i> (Rögl and Bolli 1973) (Plate 2.15) . . . . .	48
2.2.16	<i>Turborotalita humilis</i> (Bardy 1884) (Plate 2.15) . . . . .	48
2.2.17	<i>Turborotalita quinqueloba</i> (Natland 1938) (Plate 2.16) . . . . .	50
2.3	Monolamellar Spinose Species. . . . .	53
2.3.1	<i>Hastigerina pelagica</i> (d'Orbigny 1839) (Plate 2.17) . . . . .	53
2.3.2	<i>Hastigerinella digitata</i> (Rhumbler 1911) (Plate 2.17) . . . . .	53
2.4	Macroperforate Non-spinose Species. . . . .	55
2.4.1	<i>Berggrenia pumilio</i> (Parker 1962) (Plate 2.18) . . . . .	55
2.4.2	<i>Dentigloborotalia anfracta</i> (Parker 1967) (Plate 2.18) . . . . .	57
2.4.3	<i>Globoquadrina conglomerata</i> (Schwager 1866) (Plate 2.19) . . . . .	57
2.4.4	<i>Neogloboquadrina dutertrei</i> (d'Orbigny 1839) (Plate 2.20) . . . . .	59
2.4.5	<i>Neogloboquadrina incompta</i> (Cifelli 1961) (Plate 2.19) . . . . .	61
2.4.6	<i>Neogloboquadrina pachyderma</i> (Ehrenberg 1861) (Plate 2.21). . . . .	63
2.4.7	<i>Pulleniatina obliquiloculata</i> (Parker and Jones 1865) (Plate 2.22) . . . . .	66
2.4.8	<i>Globorotalia cavernula</i> Bé 1967. . . . .	66
2.4.9	<i>Globorotalia crassaformis</i> (Galloway and Wissler 1927) (Plate 2.23) . . . . .	66
2.4.10	<i>Globorotalia hirsuta</i> (d'Orbigny 1839) (Plate 2.24) . . . . .	70
2.4.11	<i>Globorotalia inflata</i> (d'Orbigny 1839) (Plate 2.25) . . . . .	70
2.4.12	<i>Globorotalia menardii</i> (Parker, Jones and Brady 1865) (Plate 2.26) . . . . .	74
2.4.13	<i>Globorotalia scitula</i> (Brady 1882) (Plate 2.27) . . . . .	74
2.4.14	<i>Globorotalia theyeri</i> Fleisher 1974 (Plate 2.27) . . . . .	76
2.4.15	<i>Globorotalia truncatulinoides</i> (d'Orbigny 1839) (Plates 2.28 and 2.29) . . . . .	78
2.4.16	<i>Globorotalia tumida</i> (Brady 1877) (Plate 2.30) . . . . .	81
2.4.17	<i>Globorotalia unguolata</i> Bermudez 1960 (Plate 2.30) . . . . .	83
2.4.18	<i>Globorotaloides hexagonus</i> (Natland 1938) (Plate 2.31) . . . . .	83
2.4.19	<i>Streptochilus globigerus</i> (Schwager 1866) . . . . .	85

2.5	Microperforate Species . . . . .	85
2.5.1	<i>Gallitellia vivans</i> (Cushman 1934) (Plate 2.32) . . . . .	85
2.5.2	<i>Globigerinita glutinata</i> (Egger 1893) (Plate 2.33) . . . . .	87
2.5.3	<i>Globigerinita minuta</i> (Natland 1938) (Plate 2.34) . . . . .	89
2.5.4	<i>Globigerinita uvula</i> (Ehrenberg 1861) (Plate 2.32) . . . . .	89
2.5.5	<i>Candeina nitida</i> (d'Orbigny 1839) (Plate 2.34) . . . . .	91
2.5.6	<i>Tenuitella compressa</i> (Fordham 1986) (Plate 2.35) . . . . .	91
2.5.7	<i>Tenuitella fleisheri</i> Li 1987 (Plate 2.35). . . . .	91
2.5.8	<i>Tenuitella iota</i> (Parker 1962) (Plate 2.35). . . . .	93
2.5.9	<i>Tenuitella parkerae</i> (Brönnimann and Resig 1971) (Plate 2.35) . . . . .	93
	Appendix . . . . .	94
	References . . . . .	99
<b>3</b>	<b>Cellular Ultrastructure.</b> . . . .	111
3.1	Cytoplasmic Streaming . . . . .	114
3.2	Peripheral Cytoplasm and Rhizopodial Morphology . . . . .	116
3.3	Cytoskeletal Structures . . . . .	118
3.4	Filaments . . . . .	120
3.5	Fine Structure of Cytoplasmic Organelles . . . . .	120
3.5.1	Nucleus . . . . .	120
3.5.2	Mitochondria . . . . .	122
3.5.3	Peroxisomes . . . . .	122
3.5.4	Endoplasmic Reticulum, Golgi Complex, and Vacuolar System. . . . .	123
3.5.5	Fibrillar Bodies. . . . .	124
3.5.6	Lipids and Various Cytoplasmic Inclusions . . . . .	125
3.6	Summary and Concluding Remarks . . . . .	125
	References . . . . .	126
<b>4</b>	<b>Nutrition, Symbionts, and Predators.</b> . . . .	129
4.1	Capture and Digestion of Prey . . . . .	129
4.1.1	Natural Prey . . . . .	131
4.1.2	Laboratory Studies on Trophic Activity . . . . .	133
4.1.3	Laboratory Experiments on Omnivorous Feeding . . . . .	134
4.1.4	Cannibalism . . . . .	135
4.1.5	Effect of Food Availability on Test Development . . . . .	136
4.1.6	Feeding Frequency . . . . .	136
4.1.7	Trophic Activity and Longevity . . . . .	136
4.2	Biomass . . . . .	138
4.3	Symbiosis . . . . .	140

4.3.1	Host-to-Symbiont Associations . . . . .	142
4.3.2	Acquisition of Symbionts During Ontogeny . . .	144
4.3.3	Structural Host-to-Symbiont Associations . . . . .	146
4.3.4	Physiological Interactions Between Symbiont and Host . . . . .	146
4.3.5	Dinoflagellate Symbiont Fine Structure . . . . .	151
4.3.6	Chrysophycophyte Symbiont Fine Structure . . .	151
4.4	Commensalism . . . . .	152
4.5	Parasitism . . . . .	152
4.6	Predation . . . . .	154
4.7	Summary and Concluding Remarks . . . . .	154
	References . . . . .	155
<b>5</b>	<b>Reproduction . . . . .</b>	<b>159</b>
5.1	Gametogenesis . . . . .	160
5.1.1	Succession of Events in Gametogenesis . . . . .	160
5.1.2	Fine Structural Processes During Gametogenesis . . . . .	161
5.1.3	Morphological Changes of Tests During Gametogenesis . . . . .	164
5.1.4	Gametogenic Calcification . . . . .	166
5.2	Reproduction Inferred from Population Dynamics . . . . .	168
5.3	Deviations from the Synodic Lunar Cycle in <i>H. pelagica</i> According to Laboratory Experiments . . . . .	172
5.4	Summary and Concluding Remarks . . . . .	174
	References . . . . .	174
<b>6</b>	<b>Ontogeny and Test Architecture . . . . .</b>	<b>177</b>
6.1	Morphological Development of Spinose Species . . . . .	178
6.2	Morphological Development of Non-spinose Species . . . . .	182
6.3	Coiling Directions of Tests . . . . .	183
6.4	Formation of Chambers and Pores . . . . .	183
6.4.1	Chamber Formation in Non-Spinose Species . . . . .	185
6.4.2	Calcification of the Test Wall and Pore Formation . . . . .	187
6.4.3	Keel Development . . . . .	190
6.4.4	Pustule Formation . . . . .	191
6.4.5	Chamber Formation in Spinose Species . . . . .	193
6.4.6	Types of Spines . . . . .	194
6.5	Test Wall Thickening . . . . .	195
6.6	Biomineralization and Test Calcite Mass . . . . .	197
6.7	Resorption and Repair Processes . . . . .	201
6.8	Organic Composition of the Test Wall . . . . .	202
6.9	Summary and Concluding Remarks . . . . .	203
	References . . . . .	203

<b>7 Ecology</b>	209
7.1 Distribution in the Global Ocean	211
7.1.1 Biogeographic Provinces	211
7.1.2 Diversity	214
7.2 Interannual and Seasonal Distribution	214
7.3 Trophic Effects	216
7.4 Vertical Distribution in the Water Column	219
7.5 Diurnal Vertical Migration	221
7.6 Test Size	221
7.7 Summary and Concluding Remarks	224
References	224
<b>8 Sedimentation and Carbon Turnover</b>	231
8.1 Test Flux Dynamics	231
8.1.1 Accumulation of Tests Within the Water Column	235
8.1.2 Pulsed Test Flux	236
8.1.3 Mass Sedimentation of Tests	238
8.1.4 The 'Large Tests' Phenomenon	240
8.2 Transportation and Expatriation	241
8.3 Dissolution	241
8.4 Overgrowth	246
8.5 Carbon Turnover	249
8.5.1 Regional Calcite Budgets	250
8.5.2 Global Calcite Budget	252
8.5.3 Global Biomass	255
8.6 Summary and Concluding Remarks	256
References	258
<b>9 Biogeochemistry</b>	263
9.1 Stable Isotopes and Element Ratios	264
9.1.1 $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$	266
9.1.2 Vital Effects on Stable Isotopes and Element Ratios	267
9.1.3 Effect of Photosynthesis on Stable Isotopes	268
9.1.4 Effect of Carbonate Ion Concentration on Stable Isotopes	268
9.1.5 Paleotemperature Equations	271
9.2 Clumped Isotopes	273
9.3 Mg/Ca Ratio and $\delta^{44}\text{Ca}$	273
9.4 Boron Isotopes and B/Ca Ratio	277
9.5 Cd/Ca Ratio	281
9.6 Other Isotope and Element Ratios	284
9.6.1 Sr/Ca Ratio	284
9.6.2 Ba/Ca, U/Ca, Nd/Ca, and $\text{SO}_4/\text{Ca}$ Ratios	284
9.7 Summary and Concluding Remarks	285
References	286

<b>10 Methods</b>	295
10.1 Sampling	295
10.1.1 Manual Collection of Live Specimens by SCUBA Divers	296
10.1.2 Assemblage Sampling	296
10.1.3 Single Nets	296
10.1.4 Multiple Opening-Closing Nets	297
10.1.5 Continuous Plankton Recorder (CPR)	298
10.1.6 Seawater Pumps	298
10.1.7 Sampling the Test Flux	298
10.2 Processing of Samples	307
10.2.1 Fixation for Transmission Electron Microscopy (TEM)	307
10.2.2 Analysis of Wet Samples	308
10.2.3 Analysis of Dry Samples	308
10.2.4 Wet Oxidation of Organic-Rich Samples	309
10.3 Methods in Molecular Genetics	309
10.3.1 DNA Isolation	309
10.3.2 Selection of Primers and PCR	309
10.3.3 Cloning and Nucleotide Sequencing	310
10.3.4 Molecular Marker	311
10.3.5 Next Generation Sequencing (NGS)	312
10.3.6 Computer Evaluation of the Nucleotide Sequences used for Phylogenetic Studies	312
10.4 Culturing in the Laboratory	313
10.4.1 Preparation of Specimens for Culture Experiments	313
10.4.2 Feeding in Laboratory Culture	314
10.4.3 Illumination of Symbiont-Bearing Species in Culture	316
10.5 Microsensor Analysis	316
10.6 Micro X-Ray Imaging and Computer Tomography (CT)	317
10.7 Analyses of the Chemical Composition of Tests	317
10.7.1 Analyses of Stable Isotopes	317
10.7.2 Analyses of Element Ratios	318
10.7.3 Radiocarbon Analyses	320
10.8 Biomass Analysis	320
10.9 Determination of Test Calcite Mass	321
10.10 Automated Microscopy	322
10.11 Electron Microscopy	324
10.12 Modeling	324
10.13 Census Data for Assemblage Analysis	325
10.13.1 Statistical Analysis of Assemblage Data	326
10.13.2 Analyses of Test Size Data	326
10.13.3 Transfer Functions	328

---

10.14 Applications . . . . .	329
10.14.1 First Example: Ocean Acidification (OA). . . . .	330
10.14.2 Second Example: Sapropel Formation . . . . .	331
References . . . . .	333
<b>Glossary</b> . . . . .	345
<b>Index</b> . . . . .	351

<http://www.springer.com/978-3-662-50295-2>

Planktic Foraminifers in the Modern Ocean

Schiebel, R.; Hemleben, C.

2017, XVII, 358 p. 164 illus., 54 illus. in color.,

Hardcover

ISBN: 978-3-662-50295-2