

Contents

	Preface	<i>xv</i>
	List of Contributors	<i>xvii</i>
	About the Companion Website	<i>xxv</i>
1	Themes in Bacterial Pathogenesis	1
	<i>John F. Prescott</i>	
	Introduction	1
	The Basic Elements of Bacterial Pathogenesis	1
	Concepts of Bacterial Virulence are Being Refined	5
	Host–Pathogen Communications are Critical	9
	Pathogenesis in the Post-Genomic Era	11
	Gaps in Knowledge and Anticipated Directions	13
	References	13
2	Evolution of Bacterial Pathogens	15
	<i>Patrick Boerlin</i>	
	What are Pathogens and How Do They Emerge?	15
	Bacterial Fitness and Virulence	17
	Sources of Genetic Diversity, Population Structure, and Genome Plasticity	18
	Pathogenicity Islands	20
	Bacteriophages and Their Role in Pathogen Evolution and Virulence	22
	Examples of Virulence Evolution	23
	Gaps in Knowledge and Anticipated Directions	27
	References	28
3	Understanding Pathogenesis Through Pathogenomics and Bioinformatics	32
	<i>Gregorio Iraola and John D. Boyce</i>	
	Introduction	32
	How Mutations Generate Bacterial Diversity	34
	Genome Sequencing Technologies	36
	Genome Assembly	38
	Gene Prediction and Annotation	39
	Defining Prokaryotic Species from Genomes	41
	The Pangenome Concept, Reconstruction, and Comparative Analyses	41
	Phylogenomics and Genome-Wide Association Studies	42
	Functional Genomics for Understanding Host–Pathogen Interactions	44
	Reverse Vaccinology	48
	Gaps in Knowledge and Anticipated Directions	51
	References	52

- 4 Experimental Approaches to Understanding Pathogenesis 57**
Francesca L. Short and Janet I. MacInnes
 Introduction 57
 Testing Koch's Postulates 57
 Virulence Factors and Main Steps in Pathogenesis 58
 Molecular Koch's Postulates 60
 Refining Animal Usage 60
 Experimental Approaches for Virulence Factor Discovery and Validation 62
 Approaches for Virulence Factor Discovery 63
 Gene Disruption Approaches for Virulence Factor Discovery 71
 Bringing It All Together: Validation and Further Characterization of Virulence Factors 73
 Two Stories of Virulence Factor Discovery and Characterization: *Pasteurella multocida* Capsule, and *Mycoplasma bovis* Adhesins 74
 Gaps in Knowledge and Anticipated Directions 75
 References 76
- 5 Subversion of the Immune Response by Bacterial Pathogens 79**
Douglas C. Hodgins, Raveendra R. Kulkarni, and Patricia E. Shewen
 Introduction 79
 Subversion of Innate Responses 80
 Subversion of Adaptive Immunity 85
 Manipulation of Cell Fate 88
 Non-Coding RNA and Host-Pathogen Interactions 91
 Epigenetic and Genetic Modulation 92
 Gaps in Knowledge and Anticipated Directions 94
 References 94
- 6 Chinks in the Armor 99**
Allison C. Leonard, Celine Stoica, and Georgina Cox
 Introduction 99
 Virulence Factors: Pathogenesis-Based Targets to Combat Bacterial Pathogens 99
 Targeting Bacterial Host Cell Adhesion and Biofilm Formation 100
 Quorum Sensing Inhibition 104
 Interfering with Two-Component Regulatory Systems 105
 Inhibiting Bacterial Motility 106
 Toxin Neutralization 107
 Inhibitors of Bacterial Secretion Systems 107
 Targeting Nutrient Acquisition: Starving the Pathogen 110
 Antiviral Phage Therapy 111
 Bacterial Drug Efflux Pumps as Pathogenesis-Based Antibacterial Targets 112
 Gaps in Knowledge and Anticipated Directions 112
 References 113
- 7 *Escherichia coli* 117**
John M. Fairbrother and Carlton L. Gyles
 Introduction 117
 Pathotypes of *E. coli* and Associated Disease and Pathological Changes in Animals 119
 Virulence Factors of Pathogenic *E. coli* 126
 Pathogenesis of Enterotoxigenic *E. coli* 141
 Pathogenesis of Enteropathogenic *E. coli* Disease 144

- Pathogenesis of Shiga Toxin-Producing *E. coli* Disease 146
 Pathogenesis of Extraintestinal Pathogenic *E. coli* Infections 149
 Gaps in Knowledge and Anticipated Directions 156
 References 157
- 8 *Salmonella* 162**
Paul A. Barrow, Michael A. Jones, Kate C. Mellor, and Nick R. Thomson
 Introduction 162
 Characteristics of the Organism 162
 Types of Disease and Pathologic Changes 167
Salmonella Infections in Different Major Farmed Animal Species 169
 Virulence Factors 174
 Pathogenesis 179
 Immunity to Infection and its Manipulation by *Salmonella* 186
 Antimicrobial Resistance 190
 Gaps in Knowledge and Anticipated Directions 191
 References 192
- 9 *Yersinia* 200**
Anne-Sophie Le Guern and Javier Pizarro-Cerdá
 Introduction 200
 Characteristics of the Organism 200
 Pathogenic Species 200
 Taxonomy 201
 Major Virulence Factors of the Highly Pathogenic *Yersinia* 203
Yersinia pestis 205
Yersinia pseudotuberculosis and *Yersinia enterocolitica* 209
Yersinia ruckeri 213
Yersinia entomophaga 213
 Control of *Yersinia* Infections 214
 Gaps in Knowledge and Anticipated Directions 214
 References 215
- 10 *Pasteurella* 221**
Marina Harper, Thomas R. Smallman, and John D. Boyce
 Introduction 221
 Characteristics of the Organism 221
 Source of Infection: Ecology, Evolution, and Epidemiology 223
 Types of Disease and Pathologic Changes 223
 Virulence Factors and Pathogenomics 225
 Regulation of Virulence 233
 Pathogenesis 235
 Immunity 236
 Control 238
 Gaps in Knowledge and Anticipated Directions 239
 References 239
- 11 *Mannheimia and Bibersteinia* 244**
Jeff L. Caswell and Charles J. Czuprynski
 Introduction 244
 Characteristics of the Organism 244
 Pathogenic Species 245

- Source of Infection: Ecology, Evolution, and Epidemiology 245
 - Types of Disease and Pathologic Changes 247
 - Virulence Factors and Pathogenomics 249
 - Regulation of Virulence 250
 - Pathogenesis 251
 - Immunity 254
 - Control 254
 - Gaps in Knowledge and Anticipated Directions 255
 - References 256
- 12 Actinobacillus 262**
Janine T. Bossé, Adina R. Bujold, and Lu Li
- Introduction 262
 - Actinobacillus pleuropneumoniae* 262
 - Actinobacillus lignieresii* 277
 - Actinobacillus equuli* 278
 - Actinobacillus suis* 279
 - Gaps in Knowledge and Future Directions 281
 - References 283
- 13 Other Pasteurellaceae: Avibacterium, Bibersteinia, Gallibacterium, Glaesserella, and Histophilus 290**
Anders M. Bojesen, Virginia Aragon, and Pat J. Blackall
- Introduction 290
 - Avibacterium* 290
 - Bibersteinia* 292
 - Gallibacterium* 295
 - Glaesserella parasuis* 301
 - Histophilus* 309
 - References 311
- 14 Pseudomonas 318**
Erin L. Westman, Véronique L. Taylor, and Joseph S. Lam
- Introduction 318
 - Characteristics of the Organism 318
 - Pathogenic Species 319
 - Sources of Infection: Ecology, Evolution, and Epidemiology 320
 - Types of Disease and Pathologic Changes 320
 - Virulence Factors and Pathogenomics 321
 - Pathogenesis 328
 - Immunity 330
 - Control, Prevention, and Treatment 331
 - Gaps in Knowledge and Anticipated Directions 335
 - References 337
- 15 Moraxella 344**
John A. Angelos
- Introduction 344
 - Infectious Bovine Keratoconjunctivitis 344
 - Pathogenesis of *Moraxella bovis* Infection 346
 - Immunity 352
 - Control 354

- Gaps in Knowledge and Future Directions 354
References 355
- 16 *Brucella* 361**
Clayton C. Caswell, Angela Arenas-Gamboa, and Jeff T. Foster
Introduction 361
Characteristics of the Organism 361
Pathogenic Species 362
Source of Infection: Ecology, Evolution, and Epidemiology 362
Types of Disease and Pathologic Changes 363
Virulence Factors 366
Regulation of Virulence 368
Pathogenomics 369
Pathogenesis 370
Immunity 370
Control 371
Gaps in Knowledge and Anticipated Directions 371
References 372
- 17 *Bordetella* 376**
Colleen J. Sedney, Tracy L. Nicholson, and Eric T. Harvill
Introduction 376
Characteristics of the Organisms 376
Pathogenic Species 377
Source of Infection: Ecology and Epidemiology 379
Types of Disease and Pathologic Changes 380
Virulence Factors 380
Regulation of Virulence 385
Pathogenesis 385
Immunity 385
Control 387
Gaps in Knowledge and Anticipated Directions 389
References 389
- 18 *Campylobacter* 393**
Zuowei Wu, Orhan Sahin, and Qijing Zhang
Introduction 393
Diseases, Etiology, and Ecology 394
Clinical Observations and Pathologic Changes 397
Pathogenesis and Virulence Factors 398
Pathogenomics and Evolution 402
Immunity 405
Control 406
Gaps in Knowledge and Future Directions 407
References 408
- 19 *Helicobacter* 413**
Chloë De Witte, Helena Berlamont, and Freddy Haesebrouck
Introduction 413
Gastric Helicobacters 413
Enterohepatic Helicobacters 425
Gaps in Knowledge and Future Directions 426
References 427

20 Chlamydia and Coxiella 433

Martina Jelocnik, Wilhelmina M. Huston, and Hayley J. Newton

Introduction 433

Chlamydiae 433

Characteristics of the Organism 433

Source of Infection: Ecology, Evolution and Epidemiology 436

Types of Disease and Pathologic Changes 436

Pathogenesis 442

Immunity and Control 442

Gaps in Knowledge and Anticipated Directions 443

Coxiella burnetii 443

Characteristics of the Organism 444

Source of Infection: Ecology, Evolution and Epidemiology 445

Types of Disease and Pathologic Changes 445

Virulence Factors and Pathogenomics 447

Immunity and Control 448

Gaps in Knowledge and Anticipated Directions 449

References 449

21 Rickettsiales 456

Jere W. McBride, Roman R. Ganta, and David H. Walker

Introduction 456

Family Anaplasmataceae 457

Anaplasma Species 457

Ehrlichia Species 463

Neorickettsia Species 474

Family Rickettsiaceae 476

Rickettsia Species 476

References 480

22 Lawsonia intracellularis 486

Roberto M. C. Guedes, Fabio A. Vannucci, and Connie J. Gebhart

Introduction 486

Characteristics of the Organism 486

Sources of Infection: Ecology and Epidemiology 489

Types of Disease and Pathologic Changes 490

Virulence Factors and Pathogenomics 491

Pathogenesis 492

Immunity 496

Control 497

Gaps in Knowledge and Anticipated Directions 497

References 498

23 Leptospira 502

Cyrille Goarant, Ben Adler, and Alejandro de la Peña Moctezuma

Introduction 502

Characteristics of the Organism 502

Leptospira Species 505

Source of Infection: Ecology, Evolution, and Epidemiology 505

Clinical Presentation and Signs 511

Virulence Factors and Pathogenomics 511

Regulation of Virulence 514

- Pathogenesis 514
Immunity 516
Control 518
Gaps in Knowledge and Anticipated Directions 518
References 519
- 24 *Brachyspira* 528**
Joseph E. Rubin and Judith Rohde
Introduction 528
Characteristics of the Organism 528
Pathogenic Species and Disease Associations 529
Source of Infection: Ecology, Evolution, and Epidemiology 530
Virulence Factors and Pathogenomics 531
Pathogenesis 531
Immunity 537
Control 538
Gaps in Knowledge and Anticipated Directions 538
References 539
- 25 *Staphylococcus* 543**
Amy C. Pickering, Andreas F. Haag, José R. Penades, and J. Ross Fitzgerald
Introduction 543
Characteristics of the Organism 543
Pathogenic Species 544
Staphylococcus aureus Infections in Cattle 546
Staphylococcus aureus Infections in Poultry 551
Staphylococcus aureus Infections in Rabbits 553
Staphylococcus hyicus Infections in Pigs 554
Staphylococcus pseudintermedius Infections in Dogs 556
Gaps in Knowledge and Future Directions 559
References 560
- 26 *Streptococcus* 565**
John F. Timoney
Introduction 565
Characteristics of the Organism 565
Pathogenic Species 565
Streptococcus agalactiae 567
Streptococcus dysgalactiae 569
Streptococcus uberis 570
Streptococcus equi 571
Streptococcus zooepidemicus 577
Streptococcus canis 579
Streptococcus suis 580
Gaps in Knowledge and Anticipated Directions 583
References 583
- 27 *Bacillus anthracis* 588**
Joachim Frey
Introduction 588
Characteristics of the Organism: Taxonomy and Phylogeny 588
Source and Spread of the Infection: Ecology, Evolution, and Epidemiology 591

Types of Disease and Pathologic Changes 592
 Virulence Factors and Pathogenomics 594
 Regulation of Virulence 595
 Pathogenesis 596
 Immunity and Vaccines 598
 Control and Prevention of Anthrax 598
 Gaps in Knowledge and Anticipated Directions 600
 References 601

28 Enteric Clostridia 607

Evelien Dierick, Evy Goossens, John F. Prescott, Richard Ducatelle, and Filip Van Immerseel

Introduction 607

Clostridium perfringens 607

Characteristics of the Organism 607

Pathogenic Types 608

Sources of Infections: Ecology, Evolution and Epidemiology 608

Types of Disease and Pathologic Changes 611

Virulence Factors 616

Regulation of Virulence 622

The Pathogenesis of *Clostridium perfringens* Enteric Disease 622

Control 625

Gaps in Knowledge and Anticipated Directions 625

Clostridioides difficile 626

Characteristics of the Organism 626

Source of Infection: Ecology, Evolution and Epidemiology 626

Types of Disease and Pathologic Changes 627

Disease 627

Virulence Factors and Pathogenomics 627

Regulation of Virulence 628

Pathogenesis 629

Immunity 630

Control 630

Gaps in Knowledge and Anticipated Directions 630

Other Enteric Clostridia 630

References 631

29 Histotoxic Clostridia 635

Andrew N. Rycroft

Introduction 635

Characteristics of the Organisms 635

Source of Infection and Basic Pathogenesis 636

Pathogenic Species 636

Clostridium septicum (Malignant Edema/Gas Gangrene) 638

Clostridium chauvoei (Blackleg) 639

Paeniclostridium sordellii 640

Clostridium novyi Type B (Black Disease/Bighead) 642

Clostridium haemolyticum 643

Clostridium perfringens 644

Control 645

Gaps in Knowledge and Future Directions 645

References 646

- 30 Neurotoxic Clostridia 648**
Michel R. Popoff
 Introduction 648
 Characteristic of the Organisms 648
 Clostridium botulinum 648
 Clostridium tetani 650
 Sources of Infection: Ecology and Epidemiology 652
 Diseases 656
 Botulism 656
 Tetanus 657
 Virulence Factors 658
 Pathogenesis 659
 Control 663
 References 664
- 31 Mycoplasmas 667**
Pollob K. Shil, Nadeeka K. Wawegama, Glenn F. Browning, Amir H. Noormohammadi, and Marc S. Marena
 Introduction 667
 Characteristics of the Organisms 667
 Pathogenic Species 668
 Source of Infection: Ecology, Evolution, and Epidemiology 668
 Virulence Factors and Pathogenomics 670
 Regulation of Virulence 674
 Types of Disease and Pathologic Changes 674
 Pathogenesis 680
 Immunity 688
 Control 690
 Gaps in Knowledge and Anticipated Directions 690
 References 691
- 32 *Corynebacterium*, *Arcanobacterium*, and *Trueperella* 701**
Thiago D. Barral, Ricardo W. Portela, Nbia Seyffert, and Robert J. Moore
Corynebacterium 701
Corynebacterium pseudotuberculosis 701
 Bovine Pyelonephritis Caused by *Corynebacterium* Species 706
 Other Animal Pathogenic *Corynebacterium* Species 706
Arcanobacterium 707
Trueperella 709
 Gaps in Knowledge and Future Directions 710
 References 710
- 33 *Rhodococcus equi* 715**
Jos A. Vzquez-Boland, Macarena G. Sanz, and John F. Prescott
 Introduction 715
 Characteristics of the Organism 715
 Source of Infection and Epidemiology 717
 Types of Disease and Pathologic Changes 720
 Virulence Factors 721
 Evolution of *Rhodococcus equi* Virulence 723
 Pathogenesis 724
 Immunity 726
 Treatment and Control 728

Gaps in Knowledge and Anticipated Directions 730
References 731

34 Mycobacterium 736

Karren M. Plain, Karen Stevenson, Richard J. Whittington, and Nathalie Winter

Introduction 736

Characteristics of the Organism 736

Sources of Infection 738

Source of Infection: Evolution and Epidemiology 739

Virulence Factors and Pathogenomics 740

Regulation of Virulence 742

Types of Disease 743

Pathogenesis 744

Adaptive Immunity and Mycobacterial Pathogenesis 748

Control 750

Gaps in Knowledge and Anticipated Directions 750

References 752

35 Gram-Negative Anaerobes 757

John F. Prescott

Introduction 757

General Bacterial Pathogenesis Aspects 757

Fusobacterium 759

Bacteroides 763

Prevotella and *Porphyromonas* 764

Dichelobacter nodosus 765

Treponema 767

Gaps in Knowledge and Anticipated Developments 768

References 768

Index 773