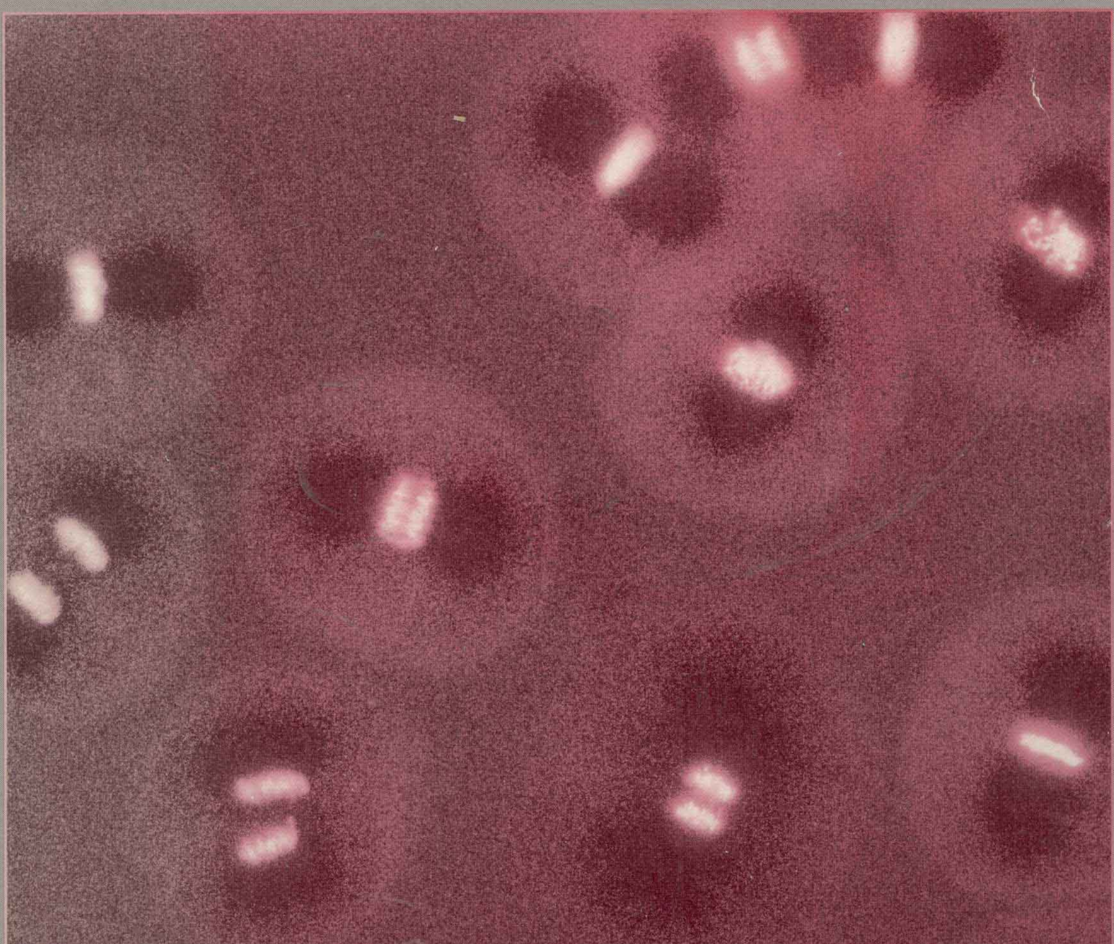
STUDENT HANDBOOK
A GUIDE TO CONCEPTS AND PROBLEM SOLVING

PREPARED BY
HARRY NICKLA

CONCEPTS OF GENETICS
THIRD EDITION



WILLIAM S. KLUG

MICHAEL R. CUMMINGS

STUDENT HANDBOOK

A GUIDE TO CONCEPTS AND PROBLEM SOLVING

PREPARED BY
HARRY NICKLA
Creighton University, Omaha

THIRD EDITION

CONCEPTS OF GENETICS

William S. Klug
Trenton State College at Hillwood Lakes

Michael R. Cummings
University of Illinois, Chicago

Macmillan Publishing Company
New York

Collier Macmillan Canada, Inc.
Toronto

Maxwell Macmillan International Publishing Group
New York Oxford Singapore Sydney

Printed in the United States of America SEM

Macmillan Publishing Company
866 Third Avenue, New York, New York 10022

Collier Macmillan Canada, Inc.

Printing: 1 2 3 4 5 6 7 Year: 1 2 3 4 5 6 7

ISBN 0-02-364795-7

Contents

Introduction

Purpose of this book

The intent of this book is to help you understand introductory genetics as presented in **Concepts of Genetics** (3rd edition) by Klug and Cummings. To do so, you must build the conceptual framework in which to place various experiments, examples, and illustrations which are prevalent in genetics and which usually represent the basis of specific homework problems and test questions. To succeed, you must be able to recognize from where in that framework each particular test question is drawn, and what examples are likely to pertain to each concept.

A first course in genetics can be a humbling experience for many students. It is possible that the lowest grades received in ones major, or even in ones undergraduate career, may be in genetics. It is not unusual for some students to become frustrated with their own inability to succeed in genetics. This frustration is felt by most teachers as they field most of the following student comments:

Student frustrations

"I studied all the material but failed your test."

"I must have a mental block to it. I just don't get it. I just don't understand what your are asking."

"I know all the material, but I can't take your tests."

"Where did you get that question? I didn't see anything like that in the book or in my notes."

"This is the first test I have **ever** failed."

"I helped three of my friends last night and I got the lowest grade."

"I am getting a "D" in your course and I have never received less that a "B" in my whole life."

"I stayed up all night studying for your exam and I still failed."

Similar to Algebra

Think back to the first time you encountered "word problems" in your first algebra class. How many times did you say to yourself, your parents, or to your teacher,

> "I hate word problems, I just can't understand them, and why do I need to learn this anyway, I'll never use it."

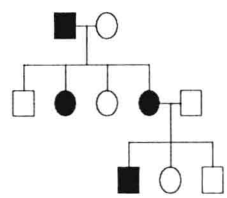
At that time you had two choices, drop out and be afraid of problem-solving for the rest of your life (which unfortunately happens too often) or regroup, seek help, strip away distractions, and focus in on learning something new and powerful. Because you are taking genetics, you probably succeeded in algebra, perhaps with difficulty at first, and you will probably succeed in genetics.

You were forced in algebra to convert something real and dynamic (two trains leaving at different times from different stations at different speeds - when do they meet?) to a somewhat abstract formula which can be applied to an infinite

number of similar problems. In genetics you will again learn something new. It will involve the conversion of something real and dynamic (genes, chromosomes, hereditary elements, gamete formation, gene splicing, and evolution) to an array of general concepts (similar to mathematical formulas) which will allow you to predict the outcome of an infinite number of presently known and yet to be discovered phenomena relating to the origin and maintenance of life.

Mental pictures and symbols

When working almost any algebra word problem it is often helpful to make a simple drawing which relates, in space, the primary participants. From that drawing one can often predict or estimate a likely outcome. A mathematical formula and its solution provides the precise outcome.



In understanding genetics it is often helpful to make drawings of the participants whether they be crosses (*Aa* X *Aa*), gametes (*A* or *a*), or the interactions of molecules (anticodon with codon).

As with algebra, the symbolism used to represent a multitude of structures, movements, and interactions, is abstract, informative, and fundamental to understanding the discipline. It is the set of symbols and the relationships among symbols which comprise the universal set of concepts (paradigms) which, as specific examples, make up the framework of genetics. Test questions and problems which, as examples, may be completely unfamiliar to the student, nevertheless refer directly to the basic concepts of genetics.

Concepts of Genetics

Part One: Heredity and Phenotype

Part Two: Molecular Basis of Heredity

Part Three: Organization and Regulation of Genetic Information

Part Four: Genetics of Organisms and Populations

The genetics instructor is competent

Teachers usually adjust the level of a course, the selection of a text, test questions, and lecture material, on two criteria:

(1) the capability of the students which is determined by factors such as the course prerequisite pattern, and the entry standards of the institution, and

(2) the experience and expertise of the instructor.

While the instructor may do his/her best to present the material clearly, the burden is on the student to learn genetics. Regardless of how hard a teacher tries to explain certain concepts, the student must be an active participant in the learning process. A student can not enter a genetics classroom, forgetting all that was learned in the prerequisite course(s), and expect the instructor to start from scratch and teach them genetics.

There are interesting, important, and somewhat complex concepts to learn. Such learning requires a focused effort not only by the instructor but also by the student. The student should expect that a competent instructor is attempting to teach them how life, with its variation and constancy, is passed from one generation to the next. The instructor expects that students are responding with a thoughtful, mature, disciplined effort to learn. Anything short of those expectations is likely to result in disappointment on the part of the instructor and the student.

Granted, there may be idiosyncrasies of a given instructor which may be distracting or even annoying to students. But mature students are able to dismiss surface distractions and focus on the subject material. They are unwilling to let an individual stand between them and their right to an understanding of significant biological information.

The tests are fair

Because many students may fail a particular test, it is no indication that the test is not fair. It is expected that some students will have a more difficult time with certain concept areas than others and as a result will do poorly on certain tests. It would be a tremendous disservice to our students if instructors "watered down" or omitted difficult material so that more students would receive better grades. For a variety of reasons, there are temptations (student evaluations, fewer enemies) to give high grades and fail few.

Get Help

Experienced teachers recognize conceptual areas which are the most difficult for students and often attempt different teaching strategies or hold extra review sessions for students when those areas are encountered. It is up to the student to take advantage of the instructor's offer to help. It is important for the student to be confident that the instructor is competent and that the tests are designed to properly evaluate what the student understands.

There is considerable uniformity in the instruction of genetics. Instructors expect students to learn certain fundamental concepts before passing grades are awarded. Students should expect little compromise in this aspect of evaluation.

It is likely that a student will encounter a test question which involves an unfamiliar example or situation. Genetics teachers may use literally thousands of ways to test a student's understanding of a simple dihybrid cross. Students who do well in genetics are able to focus on understanding concepts, rather than memorizing a multitude of examples.

Attendance and attention are mandatory

Many professors do not take attendance in lectures, therefore, it is likely that some students will opt to take a day off now and then. Unless those students are excellent readers and excellent students in general, continual absences will ususally result in failure.

Remember how difficult it was to set-up and understand the first algebra word problem on your own. It is likely that your ultimate source of understanding came from the course instructor. While using the text is important in your understanding of genetics, the teacher can walk you through the concepts and strategies much more efficiently than a text because a text is organized in a *sequential* manner. A good teacher can "cut and paste" an idea from here and there as needed. To benefit from the wisdom of the instructor, the student must concentrate during the lecture session rather than sit, passively taking notes, assuming that the ideas can be figured out at a later date. Too often the student will not be able to relate to notes passively taken weeks before.

It is necessary for students to attend class and take advantage of the instructor's insights during the lecture sessions. The instructor will not be able to cover all the material in the text. Parts will be emphasized while other areas may be omitted entirely. Since it is the instructor who writes and grades the tests, who is in a better position to prepare the students for those tests?

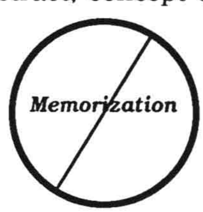
There is no magic formula for understanding genetics or any other discipline of significance. Learning anything, especially at the college level, requires time, patience, and confidence. First, a student must be willing to focus on the subject matter for an hour or so each day over the entire semester (quarter, trimester, etc.). Study time must be free of distractions and pressured by the presence of clear, realistic goals.

The student must be patient and disciplined. It will be necessary to study when there are no assignments due and no tests looming.

The majority of successful students are willing to read the text ahead of the lecture material, spend time thinking about the concepts and examples, and work as many sample problems as possible. They study for a period of time, stop, then return to review the most difficult areas. They do not try to cram information into marathon study sessions a few nights before the examinations. While they may get away with that practice on occasion, more often than not, understanding the concepts in genetics requires more mature study habits and preparation.

Perhaps a different way of thinking

Because the acquisition of problem-solving ability requires that students rely on new and important ways of seeing things rather than memorizing the book and notes, some students find the transition more difficult than others. Some students are more able to deal in the abstract, concept-oriented framework than others. Students who have typically relied on "pure memory" for their success, will find a need to focus on concepts and problem-solving. They may struggle at first just as they may have struggled with the first word problem in algebra. But the reward for such struggle is intellectual growth.



Students should expect to grow intellectually in a genetics course and with such growth will come an increased ability to solve a variety of problems beyond genetics. Problem-solving is a process, a style, which can be applied to many disciplines. Few people are actually born with the touch of synthetic brilliance. It comes from probing deeply in a few areas to see how one "gets to the bottom" of things. Then, because the "path is universal" it is easier to know when the bottom has or has not been reached in all disciplines.

At each particular point in a lifetime one has different capabilities. Certain intellectual areas are less developed than others, perhaps because of a particularly simulating teacher in grade school or a particularly poor teacher. It may be a neighbor or a relative that gave you, by chance or by insight, the stimulation (in the form of a particular book or an extended conversation or explanation) that helped you take a mental leap. There is often the misguided impression that if you work hard enough, you can accomplish anything. That is simply not true in all ones endeavors. By working hard in a focused, concentrated fashion, one can accomplish a great many things perhaps the most important of which is the confidence that comes from achieving goals, even if small at first. Hard work, in combination with intellectual maturity, often leads to academic success.

How to study

Genetics is a science which involves symbols (*A*, *b*, *p*), structures (chromosomes, ribosomes, plasmids), and processes (meiosis, replication, translation) which interact in a variety of ways. Models describe the manner in which hereditary units are made, how they function, and how they are transmitted from parent to offspring. Because many parts of the models interact both in time and space, genetics can not be viewed as a discipline filled with facts which should be memorized. Rather, one must be, or become, comfortable with seeking to understand not only the components of the models but also how the models work.

Time, Work, Patience

One can memorize the names and shapes of all the parts of an automobile engine, but without studying the interrelationships among the parts in time and space, one will have little understanding of the real nature of the engine. It takes time, work, and patience to see how an engine works and it will take time, work, and patience to understand genetics. And just as one is likely to be fascinated with the movement and power of an engine, such fascination is quite likely to come with an understanding of genetics.

Don't cram. A successful tennis player doesn't learn to play tennis overnight; therefore, you can't expect to learn genetics under the pressure of night-long cramming. It will be necessary for you to develop and follow a realistic study schedule for genetics as well as the other courses you are taking. It is important that you focus your study periods into intensive, but relatively short sessions each day throughout the entire semester (quarter, trimester). Because genetics tests often require you to think "on the spot" it is very important that you get a good night's sleep before each test. Avoid caffeine in the evening before the test because a clear, rested, well-prepared mind will be required.

Study when there are no tests

Tuesday

Study times:	***Subject:***
1st hour:	*Genetics*
	History
	Physics
	Literature

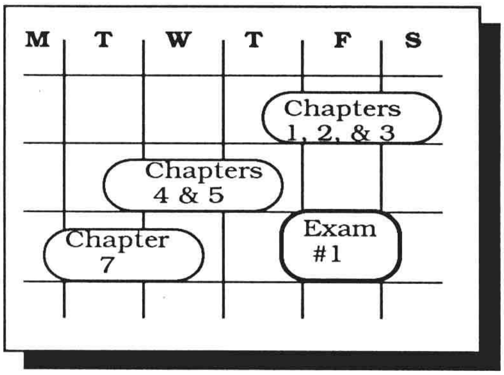
Monday

Study times:	***Subject:***
1st hour:	*Psychology*
2nd hour:	*Genetics*
Recreation	
3rd hour:	*History*
4th hour:	*Literature*

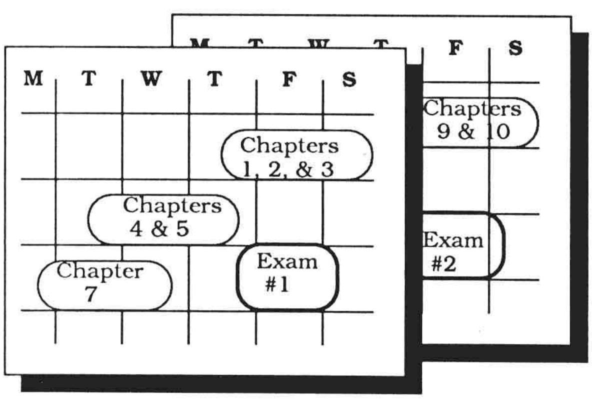
Develop a realistic schedule

Study goals. The instruction of genetics is often divided into large conceptual units. A test usually follows each unit. It will be necessary for you to study genetics on a routine basis long before each test. To do so, set specific study goals. Adhere to these goals and don't let examinations in one course interfere with the study goals of another course. Notice that each course being taken is handled in the same way — study ahead of time and don't cram.

Develop a monthly plan



Read ahead. You have been told that it is important to read the assigned material before attending lectures. This allows you to make full use of the information provided in the lecture and to concentrate on those areas which are unclear from the readings. An opportunity is often provided for asking questions. Your questions will be received much more favorably if you can say that after reading the book and listening to the lecture a particular point is still unclear. It is very likely that your question will be quickly dealt with to your benefit and the benefit of others in the class.



Develop a plan for the semester

Work the assigned problems. The basic concepts of genetics are really quite straightforward but there are many examples which apply to these models. To help students adjust to the variety of examples and approaches to the models, instructors often assign practice problems from the back of each chapter. If your instructor has assigned certain problems, finish working them *at least* one week before each examination. Before starting with a set of problems, read the chapter carefully and consider the information presented in class.

Suggestions for working problems:

(1) work the problem *without* looking at the answer,

(2) check your answer in this book,

(3) if incorrect, work the problem again,

(4) if still incorrect, you don't understand the concept,

(5) re-read your lecture notes and the text,

(6) work the problem again,

(7) if you still don't understand the solution, mark it, and go to the next problem.

In your next study session, return to those problems which you have marked. Expect to make mistakes and learn from those mistakes. Sometimes what is difficult to see one day may be obvious the next day. If you are still having problems with a section, schedule a meeting with your instructor. Usually the problem can be cleared up in a few minutes.

You will notice that in this book, I have presented the solution to each problem. I provide different ways of looking as some of the problems. Instructors often take a problem directly from those at the end of the chapters or they will modify an existing probem. Reversith the "direction" of a question is a common approach. Instead of giving characeristics of the parents and asking for characteristics of the offspring, the question may provide characteristics of the offspring and ask for particulars on the parents.

Separate examples from concepts. As mentioned earlier, genetics boils down to a few (perhaps 15 to 20) basic concepts; however there are many examples which apply to those concepts. Too often students have trouble separating examples from the concepts. Notice that in the "Sample Test" section in this book, I have made such separations clear. Examples allow you to picture, in concrete terms, various phenomena but they don't exemplify each phenomenon or concept in its entirety.

Caution in the use of old examinations. Often it is customary for students to request or otherwise obtain old examinations from previous students. Such a practice is loaded with pitfalls. First, students often, albeit unconsciously, find themselves "second guessing" about questions on an upcoming examination. They forget that an examination usually only tests over a subset of the available information in a section. Therefore entire "conceptual areas" may be available which have not appeared on recent exams.

Often the reproductions of old examinations are of poor quality (having been copied and passed around repeatedly) and it is difficult to determine whether the answer provided is the correct one or if it was incorrect and marked wrong. In addition, if a question has the same general structure as one on a previous examination, but is modified, students often provide an answer for the "old" question rather than the one being asked.

Granted, it is of value to see the format of each question and the general emphasis of previous examinations, but remember that each examination is potentially a new production capable of covering areas which have not been tested before. This is especially likely in a course such as genetics where the material changes very rapidly. Don't try to figure out what will be asked. Study all the material as well as possible.

Structure of this book

The intent of this book is to help you understand the concepts of genetics as given in the text and most likely in the lectures, then to apply these concepts to the solution of all problems and questions at the ends of the chapters. Rather than merely provide you with the solutions to the problems I have tried to walk you through each component of each question so that you can see where information is obtained and how it can be applied in the solution.

Vocabulary: Organization and listing of terms. Understanding the vocabulary of a discipline is essential to understanding the discipline. Throughout the text by Klug and Cummings you will find terms in bold print. Such terms generally refer to structures or substances, processes/methods, and concepts. I have separated these terms and *other important terms* into these categories.

Structures and Substances

Processes/Methods

Concepts

Those terms or concepts which require special explanation or are more complex or intimately related to other terms are denoted with a code (F2.1, F23.2, etc.) which refers you to the figures immediately following the ***Concepts*** section.

You may see a term present in several categories or in categories other than those you would envision. Since categorization *per se* is of little significance, don't worry about category location. Use the listings as checklists to make certain that you understand the meaning of each term in each chapter. Also, by a given term's category, you can begin to understand whether it refers to a structure or substance, a process or method, or a more general concept. Notice that the various terms are not redefined. It is important that you use the Klug and Cummings text for the original definitions.

Concepts. In the section *"Vocabulary: Organization and Listing of Terms"* you will find a section called *"Concepts"* after which there may be a simple sketch or two to help you focus a particular concept. Such sketches are oversimplifications and you should fill in the details by examining the textbook and the lecture notes.

Understand the words and phrases of the discipline

Solved problems. Each of the problems at the end of each chapter is solved from a beginner's point of view. There are other features of this section. Most of the answers to the questions and problems will refer you to specific sections, usually specific tables and figures, of the Klug and Cummings (K/C) text. Be certain that you fully understand the solution to each of the questions suggested or assigned by your instructor.

Supplemental questions. A series of solved sample test questions supplement the questions provided in the text and help you determine your level of preparation. These sample test questions are located at the end of each of the major units. Concepts relating to each question as well as common errors are presented in boxes before and after each answer.

Supplemental Questions

Concepts

Comprehensive Solution

Common errors

1

An Introduction to Genetics

Vocabulary: Organization and Listing of Terms

Historical

- Prehistoric times
  - domesticated animals
  - cultivated plants
- Greek Influence
  - Hippocrates
  - Aristotle
  - Lamarck (1809) - **Philosophie Zoologique**
    - pangenesis
    - acquired characteristics
  - procreation
    - religious beliefs
    - special creation
    - Harvey
      - epigenesis
  - preformation
    - homunculus
      - ovists
      - spermists
  - spontaneous generation
- Fixity of species
  - Linnaeus
  - Kolreuter
    - hybridization
    - parental types
    - backcross
  - **Naturphilosophie**
- Evolution
  - Darwin (1859)
    - **The Origin of Species**
    - natural selection
    - pangenesis

- Genetics
  - Mendel (1865)
  - Rediscovery (1900)
    - Correns, de Vries, Von Tschermak
    - Bateson
- Soviet Genetics
  - Lysenko
    - vernalization
  - Vavilov

Structures and Substances

- Center for heredity
  - nucleus
  - nucloid region
  - viral head
- Genetic material
  - DNA (deoxyribonucleic acid)
  - RNA (ribonucleic acid)
    - nitrogenous bases
  - genes
  - chromosomes
    - chromatin fibers
- Associated substances/structures
  - amino acids
  - messenger RNA
  - ribosome
  - ribosomal RNA
  - transfer RNA
  - enzymes

Processes/Methods

- Mitosis
- Meiosis
- Transmission genetics
  - pedigree analysis
  - cytological investigations
  - chromosome theory of inheritance
  - karyotypes
- Molecular and biochemical analysis
  - recombinant DNA technology
- Genetic structure of populations
- Basic research
- Applied research
  - agriculture
    - "Green Revolution"
    - Borlaug
  - medicine
    - genetic counseling
    - human genetic engineering

Concepts

Genetic information
- stored
- altered
- expressed
- regulated

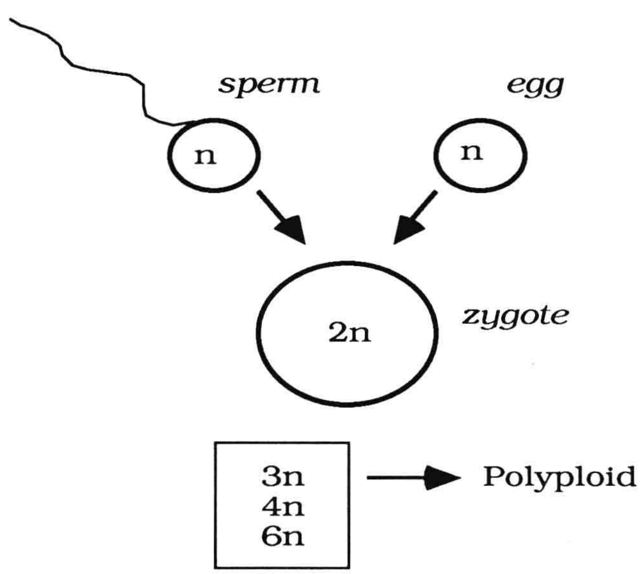
Genetics
- heredity
- variation
  - alleles

Diploid number (2n) (F1.1)
- polyploid
- haploid number (F1.1)
- homologous chromosomes (F1.2)

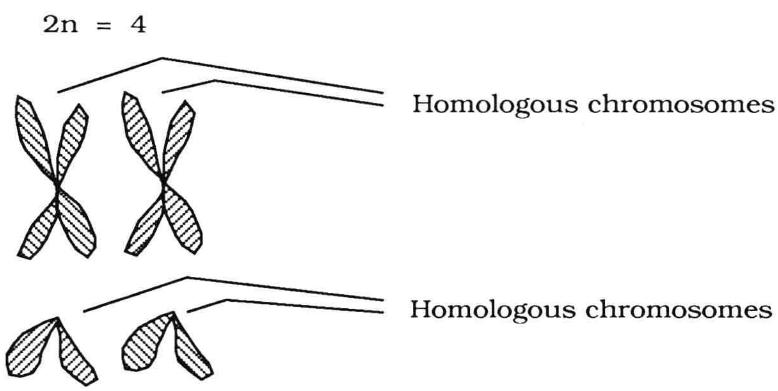
Genetic variation
- gene mutations
- chromosomal aberrations

Genetic information
- genetic code
- triplet
- transcription
- translated (translation)

F1.1. Below is pictured the union of two gametes, each with the *n* chromosome number. The haploid chromosome number (n) is usually found in gametes while the diploid chromosome number (2n) is usually found in the zygote and somatic tissues of the individual. There are higher levels of "ploidy" such as 3n, 4n, and so on.



F1.2. One of the most important concepts to be mastered involves an understanding of homologous chromosomes. Each parent normally contributes one of each type of chromosome to the zygote. Since there are two gametes which unite to form the zygote, there must be two of each type of chromosome in each zygote. These two chromosomes of the same type are called homologous chromosomes or homologous pairs of chromosomes. In humans we have 23 pairs of homologous chromosomes. One of each pair came from our mother, the other member of each pair came from our father (as shown in F1.1).



Criteria:

1. Size
2. Centromere position
3. Other similarities

Homologous chromosomes are similar in that they are generally of the same size, have the same centromere position, and have many other characteristics in common.

Solutions to Problems and Discussion Questions

1. Both were concerned with subjects of the reproduction, heredity, and origin of humans, and the shifting of interest from religious mythology to philosophical and scientific inquiries. Hippocrates argued that male semen is formed in various parts of the body (healthy or diseased) and transported through blood vessels to the testicles. Such "humors" carried the hereditary traits. Thus the theory of pangenesis was formed. Aristotle was critical of pangenesis because it did not explain the appearance of features which skipped generations. Aristotle suggested that semen contained a vital heat which could produce offspring in the form of the parents.

2. *Pangenesis* refers to a theory that various parts of the body contain "humors" which bear the hereditary traits and gather in the reproductive organs. *Epigenesis* refers to the theory that organisms are derived from the assembly and reorganization of substances in the egg which eventually lead to the development of the adult. *Preformationism* is a 17th century theory which states that the sex cells (eggs or sperm) contain miniature adults, called homunculi, which grow in size to become the adult.

3. Darwin was aware of the physical and physiological diversity of members within and among various species. He was aware that varieties of organisms could be developed through selective breeding (domestication), that a species is not a fixed entity, and that while certain groups of organisms could be hybridized, other groups could not. He was aware of conflicts between religious views and the fossil record. He understood geology, geography, and biology and that organisms tend to leave more offspring than the environment can support.

4. Darwin's theory of natural selection proposed that more offspring are produced than can survive, and that in the competition for survival, those with favorable variations survive. Over many generations, this will produce a change in the genetic make-up of populations if the favorable variations are inherited. Darwin did not understand the nature of heredity and variation which led him to lean toward older theories of pangenesis and inheritance of acquired characteristics.

5. DNA is composed of polymers of nucleotides which can exist either in either single-stranded or double-stranded forms. In non-viral systems, DNA is usually double-stranded. DNA and in some cases proteins associate to form chromosomes. During the cell cycle, DNA is duplicated by a variety of enzymes so that daughter cells inherit copies of the parental DNA. Sections of DNA which produce some influence on the organism are called genes. Genes usually exert their influence by producing proteins through the process of transcription and translation. These topics will be described in considerable detail in Part Two of the K/C text. A simplified diagram of these phenomena is given below: