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Chapter 2: The Study of Heredity

Chapter 2 presents a general, comprehensive introduction to the study of genetics. The focus of this chapter is to present the basic principles of genetics that are necessary for an understanding of the evolutionary theory. The implications of genetics and many of the new advances in the field have been discussed in Chapter 3.

The field of genetics is undergoing very rapid and major changes. However, many of these would be overwhelming to introductory students. While we mention many of the new developments in the next chapter, here we focus on genetics as a necessary component in the understanding of the mechanism of evolution. We start with simple Mendelian genetics. Next, we move on to cytogenetics, or the genetics of the cell. Finally, we focus on molecular genetics, where we examine the deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) molecules.

Chapter Summary

The basic principles of heredity were first worked out using nonhuman organisms. Through careful experimentation with the common pea plant, Gregor Mendel was the first scientist to discover the basic principles of heredity. The principle of segregation states that in the formation of sex cells, the hereditary factors separate, forming sex cells that contain either one or the other of the paired factors. The principle of independent assortment states that the inheritance patterns of differing traits are independent of one another. At the most basic level, these principles are universal among all living organisms, including the human species.

Early geneticists began to search for the physical reality of the gene. Their work led them to the cell and to small bodies within the nucleus of the cell, the chromosomes. Each chromosome consists of two strands, the chromatids, held together by the centromere. For a particular species, there is a characteristic chromosome number, which in humans is 46.

There are two basic forms of cell division. Mitosis is the division of body cells, while meiosis is the production of gametes—sperm and ova. Studies of the behavior of chromosomes during cell division have provided a physical explanation for Mendelian genetics. Deeper probing of the mechanisms of inheritance has shown that Mendel's principles do not always apply, simply because hereditary mechanisms are usually more complex than those postulated by Mendel.

Scientists also began investigating the chemical nature of genetic transmission. The genetic material is a nucleic acid, DNA. DNA controls cell activities and hence determines physical characteristics. DNA has the ability to replicate itself. It is, in part, this ability of DNA to replicate that

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is the mechanism through which one generation passes its characteristics on to the next.

The information contained in the DNA molecule is coded by the arrangement of base pairs. The information on the nuclear DNA molecule is transmitted by messenger RNA to the ribosome, the site of protein manufacture, where transfer RNA functions to bring the appropriate amino acids into position. On the molecular level, a gene is a segment of the DNA molecule that codes for a particular functioning protein or segment of a protein. When random changes occur in this code, they increase genotypic variation by creating "new" alleles. The various alleles of a particular gene are simply slight variants in the code itself.

Student Learning Outcomes for Chapter 2

Upon satisfactory completion of Chapter 2, students should be able to do the following:

1. Explain the basic concepts of Mendelian genetics, cytogenetics, and molecular genetics.
2. Explain the importance of genetic theory to the understanding of the mechanisms of evolution.

Learning Objectives for Chapter 2

Upon satisfactory completion of Chapter 2, students should be able to do the following:

1. Explain the basic terminology used in the study of genetics.
2. Describe the work of Gregor Mendel, including the principles of inheritance, and the ways in which Mendel's work disproved the blending theory of inheritance and the concept of pangenesis.
3. Analyze how inheritance and other factors are involved in the expression of a trait.
4. Describe the basic mechanism of cell division, and describe how the nature of chromosomes and cell division relates to Mendel's principles.
5. Know the structure and functions of DNA.
6. Illustrate how DNA controls cellular activity and, in general, the process of protein synthesis.
7. Explain how all plant and animal life variations are of the same basic biological mechanisms.

Chapter Outline

I. The Study of Heredity
   A. The Work of Gregor Mendel
   B. An Overview of Mendelian Genetics
   C. Human Blood-Type Systems
   D. Mendelian Genetics in the Twenty-First Century

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E. Summary

II. Cytogenetics
A. The Chromosomes
B. Cell Division
C. Reexamining Mendelian Genetics
D. Summary

III. The Molecular Basis of Heredity
A. Proteins
B. Deoxynucleic Acid
C. The Genetic Code
D. Protein Synthesis
E. Summary

Box 2-1 The Rh Blood-Type System
Box 2-2 Facts about DNA

Discussion Launchers

1. Why is an understanding of genetics so important to an overall understanding of evolution? How does genetic knowledge show that earlier ideas about evolution and inheritance, such as those of Lamarck, cannot be correct?
2. How does some of the current research in the field of epigenetics seem to conform, at least in part, to some of Lamarck's ideas?
3. Why is DNA so well suited to being the hereditary material?

Films and Videos

1. *Cell Division: Mitosis, Meiosis, and Cytokinesis* (20 minutes, Carolina Biological Supply).

   This is an inspiring and challenging video that discusses cell division through video and 3-D animation.

2. *Cracking the Code: The Continuing Saga of Genetics* (5-part series, 30 minutes each, Films Media Group).

   This five-part intro-level series reveals the history and development of genetics, reconstructing its journey from the 1700s to the cutting edge of the twenty-first-century microbiology.

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3. *DNA* (285 minutes, Films for the Humanities & Sciences).

   This five-part series depicts the story of DNA.

4. *DNA: Secret of Photo 51* (54 minutes 56 seconds, Public Broadcasting Service).

   This video depicts the story of the discovery of the DNA structure and the role played by Rosalind Franklin.

5. *DNA and the Evidence for Evolution* (23 minutes, Films Media Group).

   This program discusses the general structure and functioning of DNA.

6. *The DNA Obsession* (30 minutes, Films Media Group).

   This video explains the story of the discovery of DNA and its structure.

7. *The Gene Machine* (30 minutes, Films Media Group).

   This program discusses the role of RNA in protein syntheses, mutagenic agents, and restriction enzymes.

8. *Genes and Inheritance: Priests, Peas, Punnets, and Pedigrees* (32 minutes, Video Education Australasia).

   This program examines Mendelian inheritance, including punnet squares, gene linkage, sex linkage, and crossing over.

9. *Lifelines: Darwin and the Theory of Inheritance* (30 minutes, Films for the Humanities & Sciences).

   Richard Dawkins and others discuss Charles Darwin, Gregor Mendel, and Friedrich Miescher.

10. *Patterns of Inheritance* (28 minutes, Coast Community College District).

    This video defines and illustrates the basic terms and concepts of Mendelian inheritance.

11. *Peas in a Pod* (29 minutes, Films Media Group).

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This program explores the discoveries in the eighteenth and nineteenth centuries that gave birth to the science of genetics.

12. *The Theory of Inheritance* (27 minutes, Films Media Group).

    This program explains the ideas of Lamarck, Weismann, Mendel, and the role of DNA.

13. Following are two short videos you may wish to watch:
    The Story of You: ENCODE and the Human Genome
    (http://www.youtube.com/watch?v=TwXXgEz9o4w)

    ENCODE: Encyclopedia of DNA Elements
    (http://www.youtube.com/watch?v=Y3V2thsJ1Wc)

14. TED Talks: There are many interesting TED Talks that relate to this chapter. Some of the speakers are James Watson, Craig Venter, and Barry Schuler. For a complete list, see http://www.ted.com/talks/tags/genetics.

Other Resources Including Resources for Distance Learning

An excellent site with a wealth of information and slideshows is Learn.Genetics by The University of Utah at https://learn.genetics.utah.edu/content/basics/.

Resources about Gregor Mendel can be found at MendelWeb at http://www.mendelweb.org.

The company "23 and Me" has a series of short but instructive videos on various introductory topics in genetics. You can find it at https://www.23andme.com/en-int/gen101/genes/.

A source of information and photographs on cytogenetics is Cytogenetics Gallery at http://www.pathology.washington.edu/galleries/Cytogallery/main.php?file=intro.

James Watson recounts the story of the discovery of the structure of DNA in his 2005 TED Talk video, available at https://www.ted.com/talks/james_watson_on_how_he_discovered_dna?.

Barry Schuyler explains DNA, genomes, and genomics and the possible applications of our knowledge of genomics in his 2008 TED Talk video, available at http://www.ted.com/index.php/talks/barry_schuler_genomics_101.html.

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Following are some additional websites that might be of interest:

- For more information on genetic disorders, go to Learn.Genetics by The University of Utah at http://learn.genetics.utah.edu. Click on "Genetic Disorders" in the center band to read more on this topic.
- Perhaps the most complete listing of inherited conditions is the Online Mendelian Inheritance in Man (OMIM) by the National Center for Biotechnology Information, which is available at http://www.ncbi.nlm.nih.gov/sites/entrez?db=omim.
- A less formidable presentation with a lot of useful information on the most commonly encountered conditions can be found at Medline Plus at http://www.nlm.nih.gov/medlineplus/geneticdisorders.html, a service of the United States National Library of Medicine and the National Institutes of Health. There are many websites available for specific conditions, some of which are listed in Medline Plus.

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