

Contents

Preface to the Second Edition

vii

Preface to the First Edition

ix

Acknowledgements

xi

Part I: Mendelian Genetics

1. Mendel's Laws of Inheritance

3

Historical Background 3

G.J. Mendel—Biographical Sketch 3

Re-discovery of Mendel's Laws 4

Choice of Material by Mendel 4

Experimental Technique 4

Monohybrid Ratio (3:1) or "Law of Dominance" or "Principle of Segregation" 6

Testing the Validity of Gene Hypothesis 7

Dihybrid Ratio (9:3:3:1) or the Law of Independent Assortment 8

Dihybrid Ratio in Summer Squashes 8

Dihybrid Test Cross 9

Incomplete Dominance (1:2:1 Ratio) 10

Incomplete Dominance in Fowls 11

Incomplete Dominance in Snapdragons (*Antirrhinum majus*) (Dihybrid Cross) 12

Trihybrid Ratio 13

Problems 15

2. Deviations of Mendel's Laws

66

Interaction of Genes 66

Complementary Genes 67

Reversions, Atavism or Throwbacks 69

Epistasis (13:3 Ratio) 70

Multiple Factor Inheritance (15:1 Ratio) 71

Problems 74

3. Sex-linked Inheritance

- Chromosome Theory of Inheritance 109
- Examples of Sex-linked Inheritance 110
- Reciprocal Cross 111
- Haemophilia and Colour Blindness in Man 112
- Inheritance of Haemophilia 112
- Colour Blindness 112
- Sex-linked Genes in Poultry 112
- Non-disjunction in *Drosophila* 114
- Secondary Non-disjunction 115
- Inheritance of "Attached" X Chromosome in *Drosophila* 116
- Problems 117

129

4. Sex Determination

- Sexual Function of X and Y Chromosomes 129
- Gynandromorphs 130
- Inter- and Super-sexes in *Drosophila* 130
- Theory of Gene Balance for Sex Determination 131
- Intersexes in *Lymantria* (Gypsy Moth) 132
- Effect of Hormones 132
- "Freemartin" 132
- Sex in *Melandrium* 132
- Y Chromosome and Sex Determination in Mammals 132
- Effect of Environment on Sex Determination (Sex in *Bonellia*) 133
- Sex Differentiation 133
- Lyon's Hypothesis 134
- Fragile X Chromosome 135
- Hormones and Sex Differentiation 135
- Human Y Chromosome 135

136

5. Multiple Alleles

- Coat Colour in Rabbits 136
- Multiple Alleles in Maize 138
- Blood Groups in Man 138
- "Rhesus" Alleles in Man 142
- Histocompatibility Genes 144
- Sterility Genes in *Nicotiana* 145
- Pleiotropism 145
- Problems 145

6. Linkage and Crossing Over

- Linkage in Maize 153
- Crossing Over 156

1

Chiasmata Formation at Meiosis	156
Types of Crossing Over	156
Tetrad Analysis in <i>Neurospora</i>	158
Tetrad Analysis in <i>Chlamydomonas</i>	159
Factors Affecting the Strength of Linkage	160
Measurement of Linkage	160
Linkage Groups and Chromosomes	160
Absence of Crossing Over in <i>Drosophila</i> Males	162
Cytological Proof of Crossing Over	167
Tetrad Analysis in <i>Saccharomyces cerevisiae</i>	169
Features of Genetic Cross <i>Saccharomyces cerevisiae</i>	169
Setting up the Cross	170
Analysing the Results of the Cross	170
Gene Mapping with <i>S. cerevisiae</i>	170
Gene Mapping in Yeast—A Worked Example	172
Problems	173
7. Chromosome Mapping: Genetic Maps or Linkage Maps of Chromosomes	196
Three Point Test Cross	196
Calculation of Percentage of Recombinations Between Region I and II	199
Second Example with Double Crossovers	199
Test Cross Progeny	200
Interference and Coincidence	200
Problems	203
8. Statistical Genetics	215
Probability	215
Calculation of Genetic Ratios	216
Chi-square	217
Chi-square Method with More than one Degree of Freedom	218
The Binomial Expansion	219
Problems	223
9. Population Genetics	248
Introduction	248
The Hardy-Weinberg Law	248
PTC Inheritance (<i>Tasters</i> vs. <i>Non-tasters</i>)	249
Factors Affecting the Equilibrium in Populations	250
Migration	250
Mutation	250
Random Drift or Genetic Drift	251

Inbreeding	251
Selection	251
Random Mating	251
Assumptions of Hardy-Weinberg Equilibrium	251
No Selection	252
Genetic Drift	252
No Mutation or Migration	252
Genetic Load	252
Mutational Load	252
Segregational Load	253
Darwinian Evolution	253
Evolution and Speciation	253
Reproductive Isolation	253
Mimicry	254
Industrial Melanism	254
Problems	254

10. Extranuclear Inheritance

260

Milk Factor in Mice	260
Inheritance of Milk Factor in Horses	261
Inheritance of Coiling in Shells of <i>Limnaea</i>	262
CO ₂ Sensitivity in <i>Drosophila</i>	266
Mitochondrial DNA	266
Chloroplast DNA	269

11. Human Genetics

272

Human Chromosomes and Karyotype	272
Dosage Compensation and Sex-chromatin Bodies	273
Chromosomal Aberrations and Variation of Chromosome Number in Humans	275
Structural Chromosomal Anomalies	275
Cri-du-chat or Cat's Cry Syndrome	276
Edward Syndrome	277
Mongolism/Down's Syndrome/Trisomy	280
Physical and Physiological Features	281
Chromosomal Findings in Down's Syndrome	281
Incidence	281
Klinefelter's Syndrome	282
Turner's Syndrome	284
XYY-males and Criminal Behaviour	287
Autosome-linked Dominant Genetic Diseases	287
Sickle Cell Anaemia	288
Symptoms of Sickle Cell Anaemia	288

Molecular Basis of Sickle Anaemia	288
Explanation of Sickle Cell Anaemia from Genetic Code	289
Alkaptonuria (Black Urine Disease)	290
Inheritance Pattern	290
Phenylketonuria	290
Disease Symptoms	292
Genetic Aspects	292
Advice for PKU's Individuals	292
Sex-linked Genetic Diseases and their Mode of Inheritance	292
Y-linked Genes	293
Is Baldness an Example of Sex-linked Genes?	294
Meiosis, Crossing Over and Human Genetics	296

Part II: Molecular Genetics

12. DNA Structure

301

Introduction to Molecular Biology	301
From Peas to <i>Drosophila</i>	301
Birth of Molecular Biology	302
Beginnings of Experimental Proof of DNA (Deoxyribose Nucleic Acid)	302
The Transforming Principle	302
The Transforming Principle is Genetic Material	303
The Transforming Principle is DNA	303
Bacteriophage Genes are Made of DNA	305
Bacteriophages are Viruses that Infect Bacteria	305
Phage Protein and DNA can be Labelled with Radioactive Markers	305
The Hershey-Chase Experiment	305
Acceptance of DNA as the Genetic Material	306
The Structure of DNA	307
DNA is a Polymer	307
Nucleotides—the Monomers in DNA	307
The Sugar Component	307
Nitrogenous Bases	308
The Phosphoric Acid Component	308
Nomenclature of Nucleotides	308
Polynucleotides	310
Nucleotides are Joined by Phosphodiester Bonds	310
Polynucleotides have Chemically Distinct ends	310
Polynucleotides can be of any Length and have any Sequence	310
RNA is also a Polynucleotide	312

Chargaff's Base Ratios Paved the Way for Correct Structure	313
X-ray Diffraction Analysis Indicates that DNA is a Helical Molecule	314
Watson and Crick Solve the Structure	314
Complementary Base Pairing is the Fundamental Fact of Molecular Genetics	316
The Double Helix Exists in Several Different Forms	316
Molecular Genetics in a Nutshell	319

13. DNA Replication

323

Replication of DNA Molecules	323
Overall Pattern of DNA Replication	323
The Meselson and Stahl Experiment	325
Mechanism of DNA Replication in <i>E. coli</i>	328
DNA Polymerase	329
DNA Polymerase I and DNA Polymerase III	329
Events at the Replication Fork	329
Breakage of the Parent Double Helix	329
Leading and Lagging Strands	329
The Priming Problem and Joining up the Okazaki Fragments	330
The Topological Problem	331
DNA Topoisomerases Function in Unexpected Ways	331
Replication of Molecules	331
Replication of Circular DNA Molecules	332

14. RNA and Protein Synthesis

334

Introduction	334
Nucleotide Sequence—the Crucial Feature of Gene	334
Organisation of Genes on DNA Molecules	334
Genes in Clusters	335
Operons	335
Multi Gene Families	335
Discontinuous Genes	335
The Central Dogma	336
Transcription—the First Stage of Gene Expression	336
Translation—the Second Stage of Gene Expression	337
Protein Synthesis—the Key to Expression of Biological Information	337
Transcription	338
Eukaryotes and Prokaryotes	338
Nucleotide Sequences	339
RNA Synthesis	339
RNA Polymerase	339
RNA Polymerase Synthesises RNA in the 5' to 3' Direction	340

Eukaryotes Possess More Complex RNA Polymerases	340
Events in Transcription	341
Initiation	341
The Transcription Initiation Site is Signalled by the Promoter	341
'Pribnow Box'	341
Eukaryotic Promoters are Slightly Different	342
The Subunit of RNA Polymerase Recognizes the Promoter	342
Elongation	343
Termination	344
Completion of Transcription	346
Types of RNA Molecule: rRNA and tRNA	346
Ribosomal RNA (rRNA)	347
The Structure of Ribosomes	347
rRNA Molecules may have Enzymatic Roles During Protein Synthesis	348
Synthesis of rRNAs	348
The rRNA Transcription Unit	349
There are Multiple Copies of the rRNA Transcription Unit	349
Transfer RNA	350
Structure of tRNA	350
The tRNA Cloverleaf Model	350
The Tertiary Structure	350
Processing and Modification of tRNA Transcripts	352
Three Nucleotides at the 3' end may be Added after Transcription	353
Certain Nucleotides Undergo Chemical Modification	353
Types of RNA Molecules: mRNA	353
Discovery of mRNA	354
Most mRNA Molecules are Unstable	355
Modification and Processing of mRNA	355
All Eukaryotic mRNAs are Capped	355
Most Eukaryotic mRNAs are Polyadenylated	356
Introns must be Removed from the Primary Transcript	356
Splicing Occurs in the Nucleus	356
Splicing Pathway for Nuclear Pre-mRNA	357
Other Types of Introns	357
15. The Genetic Code and Protein Synthesis	359
Introduction	359
Polypeptides are Polymers	359
Amino Acids	360
Amino Acids are Linked by Peptide Bonds	360

Different Levels of Protein Structure	361
Amino Acid Sequence is the Key to Protein Structure and Function	362
Importance of Amino Acid Sequence	363
The Genetic Code	363
Colinearity between Gene and Protein	364
Each Codeword is a Triplet of Nucleotides	364
Elucidation of the Code	365
Completion of Genetic Code	366
Features of the Code	366
Translation and Protein Synthesis	371
Role of tRNA in Translation	371
Aminoacylation of tRNA	371
Aminoacyl-tRNA Synthetases Control Charging	371
Codon Recognition	372
Mechanics of Protein Synthesis	375
Initiation of Translation	376
Ribosome Binding Sites Ensure that Translation Starts at the Correct Position	376
Formation of the Initiation Complex	376
Elongation of the Polypeptide Chain	378
Peptide Bond Formation and Translocation	379
Each mRNA can be Translated by Several Ribosomes at Once	381
Chain Termination	382
Antibiotics	382
Puromycin	382
Tetracycline	383
Chloramphenicol	383
Streptomycin	383

16. Control of Gene Expression

386

Why Control Gene Expression?	386
Control of Gene Expression—the Operon Concept	387
Jacob and Monod's Lac Operon	387
Regulation of Lactose Utilisation	387
The Lactose Utilisation Genes form an Operon	388
The Lactose Repressor	389
Lactose Induces Transcription	390
Regulation of the Tryptophan Operon	391
Complications with <i>Lac</i> and <i>Trp</i> Operons	392
Glucose Represses <i>Lac</i> Operon	393
Attenuation of <i>Trp</i> Operon	393

Control of Gene Expression In Eukaryotes	396
Control Elements for Yeast Genes	396
Enhancers for Mammalian Genes	396
Control of Gene Expression During Development	397
Role of Z-DNA in Gene Regulation	398
Hormonal Control of Gene Expression	398
<i>Caenorhabditis elegans</i> : A Model System for the Study of Development	398
Catabolite Repression	399
<i>his</i> Operon (Repressible System)	401
Histidine Synthesis	403
Operator Control	403
<i>Trp</i> Operon (Repressible System)	403
Leader Peptide Gene	403
Developmental Genetics	405
17. Microbial Genetics: Viruses and Bacteria	412
Viruses-the Simplest form of Life	412
Bacteriophages	413
Introduction to Bacteria and Viruses	420
Virus Culture	421
Plasmids	423
Conjugation	425
Mapping Genes in Bacteria	432
Contrastduction	441
Recombination	443
Holliday Model	444
Genes in Eukaryotic Organelles	447
18. Fine Structure of the Gene and Biochemical Genetics	451
Introduction	451
Fine Structure Analysis in <i>E. coli</i> <i>rII</i> Region	451
The Complementation Test, Determines if two Mutations are in the same Gene	455
Length of Cistron	457
Fine Structure of the Gene	457
Pseudoalleles	458
The Cistron, Recon and Muton	458
Biochemical Genetics	459
Alcaptonuria	461
Beadle and Tatum's Experiments with <i>Neurospora</i>	465
Importance of Biochemical Genetics	471

19. Mutations

472

- Classification of Mutations 472
- Mutations at the Level of the Gene 473
- Mutations at the Level of an Organism 475
- Radiation Genetics—X Rays 476
- Units of Radiation 478
- Mutations in Bacteria 479
- Mutation Rates 481
- H.J. Muller's CIB Technique 481
- Molecular Mechanism of Mutations 485
- Reverse Mutation 490

20. Unstable Genetic Systems, Cancer Genetics and Immunology

508

- Unstable Genetic Systems 508
- Oncogenes and Cancer Genetics 513
- Immunology and Immunity 524

21. Gene Cloning, Recombinant DNA Technology and Biotechnology

529

- Gene Cloning 529
- DNA Sequencing 540
- DNA Fingerprinting 541
- Examples of Genetic Engineering Techniques 543
- Vector Systems 545
- Bio-technology—Genetic Engineering Institutes and Scope 546
- Protoplast Fusion 550
- Recombinant-DNA Technology 550
- Applications of Biotechnology 552
- Applications of Genetic Engineering—Some More Examples 552
- Recent Advances in Plant Genetic Engineering (Summary) 558
- Conclusion 560

Part III: Cytogenetics**22. Cell Cycle, Mitosis and Meiosis**

563

- Cell Cycle in Eukaryotes 563
- Mitosis 565
- Meiosis 569
- Chromosome Movement in Mitosis and Meiosis 576

23. Karyotype

579

- Staining and Banding Chromosomes 579

24. Eukaryotic Chromosome Structure

585

- Chromosome Shape 585
- Chromosome Size 587

Chromosome Number	587	
Detailed Morphology of the Chromosome	587	
Heterochromatin and Euchromatin	589	
Special Types of Chromosomes	590	
Salivary Gland Chromosomes	591	
Organisation of Eukaryotic Genomes	593	
Most Eukaryotic Genomes Contain Repetitive DNA	593	
Molecular Structure and Organisation of Eukaryotic Chromosomes	595	
Genome Complexity	596	
Chemical Composition of Eukaryotic Chromosomes	596	
Molecular Structure of Eukaryotic Chromosomes	596	
One Giant DNA Molecule Per Chromosome	597	
Viscoelastometric Evidence for Chromosome Size DNA Molecules	598	
Packaging the Giant DNA Molecules into Chromosomes	599	
Nucleosome Structure	599	
Summary	602	
Euchromatin and Heterochromatin	602	
Repetitive DNA and Sequence Organisation	603	
25. Chromosomal Aberrations		605
Genome Mutations: Alterations of Chromosome Number (Polyploidy, Haploidy and Aneuploidy)	605	
Chromosome Mutations or Chromosomal Aberrations	606	
Extranuclear Mutations	621	
Problems	621	
26. Polyploidy		635
Introduction	635	
Aneuploidy	635	
Cytology of Polyploids	637	
Origin of Polyploids	638	
Polyploidy in Cultivated Plants	638	
Uses of Polyploidy in Plant Breeding	641	
Part IV: Plant Breeding		
27. Principles of Plant Breeding		651
Objectives	651	
Selfing and Crossing Techniques	652	
28. Methods of Selection		656
Pure Line Selection	656	
Pedigree Selection	657	

Gamma-garden	694
Directed Mutagenesis	694
Applications of Mutation Breeding	694
Limitations of Mutation Breeding	695
Achievements	696
33. Molecular Farming—Transgenic Plants	698
Abstract	698
Introduction	699

Part V: Genomics

34. Beginnings of Genomics	717
Genomics: An Overview	717
Correlated Genetic, Cytological, and Physical Maps of Chromosomes	718
Map Position-based Cloning of Genes	726
The Human Genome Project	730
Human Gene Prospecting in Iceland	735
Genomics—How to Sequence a Genome	736
The Shotgun Approach to Genome Sequencing	736
The Clone Contig Approach	739
Using a Map to Aid Sequence Assembly	742
Post-genomics-trying To Understand A Genome Sequence	746
Identifying the genes in a Genome Sequence	746
Determining the Function of an Unknown Gene	749
Studies of the Transcriptome and Proteome	750
Studying the Transcriptome	750
Studying the Proteome	751
<i>Glossary of Plant Breeding Terms</i>	754
<i>Glossary of Genetic Terms</i>	765
<i>Glossary of Molecular Genetics</i>	782
<i>Suggested Readings</i>	843

Part VI: Appendices

Cytological Techniques	847
Questions	856
Life Cycles	866
Genetic Terms and Geneticists	871
Index	896

Bulk Population Method	657	
Multiple Crossing	658	
Backcross Method	659	
Recurrent Selection	660	
Heritability	661	
Plant Introduction	662	
Plant Introduction Agencies in India	662	
29. Male Sterility		664
Genetic Male Sterility	664	
Cytoplasmic Male Sterility	664	
Cytoplasmic-Genetic Male Sterility	665	
Overcoming Male Sterility	666	
Self-incompatibility	667	
Overcoming Self-incompatibility	668	
Summary	668	
30. Polyploidy in Plant Breeding		669
Aneuploidy	669	
Meiosis in Aneuploids	671	
Artificial Induction of Polyploids	672	
Autopolyploidy	672	
Cytogenetics of Polyploids	673	
Allopolyploidy	675	
31. Heterosis Or Hybrid Vigour		681
Introduction	681	
Inbreeding Depression	681	
Inbreeding Effects	681	
Heterosis	682	
Genetic Basis of Heterosis and Inbreeding Depression	683	
32. Mutation Breeding		686
Historical Account of Mutation Breeding	687	
Spontaneous and Induced Mutations	687	
Effects of Mutations	688	
Mutagens	688	
Mechanism of Action of Radiations	690	
Mechanism of Action of Chemical Mutagens	691	
Methods of Mutation Breeding	692	
Generations M_1 To M_8	693	
Recurrent Irradiation	693	