

Contents

Preface to the First Edition	xiii
Preface to the Second Edition	xiv
Preface to the Third Edition	xv
1 General Aspects of Growth	1
1.1 Introduction	1
1.2 Being the Right Size	1
1.3 Why Do Animals Change in Form as They Grow?	2
1.3.1 Growth of the eye	2
1.3.2 Growth of wings	3
1.3.3 The pinna of the ear	4
1.4 Shape and Mass	4
1.5 Domestication and Size of Animal	4
1.6 Growth and Form	5
1.7 Domestication and Growth	5
2 Cells	6
2.1 Introduction	6
2.2 Cell Structure	7
2.2.1 Size of cells	7
2.3 Chemical Composition of Cells	7
2.4 The Cytoplasm and Organelles	10
2.5 The Nucleus	11
2.5.1 DNA packaging into chromosomes	11
2.5.2 DNA transcription into RNA	12
2.5.3 Protein synthesis from RNA	13
2.6 Variation between Individuals	14
2.6.1 Gene sequences	14
2.6.2 Epigenetic modifications	15
2.6.3 Regulation by non-coding RNA	15
2.6.4 Regulation of gene transcription	16
2.6.5 Signal transduction	18
2.7 Organelles of Protein Degradation	19
3 Principles of Cell Growth	22
3.1 Introduction	22
3.2 The Cell Cycle and Mitosis	22
3.2.1 Control of cell proliferation	24
3.2.2 Cell cycle checkpoints	26
3.3 Control of Cell Hypertrophy	27
3.4 Cell Death	28
3.5 Differentiation of Specialized Cell Types	30

3.6	Stem Cells	32
3.7	Basic Cell Types	33
3.7.1	Cell adhesion	35
3.8	Characteristics of Proliferation in Tissues and Organs	35
4	Tissues: Basic Structure and Growth	38
4.1	Introduction	38
4.2	Nervous Tissue	38
4.2.1	Structure of nervous tissue: cells and fibres	38
4.2.2	Major divisions and development of the nervous system	39
4.2.3	Growth of the nervous system	40
4.3	Connective Tissue	40
4.3.1	Components of the extracellular matrix	40
4.3.2	Structure and classification of connective tissues	45
4.4	Cartilage and Bone	46
4.4.1	Cartilage cells and structure	47
4.4.2	Bone cells and structure	49
4.4.3	Bone strength	50
4.5	Growth of the Skeleton	51
4.5.1	Patterning and endochondral bone formation	51
4.5.2	Formation of the growth plate	53
4.5.3	Intramembranous ossification	55
4.5.4	Bone remodelling	55
4.5.5	Factors affecting bone growth	56
4.5.6	Antlers	56
4.5.7	Teeth	56
4.6	Haematopoietic Connective Tissue	56
4.7	Adipose Tissue	57
4.7.1	Adipose types and functions	57
4.7.2	Distribution of adipose tissue	58
4.7.3	Adipose cells	58
4.7.4	Adipose metabolism	59
4.7.5	Adipose blood supply	60
4.7.6	Adipogenesis: development of the fat cell	60
4.7.7	Embryonic and fetal adipose development	62
4.7.8	Postnatal adipose growth	63
4.7.9	Excess adipose tissue	65
4.7.10	Adipose growth in cattle	65
4.7.11	Adipose growth in pigs	67
4.7.12	Adipose growth in sheep	67
4.7.13	Adipose tissue composition	69
4.7.14	Fatty acid composition	69
4.7.15	Species and nutrition effects on fatty acid composition	70
4.7.16	Age and fatty acid composition	72
4.7.17	Growth rate and fatty acid composition	72
4.7.18	Breed, genotype, sex and fatty acid composition	73
4.8	Muscle Tissue	74
4.8.1	Muscle types	74
4.8.2	The muscle fibre	75
4.8.3	Muscle fibre types	78
4.8.4	Muscle force transmission and the muscle–tendon junction	80

4.8.5	Chemical composition of muscles	81
4.8.6	Normal muscle growth	83
4.8.7	Myoblast fusion establishes fibre number and type	83
4.8.8	Myogenic determination factors	84
4.8.9	Postnatal muscle hypertrophy	85
4.8.10	Muscle atrophy	87
4.8.11	Abnormal muscle growth	87
4.8.12	Dwarfism	87
4.8.13	Double muscling	87
4.8.14	Nutritional muscular dystrophy	88
4.8.15	The callipyge gene	89
4.8.16	Soft and exudative muscle	90
4.9	Epithelial Tissues	91
4.9.1	Types and structure	91
4.9.2	Integument	92
4.9.3	Hair and wool	93
5	Tissues: Growth and Structure Relative to Product Value for Human Consumption	101
5.1	Introduction	101
5.2	Grading Schemes and Value	101
5.3	Yield and Composition	101
5.3.1	Maturity	103
5.3.2	Breed and gender	105
5.4	Carcass Tissues and Concepts of Meat Quality	106
5.4.1	Introduction	106
5.5	The Transition from Muscle to Meat	107
5.5.1	Effects of pH on muscle	108
5.6	Visual Perception of Meat Quality	110
5.6.1	Meat colour	110
5.6.2	Dark-cutting meat	110
5.6.3	Pale, soft and exudative meat	111
5.7	Eating Quality of Meat	112
5.7.1	Tenderness	112
5.7.2	Growth rate, marbling and tenderness	113
5.7.3	Post-mortem proteolysis and ageing	114
5.7.4	The calpain enzyme system	114
5.7.5	Effects of breed and gender on tenderness	114
5.7.6	Meat flavour	115
5.7.7	Boar odour	116
5.8	Adipose Tissue and Meat Quality	117
5.8.1	Fat colour	117
5.8.2	Fat firmness	118
5.8.3	Nutritive value and keeping quality	118
5.9	Fibre Yield and Quality	118
5.9.1	Wool yield	118
5.9.2	Fibre diameter and length	119
5.9.3	Staple strength and length	120
5.9.4	Crimp	120
5.9.5	Colour	120
5.9.6	Kemp and hair fibres	120
5.9.7	Goat hair	121

6 Mammary Gland Growth and Product Yield	124
6.1 Introduction	124
6.2 Mammary Gland Structure	124
6.3 Measurement of Growth and Size	125
6.4 Mammogenesis in the Prenatal Period in Cattle, Sheep, Goats and Pigs	126
6.4.1 Introduction	126
6.4.2 Cattle	127
6.4.3 Sheep and goats	128
6.4.4 Pigs	128
6.5 Development at Birth and Mammogenesis in Postnatal Life in Cattle	129
6.5.1 At birth	129
6.5.2 To puberty and in recurring oestrous cycles	129
6.5.3 During pregnancy	130
6.5.4 Parturition and during lactation and at involution	130
6.6 Hormonal and Growth Factor Control of Mammogenesis	131
6.7 Effects of External Factors	132
6.8 Products of the Mammary Gland	134
6.8.1 Introduction	134
6.8.2 Nutrient composition of colostrum and milk	135
6.9 Nutrient Content and Growth of Sucking Animals	136
7 Hormonal Influences on Growth	139
7.1 Introduction	139
7.2 Homeostasis and Homeorhesis	139
7.3 Communication between Cells and Tissues	140
7.3.1 Juxtacrine signalling	141
7.3.2 Paracrine and autocrine signalling	141
7.3.3 Endocrine signalling	141
7.3.4 Neural signalling	142
7.3.5 Signalling in development	142
7.4 Common Features of Communication between Cells	142
7.4.1 Binding proteins	143
7.4.2 Hormone receptors	143
7.5 Individual Hormones	144
7.5.1 Insulin-like growth factors	144
7.5.2 Insulin	148
7.5.3 Growth hormone	151
7.5.4 Catecholamines	155
7.5.5 Thyroid hormones	156
7.5.6 Glucocorticoids	159
7.5.7 Sex steroids	161
7.5.8 Prolactin	165
7.6 Hormones, Appetite and Satiety	165
7.6.1 Short-term control of intake and satiety	165
7.6.2 Ghrelin	166
7.6.3 Cholecystokinin	166
7.6.4 Peptide YY	167
7.6.5 Incretins: GIP and GLP-1	167
7.6.6 Leptin: long-term regulation of food intake	167
7.7 Hormones and the Photoperiodic Control of Growth	169

8	Genetic Influences on Growth	174
8.1	Introduction	174
8.2	Heritability of Growth and Growth-related Traits	174
8.2.1	Introduction	174
8.2.2	Selection differential, generation interval and genetic gain	176
8.3	Cross-breeding and Hybrid Vigour	177
8.4	Undesirable Genetic Effects on Growth and Related Traits	179
8.5	Breeds	180
8.6	Prediction Markers of Growth	183
9	The Immune System and Growth	186
9.1	Introduction	186
9.2	The Immune System, Disease and Growth	186
9.3	Endocrine and Immune System Interactions	188
9.4	The Immune System and Manipulation of Endocrine Function	190
10	Gametes, Fertilization and Embryonic Growth in Mammals	193
10.1	Introduction	193
10.2	Meiosis, Gametes and Fertilization	193
10.2.1	Introduction	193
10.2.2	Meiosis and gametogenesis	194
10.2.3	Gametes and fertilization	197
10.3	Embryonic Development	199
10.3.1	Cleavage	199
10.3.2	Blastocyst formation and hatching	201
10.3.3	Gastrulation and tubulation	202
10.4	The Uterus, the Placenta and Embryonic Attachment	204
10.4.1	The uterus	204
10.4.2	The placenta and embryonic attachment	206
10.5	Post-gastrulation and Post-tubulation Embryonic Development	209
10.6	New Technologies and Embryo Growth	209
10.6.1	Techniques	209
10.6.2	Embryo growth	211
11	Prenatal and Postnatal Growth in Mammals	213
11.1	Problems of Describing Growth	213
11.1.1	Growth in relation to time	213
11.2	Describing Prenatal and Postnatal Growth	216
11.3	Targets of Growth	216
11.4	Sequential Growth Targets	217
11.4.1	The embryo as an effective parasite	217
11.4.2	The fetus as a competitor	218
11.4.3	The fetus as a template for growth	218
11.4.4	Semi-independence at birth	218
11.4.5	The newly weaned juvenile	218
11.4.6	The growth phase	218
11.4.7	Puberty and the onset of reproductive capability	218

11.4.8	Reproductive phase	219
11.4.9	Senescence and death	219
11.5	Changes in Proportion during Growth	219
11.5.1	Changes in proportion during prenatal growth	221
11.5.2	Size at birth	223
11.5.3	The first controversy: live weight as a determining variable	224
11.5.4	The second controversy: should fat be included as part of the independent variable?	225
11.6	Functional Units	227
11.7	Tissue Proportions: Breed and Slaughter Weight	228
11.8	Conclusions	229
12	Growth of Avian Species	232
12.1	Introduction	232
12.2	Classification of Domesticated Avian Species	232
12.2.1	Altricial and precocial birds	233
12.2.2	Carinates and ratites	233
12.3	Egg Formation and Egg Production	233
12.3.1	Ovulation and egg formation	233
12.3.2	Fertilization	234
12.3.3	Sex determination	235
12.3.4	Oviposition	235
12.3.5	Onset of egg laying	236
12.3.6	Development of the chick within the egg	236
12.4	Growth from Hatching to Maturity	236
12.4.1	Growth rate from hatching	236
12.4.2	Proportions of economically important tissues	237
12.4.3	Body composition and plane of nutrition	238
12.4.4	Body composition of culled laying birds	239
12.5	Conclusions	239
13	Efficiency and Growth	241
13.1	Introduction	241
13.2	Numerical Concepts of Efficiency	241
13.3	Energy as a Baseline for Feed Input	241
13.4	Units of Energy	242
13.4.1	The joule	242
13.4.2	The calorie	242
13.5	The Gross Energy of Feed	243
13.6	Definitions of Feed Energy in Animal Systems	243
13.7	The Partition of Metabolizable Energy in the Growing Animal	244
13.8	Maintenance and Basal Metabolism	244
13.9	The Utilization of Dietary Energy above Maintenance	246
13.10	Growth Rate, Feed Intake and Efficiency	247
13.11	The Effect of Choice of Slaughter Weight on Efficiency	249
13.12	Once-bred Gilts and Once-bred Heifers	250
13.13	Efficiency, Slaughter Weight and Marketing	250
14	Compensatory Growth	251
14.1	Introduction	251
14.2	Factors Affecting Compensatory Growth: Classification	252
14.2.1	Animal Factors	252
14.2.2	Nutritional factors	255

14.3	Components of Compensatory Growth	259
14.3.1	Introduction	259
14.3.2	Changes in tissue proportions	259
14.4	Compensatory Growth and Overall Efficiency	264
14.5	Compensatory Growth: Basic Considerations	264
14.6	Compensatory Growth: Problems of Interpretation	265
15	Growth and Puberty in Breeding Animals	270
15.1	Introduction	270
15.2	The Endocrinology of Puberty in the Female	270
15.3	The Endocrinology of Puberty in the Male	271
15.4	Factors Affecting Puberty in the Female	272
15.5	Effects of Growth Rate on Puberty in the Female and Male	272
15.5.1	Introduction	272
15.5.2	Cattle: heifers	273
15.5.3	Cattle: bulls	277
15.5.4	Pigs: gilts	277
15.5.5	Pigs: boars	280
15.5.6	Sheep: ewe lambs	280
15.5.7	Sheep: ram lambs	283
15.5.8	Horses: fillies	284
15.5.9	Horses: colts	285
15.5.10	Fowl: pullets	285
15.5.11	Fowl: cockerels	287
16	Measuring and Predicting Growth and Body Composition in the Live Animal	290
16.1	Introduction	290
16.2	Measuring and Predicting Live Weight and Conformation Changes	290
16.2.1	Weighing animals	290
16.2.2	Measuring animals	292
16.2.3	Video image analysis	295
16.3	Measuring and Predicting Body Composition in Live Animals	296
16.3.1	Predictions based on live weight	296
16.3.2	Visual appraisal of live animal conformation and prediction of body composition	296
16.3.3	Dilution techniques	298
16.3.4	Neutron activation analysis	299
16.3.5	Probes	299
16.3.6	Balance studies	300
16.3.7	X-ray computed tomography	300
16.3.8	Nuclear magnetic resonance	301
16.3.9	Ultrasonic techniques	304
16.3.10	Bioelectrical impedance analysis	307
16.3.11	Cell size in adipose tissue	307
16.3.12	Urinary creatinine excretion	307
17	Measurements on the Carcass	310
17.1	Introduction	310
17.2	Carcass Weight and Killing-out (or Dressing-out) Proportion	311
17.3	Specific Gravity or Density	311
17.4	Measurements Taken by Ruler and Probe	312
17.5	Visual Appraisal (Scoring)	316
17.6	Jointing and Dissection Techniques	318

17.7	Ultrasonic Devices	321
17.8	Video Image Analysis	322
17.9	Bioelectrical Impedance Analysis	322
17.10	Electromagnetic Scanning	322
18	'Growth Promoters', Performance Enhancers, Feed Additives and Alternative Approaches	325
18.1	Introduction	325
18.2	Classification of Growth Promoters and Performance Enhancers	325
18.3	Historical Note	325
18.3.1	Discovery	325
18.3.2	Concerns	326
18.3.3	The situation since 1999	327
18.3.4	How do antibiotics and antibacterials work?	327
18.4	Additives with the Potential to Replace Antibiotics in the Feeds of Pigs and Pre-ruminant Ruminants	327
18.4.1	Probiotics	327
18.4.2	Chemical probiosis	328
18.4.3	Diet pre-fermentation	328
18.4.4	Organic acids	328
18.4.5	Inorganic acids	328
18.4.6	Enzymes	329
18.4.7	Nutraceuticals	329
18.4.8	Zeolites and clay minerals	330
18.4.9	Inert organic substances	330
18.4.10	Antibacterials based on inorganic salts	330
18.4.11	Nitrates	330
18.4.12	Fermentable substrates: prebiotics, nutribiotics and synbiotics	331
18.4.13	Physiological regulators	331
18.5	Overview of Growth Promotion	331
18.6	Alternatives: Immunization and Immuno-nutrition	332
18.7	Alternatives: New Systems of Production	332
18.7.1	Optimal nutrition	332
18.8	Conclusions	332
19	The Future	334
19.1	Introduction	334
19.2	Future Demand for Meat and Meat Products	334
19.2.1	Change in ethical views	334
19.2.2	Changes in the perception of meat as a healthy food	334
19.3	The Future Possibilities for Technical Advance	338
19.3.1	Nutrition	338
19.3.2	Technology and growth	338
19.3.3	Health of those engaged in animal production	338
19.3.4	Breeding	339
19.3.5	Meat processing and the image of meat	339
19.4	Growing Animals and Global Warming	339
19.5	Conclusions	340
Index		341