

Contents

About the Author

Foreword

Preface

1 Amphioxus is a model for understanding the evolution of vertebrate	1
1.1 Brief introduction of amphioxus.....	1
1.2 Biology of amphioxus	4
1.2.1 Reproduction and embryogenesis of amphioxus	4
1.2.2 Anatomy of amphioxus	7
1.3 The Story of amphioxus and its early researches in China	11
References	15
2 Basic knowledge of immunology	17
2.1 Immune organs	17
2.1.1 Primary lymphoid organs	17
2.1.2 Secondary lymphoid organs	19
2.2 Immune cells	21
2.2.1 Lymphoid cells	21
2.2.2 Innate immunity associated cells.....	23
2.3 Innate immunity.....	25
2.3.1 Toll-like receptors involved signaling pathway.....	26
2.3.2 Nod-like receptors and their functions	28
2.3.3 RIG-like receptors	30
2.3.4 C-type lectins.....	32
2.3.5 The scavenger receptors	34
2.3.6 Inflammation	36
2.4 Adaptive immunity	38
2.4.1 Specificity.....	39

2.4.2	Diversity	40
2.4.3	Immunological memory	41
2.4.4	Self-nonsel self recognition	42
2.5	Complement system	44
2.5.1	Complement pathways	44
2.5.2	Complement in host defense	47
	References	48
3	Immune organs and cells of amphioxus.....	51
3.1	Introduction	51
3.2	Organs of the amphioxus immune system	52
3.2.1	Amphioxus gill slits: the first immune defense line	53
3.2.2	Amphioxus intestine: not just a digestive organ but also an immune organ.....	55
3.3	Cells of the amphioxus immune system	58
3.3.1	Phagocytes.....	58
3.3.2	Lymphocyte-like cells	61
	References	65
4	Genomic and transcriptomic view of the amphioxus immunity ...	67
4.1	Introduction	67
4.2	Trace evidence of adaptive immunity	69
4.2.1	TCRs, Igs and VLRs.....	69
4.2.2	MHC and genes involved in antigen presentation.....	70
4.3	Extraordinary gene expansion in the amphioxus innate immunity	71
4.3.1	The TLR system	71
4.3.2	The NLR system.....	73
4.3.3	LRRIG proteins	73
4.3.4	Other LRR-containing genes	74
4.3.5	C-type lectins.....	74
4.3.6	Scavenger receptors.....	75
4.3.7	RIG-I-like helicases.....	76
4.3.8	Complement-related receptors.....	76
4.3.9	The TNF system	77
4.3.10	Expansion and reshuffling of the death-fold domains	78
4.3.11	Expansion of TIR adaptors, TRAFs and initiator caspases	79

4.3.12	Cytokines, kinases and transcription factors	80
4.4	Regulation of the amphioxus immune system	81
4.4.1	Differential regulatory patterns between expanded gene families	82
4.4.2	The regulation during bacterial infection	83
4.4.3	The regulation of the terminal signaling network.....	84
4.4.4	Differential expression patterns observed within TNF and IL-1R systems	84
4.4.5	Major pathways in a complex signaling network	85
4.4.6	A functional prototypic complement system	87
4.4.7	The prototype of oxidative burst-like system	88
4.4.8	Amphioxus PGRPs and GNBPs are important effectors in the gut.....	90
4.4.9	Chitin-binding proteins.....	91
4.4.10	Other effector genes	92
4.5	Discussion.....	93
	References	97
5	Pattern recognition system in amphioxus.....	101
5.1	TLR signaling pathway in amphioxus	101
5.1.1	The overview	101
5.1.2	TLR family in amphioxus	102
5.1.3	The TIR containing adaptors in amphioxus.....	105
5.1.4	The putative bypass pathway mediated by novel TIR adaptors	111
5.1.5	The transduction and regulation of amphioxus TLR signaling	112
5.1.6	Summary	119
5.2	Innate antiviral immunity in Amphioxus	120
5.2.1	RLR signaling pathway	121
5.2.2	Innate antiviral defense in <i>drosophila</i>	122
5.2.3	Immune-related genes for antiviral response in amphioxus	123
5.3	NLR signaling pathway	125
5.3.1	NLR in amphioxus	125

5.3.2	The NLR diversity in amphioxus	126
5.3.3	The NLR signaling in amphioxus.....	132
	References	138
6	Transcription factors in amphioxus	143
6.1	NF- κ B family members in amphioxus	143
6.2	The interferon regulatory factor family in amphioxus.....	148
6.3	The STATs in amphioxus.....	155
6.3.1	The JAK-STAT pathway	155
6.3.2	The JAK-STAT pathway in invertebrate	157
6.3.3	The STAT family of mammals	157
6.3.4	The structure and function of STATs in amphioxus.....	158
6.3.5	Evolution	160
	References	162
7	The complement system of amphioxus.....	165
7.1	Introduction	165
7.2	Tracing evolutionary origin of complement system	166
7.3	The complement system of amphioxus	168
7.3.1	The lectin pathway	169
7.3.2	The alternative pathway	173
7.3.3	The terminal pathway.....	173
	References	176
8	The oxidative burst system in amphioxus.....	179
8.1	Introduction	179
8.2	NADPH Oxidases 2 and the other NOX families.....	180
8.2.1	NOX2	181
8.2.2	NOX4	184
8.2.3	NOX5	184
8.2.4	DUOX1 and DUOX2	185
8.3	NOX Subunits and Regulatory Proteins	187
8.3.1	P22 ^{phox}	187
8.3.2	Organizer subunit: p47 ^{phox}	187
8.3.3	Activator subunit: p67 ^{phox}	189
8.3.4	P40 ^{phox}	189

8.4	Functions of ROS generated by NADPH oxidases.....	190
	References	191
9	Immune effectors in amphioxus	194
9.1	Galectin.....	194
9.2	C-type lectin	198
9.3	Peptidoglycan recognition protein.....	202
9.4	Gram-negative bacteria-binding protein.....	204
9.5	Chitin-binding protein	204
9.6	Apextrin.....	206
9.7	Bactericidal/permeability-increasing protein.....	207
9.8	Other effector genes.....	209
	References	210
10	Lipid signaling of immune response in amphioxus.....	213
10.1	Introduction	213
10.2	The classification, structure and function of lipids	214
10.2.1	Membrane and energy storage.....	215
10.2.2	Lipid signaling.....	216
10.3	Origin of the vertebrate lipid signaling.....	216
10.3.1	The origin of vertebrate eicosanoid signaling in amphioxus	217
10.3.2	Conserved phospholipid signaling pathway	218
10.3.3	Typical cholesterol accumulation of inflammation in amphioxus	219
10.3.4	Downstream signaling and nuclear receptors	220
10.4	Future directions.....	221
10.5	Summary.....	222
	References	223
11	Apoptosis in amphioxus.....	225
11.1	General knowledge of apoptosis	225
11.2	Apoptosis related gene families in amphioxus	227
11.2.1	The Apaf-1 and Bcl2 homologues in amphioxus.....	227
11.2.2	The caspase family in amphioxus.....	230
11.2.3	The TRAIL-DR apoptosis system	233

11.2.4 Perspectives: The death domain superfamily: a tale of two interfaces.....	236
References	238
12 Primitive adaptive immune system of amphioxus.....	240
12.1 Evidence of the emergence of adaptive immunity in amphioxus	242
12.1.1 Lymphocyte-like cells and related genes in amphioxus	242
12.2 The primary building blocks for MHC and Rag protein.....	246
12.2.1 An antecedent MHC-linked genomic region.....	246
12.2.2 The common ancestor of RAG 1- and RAG 2- like genes	251
12.3 The alternative forms of variable immune receptors	253
12.3.1 Amphioxus candidates for adaptive immune receptors	254
12.3.2 Other variable receptors in invertebrates.....	257
References	259
13 Future research directions.....	263
13.1 Ubiquitination of immune signaling in amphioxus.....	263
13.1.1 Posttranslational modification of immune response in mammals.....	263
13.1.2 Ubiquitination of immune regulation in <i>drosophila</i>	267
13.1.3 Ubiquitination of immune regulation in amphioxus.....	268
13.2 The microRNAs in amphioxus	272
13.3 Alternative 3' UTRs in amphioxus immune response	277
References	281
Abbreviation Index	287
Key Words Index.....	297