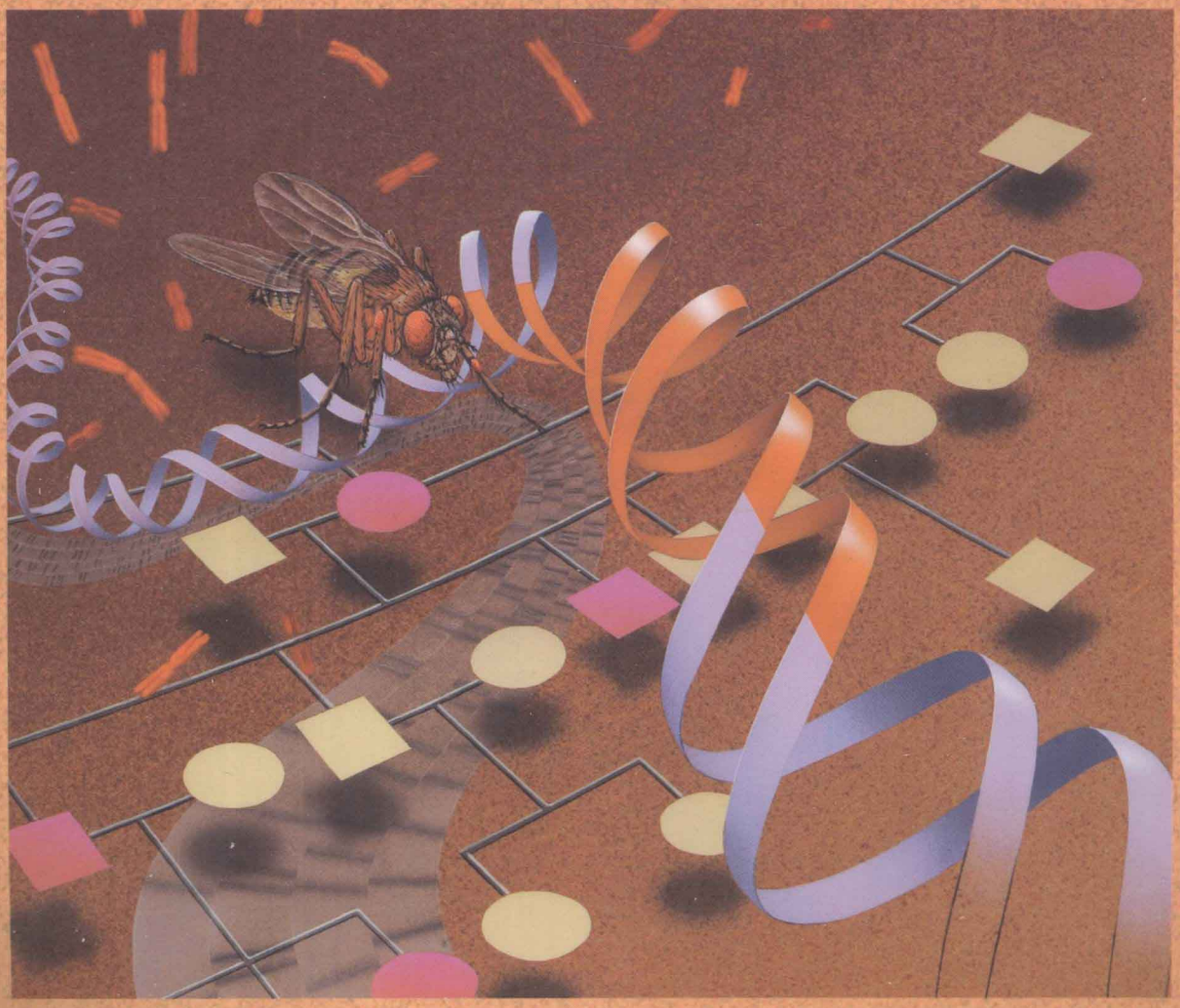
STUDENT COMPANION WITH COMPLETE SOLUTIONS

FOR

AN INTRODUCTION TO GENETIC ANALYSIS

SIXTH EDITION



Diane K. Lavett

Student Companion with
Complete Solutions for

An Introduction to Genetic Analysis

Sixth Edition

by
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Preface to the First Edition

Unlike many solutions manuals, the *Student Companion with Complete Solutions for An Introduction to Genetic Analysis,* Fourth Edition, attempts to provide a logical approach to solving genetics problems. While explaining the reasoning behind each answer given, the book also recognizes that what is obvious to geneticists is seldom apparent to the beginning student.

The *Companion* was written from the perspective of a teacher who is standing in front of a blackboard, trying to explain a problem to a class of beginning genetics students. Because I have been in that position many times, my students have taught me exactly where it is that difficulties will occur. I have tried to anticipate each of these potential obstacles in the explanations that follow.

The *Companion* has been tested in the classrooms at the State University of New York at Cortland and at Emory University. In addition, Dr. Anthony J. Pelletier of the Department of Molecular, Cellular, and Developmental Biology of the University of Colorado at Boulder has independently worked all the problems presented in the text. His careful, thorough work resulted in the detection of many errors, and he has my deepest respect and gratitude for his magnificent effort. Although Dr. Pelletier provided this invaluable service, he should not, however, be held responsible for any errors that may still remain. Those errors are mine, and I hope that all users of the *Companion* will feel free to communicate directly with me about any mistakes that they detect.

Diane K. Lavett
Department of Biological Science
The State University of New York
at Cortland

Preface to the Second Edition

As with the first edition, all new problems in this second edition have been checked by another geneticist, in this case, Michael T. Lewis and Mignon C. Fogarty of the Department of Biology at the University of California, Santa Cruz. Their sincere desire to see an answer book with no wrong answers has been much appreciated, and I thank them for their dedication to our common goal. They, however should not be held responsible for any errors that still remain; the errors are mine.

To the users of this text: Do not assume that just because an answer appears in a printed text that it is correct. If you do not follow an answer in this book and you have an answer of your own that you think is correct, please write me directly and give me the benefit of your thinking. You could be right, you know.

This edition has been written while on leave from SUNY Cortland and while a Visiting Scholar in the Department of Biology at Emory University. I am indebted to the former for time and the latter for space. I especially thank Ms. Joyce Woodward and Ms. Anne Kirk for their assistance so freely given and so unexpected because they had no obligation to do anything at all.

The people at Freeman are a wonderful group, dedicated to turning out the best books possible. As they turn to their next projects, I wish them all authors who pay attention to deadlines and respond to requests. Janet Tannenbaum and Erica Seifert bore the brunt of the task, and they have my deep appreciation. I owe Patrick Shriner special thanks for his patience with me.

Now, to correct an omission from the last edition: for reasons I cannot comprehend, I failed to acknowledge Patrick Fitzgerald's guidance throughout the entire project. He was the one who talked me into doing the writing, the one who gave me support and encouragement at each point that my frustrations reached a new high, and the one who somehow became a friend in the process.

Diane K. Lavett
Department of Biological Science
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at Cortland
and
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Preface to the Third Edition

I am very excited about this edition because of the concept maps that were drawn for each chapter of the text. They are such a powerful way of learning material and integrating concepts! If I could learn from drawing them, then surely students can learn from contemplating them or, even better, by doing their own maps of the same concepts. Just as "new math" taught everyone the "secrets" that the very best of students discovered on their own before the development of new math, the concept maps visualize what the very best of geneticists have done mentally as they have struggled to master this material. Now, the only secrets that remain are the ones that need to be discovered by experimentation. My hope is that all students will take advantage of this method for learning.

This edition was written while I was on the faculty of the Biology Department of Emory University. The encouragement of my colleagues with it, especially in the development of the concept maps, has been very important to me. Likewise, the assistance provided by the office staff has been invaluable. I specifically thank Ms. Anne Kirk, Ms. Joyce Woodward, and Ms. Barbara Shannon for their cheerful help at every step.

The same people are at Freeman as with the last edition; they remain unchanged in their dedication and they have all become even better at their tasks than with the last edition. Erica Seifert, especially, has put much of herself into this edition, and I am very grateful to her.

As with the previous editions, if you discover an error, it is all mine, and I would appreciate it if you wrote to me at the address below so that any errors can be corrected.

Diane K. Lavett
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To my teacher,
Dr. Charles Ray, Jr.
Professor Emeritus of Genetics
Biology Department, Emory University

Introduction

▶ HOW TO THINK LIKE A GENETICIST

You will sharpen a number of skills as you work through your textbook and this *Companion.* Because genetics requires very careful reading, you should become a more careful reader by the end of your course of study. For example, a great deal of information is conveyed by the sentence, "Two mutants were crossed and a wild-type phenotype was observed in the male offspring." If you doubt the amount of information meant to be conveyed by that sentence, I will list it, even though the information may have little meaning for you until later:

1. Two separate genes are involved.
2. Both mutants are recessive.
3. The mutant gene in the female is located on an autosome.

There are seldom superfluous words in a genetics problem. Consequently, you must learn to think about each word that is provided.

A second skill that will be sharpened as you progress through this course is systematic thought. To approach a problem in genetics in a haphazard manner is to enter quickly into the realm of chaos and confusion. I hope that this book will be of real assistance in sharpening your ability to think systematically.

A third skill that you should learn is what I call being gentle with your so-called mistakes. Our educational system has labeled as a mistake the failure to arrive at the correct answer on the first try. Yet, in genetics, as in all of science, progress is made by learning through trial and error what the explanation is *not.* No hypothesis can ever be proved in science, it can only be disproved or tentatively accepted. When you think in this way, I hope that you will begin to view your attempts to solve a problem as hypotheses that are being rejected rather than as errors. If you are not able to answer a particular problem, you need only go back to your initial assumptions and revise them. Perhaps you have misread the problem. Perhaps you have not understood what the question is. Perhaps you have thought correctly but have made a simple mathematical error. An important point to keep in mind is that in any trial and error learning, there often must be a number of "trials." The only true mistake that you can make is to stop generating hypotheses and to give up.

▶ HOW TO READ LIKE A GENETICIST

There is a big difference between studying and learning. Studying is the review of material already known; learning is an increase in the level of understanding. Most students confuse these two activities and equate all time spent reading the textbook with learning, when, in some instances, not even studying is occurring.

When I first pick up a book, I have to have a reason for opening it. When I was a student, very frequently my reason was simply that I was taking a course for which the book was required and I wanted to pass the course. Now, the first level of my reason is that I want to know what the authors are saying about the topic. I may, of course, have many other levels for wanting to read a specific book. If I do not want to know what the authors are saying, I will put down the book unopened. If your response to the textbook is that you do not want to know what is contained in it at any level, you should seriously think about why you are beginning a course of learning that holds no interest for you.

Once I open the book to a specific chapter, I skim through that chapter. I read the titles of the different sections. I look at the pictures and read the captions. I then read the chapter introduction and summary. I read some of the problems at the end of the chapter. With this cursory examination, I now know the general information that is presented in the chapter and the structure in which it will be presented. More importantly, I know whether the chapter contains the information that I am seeking. As a student reading a required text, I knew in a very general way the information that I was expected to master. Then and now, I ask myself what I already know about the material and ask myself questions that, from my little knowledge of the material, I would like to have answered. Only at this point am I ready to begin learning the material covered in the chapter.

Learning requires active reading, and most students are not accustomed to reading as carefully as is required for the learning of genetics and solving genetics problems. Ideally, as you read each sentence in the textbook, you should ask yourself the following questions:

1. What did the author say?
2. What did the author mean?
3. What is implied by what the author said and meant?
4. Do I agree with both what the author meant and what is implied by what she or he meant?
5. How does it connect with what I already know?

Until you can answer each of these questions with regard to a sentence, you should not read any further.

This type of reading is an exhausting process that at first will seem very artificial to you. However, there is no substitute for reading in this fashion if you wish to learn at anything but the superficial level. With practice, these questions will become automatic, will be asked and answered very rapidly, and from that point on you will always be learning instead of simply reading.

To get to the level of automatic questioning, I suggest you work with one or more classmates, reading out loud a sentence at a time and discussing it thoroughly before proceeding to the next. You might find that active reading is fun after a while, as you begin to anticipate a point that the author is trying to make or as you discover implications that the author does not realize. As you become increasingly skilled in active reading, you may find that you have begun to generalize these skills to other parts of your life, such as listening to a friend or the news on television, your own writing, and nonverbal events in your life. If this generalization occurs, you are well on your way to becoming a person who learns from all aspects of your existence.

▶ HOW TO SOLVE PROBLEMS LIKE A GENETICIST

Genetics is not a spectator sport; you cannot learn genetics without solving problems. Each problem should first be read in the same way that you read the textbook. Once you have read the problem, *write* the answers to the following questions:

1. What question is being asked?
2. What information is known?
3. What information is missing?
4. What information is extraneous?
5. How will I symbolize the genes?
6. What assumptions am I making?
7. What are the possible hypotheses that will answer the question being asked?

Using this approach, the problems will literally solve themselves.

A serious threat to your ability to solve the problems in your text is misuse of this *Companion.* You can convince yourself far too easily that you understand a problem as you read the solution to it, when, in fact, you do not understand it at all. Let me suggest the proper way to use this book:

1. Read the section entitled "Important Terms and Concepts" first. If any term or concept does not cause you to recall exactly what the text said about it, reread that section of the text.
2. Work with the concept map for the chapter until you have gained all that you can from it. "Using Concept Maps" is discussed later in this introduction.
3. Work on a problem without reading the *Companion* until you are truly stuck.
4. Read the explanation of the solution.
5. Without consulting the *Companion,* immediately rework the problem.
6. Two or three days later, work the problem without consulting the *Companion.* If you cannot do it at this point, you probably did not understand the problem earlier.
7. If you cannot work the problem without consulting the *Companion,* repeat steps 3 to 5 once. If you cannot work the problem at that point, consult your teacher or a friend who can explain the problem to you.
8. Throughout the problem-solving process consult the section entitled "Tips on Problem Solving" as needed. There are a limited number of types of problems. For each type of problem, there is a pattern to the method of solution. Each problem solved in this book has followed the pattern best-suited for the problem. Learn to duplicate the patterns.

If you can eventually solve all the problems at the back of a chapter correctly without referring to the answers supplied, you should be in a good position to handle whatever your teacher may ask you in a test.

▶ HOW TO LEARN GENETICS

In addition to all that has been outlined above, as a student you have the task of integrating what you learn from the textbook with the lectures that you attend. That is your task as a student.

In order to achieve that task, you need to work at it. Actively read the assigned chapter and try at least some of the problems before going to the class that deals with that chapter. Define for yourself what you understand and do not understand about the chapter material. Ask as many questions as is necessary in class to clarify any difficulties. Interrupt your teacher as often as is necessary when he or she says something that you do not understand. If your questions are framed in such a way and asked in such a manner that they demonstrate that you are struggling with this material and not simply harassing your teacher, all your questions will be welcomed. There is no such thing as a stupid question, except the question that is not asked.

A student frequently does not ask questions in class, thinking that she or he is the only one who could be so dumb as not to understand a specific point. The reality is that if one student does not understand a point, most students in the class do not understand the point, and will be grateful that you have asked the question. Your teacher needs to know what you do not understand in order to do the best job of teaching possible. I urge you to engage with your teacher in active learning. Do yourself, all your classmates, and your teacher a favor by asking those questions that you are convinced are dumb. The first time, asking will be difficult; it becomes easier with practice.

Once class is over, do not put away your notebook until the next class. Go home and review every note that you made in class. You might try having a second notebook for each class into which you write out your class notes more fully and add to them while the class is still fresh in your mind. After doing this, each time read all the previous notes that you have taken since the beginning of the course. Identify the material that you know thoroughly and the material that you need to assimilate. Right then, as you are reminded of what you do not yet know, learn that material. If you go through this process after every class, you will not need to study at exam time.

The process of learning outlined above obviously cannot be completed in a "cram" session the night before a test or a final exam. The attempt to learn genetics in that fashion is doomed to failure. The best approach is to study genetics almost every day, weekends included. Keep your sessions short, not more than two or three hours at a time. Pick a quiet place where you will not be interrupted or distracted. If you find your concentration wavering, take a short break. If you find that anxiety is interfering, do some physical exercise. Avoid caffeine, both while studying and, most importantly, before taking a test. If the night before a test you are forced to make a choice between a good night's sleep and trying to learn far too much material for the time available, choose sleep.

Many students will have some difficulty with the material and problems in Chapters 2 through 6. Thereafter, the material will be easier to conceptualize, and the problems will be easier to do. The reason for the difficulty with the earlier chapters is that they require a level of abstract thought not usually demanded in undergraduate courses. Beginning with Chapter 7, however, the material becomes more descriptive and, simultaneously, more consistent with the skills required for success in other biology courses. Be aware that you will have to work quite hard in dealing with this early material; also be aware that you are not alone in your difficulty.

Generations of students have struggled with genetics, and the vast majority have been successful in their struggle. Their reward has been that they have learned a new way to view the universe. It is my sincere hope that this will be your reward, too.

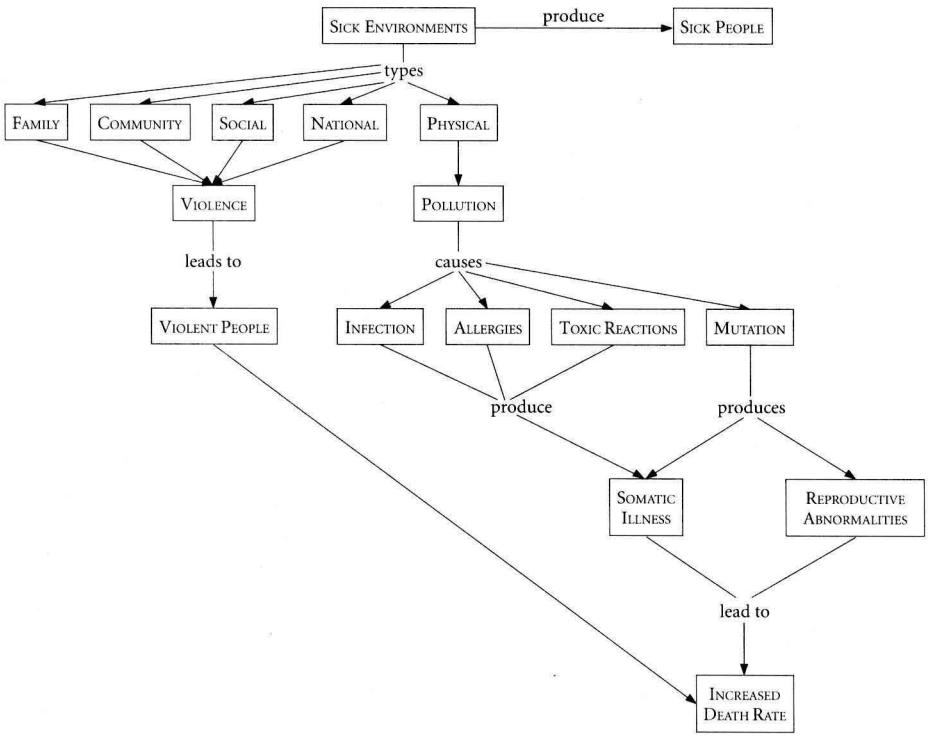
▶ USING CONCEPT MAPS

You are introduced to concept maps in the first chapter of the text, and at the end of each chapter there is a list of terms that you are to arrange in a concept map. In this *Companion,* there is at least one concept map for each chapter. These differ from the terms at the back of each text chapter in that this *Companion* includes many more terms, the terms used are a more complete presentation of the ideas in the chapter than the suggested terms, and the terms are presented as drawings rather than as a list.

There is not just one right concept map; 10 people could take the same terms and produce at least 10 different maps from them. Each map would be a valid visual representation of the linking of concepts. Ideally, each student will make his or her own concept map because the active learning that occurs with making a concept map cannot be duplicated in any other fashion. It was decided, however, to produce concept maps for each chapter as an alternative way of presentation of the material for the sake of those students who are unwilling to invest the time required for making them.

The first step in using each concept map should be simply attempting to understand it. Look at it. Recall the meaning of each term. Ask yourself why two or more terms are linked in the concept map. If you cannot work at this level with a concept map, you need to return to the text and reread the chapter.

▶ CONCEPT MAP I-1: SICK ENVIRONMENTS PRODUCE SICK PEOPLE



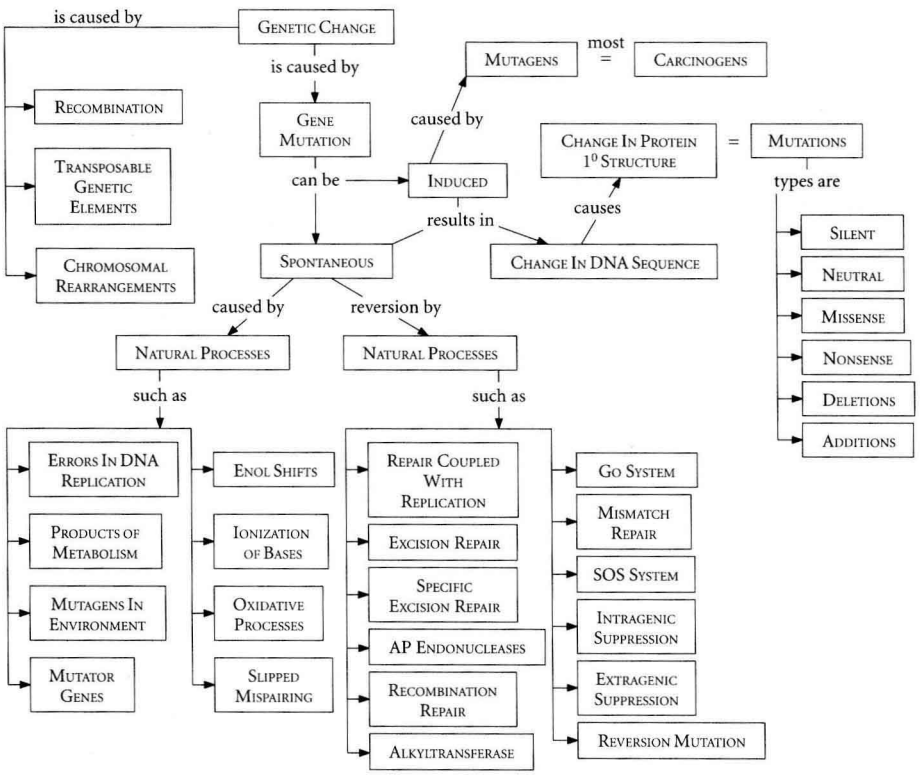
Each concept map in this *Companion* is accompanied by a series of simple questions that check whether the basics that were presented in the chapter have been learned. If you cannot answer one or more of these questions, you need to reread the chapter before proceeding to attempt the problems.

Once you can answer all the questions without resorting to looking at the answers, return to the concept map. Now begin to fill in details for which there were no questions.

As an illustration of this process, look at Concept Map I-1: Sick Environments Produce Sick People. Probably no one would argue with the title, but it is very unspecific. However, the concept map lists a number of different types of environments. The list is incomplete, for one could also add "International Environment" and perhaps others. The list is also mostly irrelevant to genetics because most of the terms are the province of the fields of psychology, sociology, and anthropology. You might ask yourself what you recall from these other fields before focusing on the physical environment, however.

When focusing on the physical environment, first ask yourself what "sick" means with regard to the environment. Now, ask yourself if the environment can be sick in ways other than by pollution. If so, explore those ways. Next, you might focus on any of the subtopics such as infection: how does pollution cause infection? To illustrate this process further, focus on the concept that pollution causes mutation. Look at Concept Map I-2: Gene Mutation (taken from Chapter 19).

▶ CONCEPT MAP I-2: GENE MUTATION



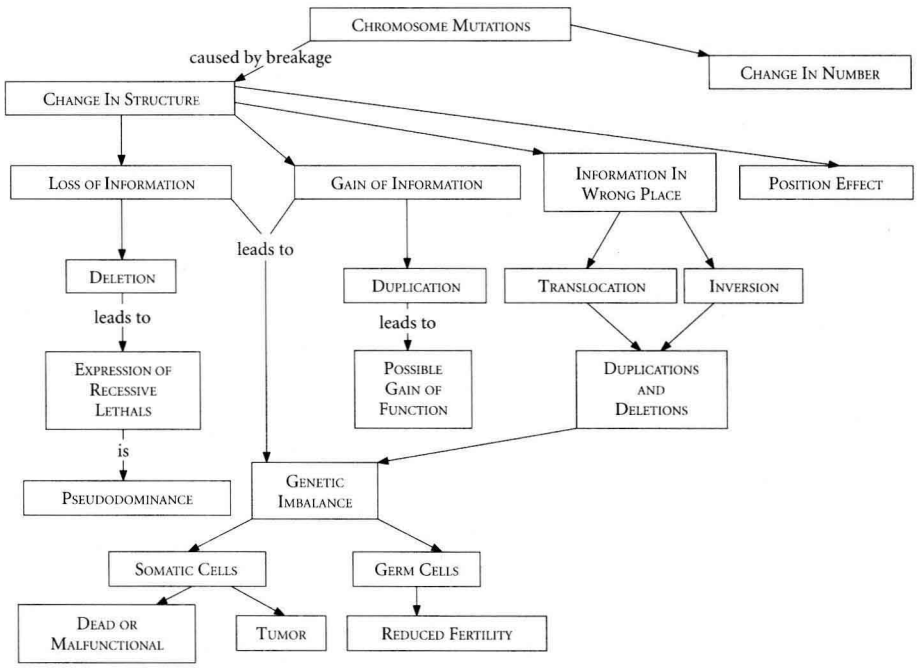
In this map, you see that one form of mutation, gene mutation, is one of four different mechanisms for genetic change. What are the other mechanisms? What types of gene mutations occur? What happens to the DNA sequence with a gene mutation? Again, ask yourself these questions and many more besides. Each question you ask yourself will lead to others and help you integrate the facts presented in the text into a coherent body of knowledge.

Remember that each term in this concept map, as with all terms in all concept maps, stands for a large body of knowledge that you are expected to

learn. For example, the concept map dealing with mutation states that genetic change is also caused by chromosomal rearrangements. Concept Map I-3: Chromosome Mutations (taken from Chapter 8) is a detailed look at the chromosomal rearrangements. What types of chromosomal rearrangements exist? What are their consequences? Can you draw them? Can you draw synapsis and crossing-over for heterozygotes with a specific type of chromosomal rearrangement?

The list of questions is limited only by your engagement with this material. To help facilitate engagement and the learning that can occur with it, work on a concept map with a friend, take turns asking each other questions. Discuss each concept, and its ramifications, as deeply as you can. Return to each concept map periodically, as you learn new material.

► CONCEPT MAP I-3: CHROMOSOME MUTATIONS

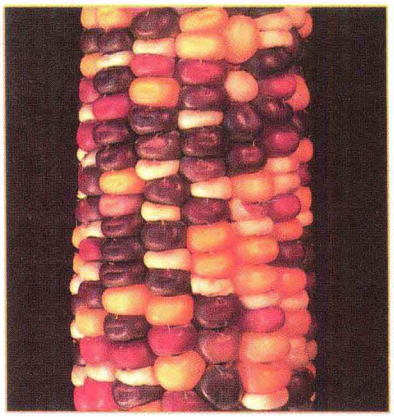


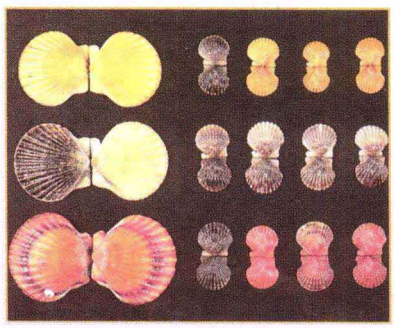
I would like you to point out to your teacher that a projected concept map is an excellent way in which to teach this material. Ask your teacher to try teaching a class once simply by asking questions based on a concept map. If your teacher does try this, be tolerant *and* read the assignment before going to class. Teaching in this manner is an exhausting yet exhilarating way to teach. It is also somewhat scary because the teacher loses control of the classroom as discussion takes your teacher in unknown, unpredicted directions. It is also a lot of fun.

In summary, if you follow the earlier directions on how to think like a geneticist, read like a geneticist, solve problems like a geneticist, and how to learn genetics, and if you work with the concept maps for each chapter, you will discover that, although it takes a lot of work, you will have learned genetics, and, perhaps more important, you will have learned how to learn.

Contents in Brief

Contents





1

Genetics and the Organism

► IMPORTANT TERMS AND CONCEPTS

Genetics is the study of the inheritance of traits by means of the examination of their variation.

Genes are the basic functional units of heredity. They are composed of DNA and contain information that determines specific traits.

Chromosomes consist of long DNA molecules complexed with protein. They contain many genes.

All life-forms can be divided into **eukaryotes** and **prokaryotes.** Eukaryotes are organisms in which the genetic material is contained within a membrane-bound nucleus. Prokaryotes are organisms that do not have their genetic material contained within a membrane-bound nucleus. In both eukaryotes and prokaryotes, **the flow of information** is from DNA to RNA to protein.

Protein can be either structural or enzymatic. **Structural proteins** result in the physical forms of life. **Enzymatic proteins** result in the biochemical processes of life.

The life of any particular organism results from the interaction of its inherited material with the historical sequence of environments that it encounters. The **genotype** refers to the inherited genes in an organism. The **phenotype** refers to the physical appearance of an organism. The **norm of reaction** refers to the environment-phenotype relationship for a specific genotype. **Developmental noise** is the random variation that occurs in phenotype when both genotype and environment are held constant.

Genetic dissection is the process of identifying the specific hereditary components of a biological system. This process is aided by the use of **markers,** which are specific phenotypes produced by specific genotypes that allow the researcher to keep track of chromosomes, cells, or individuals.

Questions for Concept Map 1-1

1. What does the abbreviation *DNA* mean?
2. How many different DNA molecules are there in an organism that has 10 pairs of chromosomes?
3. Is the DNA in your father identical with the DNA in your mother?
4. Is your DNA totally different from the DNA found in a dog? An oak tree?