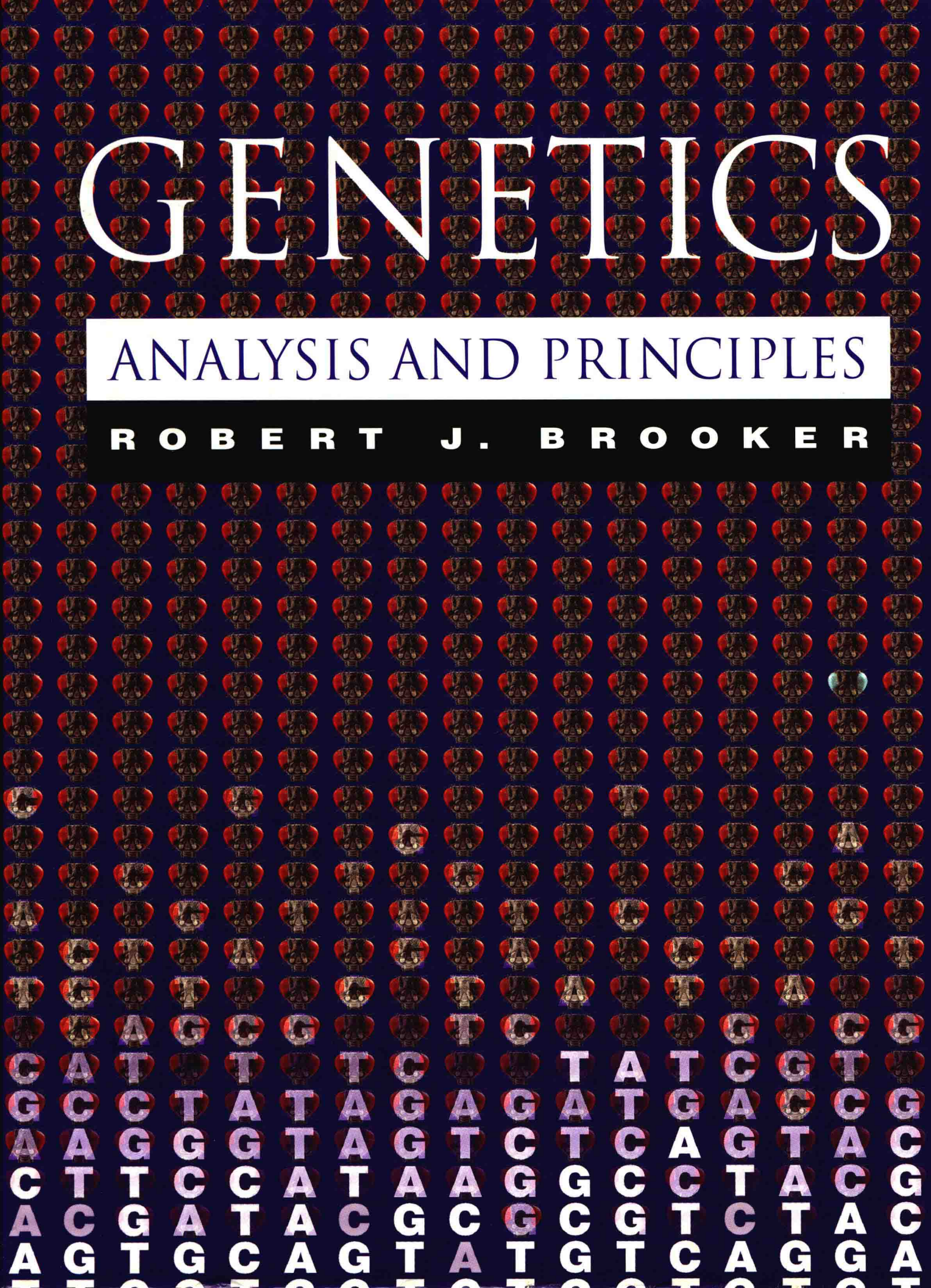
GENETICS

ANALYSIS AND PRINCIPLES

ROBERT J. BROOKER



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ROBERT J. BROOKER
UNIVERSITY OF MINNESOTA, TWIN CITIES

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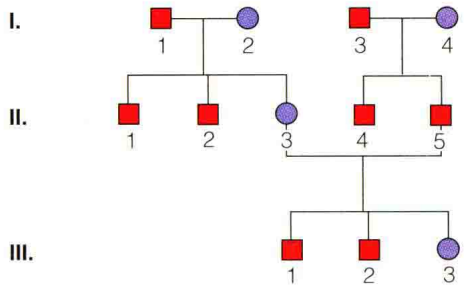
DEDICATION



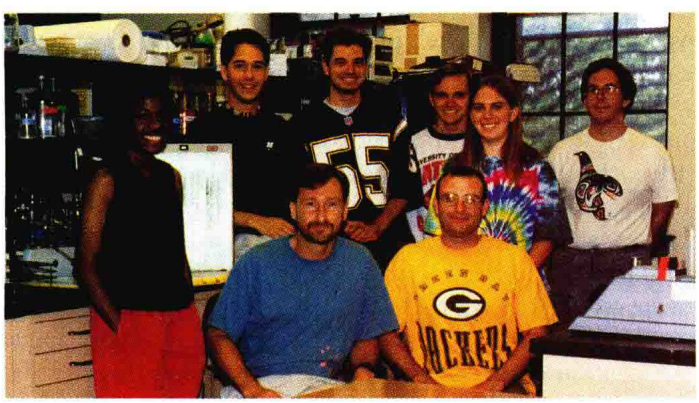
It seems wonderfully appropriate to dedicate this genetics textbook to my family (see pedigree at left). Most importantly, this book is dedicated to my wife, with love, and to my three children. My family provides me with a daily reminder of the continuity of life and its true meaning.

I-1, Stanley Verrill; I-2, Genevieve Verrill; I-3, Charles Brooker; I-4, Katherine Brooker
II-1, Harland Verrill; II-2, Andrew Verrill; II-3, Deborah (Verrill) Brooker; II-4, David Brooker; II-5, Robert Brooker
III-1, Daniel Brooker; III-2, Nathan Brooker; III-3, Sarah Brooker

ABOUT THE AUTHOR

Robert J. Brooker (Ph.D., Yale University) is a Professor in the Department of Genetics, Cell Biology, and Development at the University of Minnesota, Twin Cities. He received his B.A. in Biology at Wittenberg University in 1978. Working with Dr. Caroline W. Slayman, he obtained a Ph.D. in Human Genetics at Yale University. In 1982, he began a four year post-doctoral fellowship in the laboratory of Dr. Thomas H. Wilson at Harvard University. At Harvard, he studied the lactose permease, the product of the *lacY* gene of the *lac* operon. He continues that work at the University of Minnesota, where he has an active research lab composed of undergraduates, Ph.D. students, post-doctoral fellows, and laboratory technicians (see photo). In addition to the lactose permease, Dr. Brooker's laboratory also investigates the structure, function, and expression of amino acid transporters found in various bacterial species. He regularly publishes research papers in scientific journals such as *Protein Science, Journal of Bacteriology,* and *The Journal of Biological Chemistry.* He attends many scientific meetings, is a member of the editorial board of *The Journal of Biological Chemistry,* and is a member of the Metabolic Biochemistry Panel of the National Science Foundation.

At the University of Minnesota, Dr. Brooker teaches undergraduate courses in biology, genetics, human genetics, and cell biology. He has received the Outstanding Teacher of the Year Award from the Biological Sciences Student Association at the University of Minnesota. Through the Department of Independent Study at the University of Minnesota, he has adapted several of his undergraduate courses so that students can complete them through correspondence or by Interactive Television (ITV). In 1996, Dr. Brooker was appointed the Director of Graduate Studies for the Ph.D. program in Molecular, Cellular, Developmental Biology, and Genetics at the University of Minnesota, Twin Cities. He also teaches students at the graduate level and greatly enjoys the more informal method of discussing research papers in class.



Front row: Aileen Green, Rob Brooker, and Jason Patzlaff.
Second row: Paul Judd, Shane Cain, Jerry Johnson, Sara Brokaw, and Doug Stemke.

Rob Brooker with his undergraduate genetics professor, Dr. Elizabeth Powelson.

PREFACE

My desire to write this genetics textbook actually stemmed from a cell biology course that I introduced at the University of Minnesota many years ago. Our department decided to offer an intermediate level cell biology class to bridge the gap between our basic undergraduate cell biology and a more advanced graduate course, and I was asked to create it. I developed and taught this course for many years. It was a particularly fun experience, but I must admit that it was very scary the first time I taught it. Let me explain.

I developed an intermediate cell biology course which combined an undergraduate level of explanation but incorporated experiments from actual research papers. For each class session, the students were expected to read one or two research papers and understand them, and then we were supposed to discuss them in class. So as a young, naive, yet enthusiastic assistant professor, this seemed like a good plan. During the first few weeks of this course, however, I would walk into the classroom each day and ask the class, "So tell me about the first experiment in the paper you were supposed to read for today." I was expecting half the class to raise their hands and want to rush to the blackboard and explain the experiment. But instead, I basically got the "deer in the headlights"response. Obviously something was wrong.

I knew that the problem wasn't the students in the course, because many of our brightest and hardest working students were enrolled. And I (desperately) hoped that I wasn't the problem. So it had to be something else. Over time, the students and I uncovered the problem. Their previous coursework was not training them to analyze experiments according to the scientific method. They had learned many "facts" and bits and pieces of experiments, but they hadn't been exposed, in a rigorous way, to the scientific process. We needed to fix that. The good news was that the intermediate cell biology class turned out to be really fun for the students (and for me), because it was the first time that many of them had taken a college course that allowed them to unleash their curiosity and utilize their critical thinking skills.

For the intermediate cell biology course to be a success, the class and I had to develop a strategy to coherently discuss the experiments within research papers. Looking back on it, the solution seems obvious. We needed to follow the scientific method as a way to dissect the parts of each experiment. We ended up doing that. For each experiment, I would ask the class a series of questions.

1. **Why was this experiment done?** The students' answers would have two parts. First, they would need to consider the background work that led to the experiment. And second, the students would have to explicitly state the hypothesis that the researchers were trying to test.
2. **How was this experiment done?** As a class, we would generate a flow diagram that described the experimental methods.
3. **What are the results?** We would look at the raw data and quantitatively analyze it.
4. **What do the results mean?** We would discuss our interpretations of the data. Sometimes, our interpretations were quite different from the interpretations of the researchers who had actually done the experiments. The occasional conflict between our interpretations and those of the researchers provided the most meaningful moments in the classroom. It caused many students to realize that the scientific principles they had learned about in previous courses are the result of scientists' interpretations of their own data. And maybe, they aren't always right!

I have to say that the intermediate cell biology course has been my most inspiring teaching experience. What I mean is that the students were inspiring to me. (I hope that I was inspiring to them as well). On the positive side, it was impressive to see how the students improved their abilities to analyze experiments as the course progressed. On the negative side, however, it left me with a deeply disappointing sense that most college-level science courses do not provide students with an adequate exposure to the scientific process. To some extent, I felt that textbooks were to blame. In an effort to include too much information, science textbooks had deleted the essence of science: the scientific method. At that point, I decided to write a textbook that would incorporate the scientific method into each chapter. Since my primary background is in genetics rather than cell biology, it was logical for me to write a genetics textbook, although I strongly feel that all scientific disciplines would benefit from this approach.

As you will see when you use this book, each chapter (beginning with Chapter 2) has one or two experiments which are incorporated into the chapter and which are analyzed according to the scientific method. These experiments are not "boxed off" from the rest of the chapter for you to read in your spare time. Rather, they are within the chapters and cannot be skipped. As you are reading the experiments, you will simultaneously explore the scientific method and the genetic principles that are derived from the method. For students, I hope this book will help you to see the fundamental connection between scientific analysis and principles. For both students and instructors, I expect that this strategy will make genetics much more fun to explore.

UNIFYING THEME

When I first began to write this book, my acquisitions editor said that it needed to have a unifying theme. I must confess that, at the time, I wasn't aware that any textbooks are actually written with a particular theme in mind. Nevertheless, she insisted that "all good books have a theme," so this caused me to consider an appropriate theme for my genetics text. It seemed to me that the theme should capture the essence of genetics. Eventually, I stumbled upon the obvious. The essence of genetics is the relationship between genes and traits. More explicitly, the theme of this book is to examine how the molecular expression of genes leads to the outcome of traits in individuals and in populations. As such, this theme encompasses the three traditional subdivisions of genetics: transmission, molecular, and population genetics. With regard to transmission genetics, we need to understand the relationships between the patterns of gene transmission, and how those patterns ultimately influence the outcome of traits in offspring. At the molecular level, we also need to

appreciate how the biochemical expression of genes determines the phenotypic characteristics of cells and of complete organisms. Finally, at the populational level, geneticists want to understand the relationship between genetic variation and the prevalence of genes within populations.

As a way to remind the student of this theme, each chapter has one or more figures in which the figure legends emphasize the theme. The theme legends are shown in blue type. Each theme legend connects the material within the chapter to the broad theme of the text. A unifying theme throughout this book provides a framework on which to relate many different genetic concepts.

CHAPTER ORGANIZATION

Each chapter is organized into a limited number of sections, usually two to four. Each section begins with an overview of the material that will be covered in that section. The subsections that follow are given subtitles in the form of complete sentences that emphasize the key points of the material. Important terms are shown in **bold-faced type,** and these are included in the glossary. Other less commonly used terms are shown in *italic,* as are the names of specific genes. Each chapter ends with a Conceptual Summary which emphasizes the principles and concepts that were covered in the chapter and also reminds the student of the terms that they have learned. In addition, there is an Experimental Summary which discusses some of the key experiments that led to the formulation of the genetic principles.

TEXT ORGANIZATION

The text is organized into six parts. Following an overview of genetics in Part I, Part II "Patterns of Inheritance" (Chapters 2–8) covers the traditional field of transmission genetics. It emphasizes patterns of genetic transmission and how those patterns affect the outcome of traits, both in eukaryotes and prokaryotes. We consider how genetic crosses and gene transfer can be analyzed as a way to map genes. In addition, this section emphasizes the relationships between chromosome transmission, structure, and number in the outcome of traits. Part III "Structure and Replication of the Genetic Material" (Chapters 9–11) begins an in-depth discussion of molecular genetics. This section is primarily devoted to nucleic acid structure rather than function. It also considers how the genetic material is copied. The emphasis on molecular genetics continues in Part IV "Molecular Properties of Genes" (Chapters 12–18). In these chapters, however, the emphasis is primarily on gene function. Much of the section pertains to the relationships between DNA sequences within genes, and how they are expressed at the molecular level. The last two sections of the text include Part V "Genetics and Technology" (Chapters 19–22), which focuses on the many techniques, tools, and strategies that researchers use to investigate genetic questions, and Part VI "Genetic Analysis of Individuals and Populations" (Chapters 23–27).

In our surveys of genetics instructors, we found that about two-thirds liked to cover transmission genetics first and then molecular genetics, while the other one-third preferred the opposite approach. In this text, we have presented transmission genetics first (Chapters 2-8) and molecular genetics later (Chapters 9-18). Nevertheless, as we have constructed this book, we have been mindful of those instructors (which includes the author of this text, incidentally) who choose to discuss molecular genetics first. The book is written in such a way that it is perfectly fine to begin with Chapters 9-18 and then follow them with Chapters 2-8. We have provided adequate explanations and term definitions so that either strategy will work. Also, the unifying theme within the book provides a framework that can be followed with either approach.

EXPERIMENTS AND ILLUSTRATIONS

A special strength of this text is the quality of illustrations, particularly those that involve experimentation and analysis. There are hundreds of illustrations that emphasize experimentation in this text. Not only do these figures describe techniques, but they also often contain raw data. In this way, students can appreciate the relationship between experimentation and quantitative analysis. Each figure, whether it be a conceptual or experimental one, has been carefully designed to follow closely with the textual material. Great effort has been made to define all the labels in each figure, either in the figure legend or in the text.

This textbook also has a completely novel way to illustrate the one or two experiments in each chapter that are rigorously examined according to the scientific method. For these experiments, there are carefully worded descriptions that explain each step in the procedure. Next to these descriptions, you will find parallel illustrations that depict how the experiment was actually conducted (i.e., at the Experimental Level), and what is happening at the Conceptual Level. With this layout, the student can correlate experimental procedures with their aim of elucidating scientific principles. These unique illustrations are then followed by the data of the experiment, as it was reported in the original research paper. This visual integration of techniques, concepts, and data provides the student with a direct way to view the scientific method.

PROBLEM SETS

The problems sets continue to bolster the relationship between concepts and experimentation. The conceptual questions are aimed at testing a student's ability to understand the basic genetic principles. The student is given many questions with a wide range of difficulty. Some of these questions require critical thinking skills, and some require the student to be able to write coherent essay questions. Thus, the conceptual questions should improve a student's cognitive and writing skills. The experimental questions are aimed at testing the student's ability to analyze data, design experiments, and/or appreciate the relevance of experimental techniques. At the end of the problem sets, there are also student discussion/collaboration questions that can be given to groups of students. Some of these are meant to foster discussion of practical problems or to consider broad concepts within a chapter. Other questions may require a substantial amount of computational activities which can be worked on as a group.

SUPPLEMENTS

To enhance the teaching and learning of genetics, several supplements have been developed to help instructors and students. An **Instructor's Presentation CD-ROM** is available that includes nine animations on key genetic concepts and [all] full color figures from the text. The set of **transparency acetates** includes 102 key conceptual figures, including several of the integrated experiments from the text, in full color. A **transparency sampler** of selected key figures is available to allow instructors to easily preview the transparency acetates.

With this edition we also offer student subscriptions to The Biology Place™, a web-based learning environment created and maintained by Peregrine Publishers, Inc. The Biology Place™ offers students interactive learning activities, articles from *Scientific American,* links to other high-quality science related web sites, comprehensive quizzes, and constantly updated news about reasearch developments. These subscriptions can be packaged with the text at a reduced price for the student.

The solutions to half of the problem sets in this text are printed in the back of the book. The other half of the solutions are available on-line at the **Benjamin/Cummings web site: http://www.awl.com/bc.** ***Genetics: Practice Problems and Solutions,*** by Joseph Chinnici of Virginia Commonwealth University and David Matthes of San Jose State University, provides over 400 additional problems for students.

ACKNOWLEDGMENTS

It is perhaps unfair that this textbook has a single author since I truly feel that the writing of this book has been an enormous collaborative effort. Each chapter went through three rigorous revisions and was reviewed by many scientists and editors. The collective contributions of all these people are reflected in the final outcome. In particular, I wish to acknowledge Cathy Pusateri, my acquisitions editor, who initially contacted me about writing a genetics textbook. When I discussed my vision of including complete experiments within each chapter of a textbook, her response was overwhelmingly enthusiastic. My first interactions with Cathy were instrumental in galvanizing my resolve to complete this textbook. In addition, I'm extremely grateful to my development editor, Suzanne Olivier, who has worked most closely with me on the creation of this book. Her imprint is found on nearly every page. Not only did she help me develop my own skills at writing and organization, but she also had a substantial amount of creative input into the pedagogy of this book. I think she even enjoyed learning genetics, which made our phone conversations particularly fun.

I would also like to thank Nina Horne, my sponsoring editor, for her skillful guidance of this project, and Laura Kenney, for her help during the production phase of the book. I am also very grateful to several people at Electronic Publishing Services Inc., who worked very hard to produce a well crafted book. In particular, Patty O'Connell did an excellent job of coordinating the art, text, and photographs, and working with me on the necessary changes. In addition, many thanks go to Andrew Schwartz and Michael Gutch, my copy editors, who did a superb job of improving the text, and Francis Hogan, who worked tirelessly to find many photographs which are found in this book.

I'm also deeply indebted to my wife, Deborah, not only for her support but also for her scientific and artistic input. Her tenacious ability to proofread chapters and examine art was a constant source of improvement. My kids, Dan, Nate, and Sarah, also helped me by asking me two questions on a weekly basis: 1. What chapter are you working on? 2. When is your book going to be done? The second question became progressively more annoying as the years wore on, but it probably provided a subconscious source of motivation.

I also want to thank the many scientists who have reviewed chapters of this book. Their critical input was an important factor that shaped its final content and organization. I am truly grateful for their time and effort.

ROB BROOKER

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A Visual Guide To

Genetics: Analysis and Principles

Robert J. Brooker
University of Minnesota, Twin Cities

Robert J. Brooker emphasizes the five-step scientific method to reinforce for students the connection between genetics concepts and the experiments conducted by geneticists. Thirty-six text-integrated experiments reveal to students the "how" and "why" behind the most important research that led to our current knowledge of the science. This approach, along with a focus on the link between genes and traits, the fundamental principle of genetics, helps students develop their own scientific reasoning skills.

Hershey and Chase provided evidence that the genetic material injected into the bacterial cytoplasm is T2 phage DNA

EXPERIMENT 9A

A second experimental approach indicating that DNA is the genetic material came from the studies of A. D. Hershey and Martha Chase at Cold Spring Harbor. Their research centered on the study of a virus known as T2. This virus infects *Escherichia coli* bacterial cells and is therefore known as a **bacteriophage** or simply a **phage**. As shown in Figure 9-4, the external structure of the T2 phage, known as the *phage coat*, contains a *capsid*, *sheath*, *baseplate*, and *tail fibers*. Biochemically, the phage coat is composed entirely of protein, which includes several different polypeptides. DNA is found inside the T2 capsid. From a molecular point of view, this virus is rather simple, since it is only composed of two types of macromolecules: DNA and proteins.

Although the viral genetic material contains the blueprint to make new viruses, a virus itself cannot synthesize new viruses. Instead, a virus must introduce its genetic material into the cytoplasm of a living cell. In the case of T2, this first involves the attachment of its tail to the bacterial cell wall and the subsequent injection of its genetic material into the cytoplasm of the cell (Figure 9-5). The phage coat remains attached on the outside of the bacterium and does not enter the cell. After the entry of the viral genetic material, the bacterial cytoplasm provides all the synthetic machinery necessary to make viral proteins and DNA. The viral proteins and DNA assemble to make new viruses, which are subsequently released from the cell by **lysis** (i.e., cell breakage).

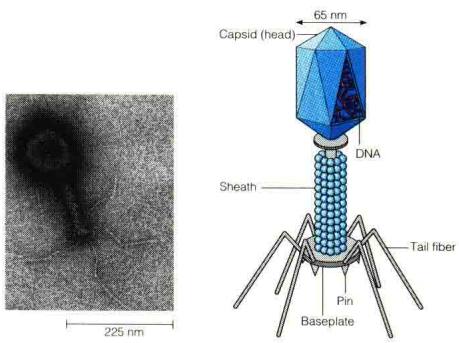


FIGURE 9-4
Structure of the T2 bacteriophage. The T2 bacteriophage is composed of a phage coat and genetic material inside the phage head. The phage coat is divided into regions called the capsid, sheath, baseplate, and tail fibers. These components are composed of proteins. The genetic material is composed of DNA.

GENES → TRAITS: The genetic material of a bacteriophage contains many genes, which provide the blueprint for making new viruses. When the bacteriophage injects its genetic material into a bacterium, these genes are activated and direct the host cell to make new bacteriophages as described in Figure 9-5.

Step 1: Background Observations

Each experiment begins with a description of the information that led researchers to study an experimental problem. Detailed information about the researchers and the experimental challenges they faced helps students to understand actual research.

Link Between Genes and Traits

The important relationship between genes and traits is emphasized both in text and in illustrations. This constant theme reinforces the relationship between abstract concepts and concrete physical expressions.

Step 2: Hypothesis

The student is given a statement describing the possible explanation for the observed phenomenon that will be tested. *The Hypothesis* section reinforces the scientific method and allows students to experience the process for themselves.

To verify that DNA is the genetic material, Hershey and Chase devised a method to separate the phage coat that is attached to the outside of the bacterium from the genetic material that is injected into the cytoplasm. They were aware of microscopy experiments by T. F. Anderson showing that the T2 phage attaches itself to the outside of a bacterium by its tail. Hershey and Chase reasoned that this is a fairly precarious attachment that could be disrupted by subjecting the bacteria to high shear forces such as those produced in a blender. As described in this experiment, their method was to expose bacteria to T2 phage, allowing sufficient time for the viruses to attach to bacteria and inject their genetic material. They then sheared the phage coats from the surface of the bacteria by a blender treatment. In this way, the phage's genetic material, which had been injected into the cytoplasm of the bacterial cell, could be separated from the rest of the phage coat, which was sheared away.

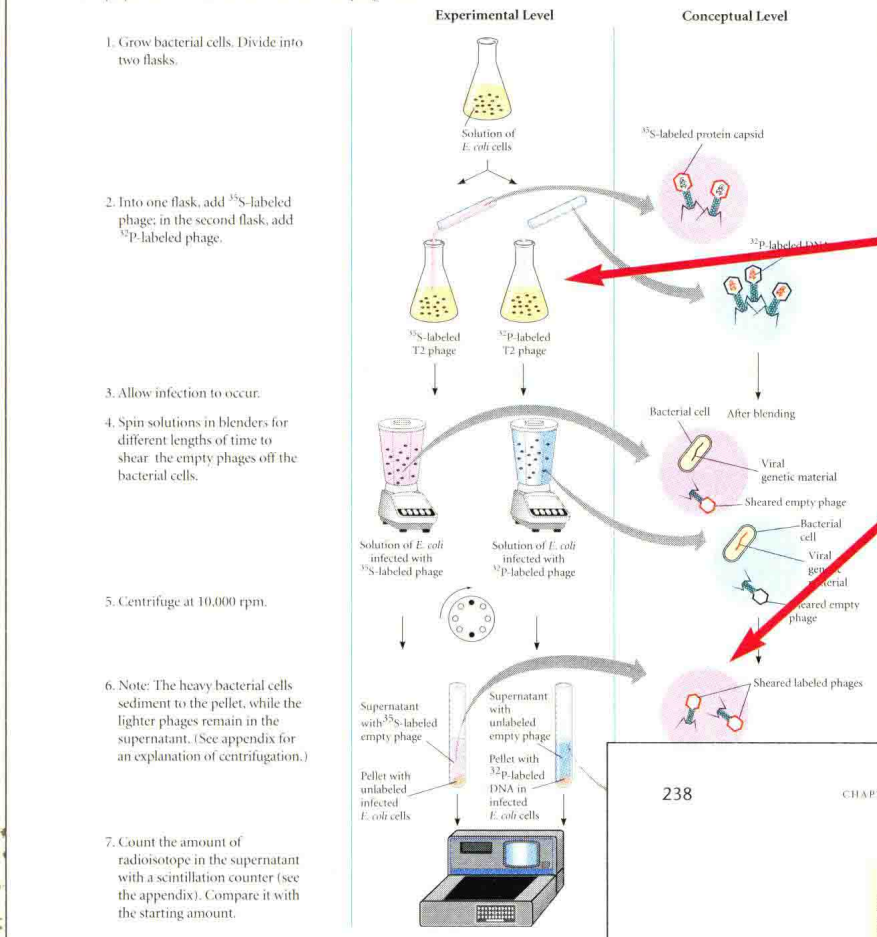
Before discussing this experiment, it should be mentioned that radioisotopes were used to distinguish between DNA and proteins. Hershey and Chase obtained T2 phages that were radiolabeled with either ^{35}S (a radioisotope of sulfur) or ^{32}P (a radioisotope of phosphorus). Sulfur atoms are found in proteins but not in DNA, whereas phosphorus atoms are found in DNA but not in viral proteins. Therefore, ^{35}S and ^{32}P were used in this experiment to specifically label proteins and DNA, respectively.

THE HYPOTHESIS

This experiment tests the hypothesis that bacteriophage T2 injects DNA rather than protein into the bacterial cytoplasm, where it functions as the viral genetic material.

TESTING THE HYPOTHESIS

Starting materials: The starting materials are *E. coli* cells and two preparations of T2 phage. One preparation is labeled with ^{35}S to label the phage proteins; the other preparation is labeled with ^{32}P to label the phage DNA.



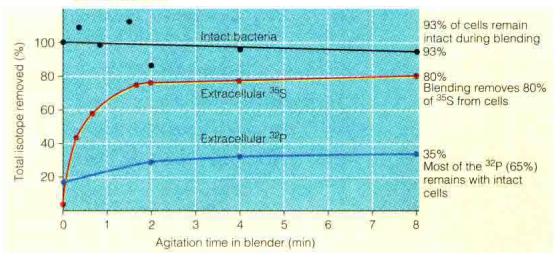
Step 3: Testing the Hypothesis

This section illustrates the experimental process, including the actual steps followed by scientists to test their hypothesis. Science comes alive for students with this detailed look at experimentation.

At each step in the experiment, experimental illustrations show what happened in the laboratory. Students gain insight into the physical nature of experimentation.

To connect concepts to research, experimental illustrations are paired with representational illustrations to show what occurs at the conceptual level. Here, the author directly relates underlying scientific principles to experimental procedure.

THE DATA



Step 4: The Data

Actual data from the original research paper helps students understand how actual research results are reported. Each experiment's results are discussed in the context of the larger genetic principle to help students understand the implications and importance of the research.

INTERPRETING THE DATA

Following infection, most of the phage protein was sheared from the bacterial cells and ended up in the supernatant. This indicated that the empty phages contain primarily protein. Furthermore, less than 40% of the DNA was found in the supernatant following shearing. Therefore, most of the DNA was located within the bacterial cells in the pellet. These results are consistent with the idea that the DNA is injected into the bacterial cytoplasm during infection. This is the expected result if DNA is the genetic material.

By themselves, the results described in Experiment 9A were not conclusive evidence that DNA is the genetic material. For example, you may have noticed that less that 100% of the viral protein was found in the supernatant. Therefore, some of the phage protein could have been introduced into the bacterial cells (and could function as the genetic material). Nevertheless, the results of Hershey and Chase leaned toward the conclusion that DNA is the genetic material rather than protein. Overall, their studies of the T2 phage, published in 1952, were quite influential in promoting the belief that DNA is the genetic material.

RNA functions as the genetic material in some viruses

We now know that bacteria, protozoa, fungi, algae, plants, and animals all use DNA as their genetic material. As mentioned, viruses also have their own genetic material. Hershey and Chase concluded from their experiments that this genetic material is DNA. In the case of T2 bacteriophage, that is the correct conclusion. However, many viruses use RNA, rather than DNA, as their genetic material. In 1956, A. Gierer and G. Schramm at the Max Planck Institute in Germany isolated RNA from the tobacco mosaic virus (TMV), which infects plant cells. When this purified RNA was applied to plant tissue, the plants developed the same types of lesions that occurred when they were exposed to intact TMV viruses. Gierer and Schramm correctly concluded that the viral genome of tobacco mosaic virus is composed of RNA. Since that time, many other viruses have been found to contain RNA as their genetic material. Table 9-1 compares the genetic compositions of several different types of viruses.

NUCLEIC ACID STRUCTURE

Geneticists, biochemists, and biophysicists have been interested in the molecular structure of nucleic acids for many decades. Both DNA and RNA are large macro-

Step 5: Interpreting the Data

This discussion, which examines whether the experimental data supported or disproved the hypothesis, gives students a feel for the art of scientific interpretation. Through this analysis, students can experience the similarities between classic experiments and their own work.

CONCEPTUAL SUMMARY

The molecular structure of nucleic acids underlies their function. *Nucleotides*, which are composed of a sugar, phosphate, and nitrogenous base, form the repeating structural unit of nucleic acids. The *primary structure* is a *strand* that contains a linear sequence of nucleotides. The formation of *secondary structure* occurs because *complementary* regions of DNA (and RNA) can form hydrogen bonds between adenine and thymine (or uracil), and between guanine and cytosine. *Base stacking* also stabilizes a double-stranded structure. The most common form of DNA is a right-handed helix; the *backbone* in the *double helix* is composed of *sugar–phosphate linkages*, with the bases projecting inward from the backbone and hydrogen bonding with each other. The two strands are *antiparallel*. In DNA, different helical conformations have been identified, including A-DNA, B-DNA, and Z-DNA. B-DNA is the predominant form found in living cells, but short regions of Z-DNA may play an important functional role in gene transcription. Within chromosomes, DNA is folded into a *tertiary conformation* with the aid of proteins. The structure of chromosomes will be discussed in the next chapter. It is also common for short segments within RNA to form double helical structures such as stem-loops, bulges, loops, and junctions. RNA secondary structures can also play many important functional roles. The final tertiary structure of RNA is dictated by several factors including double helical regions, *base stacking*, hydrogen bonding between bases and backbone, and interactions with other molecules.

EXPERIMENTAL SUMMARY

Two different experimental approaches were used to show that DNA is the genetic material. Avery, MacLeod, and McCarty took advantage of Griffith's observations regarding transformation in pneumococci. They purified DNA from type IIIS strain

PROBLEM SETS

SOLVED PROBLEMS

1. A naturally occurring DNA has the following sequence:

5′–A–A–G–G–A–A–A–A–G–G–G–A–G–G–A–G–A–G–3′
3′–T–T–C–C–T–T–T–T–C–C–C–T–C–C–T–C–T–C–5′

What sequence of DNA molecule could form triplex DNA with this double helix?

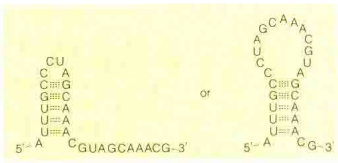
Answer: 5′–T–T–C–C–T–T–T–T–C–C–C–T–C–C–T–C–T–C–3′

2. As we will discuss in future chapters, the formation of stem-loop structures within RNA can be crucial in many functional ways. For example, the formation of a stem-loop at the beginning of mRNA can influence the rate at which that mRNA is translated into protein. A hypothetical sequence at the beginning of an mRNA molecule is

5′-AUUUGCCCUAGCAAACGUAGCAAACG. . .rest of the coding sequence

Using two out of the three underlined sequences, draw two possible models for potential stem-loop structures at the 5′ end of this mRNA.

Answer:



CONCEPTUAL QUESTIONS

1. What is the meaning of the term genetic material?

2. After the DNA from type IIIS bacteria is exposed to type IIR bacteria, list all of the steps that you think must occur for the bacteria to start making a type IIIS capsule.

3. What are the building blocks of a nucleotide? With regard to the 5′ and 3′ positions on a sugar molecule, how are nucleotides linked together to form a strand of DNA?

4. Draw the structure of guanine, guanosine, and deoxyguanosine triphosphate.

5. Draw the structure of a phosphodiest

6. Describe how bases interact with each

12. List the structural differences between DNA and RNA.

13. Draw the structure of deoxyribose, and number the carbon atoms. Describe the numbering of the carbon atoms in deoxyribose with regard to the directionality of a DNA strand. In a DNA double helix, what does the term antiparallel mean?

14. Write out a sequence of an RNA molecule that could form a stem-loop with 24 nucleotides in the stem and 16 nucleotides in the loop.

15. Compare the structural features of a double-stranded RNA stem

20. Some viruses contain single- or double-stranded RNA as their genetic material. If a virus contains the following amounts of nucleotides, would you conclude that its genetic material is single-stranded or double-stranded: A = 15%, U = 29%, G = 28%, and C = 28%?

21. Let's suppose that you have recently identified an organism that was scraped off of an asteroid that hit the earth. (Fortunately, no one was injured.) When you analyze this organism, you discover that its DNA is a triple helix, composed of six different nucleotides: A, T, G, C, X, and Y. You measure the chemical composition of the bases and find the following amounts of these six bases: A = 24%, T = 23%, G = 11%, C = 12%, X = 21%, Y = 9%. What rules would you propose govern triplex DNA formation in this organism? Note: There is more than one possibility.

22. Upon further analysis of the DNA described in problem 21, you discover that the triplex DNA in this alien organism is composed of a double helix, with the third helix wound within the major groove (just like the DNA in Figure 9-18). How would you propose that this DNA is able to replicate itself? In your answer, be specific about the base pairing rules within the double helix, and which part of the triplex DNA would be replicated first.

23. A DNA-binding protein recognizes the following double-stranded sequence:

5′–GCCCGGGC–3′
3′–CGGGCCCG–5′

This type of double-stranded structure could also occur within the stem region of an RNA molecule. Discuss the structural differences between RNA and DNA that might prevent this DNA-binding protein from recognizing a double-stranded RNA molecule.

24. Within a protein, certain amino acids are positively charged (e.g., lysine and arginine), some are negatively charged (e.g., glutamate and aspartate), some are polar but uncharged, and some are nonpolar. If you knew that a DNA-binding protein was recognizing the DNA backbone rather than base sequences, which amino acids in the protein would be good candidates for interacting with the DNA?

EXPERIMENTAL QUESTIONS

1. In the experiment described in Figure 9-3, list several possible reasons that only a small percentage of the type IIR bacteria were converted to type IIIS.

2. Another interesting trait that some bacteria exhibit is resistance to killing by antibiotics. For example, certain strains of bacteria are resistant to tetracycline, whereas other strains are sensitive. Describe an experiment that you would carry out to demonstrate that tetracycline resistance is an inherited trait encoded by the DNA of the resistant strain.

3. In Experiment 9A, give possible explanations why less than 30% of the DNA is in the supernatant.

4. Plot the results of Experiment 9A if the radioactivity in the pellet, rather than in the supernatant, had been measured.

5. In Experiment 9A, why were ^{32}P and ^{35}S chosen as radioisotopes to label the

7. It is possible to specifically label DNA or RNA by providing bacteria with radiolabeled thymine or uracil, respectively. With this type of tool, design an experiment to show whether a newly identified bacteriophage contains DNA or RNA as its genetic material. Describe your expected results depending on whether the genetic material is DNA or RNA.

8. The type of model building that was used by Pauling, Watson, and Crick involved the use of small ball-and-stick units. Now we can do model building on a computer screen. Even though you may not be familiar with this approach, discuss some potential advantages computers might provide in molecular model building.

9. In Chargaff's experiment (Experiment 9B), what is the purpose of paper chromatography?

10. Would Chargaff's experiments have been convincing if they had been done on only one species? Discuss.

From the Conceptual to the Experimental

The relationship between what scientists do in the laboratory (*the experimental level*) and the processes that occur during the experiment (*the conceptual level*) is further explored with the conceptual and experimental summaries and the end-of-chapter conceptual and experimental problems.

Problem Sets

Crafted to aid students in developing a wide range of skills, the problems develop students' cognitive, writing, analytical, computational, and collaborative abilities.

CONTENTS