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PACIFIC OCEAN
ATLANTIC OCEAN
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Jamaica
Belize
Honduras
Nicaragua
Guatemala
El Salvador
Panama
Costa Rica
Trinidad & Tobago
Venezuela
Guyana
French Guiana
Suriname
Colombia
Galápagos Islands (Ecuador)
Ecuador
Peru
Brazil
Bolivia
Paraguay
Chile
Uruguay
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Algeria
Libya
Egypt
Mauritania
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Sudan
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Senegal
Gambia
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Liberia
Burkina Faso
Cote d'Ivoire
Ghana
Togo
Benin
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Cameroon
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ANTARCTICA
Ice
Deserts
Mountains
Vegetation

LABORATORY MANUAL AND WORKBOOK FOR BIOLOGICAL ANTHROPOLOGY: ENGAGING WITH HUMAN EVOLUTION

SECOND EDITION

LABORATORY MANUAL AND WORKBOOK FOR BIOLOGICAL ANTHROPOLOGY: ENGAGING WITH HUMAN EVOLUTION

SECOND EDITION

K. ELIZABETH SOLURI CABRILLO COLLEGE
SABRINA C. AGARWAL UNIVERSITY OF CALIFORNIA, BERKELEY

W. W. NORTON & COMPANY
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CONTENTS

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K. Elizabeth Soluri (Cabrillo College) is faculty in the Anthropology Department at Cabrillo College. She received her B.A. from New York University and her M.A. and Ph.D. from the University of California, Berkeley. She has conducted anthropological field and laboratory research across the United States, including work in Valley Forge National Historical Park, Hawaii, and the central California coast. Elizabeth is especially interested in pedagogy and issues of student learning, and her ongoing research focuses on redesigning, implementing, and evaluating effective teaching methods for undergraduate anthropology courses, particularly biological anthropology. Elizabeth has taught anthropology courses at several 2-year and 4-year institutions throughout the San Francisco Bay area.

Sabrina C. Agarwal (University of California, Berkeley) is professor of anthropology at the University of California, Berkeley. She received her B.A. and M.Sc. from the University of Toronto and her Ph.D. from the same institution, working in both the Department of Anthropology and the Samuel Lunenfeld Research Institute of Mount Sinai Hospital, Toronto. Her research interests are focused broadly on age-, sex-, and gender-related changes in bone quantity and quality, particularly the application of biocultural and life course approaches to the study of bone maintenance and fragility and its application to dialogues of social identity and developmental plasticity in bioarchaeology. Sabrina has authored numerous related scholarly articles and edited volumes, and she is the co-editor-in-chief for *Bioarchaeology International*. She is interested in the philosophies of teaching, and she is actively involved in the pedagogical training of current and future college instructors.

PREFACE

FOR INSTRUCTORS

Active, Engaging, Flexible

The introductory laboratory in biological anthropology can be an inspiring place. It is exciting to see students interact with materials and concepts that may be entirely novel and unfamiliar to them. Of course, it is a challenging place, too, a place with many students who enrolled without foreseeing the scientific content and detail of the course. This was the case when we taught introductory biological anthropology at the University of California, Berkeley, and decided to redesign the laboratory portion of the course in 2005. In doing so, we had three overarching goals: (1) we wanted to emphasize active student engagement as a way to strengthen learning and long-term retention of course content, (2) we wanted to help students from diverse backgrounds and with varying degrees of experience in anthropology learn the key information about human biology and evolution, and (3) we wanted a lab manual that would be simple for instructors to implement in their classes, whether it is used in pieces or as a whole.

We decided to attack this task both with creativity and with a research and empirical approach emphasizing constant reassessment and improvement. We began simply by creating weekly lab exercises that corresponded to the topics covered in the course and were based on principles of learning from current pedagogy and cognition literature. Then, we spent the next several years trying these lab assignments in classrooms, tweaking them, and testing them again. We also collected empirical data about student engagement, initial learning, and long-term retention of knowledge from the lab component of the course. The data formed the basis for one author's (Soluri) doctoral dissertation, which explicitly examined effective pedagogical methods in biological anthropology instruction. With proof of concept at the initial implementation at U.C. Berkeley, the exercises, questions, and text were then expanded, tested, and refined in additional classroom environments, including community college courses in the San Francisco Bay area. We wanted to make sure our approach would work with as broad an audience as possible.

As a result, we believe this manual has developed into something unique among biological anthropology laboratory manuals.

1. The manual addresses a wide range of topics relevant to introductory biological anthropology courses, including genetics and evolutionary theory, skeletal biology and forensic anthropology, primatology, and paleoanthropology. We provide a balanced approach to the topics that gives students a well-rounded foundation in the discipline. We also present concepts, such as modern human variation, that are central to biological anthropology but are often not emphasized in laboratory texts. In doing this, we help students build the most comprehensive biological anthropology skill set possible. Each of the lab exercises has been designed with real students in mind, and their effectiveness has been tested and fine-tuned over many semesters in real classrooms at various institutions.
2. The authors' concern with employing effective pedagogy has resulted in a distinctive text that explicitly emphasizes a student-centered learning experience. The manual applies active-learning pedagogy, which emphasizes the importance of students' hands-on involvement in learning. It is ideal for laboratory contexts where the goal is to foster the development of key skills as well as content knowledge.
3. The text is exceptional in its further emphasis on cooperative pedagogy, which highlights the importance of student teamwork to complete learning tasks. This approach helps students develop the critical thinking and communication skills that will aid them in the biological anthropology classroom and beyond. We have designed the manual's exercises and discussions with cooperative pedagogy in mind, and we encourage instructors to have students work in groups when completing the Lab Exercises and Critical Thinking Questions.
4. We have given additional attention to designing a text that is appropriate for a variety of learning environments and types of learners. Therefore, the exercise format is varied throughout the text, offering a range of activities that target particular learning styles. This variation helps each student to connect with the material, regardless of learning background. It also allows instructors to choose particular activities suitable for the unique student makeup of each class.

5. Although the units and labs are arranged in the order in which the topics are often covered in classrooms, we have designed them to be modular. Units and labs can be taught in any order that suits the instructor's needs.
6. In addition to its topical breadth, the manual is unusual because of the varied professional experience of its authors. Dr. Soluri's research has focused on the pedagogical aspects of teaching biological anthropology, and she has experience teaching biological anthropology lecture and laboratory courses at large 4-year institutions and community colleges in the United States. Dr. Agarwal's research has focused on bioarchaeology and skeletal analysis, and she has experience teaching biological anthropology lecture and laboratory courses at large and small 4-year institutions in the United States and Canada. Together, their collective research and teaching experience results in a well-rounded text that is appropriate for a wide range of college and university classrooms.

Changes in the Second Edition

The newest edition of *Laboratory Manual and Workbook for Biological Anthropology: Engaging with Human Evolution* includes the latest scientific discoveries and fossil finds from a dynamic discipline. It also highlights the research process and people behind these discoveries to help students better understand the value of the skills they are developing and to imagine themselves as the scientists of the future. The Second Edition maintains the same core pedagogical structure and modular flexibility found in the First Edition, while adding new content and additional questions and exercises for even more instructional options. The key updates include:

- **New content on ethics in the discipline.** The Second Edition pays particular attention to the discipline's primary ethical guidelines in Lab 1. The application of these principles is reinforced through specific scenarios and real-life examples in this and other labs throughout the book.
- **New content to reflect recent discoveries.** The Second Edition updates existing content with the latest research in the discipline. New text and lab questions feature recently identified living primate species, such as *Pongo tapanuliensis*, newly discovered fossil primates, such as *Nyanzapithecus alesi*, and hominin species, such as *Australopithecus deyiremeda* and *Homo naledi*.
- **Expansion of illustrations and figures.** This edition builds on the excellent art program of the First Edition with even more illustrations in both the chapter text and the lab exercises, where students are guided with drawn instructions as they complete steps in complex multipart exercises. The image collection has been expanded to include new angles and specimens for students to study. Special attention has also been paid to the use of ethically sourced images throughout the Second Edition.
- **Revision for greater clarity, based on extensive student and instructor feedback.** As in the First Edition, complicated concepts are broken into smaller parts and reinforced with relevant figures and tables. In some labs, content has been reorganized to improve readability and learning flow. The wording of questions and exercises has also been streamlined to ensure students comprehend what is being asked.
- **Even more emphasis on the scientific method and research processes.** In addition to the specific attention paid in Lab 1, the scientific method is now more explicitly reinforced throughout the book as students complete exercises where they apply stages of the method to particular biological anthropology research topics covered in later labs.
- **Biological Anthropology in Practice features.** In each of the four units of this edition, a contemporary biological anthropology researcher is featured to show students the people and research processes behind the content they are learning.
- **New Lab Exercises.** The Second Edition adds new and expanded lab exercises. Particular attention was paid to improving student engagement with challenging content, reinforcing stages of the scientific method, and supporting the new content added to the chapter text. These lab exercises include:
    - Ethics Case Study (Lab 1)
    - Extract Your Own DNA (Lab 2)
    - Protein Synthesis (Lab 2)
    - Using the Scientific Method to Investigate Mendelian Traits in Humans (Lab 3)
    - Sex-Linked Traits (Lab 3)
    - Overlapping Forces of Evolution (Lab 4)
    - Surface Anatomy of the Skeleton (Lab 6)

  - Sexing [now including traits from the humerus, femur, and scapula] (Lab 7)
  - Fragmentary Remains [in Forensic Anthropology and Bioarchaeology] (Lab 7)
  - Clinal Distributions (Lab 8)
  - Overlap of Multiple Traits (Lab 8)
  - Body Mass Index (Lab 8)
  - Tooth Types (Lab 12)
  - Tooth Shape as Adaptation (Lab 12)
  - Locomotion and Locomotor Adaptations [now including intermembral index] (Lab 12)
  - The Bipedal Gait (Lab 14)
  - The Evolution of Bipedalism: Postural Feeding (Lab 14)
  - Australopith Dentition (Lab 15)
  - *Australopithecus sediba* (Lab 15)
  - *Homo erectus* Variation (Lab 16)

- **More instructional flexibility in Lab Exercises.** In exercises where students are asked to identify or list traits, the wording has been adjusted to allow instructors to require a greater number of traits if desired. Additional space has also been provided for students to submit longer trait lists.
- **Updates to Image Libraries.** The images provided at the end of labs, for teaching contexts with limited cast material, have been redesigned. They are organized with clearer titles and visual cues to better facilitate students' identification of the appropriate images for each exercise. They are also updated to include the highest quality and most current images available, and when possible multiple views of the same material are provided.
- **Expansion and updating of Critical Thinking Questions.** As in the earlier edition, the Critical Thinking Questions in the Second Edition ask students to think more deeply about what they have learned and to apply their knowledge and skills in new ways. The Critical Thinking Questions throughout the book have been updated to include current issues in the discipline and in students' lives, such as forensic anthropology at the U.S.-Mexico border. In labs with charts for primate or fossil species, Critical Thinking Questions have been added to help students compare and synthesize the information captured in their charts.

Organization and Pedagogy

Four flexible units. Our text covers a range of biological anthropology topics in 16 chapters, or labs. The labs are equally distributed into four units, or parts. Part One (Labs 1–4) focuses on genetics and evolutionary theory. It places biological anthropology in the context of anthropology and of science more generally, and it provides information about what evolution is and how it works. Part Two (Labs 5–8) focuses on modern humans. It introduces the major bones of the human skeleton and teaches some of the skills and methods used by forensic anthropologists. This unit also examines issues of modern human variation and adaptation. Part Three (Labs 9–12) focuses on primatology. It reviews issues of biological classification and highlights similarities and differences in primate anatomy and behavior. Part Four (Labs 13–16) focuses on paleoanthropology. It traces our fossil history from the first primates to modern humans. Within each unit is a special section, titled Biological Anthropology in Practice, that highlights the current research of an anthropologist working on topics related to the themes of that unit.

As noted earlier, although the units and labs are arranged in the order in which the topics are often covered in classrooms, we have designed them to be modular, and they can be taught in any order. For courses that have fewer class meetings, labs can be combined or eliminated as necessary. For courses that have more class meetings, labs can be divided across multiple class days. Each lab can be treated as a separate entity, allowing the instructor maximum flexibility in scheduling and lesson planning.

Chapter organization. Within each lab, there are four primary subsections. The first is the **text section**, providing a written overview of the content for the lab. It can be assigned as reading that reviews course information or introduces it for the first time. The text sections are written in a simple and easy-to-follow format, and they are supported with diagrams, images, and realistic examples to better elucidate points. At the end of the text sections of certain labs, we present more advanced concepts that instructors might want to make optional; this material is called out with the heading Exploring Further. The second section is a list of **Concept Review Questions**. These questions target foundational knowledge and are designed to reinforce the learning of basic factual content. They provide a good review of the text portion of the chapter, and they can be assigned as homework to be completed before class or as pre-lab questions to be completed at the start of class. The third section includes a set of **five to ten Lab Exercises** (the number depending on the type of content covered and the length of the exercises). Instructors can choose to assign all the exercises in a lab or only a sample, depending on their classroom needs. The exercises emphasize active and cooperative pedagogy and are designed to target higher levels of learning, such as comprehension and analysis. Instructors with access to casts and skeletal elements can easily integrate their own teaching collections with the Lab Exercises. Instructors who do not have access to casts, or who have gaps in their teaching collections, can direct their students to the images provided in the Exercise Image Libraries that accompany the Lab Exercises. The final section consists of a list of **Critical Thinking Questions**. This material often targets the highest levels of learning, such as synthesis and evaluation. It provides students with a review of lab content and a chance to think critically about that content. Instructors can assign this material as follow-up questions to be completed by student groups alongside in-class exercises or individually outside the classroom. Instructors can also use the Critical Thinking Questions and Concept Review Questions as exam questions.

Art and photo program. Biological anthropology is a visual discipline, and we have tried to illustrate this text in the best possible manner. Every chapter has multiple large and detailed figures and photographs. In most cases, to help students understand the general size of what we picture, we have included scales based on direct measurements of specimens or measurements provided in scientific literature. We strive for accuracy in our drawings and represent many bones and fossils with drawings of an almost three-dimensional appearance. The text has been laid out in a step-by-step manner with plenty of white space and a double-column design that promotes easy scanning of pages. We provide a world map and geological time line on the inside front and back covers, respectively.

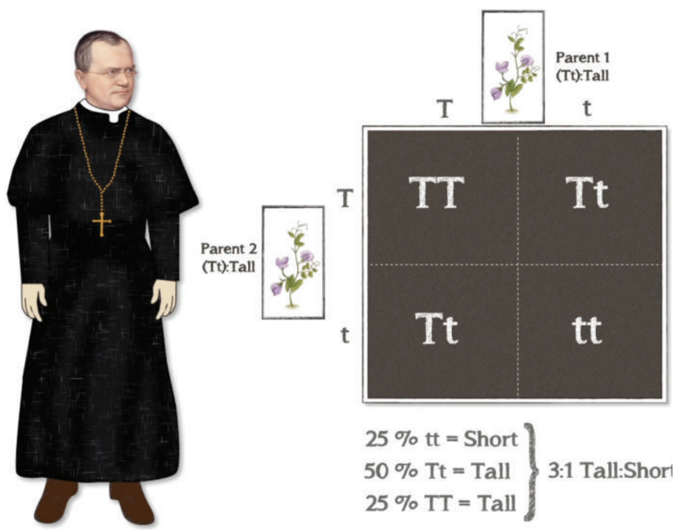
Tear-out worksheets. All worksheets are designed to be torn out and submitted by students, with plenty of room for answers. Space for student identification is on every page to aid in grading. Some instructors might also like their students to use the three-hole punched version of this manual, which lets students easily retain worksheets in a binder as they are returned.

Instructor Supplements (wwnorton.com/instructors)

Instructor's solutions manual and chapter guidelines. The entire lab manual is supplemented with a special instructor's manual that gives instructors the information they need to implement the manual in their courses. It presents guidelines for the Lab Exercises, including information about materials needed and the length of time suggested for each activity. It also provides instructors with answers to all Concept Review Questions, Lab Exercises, and Critical Thinking Questions.

Image set. Every image, table, and chart from the manual is available for download.

LMS coursepacks. Special LMS coursepacks contain versions of nearly all the Lab Exercises designed to work in your LMS. These versions facilitate online submission and grading of exercises for distance- and blended-learning students (note that students must have the lab manual for access to the Exercise Image Libraries). The Concept Review Questions, Lab Exercises, and Critical Thinking Questions in the coursepack can be selected and modified a la carte by instructors, providing the same flexible implementation as the manual itself. This allows instructors to blend formats—for example, by assigning the Concept Review Questions as easily graded, online, pre-lab homework that is then reinforced through completion of the Lab Exercises and Critical Thinking Questions in class. The coursepack also provides access to Norton's animation and video resources for biological anthropology.



Low-priced versions and bundle discounts. This manual is available in a discounted three-hole punched version, as well as an inexpensive electronic version for your distance-learning students. Discounted bundle prices are also available to keep costs reasonable for students. Please contact your W. W. Norton representative for more information.

FOR STUDENTS

This lab manual is designed to engage you in an exploration of human biology and evolution. The evolution of our species is a vast and complex topic that is studied by biological anthropologists around the world who seek to understand who we are as a species, how we came to be this way, and where we may be headed from here. Biological anthropologists tackle these issues using a range of research questions and methods, and we will investigate these different forms of analysis throughout the text. Each lab in the manual includes text that introduces important information, Concept Review Questions that can be used to test your comprehension of the text, Lab Exercises that ask you to think and act like an anthropologist, and Critical Thinking Questions that ask you to combine all of this knowledge in complex and new ways. There is no set order to the labs, and your instructor may choose to present the labs in any order. No matter where you start or finish, the labs will combine to provide a broad picture of the human species and our evolutionary history.

To facilitate your learning, we engage you as active participants. You will complete tasks, answer questions, and think critically about the information presented. You will get the chance to practice some of the comparative and analytical skills used by biological anthropologists, and you are likely to begin seeing yourself in a whole new light because of it. We provide you with up-to-date information about major topics in biological anthropology, so that you are gaining the most accurate and current knowledge possible. We also describe issues and examples that are interesting and relevant to your own life. We supply you with high-quality photos and drawings of skeletons, fossils, and living animals to illustrate key points and anatomical features throughout the text. Your instructor may then give you access to additional materials, such as skeletal elements and fossil casts, to supplement what you see and learn in the manual.

By the end of this manual and course, you will be thinking and applying analytical skills like a biological anthropologist. You will have learned more about yourself, your place in the world, and your evolutionary history, and you will be armed with this knowledge as you continue life in and outside of anthropology classrooms.

ACKNOWLEDGMENTS

We extend our gratitude to the many people who supported us and generously provided their assistance throughout the process of planning, writing, and publishing this manual. Among them, Elizabeth would especially like to thank her friends and family who supported her during the development of this project, especially the Soluri, Camp, Schneider, and Hayes/Matsunaga families. Elizabeth extends a special thank you to her husband Tsim, who participated in countless conversations about the manual, sharing his ideas and lending his unfailing support every step of the way. Sabrina would especially like to thank Rosemary Joyce, Laurie Wilkie, Ruth Tringham, and Meg Conkey for sharing all their teaching and learning wisdom while formulating ideas for this project. Sabrina also thanks her husband Peter for his support and encouragement over the years in seeing this manual to its fruition.

We greatly appreciate the help and guidance we received from everyone at W. W. Norton & Company. We thank Jack Repcheck for initially approaching us with this opportunity and bolstering us through the early stages of the project. His enthusiasm for the manual was contagious and helped get things off the ground. Eric Svendsen took on the project after Jack, and he expertly steered us through the majority of the writing and publication process. His patience and guidance were instrumental, particularly his insights and assistance during the review, revision, and production processes. We thank Sunny Hwang for her outstanding suggestions for portions of the text and activities, which kept us thinking and exploring new ideas. For the second edition, we benefited from the editorial guidance of Jake Schindel. His dedication to the project helped shepherd the manual through a rigorous revision process that has yielded a new and improved version of the text. We are also indebted to the exceptional editing of Taylere Peterson and Norma Sims Roche, who applied their keen eyes to the project from start to finish. As with the first edition, Rachel Goodman's outstanding organization and attention to detail helped keep the process streamlined and efficient. This text is supported by an excellent media and supplement package, and we thank Miryam Chandler and Ariel Eaton for their careful work in this area. Numerous people helped compile and clear permission for the wonderful images and figures, including Elizabeth Trammell and Travis Carr. Ben Reynolds carefully oversaw the production process. Ashley Lipps contributed her time and expertise in taking beautiful photographs of much of the skeletal material featured in this text. Tiffiny Tung and Melanie Miller generously shared photographs for inclusion in the text. We extend additional thanks to Alison Galloway, Adrienne Zihlman, and Richard Baldwin (Department of Anthropology at the University of California, Santa Cruz) and Chris Conroy (Museum of Vertebrate Zoology, University of California, Berkeley) for providing access to skeletal material for photographic purposes. Clark Larsen encouraged us and offered valuable advice based on his experience. The project would not have been possible without the outstanding support of the entire W. W. Norton & Company team.

A lab manual of this nature is based on our years of teaching this material in 2- and 4-year institutions in the United States and Canada. We thank all of our undergraduate students—past, present, and future—for inspiring and challenging us. We also thank the numerous graduate students and faculty who have taught with us and shared their classroom experiences and suggestions. In particular, we thank the instructors who, as graduate students at the University of California, Berkeley, helped us test some of the activities published here, particularly Patrick Beauchesne, Celise Chilcote, Julie Hui, Ashley Lipps, Melanie Miller, Andrew Roddick, and Julie Wesp. Some activities and questions included here were initially produced with the support of a Pedagogy Improvement Grant from the Graduate Student Teaching and Resource Center of the Graduate Division at the University of California, Berkeley, for which we are especially grateful. We also thank the following colleagues for the various forms of pedagogical support and insights they provided: Martin Covington, Terrence Deacon, Sandra Hollimon, Rosemary Joyce, Susan Kerr, Beth Roselyn, and Linda von Hoene. We offer a special thank you to the four researchers featured in the Biological Anthropology in Practice spotlights in the second edition: Debi Bolter, John Lindo, Vicky Oelze, and Julienne Rutherford. We also extend our special thanks to graduate student teaching assistants, Debra Martin, and Peter Gray, at the University of Nevada, Las Vegas, for their test run of the first edition of the lab manual. Their detailed feedback and ideas were instrumental in shaping the initial product.

The second edition benefited from the feedback and suggestions provided by many reviewers, and we appreciate the time and thought they put into this process.

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Sabrina C. Agarwal

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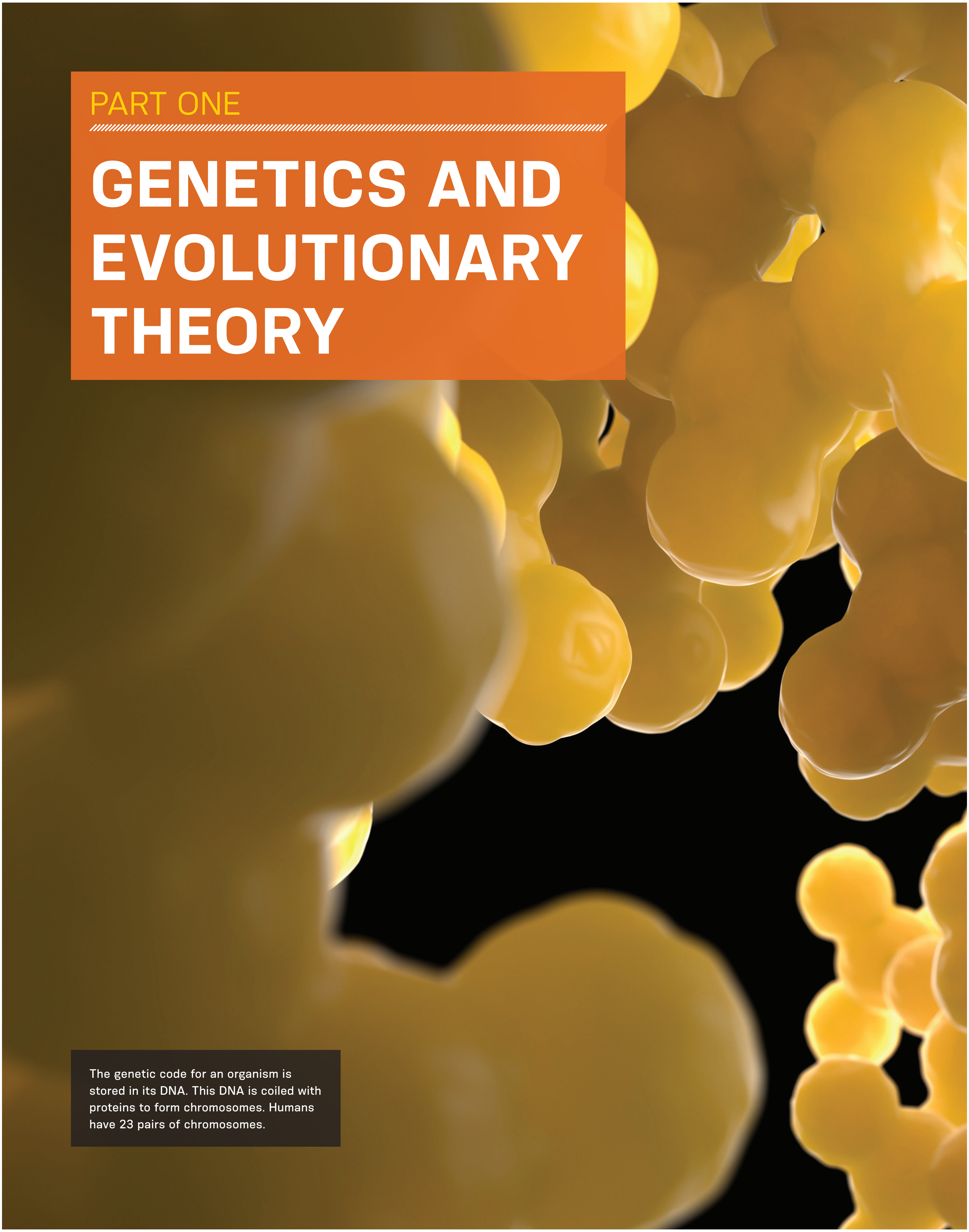
LABORATORY MANUAL AND WORKBOOK FOR BIOLOGICAL ANTHROPOLOGY: ENGAGING WITH HUMAN EVOLUTION

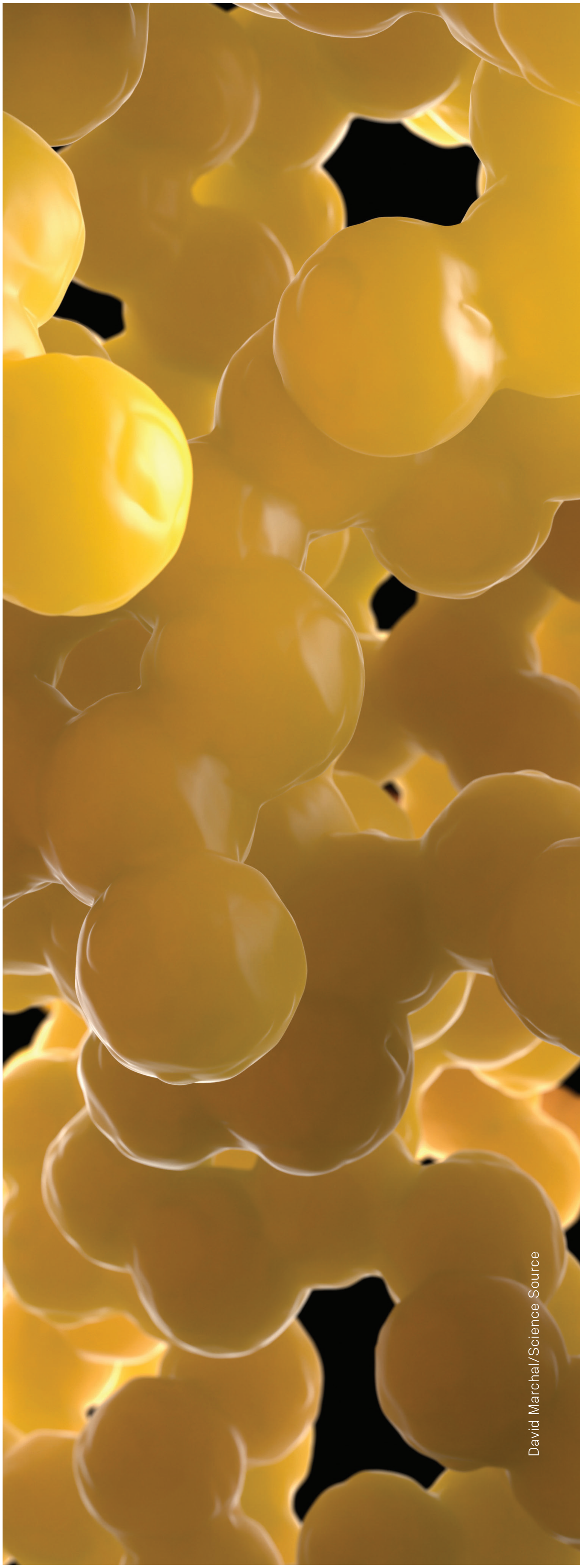
SECOND EDITION

PART ONE

GENETICS AND EVOLUTIONARY THEORY



The genetic code for an organism is stored in its DNA. This DNA is coiled with proteins to form chromosomes. Humans have 23 pairs of chromosomes.



David Marchal/Science Source

LAB 1: BIOLOGICAL ANTHROPOLOGY AND THE SCIENTIFIC METHOD

WHAT TOPICS ARE COVERED IN THIS LAB?

- An introduction to the discipline of anthropology and its four fields
- A closer look at the field of biological anthropology
- A review of science and the scientific method
- An overview of the role of scientific inquiry in biological anthropology research
- An introduction to ethical practices in biological anthropology

LAB 2: GENETICS

WHAT TOPICS ARE COVERED IN THIS LAB?

- An introduction to the cell parts related to processes of evolution and inheritance
- A look at the importance of cell division for evolution
- A review of DNA replication and protein synthesis

LAB 3: INHERITANCE

WHAT TOPICS ARE COVERED IN THIS LAB?

- An overview of Gregor Mendel's research with pea plants
- A consideration of the relationship between dominant and recessive alleles
- A review of genotypes and phenotypes
- An introduction to Punnett squares and pedigree diagrams
- A discussion of Mendelian and non-Mendelian traits
- An examination of sex-linked traits
- An exploration of the ABO blood group in humans to illuminate complex relationships of dominance and recessiveness in real life

LAB 4: FORCES OF EVOLUTION

WHAT TOPICS ARE COVERED IN THIS LAB?

- An introduction to the concept of evolution
- A discussion of the role of genetic recombination in evolution
- A review of the primary forces of evolution (mutation, natural selection, genetic drift, and gene flow)
- Use of the Hardy–Weinberg equation to determine whether evolution is happening

Image BROKER/ Superstock

HANDOUT/KRT/Newscom

Biological anthropologists address a wide range of research topics related to humans and our evolutionary history. This research often includes time in the laboratory and time in the field.

Lab Learning Objectives

By the end of this lab, students should be able to:

- describe the discipline of anthropology in general and compare the four fields of anthropology.
- discuss the similarities and differences between the subfields of biological anthropology.
- explain the scientific method and define "scientific theory."
- discuss how biological anthropologists draw on science and scientific techniques in their work.
- apply the American Association of Physical Anthropologists Code of Ethics.

LAB 1

Biological Anthropology and the Scientific Method

In Germany, a group of researchers examines modern and ancient human DNA to understand human population movements in the past. Meanwhile, researchers in Ethiopia excavate the fossil remains of some of our relatives who went extinct roughly 4 million years ago. In California, a researcher analyzes 7,000-year-old bones for evidence of changes in bone density during life related to both biological sex and gender differences. And in Borneo, other researchers observe orangutans using probing tools to fish for the insects they eat. What do all of these people have in common? They are all conducting biological anthropology research. What does it mean to be a biological anthropologist? What topics do biological anthropologists study? In this lab, we explore answers to these questions.

INTRODUCTION

We begin this lab with an overview of the discipline of anthropology. We discuss the four fields of anthropology, and we pay particular attention to how biological anthropology relates to the other three fields. We outline the subfields of biological anthropology and consider how they overlap and vary. We also explore science more generally, discussing the scientific method, its role in scientific research, and how biological anthropologists employ it in their work. We conclude by examining the ethical considerations involved in anthropological research.

WHAT IS ANTHROPOLOGY?

anthropology the study of people

context the time, space, environment, historical circumstances, and cultural practices within which a subject of anthropological investigation is situated

holistic approach a research approach that emphasizes the importance of all aspects of the study subject and requires a consideration of context to gain an understanding of the broader picture

comparative approach a research approach that emphasizes the importance of comparisons across cultures, times, places, species, and so forth

cultural anthropology the study of the cultural life of living people, including their cultural practices, beliefs, economics, politics, gender roles, and so forth; also called social anthropology

Anthropology, in the most general sense, refers to the study of people. It can take a variety of forms, including the study of people in the present and of people in the past. There are two ideas that are fundamental to all anthropological work. The first idea is the importance of **context**. Context includes issues of time, space, unique historical and environmental circumstances, and various culturally specific practices. It is important to all anthropological work because it shapes what we study. People do not live in a vacuum. Instead, they are inseparable from the context in which they live. For example, if an anthropologist were to fully understand you, they would have to consider your age, where you live, your gender, your life experience, your cultural practices, your family, your place in the broader biological world, and many other factors specific and unique to you. Where you live determines the environmental resources available to you, your food, and possibly your cultural practices. Your cultural practices influence the way you view the world and your place in it. Your biology, such as your sex or age, may affect your place in your culture. And your life experiences often tell the story of all of these factors. It would be impossible to understand you without understanding as much as possible about these other contextual issues. This emphasis on context and on how different aspects of a study subject interrelate and influence one another is often called a **holistic approach**. With a holistic approach, emphasis is placed on seeing the whole picture because anthropology recognizes that numerous factors and contextual issues contribute to what it means to be human.

The second fundamental idea in anthropology is the use of a **comparative approach**. The comparative approach can take many forms, and anthropological comparisons can be the focus of a research project or only one component of a project. For example, anthropologists often compare different cultural groups, or the same cultural group in different time periods, or people in one region with people in another region, or humans with other species. No matter what anthropologists study, they recognize the importance of considering similarities and differences through comparisons.

Anthropology is a unique field of study because it takes into account how people are shaped by both their biological and their cultural context, and because it explores and compares people in all time periods and geographic regions. Other social sciences, such as psychology and sociology, have minor components of both of these fundamental aspects of anthropology. While many social scientists consider the role of biology and/or culture in human life, most of these disciplines do not emphasize a comparative approach. They study people in the present or people in particular areas of the world. In contrast, anthropological work considers context and employs a broad, comparative perspective.

FOUR FIELDS OF ANTHROPOLOGY

Anthropology is generally divided into four fields (**FIGURE 1.1**). These four fields are united by their consideration of culture and their emphasis on the comparative approach, but they vary in the questions they ask and in the materials they study. One field of anthropology is **cultural anthropology** (often called social anthropology in Europe). Cultural anthropologists study cultural practices, beliefs, economics, politics, gender roles, and so forth; they traditionally studied non-Western groups, although

A Bettmann/Corbis/Getty Images

B Jeremy Fahringer/Living Tongues

C John T. Fowler/Alamy Stock Photo

D Horacio Villalobos/Corbis via Getty Images

FIGURE 1.1 The Four Fields of Anthropology
All four fields of anthropology emphasize the importance of context and apply a comparative approach, but they differ in the specific aspects of humanity that they study. (A) Cultural anthropologists (such as Margaret Mead, seen here with a woman and child in the Admiralty Islands) study the cultural life of living peoples. (B) Linguistic anthropologists (like K. David Harrison, seen here with Anthony Degio and Abamu Degio watching a recording of herself singing a traditional Koro song) study how people make and use language. (C) Archaeologists (like the one seen here excavating an ancient site) study the cultural life of past peoples by examining their material remains. (D) Biological anthropologists study human evolution, and their methods of analysis may be applied to help criminal investigations (as is seen here in the excavation of a war victim in Argentina).

this is not always the case in the field today. Cultural anthropologists study living (or recently living) peoples. These anthropologists make observations, conduct interviews, and examine the things made by the people being studied (their material culture). For example, a cultural anthropologist might study the seasonal rituals practiced by a particular Native American group. She would observe the rituals and the times surrounding them to understand the broader cultural context of the practices. She might interview the people involved in the rituals and the people who observe them, and she might examine the clothing and materials used in the ritual.

A second field of anthropology is **linguistic anthropology**. Linguistic anthropologists study how people make and use language. Like cultural anthropologists, linguistic anthropologists tend to research living (or recently living) peoples, and they traditionally studied non-Western populations. They use observations and interviews to collect data about language production and use. They can also use written documents, where available, and recordings of people speaking the language under study. For example, a linguistic anthropologist might study how language is used differently by men and women in an indigenous group in New Guinea. He would observe people talking with people of their same gender and with people not of their same gender. The anthropologist might also interview people about who taught them their language, how they talk to their children of different genders, and how they talk to different people in their community. He might also listen to recordings of songs made by earlier researchers studying the same group to see if there are differences in men's and women's singing.

A third field of anthropology is **archaeology**. In Europe, archaeology is sometimes treated as a discipline separate from anthropology. In the United States, however, archaeology is considered a subdiscipline of anthropology and is sometimes called anthropological archaeology to highlight this categorization. Archaeologists, like cultural anthropologists, study cultural practices, economics, gender roles, and rituals. However, archaeologists focus on people and cultures in the past. Sometimes they study the distant past, tens of thousands of years ago. Sometimes they study the recent past, maybe only a few decades ago. Archaeologists study both Western and non-Western peoples around the world. Unlike cultural and linguistic anthropology, archaeology primarily examines the material remains left by people to understand their practices and way of life. Material remains

linguistic anthropology the study of how people make and use language

archaeology the study of the cultural life of past people as seen through their material remains, such as architecture, bones, and tools are things that are made or modified by people and later recovered by an archaeologist. They include things like remnants of houses and ritual buildings, human bones and burials, tools, animal bones and charred plant parts, ceramic vessels, personal ornaments, statues, clothing, and sometimes historical documents. If an archaeologist were studying what Maya people ate in a community in Mexico a thousand years ago, she would probably try to recover and examine animal and plant remains from meals, ceramic vessels that held food and beverages, areas of the community that were used for food storage or preparation, and any documents that might help her understand food use.

The fourth field of anthropology is called **biological anthropology**. Biological anthropology has been traditionally called physical anthropology, with the term "physical" reflecting its traditional focus on the physical measurement of humans. Current trends in the field emphasize methods and theories from biology, such as the growing incorporation of DNA analysis. Thus, while both names are acceptable and continue to be used today, we will use "biological anthropology" to reflect anthropologists' increasing use of biological techniques.

biological anthropology the study of human evolution, including human biology, our close living and extinct relatives, and current similarities and differences within our species; also called physical anthropology

biocultural approach a research approach that recognizes the close relationship between human biology and culture and attempts to study these two forces simultaneously

human biology the study of human genetics, variation within our species, and how our species is affected by evolutionary processes

forensic anthropology the application of knowledge and methods of skeletal analysis to assist in legal investigations

Biological anthropology is the study of human evolution, including our biology, our close primate relatives, our fossil ancestry, and our current similarities and differences. Biological anthropologists study people in the present and in the past. They also study nonhuman species—specifically, our living primate relatives and our extinct fossil relatives. They examine a wide range of materials, including fossils, living primates, skeletons, and DNA. For example, a biological anthropologist studying the primate capacity for language might examine genes that contribute to language production and comprehension. He might also examine the bones of the skeleton related to language production or try to train living primates to produce or understand some form of language. The theme that unifies biological anthropology research is an emphasis on evolution.

One of the things that makes biological anthropology unusual among the sciences is its emphasis on a **biocultural approach**. This approach recognizes that human biology and culture are closely intertwined and need to be examined and understood simultaneously. Thus, biological anthropologists might consider how stone tool use (culture) affected past diets and dietary adaptations (biology) or how mating preferences (culture) affect current population isolation and human variation (biology).

THE SUBFIELDS OF BIOLOGICAL ANTHROPOLOGY

Within biological anthropology, there are several subfields. Each subfield emphasizes different aspects of human evolution and our place in the world. One subfield can be generally referred to as **human biology**. This broad subfield includes research on human genetics, the impact of evolutionary processes on our species, and variation among humans today. It draws heavily on theories and methods from biology. For example, a researcher in human biology might study the evolution of a particular trait, such as adult lactose tolerance. This researcher could explore the effects of different evolutionary processes in shaping this adaptation. She could also consider the genetic basis of the trait and why it might vary in human populations today. Another example of human biology research would be a study of energy demands and nutrition in different human populations. The researcher could observe and interview people in different groups to identify what people eat, how regularly they eat, how they spend their time, and how much energy is required for their lifestyle. He would probably take into account differences in age, gender, and social status that might influence energy demands and nutrition.

Forensic anthropology is an applied area of biological anthropology that has gained popular attention through television programs and crime novels. Forensic anthropology is

LukaTDB/Shutterstock

FIGURE 1.2 Forensic Anthropology
Forensic anthropologists apply methods of human skeletal analysis to aid criminal investigations. They help identify victims and describe circumstances surrounding deaths using clues in human skeletal remains.

related to human biology because it applies methods of skeletal analysis from human biology and anatomy to real-world problems. Forensic anthropologists analyze human skeletons as part of legal investigations. When a criminal investigation uncovers a body that is primarily skeletal, with little soft tissue remaining, investigators call on a forensic anthropologist for assistance (**FIGURE 1.2**). In some cases, forensic anthropologists are asked to help with investigations of war crimes, natural disasters, and other events that involve the identification of numerous victims. These anthropologists are experts on the human skeleton and use various methods and techniques to help identify victims and to suggest the circumstances surrounding their deaths. These methods include examining and measuring bones and teeth to help determine the victim's sex, age, and likely ancestry as well as noting any unusual damage to the bones that might have resulted from injuries sustained around the time of death.

Another subfield of biological anthropology is **primatology**: the study of living primates (**FIGURE 1.3**). Primatologists study similarities and differences across primate species, and they try to understand how, why, and when various primate traits evolved. Because humans are primates, this work is used to help us understand our broader biological context and evolutionary history. Primatologists draw on biological theories and methods, such as DNA analysis and observations of animals in the wild. They may also design laboratory experiments to test things such as the ability of primates to perform certain problem-solving tasks or learn language. A primatologist might study chimpanzee social interactions in the wild. In doing this, the researcher would stay near a group of chimpanzees for an extended time, observing and documenting their behavior in various social situations, such as sharing food, having sex, and fighting. This type of information could then be used to help us understand human behavior in similar situations today and in the past.

The final subfield of biological anthropology is **paleoanthropology**: the study of the anatomy and behavior of humans and our biological relatives in the past (**FIGURE 1.4**). This subfield uses methods of excavation that are similar to those used by archaeologists, and there is often overlap in the evidence used in paleoanthropology

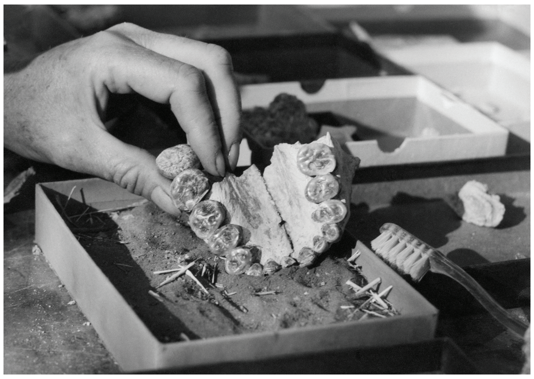
primatology
the study of living primates, particularly their similarities and differences and why those similarities and differences might exist

paleoanthropology
the study of the anatomy and behavior of humans and our extinct relatives

Penelope Breese/Liaison/Getty Images

FIGURE 1.3 Primatology
Some biological anthropologists, such as Jane Goodall, specialize in primatology.

scientific method
a cycle of scientific practices that helps scientists to gain knowledge and sparks further scientific inquiries



Des Bartlett/Science Source

FIGURE 1.4 Paleoanthropology
Paleoanthropologists examine fossilized remains for information about the anatomy and behavior of our extinct relatives.

and archaeology. However, archaeologists tend to focus on the human species (*Homo sapiens*), whereas paleoanthropologists often focus on our ancient extinct relatives, such as Neanderthals. Paleoanthropologists generally deal with the more distant past, even as far back as several million years ago. They often focus on the analysis of fossilized skeletal remains, and sometimes tools and other artifacts, that have been well preserved across long periods. For example, a paleoanthropologist might study when we first diverged from other primates. She would collect fossil remains from the relevant time period and analyze their anatomical traits and features to identify the extinct species' relationships to humans and other primates. She might explore what kinds of food our early primate relatives ate by examining fossil teeth and comparing them with modern primate teeth. She might also measure fossil limb bones to help determine whether ancient species relied on their arms and primarily moved through trees, or used their legs more and primarily walked on the ground. Work along these lines allows us to trace the evolution of particular human traits, as well as larger evolutionary trends in our history. Paleoanthropologists usually work as part of an interdisciplinary team that brings them together with researchers such as geologists and paleoecologists who study ancient environments. These interdisciplinary partnerships allow paleoanthropologists to gain a more complete picture of the past they study.

THE SCIENTIFIC METHOD

Science is a way of learning about the world. There are many ways of thinking about the world, but science is distinct because it relies on observations and tests to accumulate knowledge about phenomena seen in the natural world. These observations and tests must be repeatable and verifiable by other scientists. Scientists in all scientific disciplines use the scientific method to make their observations.

The **scientific method** is a cycle of scientific practices that helps scientists gain knowledge and sparks further scientific inquiries (**FIGURE 1.5**). There are four key stages to this cycle. The first stage is *observation*. Scientists can make observations of phenomena directly, or they can use observations of phenomena made by other scientists as part of previous research. For example, a researcher may notice that savanna baboons live in larger social groups than do forest-dwelling baboons (**FIGURE 1.6**).

The second stage of the cycle is generating a *hypothesis*. The hypothesis, which is based on the researcher's observations, is a testable explanation of those observations. There can be more than one hypothesis, but the researcher will have to handle them carefully in the next stages of the scientific method to make sure adequate data are collected and evaluated for each one. To generate a hypothesis, the researcher suggests a testable explanation for his observation. Specifically, it should be written as a statement that, if untrue, can be disproved (or falsified) by evidence obtained in data collection. For example, following his observation of savanna baboon groups, a researcher might hypothesize that savanna baboons that live in large groups have greater protection from predators than baboons that live in small groups. This hypothesis is testable because the researcher can observe baboons living in different group sizes and environments and can collect relevant data about their predation risk and rates of survival.

The third stage of the scientific method is *data collection*. During this stage, the hypothesis is actually tested. Data (or evidence) are

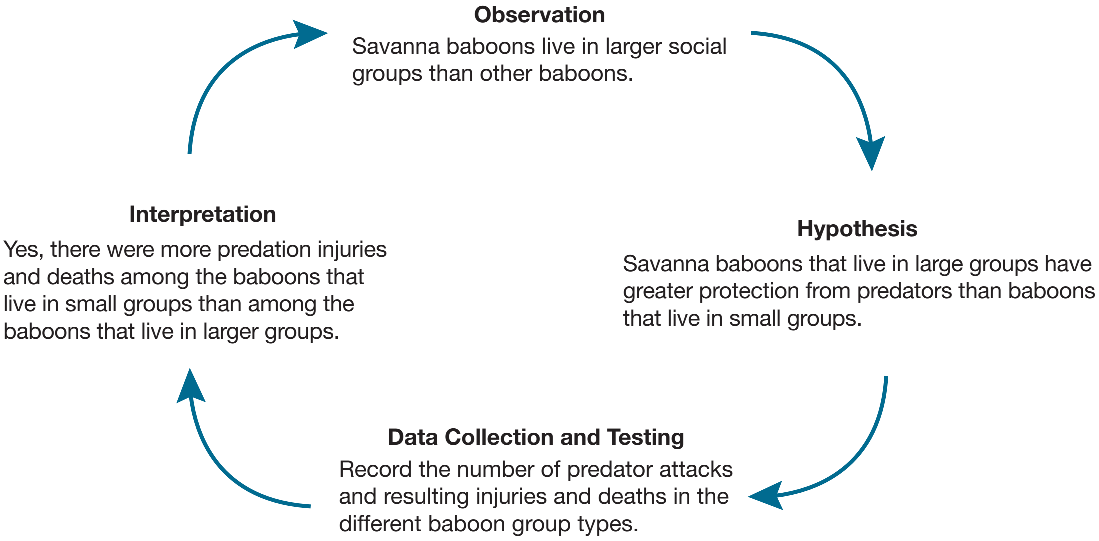


FIGURE 1.5 The Scientific Method
When conducting research, scientists follow the scientific method. They use previous research and new observations to develop hypotheses. They then collect data to test their hypotheses. They use their data to evaluate the hypotheses and make interpretations. These interpretations then serve as the starting point for further research, and the cycle begins again.

collected through experiments or further observations. What types of data are gathered and how they are collected will depend on the hypothesis being tested. In our baboon example, the researcher must collect data about the number of predator attacks, types of predator attacks, and rates of injury and death in baboon groups of different sizes and in different environments. This kind of data collection is different from traditional experiments that are conducted in laboratories. Laboratory experiments can often be strictly controlled, and the scientist can

FIGURE 1.6 Savanna Baboons
Savanna baboons often form larger social groups than baboons that live in forests.

scientific theory a scientific explanation supported by substantial evidence

social science a discipline concerned with the study of human society, such as anthropology, psychology, or sociology

target particular variables that will be manipulated or kept in check. This strategy makes it possible to identify what causes certain results relatively clearly. It also makes it easy to repeat and verify the experiments and their outcomes. In contrast, in the natural world, scientists cannot fully control the research situation, and they often have to work around various environmental barriers, such as bad weather, limited daylight, and skittish research subjects. But scientists working in these conditions still follow the basic principles of repeatability and verifiability. They closely document each factor that may affect their results so that researchers in the future can repeat their work as closely as possible to test for similar outcomes.

The final stage of the scientific method is *interpretation*, in which the collected data are used to evaluate the hypothesis. Did the hypothesis adequately explain the early observation? Is there sufficient evidence to support the hypothesis, or should the hypothesis be rejected? Let's return to our baboon example. The researcher finds more predation injuries and deaths among savanna baboons that live in small groups than among savanna baboons living in larger groups or among small groups of forest-dwelling baboons. Thus, the hypothesis is supported. Forest-dwelling baboons do not face as many risks and can get by with a smaller group size. However, baboons on the savanna face more predation, particularly when they form a small group, so savanna baboons tend to form larger groups for safety. Conclusions from this research can then be used as the observations that jump-start another research project in the future. This makes the scientific method an ongoing cycle of knowledge building. Past research feeds current research, which in turn can spark future research with new data and new interpretations.

Because past scientific research becomes the foundation for new research, the scientific method is self-correcting. To explore this concept, let's think about the savanna baboon example. Imagine that the researcher collected data that indicated the rates of predation injuries and deaths were actually the same in both small and large savanna baboon groups. In this case, the hypothesis would be rejected instead of supported because the larger group size did not protect the baboons from predators. The researcher would then need to revise the hypothesis to come up with a new, testable explanation for why savanna baboons form large social groups. The scientific method allows for knowledge correction because researchers continue to refine and retest hypotheses this way over time. Later scientists may also identify mistakes made in earlier research, and the research can then be performed again.

When the same interpretations are supported by evidence from many different researchers and they are widely accepted by the scientific community, they may become a theory. A **scientific theory** is not a guess. It is an explanation supported by substantial evidence. However, this evidence does not mean that a scientific theory is an absolute truth. A scientific theory is still open to reinterpretation and rejection in the face of new evidence. There are several widely accepted scientific theories today, including the theory of evolution (see Lab 4 for more information).

THE SCIENCE OF BIOLOGICAL ANTHROPOLOGY

Biological anthropologists are scientists. They apply the scientific method to questions about human biology. Because biological anthropologists study human biology in the context of human culture and behavior, biological anthropology is also a **social science**. Biological anthropologists use observations to generate hypotheses, and they accumulate data to evaluate those hypotheses. As previously discussed, some biological anthropology research can be conducted in controlled laboratory settings. Much of the research, however, is conducted by making observations of animals in the wild or observations and analyses of the fossil record. The lack of laboratory experiments does not make biological anthropology unscientific. Remember, the scientific method requires that data be collected to test hypotheses, which is regularly done by biological anthropologists.

ETHICS IN BIOLOGICAL ANTHROPOLOGY RESEARCH

Biological anthropologists often work closely with people and other nonhuman primates. In some cases, they directly study people, both past and present, by methods such as collecting DNA samples to identify and compare genetic traits. In other research contexts, biological anthropologists may hire local people to help observe and collect data about wild nonhuman primates. In still other research projects, biological anthropologists may conduct laboratory experiments with captive nonhuman primates, such as testing a gorilla's ability to use human-like forms of communication. Therefore, biological anthropologists must follow ethical guidelines that outline how to work with these populations safely and fairly.

The American Association of Physical Anthropologists (AAPA; shortly to be renamed the American Association of Biological Anthropologists), the leading professional organization for biological anthropologists in the United States, has outlined a Code of Ethics for biological anthropology work. This Code of Ethics includes the following guidelines:

1. The primary responsibility of anthropologists is to the people, species, and materials they study, as well as the people they partner with in their work. This responsibility takes precedence over responsibilities to others, such as funding agencies.
2. Anthropologists must not harm the people with whom they work.
3. Anthropologists must protect the anonymity of their hosts and of the people providing information if those participants so desire.
4. Anthropologists should also inform the people they are studying about the research and get their consent for the work in advance. This consent process is assumed to be dynamic and ongoing, and anthropologists may need to reobtain consent as their research continues or changes over time. The AAPA Code of Ethics also recognizes that even if anthropologists are not working directly with living people, they should still obtain consent from those who own or control access to their study material. For example, if an anthropologist would like to examine human bones uncovered from an ancient Native American site, he should obtain the informed consent of the living Native American descendants to whom those human remains are related. In many cases, this consent process is mandated by state and federal law.
5. Anthropologists often develop close and lasting relationships with research participants, so it is important to be open and maintain informed consent while also respectfully discussing and agreeing on the limits of those relationships.
6. Anthropologists must not exploit people, animals, or materials while conducting their work. They should also recognize their debt to their research participants and reciprocate in appropriate ways.

Because most biological anthropology research is complex and involves multiple, overlapping steps, biological anthropologists typically work collaboratively with other researchers. For example, a paleoanthropologist will work with other researchers, students, and local people to excavate a fossil site. Then, she will share subsets of the recovered fossil material with other experts who can each focus on specific data sets, such as an expert who examines early human teeth and an expert who studies small rodent bones. The paleoanthropologist will also want to know when the fossil creatures lived at the site, so she will send material to another group of specialists to be chemically analyzed and assigned to a certain time period. As previously discussed, she may also partner with geologists or paleoecologists who can help her understand the ancient landscape. A biological anthropologist is therefore expected to engage in responsible and professional practices as part of a larger scientific research team:

1. Anthropologists must make good-faith efforts to identify and address ethical conflicts before beginning their work.
2. Anthropologists should not falsify, plagiarize, or otherwise misrepresent their work.
3. Anthropologists should preserve opportunities for future scientists to conduct similar work. (Remember, the ability to verify research and refine knowledge is a key part of the scientific method.)
4. Anthropologists should share the results of their research with other scholars whenever possible.
5. Anthropologists should preserve their fieldwork data and seriously consider sharing them with other researchers.

Biological anthropologists conduct work that is relevant and important to the public. Therefore, they are also expected to share their results with funding agencies, students, and nonanthropologists. Anthropologists should explain and contextualize their research so that people will understand it and use the knowledge responsibly. However, anthropologists should limit information sharing if it would interfere with their primary responsibility and could cause harm to their research participants or colleagues.

An important and recent addition to the AAPA's Code of Ethics is its Statement on Sexual Harassment and Assault, which explains the AAPA's commitment to providing safe spaces that are free of harassment and discrimination. The statement also outlines what constitutes harassment and how to proceed should one be the victim of or a bystander to harassment in any professional space, including colleges, laboratories, field contexts, professional conferences, or digital and social media platforms.

CONCEPT REVIEW QUESTIONS

Name: ______________________ Section: ______________________

Course: ______________________ Date: ______________________

Answer the following questions in the space provided.

1. What are the *two* fundamental ideas in anthropology?

2. Which field of anthropology uses a wide range of data about living and past organisms to study human evolution?
   - A. Linguistic anthropology
   - B. Archaeology
   - C. Biological anthropology
   - D. Cultural anthropology

3. What is the biocultural approach in biological anthropology?

4. Which subfield of biological anthropology uses the fossil record to examine the anatomy and behavior of our relatives in the past?
   - A. Forensic anthropology
   - B. Paleoanthropology
   - C. Human biology
   - D. Primatology

5. Which subfield of biological anthropology applies methods of skeletal analysis to study humans in a legal context?
   - A. Forensic anthropology
   - B. Paleoanthropology
   - C. Human biology
   - D. Primatology

6. During which stage of the scientific method is the hypothesis evaluated?
   - A. Observation
   - B. Hypothesis generation
   - C. Data collection
   - D. Interpretation

7. In the context of the scientific method, what is the hypothesis? How is it different from a scientific theory?

8. Are scientific theories absolute truths? Why or why not?

9. Are scientific theories guesses? Why or why not?

10. According to the American Association of Physical Anthropologists (AAPA) Code of Ethics, an anthropologist is primarily responsible to ______________________________ .

LAB EXERCISES

Name: ______________________ Section: ______________________

Course: ______________________ Date: ______________________

EXERCISE 1 FIELDS OF ANTHROPOLOGY SCENARIOS

Working with a group of your classmates, pick one (or more) of the following scenarios, depending on your instructor's guidelines, and answer the questions that follow. Use a separate sheet of paper if you are completing more than one scenario.

SCENARIO A

Anthropologists have been studying the role of soybean curd and related products in the culture of Hong Kong. The researchers interview people about how frequently they eat soybean products, where they eat them (at home or in restaurants), and during what time of day they eat them. The researchers also ask people about how they prepare soybean products, where they obtain soybean products, and any beliefs they might have about soybean products (such as their nutritional value). The data are used to assess the role of soybean products in the culture. The researchers are also considering how their findings relate to global soybean consumption patterns.

SCENARIO B

An anthropologist has been researching how Native Americans in California were impacted by Spanish missionization from 1776 to 1830. The researcher is particularly interested in how Native Californians may have negotiated their identity and balanced traditional practices with colonial influences. Therefore, the anthropologist excavates material remains from areas where the Native Californians may have gone when they fled the Spanish missions. The materials include things such as stone tools, shell beads, and historic bottle glass. These materials are analyzed and used in conjunction with historical documents to help the researcher better understand what life was like for Native Californians at that time.

SCENARIO C

Building on previous research showing that people of different genders often communicate differently, an anthropologist has been studying how gendered communication affects family interactions. The anthropologist uses recorded conversations from participant families' homes. The anthropologist also uses documentary footage of family interactions. The interactions are analyzed for information about gendered communication, power relationships, and connections between various family members.

SCENARIO D

Anthropologists have been studying Y-chromosomal DNA to understand where and when humans first appeared and when they moved into various areas of the world. The Y chromosome is found only in males, and most of the DNA found on the Y chromosome is passed directly from fathers to sons. Researchers collect Y-chromosomal DNA from living men and measure the amount of genetic difference among populations. Greater amounts of genetic difference indicate longer periods of separation between different groups of people because it takes time to accumulate genetic variations. This Y-chromosomal DNA research has helped anthropologists to understand our species' origin in Africa and our various migrations to other parts of the world.

QUESTIONS:

1. Which scenario did you select?

2. What is the primary field of anthropology addressed in this research?

3. Are there any other fields of anthropology addressed in this research?

4. What aspects of context must be considered as part of this research?

5. How might this research contribute to a comparative approach?

EXERCISE 2 SUBFIELDS OF BIOLOGICAL ANTHROPOLOGY SCENARIOS

Working with a group of your classmates, pick one (or more) of the following scenarios, depending on your instructor's guidelines, and answer the questions that follow. Use a separate sheet of paper if you are completing more than one scenario.

SCENARIO A

Biological anthropologists have discovered a previously unknown fossil species. The species lived about 4.4 million years ago in Africa. The dating of this fossil species places it closer in time to the last common ancestor of humans and chimpanzees than most other known fossil species. This newly discovered species has an interesting mix of traits. For example, it has adaptations for climbing in trees as well as for walking on two legs on the ground. It does not directly resemble any of the living ape species, which suggests the living ape species (including humans) have each become adapted to their own environmental contexts over time.

SCENARIO B

Biological anthropologists have observed several chimpanzees in western Africa making tools to help them hunt. The chimpanzees were seen modifying branches and sticks into spears. They removed any leaves or small branches to make a smooth shaft. They also chewed on the ends of the branches to give them sharp points. They then thrust the sharpened branches like spears into tree trunks, where small primates called galagos make sleeping nests. Although it remains unclear how successful the chimpanzees are in actually killing galagos, multiple members of the chimpanzee group have been observed producing the spears.

SCENARIO C

Biological anthropologists have studied the relationship between stress and female reproduction in a rural community in Guatemala. The researchers collected regular urine samples from women over the course of 1 year. Stress hormone and reproductive hormone levels from the samples were measured to determine a possible relationship between stress and reproductive function. Results suggest that stress may negatively affect reproductive health.

SCENARIO D

Biological anthropologists in Australia were called on to help identify victims of a series of fires. They analyzed the skeletal material for indicators of sex and age, and they compared this information with medical records and other documents to help identify fire victims. The anthropologists worked as part of an interdisciplinary team that was investigating the mass disaster.

QUESTIONS:

1. Which scenario did you select?

2. What is the primary subfield of biological anthropology addressed in this research?

3. How does this research relate to human evolution? In other words, what can we learn about human evolution from research along these lines?

4. Which other scholarly disciplines outside anthropology do you think might be interested in this research? Why would they find this research relevant?

EXERCISE 3 BIOLOGICAL ANTHROPOLOGY NEWS ARTICLE DISCUSSION

Your instructor has provided you with a news article related to biological anthropology. Read the article and answer the following questions with a group of your classmates.

1. What is the overall topic of your article?

2. How does your article relate to human evolution? In other words, what can we learn about human evolution from the article?

3. Who do you think is the target audience for the article?

4. Is the author an expert biological anthropologist? Did the author interview or quote an expert biological anthropologist?

5. Is there some information that might be missing from the article? If so, what might have been left out?

6. Based on what you have discussed about this article, what biases and other factors should you consider when following popular media coverage of biological anthropology topics?

EXERCISE 4 APPLYING THE SCIENTIFIC METHOD

The following scenarios describe observed phenomena. Working with a group of your classmates, pick one (or more) of the scenarios, depending on your instructor's guidelines, and answer the questions that follow. Use a separate sheet of paper if you are completing more than one scenario.

SCENARIO A (HUMAN BIOLOGY)

Previous research shows that some human populations living at extremely high altitudes have larger lungs. Research also shows that at high elevations the oxygen concentration in the air is lower, and people in these areas are at risk of not getting enough oxygen.

SCENARIO B (FORENSIC ANTHROPOLOGY)

Previous research shows that, in humans, the pelvic opening tends to be wider in females than it is in males.

SCENARIO C (PRIMATOLOGY)

Previous research shows that chimpanzee males form stronger alliances with one another than do chimpanzee females. Research also shows that adult chimpanzee females often split up and go to different areas to feed during the day while adult male chimpanzees spend more time together during the day.

SCENARIO D (PALEOANTHROPOLOGY)

Previous research shows that Neanderthals successfully lived in extremely cold environments during the Ice Age in Europe. Research also shows that toward the end of the Ice Age and around the time that humans (*Homo sapiens*) moved into Europe, Neanderthals quickly became extinct.

QUESTIONS:

1. Generate a hypothesis about what causes the observed phenomena in the scenario.

2. Describe the type or types of data you would ideally collect to test this hypothesis.

3. Describe what hypothetical data might support the hypothesis—for example, "The hypothesis would be supported if we found data that indicated ______________."

4. Describe what hypothetical data might cause you to reject the hypothesis—for example, "The hypothesis would be rejected if we found data that indicated ________________."

5. If you rejected the hypothesis, how would you refine and rewrite your hypothesis to account for your findings and begin again?

EXERCISE 5 DATA COLLECTION AND INTEROBSERVER ERROR

Have you ever found yourself debating with someone about the size, shape, or color of an object? You think it is a "large" egg, but someone else thinks it is an "extra large" egg. Or, you think a house is painted "moss" green, but someone else thinks the house is painted "avocado" green. These differences of perspective are quite common and can cause real problems in scientific investigations. In science, the difference between how two or more people observe an object or phenomenon is called *interobserver error*. When collecting data, researchers need to consider the possibility of interobserver error and account for it as much as possible, or their results could be skewed and inaccurate.

To explore how dramatic interobserver error can be, complete the following tasks with a group of your classmates.

STEP 1 Collect the data. Each person in the group takes turns measuring the four objects provided by your instructor. Use the measuring implements your instructor gives you (tape measures, rulers, etc.), and enter your measurements in the appropriate column of your own copy of the chart below. Be sure to keep your measurements to yourself as you go so you don't influence other people's outcomes.

INTEROBSERVER ERROR CHART

	Observer 1 (self)	Observer 2	Observer 3	Observer 4
Object One				
Object Two				
Object Three				
Object Four				

STEP 2 Evaluate and compile the data. Now, compare and discuss your results with your group members, and enter their results in the appropriate columns of your chart as well.

1. What differences do you notice?

2. Choose one object with the greatest difference across observers and explain why you think the difference exists (remember to consider the objects being measured, the tool being used, and the people doing the measuring).

EXERCISE 6 DATA COLLECTION AND EVALUATION

Work with a group of your classmates to read this scenario and complete the tasks and questions that follow.

An employee at a shoe store has observed that taller customers have larger shoe sizes than customers who are shorter. She knows that shoe sizes are based on foot length, so she generates a hypothesis: *Compared with shorter people, taller people have longer feet*. Complete the following steps to apply the scientific method and help the salesperson evaluate her hypothesis.

STEP 1 Collect height data. For each person in your group or class, determine the individual's height using tape measures or measuring sticks. *Hint*: It may be easiest to hang a piece of paper on the wall and have each person stand next to the piece of paper. Mark the maximum height (without shoes on). Have the person step away from the wall and then measure from the floor to that mark on the paper. Make sure only one person does all the measuring so you avoid interobserver error.

STEP 2 Collect foot length data. For each person in your group or class, determine the individual's foot length using tape measures or rulers. *Hint*: It may be easiest to have each person remove a shoe and stand on a piece of paper on the floor. While the person is standing, have another person draw around the outside of the foot, keeping the pencil as close to the foot as possible. Have the person step off the paper and then measure the length of the foot outline from the back of the heel to the tip of the longest toe. Make sure only one person does all the measuring so you avoid interobserver error.

STEP 3 Tabulate the data. On a separate sheet of paper, create a list or chart for your data that shows the two sets of data for each person (height and foot length). For example, you can re-create the chart below with your own data:

Name	Height	Foot Length
Eduardo	5 ft 10 inches	10.25 inches
Jane	5 ft 1 inch	8.75 inches
Susan	5 ft 10 inches	10 inches
Devon	6 ft	11 inches
Tim	5 ft 5 inches	9.25 inches
Lily	5 ft	9 inches

STEP 4 Interpretation

1. Look for patterns in the data. Describe any patterns you find.

2. Based on the data you collected, is the hypothesis supported or rejected? Why?

EXERCISE 7 ETHICS CASE STUDY

Working together with a group of your classmates, read this case study and complete the questions that follow. Remember, when making decisions on ethical research, there may be more than one best or correct answer. The key is your ability to justify your choices and highlight how they abide by the AAPA Code of Ethics.

CASE

A paleoanthropologist conducts research at a remote fossil site in eastern Africa. The anthropologist is a researcher based at a major university in the United States, and he spends 6 weeks every summer excavating and cataloging fossil materials at the site. The anthropologist has been working in this area for over 15 years, and he has formed close partnerships with local scholars and residents. His current field team is made up of students from the United States and from Kenya, as well as professional colleagues from both countries. He also hires residents from the local village to help with the excavations and to act as field staff, including drivers, cooks, and guides.

QUESTIONS: In answering each question, be sure to support your choice with relevant information from the AAPA Code of Ethics.

1. In this situation, the anthropologist is studying fossil materials that are over 2 million years old. From whom should he obtain informed consent for his work?

2. If he continues to work here for the next 10 years, how often should he reobtain informed consent? Should this be done at regular time intervals? Or should it be done only when something changes (for example, if he moves to a different excavation area at the site)?

3. Each summer, the anthropologist hires local residents to help at the site. He compensates them with a small wage that is comparable to their local income standards, but much lower than what he would pay similar workers back in the United States. When the field season ends, he and his financial support leave the community until the next summer. Is he adequately reciprocating with the local residents, or do you have recommendations for how he should modify the financial relationship?

4. One summer, the anthropologist returns to the site at the start of a new field season. He discovers that the same local residents who he hires in the summer have allowed their cattle to graze on the site over the winter while he was gone. The cattle have trampled some of the site and have permanently damaged the irreplaceable fossil materials. How should he proceed?

5. The anthropologist is attending the annual conference of the American Association of Physical Anthropologists (AAPA), and he is chatting with another paleoanthropologist named Jane who works at a nearby fossil site in eastern Africa. Jane asks if he will share his fossil data with her so she can compare the information from the two locations. He is hesitant to do so. He has devoted his career to the information uncovered at this site, and he worries that sharing the data with Jane will undermine his authority in the discipline. How should he proceed?

6. The anthropologist is very proud of the work his team is doing, and he would like to share it with a general audience. What formats might he use to spread the word about his work to the general public? What precautions might he take to make sure the information is spread accurately? Is there anything else he should keep in mind when sharing the research with the public?

CRITICAL THINKING QUESTIONS

On a separate sheet of paper, answer the following questions.

1. How are cultural anthropology and linguistic anthropology similar? How are they different?

2. How are archaeology and cultural anthropology similar? How are they different?

3. How are archaeology and biological anthropology similar? How are they different?

4. Find a current news article, or choose one given to you by your instructor, that discusses a biological anthropology topic. Use that article to answer the following questions.
   - What is the overall topic of your article?
   - In which subfield of biological anthropology do you think this topic most belongs?
   - Are there any other fields of anthropology addressed in this research? If so, which ones?
   - Which other scholarly disciplines outside anthropology might be interested in this research? Why would they find this research relevant?
   - What do your answers to the questions above suggest about the broader significance and relevance of biological anthropology research?

5. In the scientific method, why is it important to generate hypotheses before collecting data?

6. In what way is the scientific method a continuous cycle?

7. How does a nonscientist's view of a theory differ from a scientist's view?

8. In Exercise 5, you and a group of your classmates collected data on the size of several objects and considered the resulting interobserver error. If you were going to use similar measurement data in a scientific investigation, how might you avoid interobserver error? If you were working with previously collected data, and there was no way to go back and avoid interobserver error, how might you account for this error in your results and interpretations?

9. In this lab, we explored the Code of Ethics outlined by the American Association of Physical Anthropologists (AAPA). Many anthropological organizations have similar ethical guidelines that may be relevant to biological anthropologists. Review one of the following ethics codes and describe (1) how the code is similar to the AAPA Code of Ethics, (2) how the code is different from the AAPA Code of Ethics, and (3) what changes you might make to the AAPA Code of Ethics based on what you learned.
   - American Anthropological Association: http://ethics.americananthro.org/category/statement/
   - International Primatological Society: http://www.internationalprimatologicalsociety.org/docs/Code%20of_Best_Practices%20Oct%202014.pdf
   - Society for American Archaeology: http://www.saa.org/AbouttheSociety/PrinciplesofArchaeologicalEthics/tabid/203/Default.aspx

BIOLOGICAL ANTHROPOLOGY IN PRACTICE

Exploring How Fetal Environments Shape Reproductive Health

Dr. Julienne Rutherford is a biological anthropologist whose work integrates evolutionary theory with biomedical science to study aspects of human and nonhuman primate biology (see Lab 1). Julienne grew up in a small town near Cleveland, Ohio. By the time she graduated as valedictorian of her high school class, she had developed a strong interest in the life sciences, specifically evolutionary biology. She double-majored in anthropology and zoology at Miami University in Oxford, Ohio, and she earned a Ph.D. in biological anthropology from Indiana University. Her education and research interests have always been interdisciplinary. While in graduate school, she worked on primatological field projects in Nicaragua and Costa Rica. Today, she is an associate professor in the Department of Women, Children and Family Health Science in the College of Nursing at the University of Illinois, Chicago (UIC).

Julienne's research examines the dynamic maternal environment in which a fetus develops. She studies the development, anatomy, and function of the primate placenta in her lab at UIC to answer questions about the effect of maternal ecology (nutrition, life history experience, and behavior) on placental functional morphology and birth outcomes, as well as the consequences for health later in life. For the past 15 years, she has been working with marmoset monkeys, small-bodied primates that have multiple offspring at once (usually twins) (see Lab 10). She has examined how the period of prenatal development in marmosets affects their reproductive development and function into adulthood and subsequent generations. Julienne and her team use body weight and composition, sonograms of uterine growth from birth to adulthood, and biomarkers of energetic, inflammatory, and reproductive status in the monkeys to determine how their intrauterine development affects their adult reproductive function. For example, she has found that a marmoset mother who was a triplet herself loses nearly three times as many offspring to stillbirth, on average, as a female who was a twin (38% vs. 13%). This cutting-edge work demonstrates that the reproductive performance of adult females is shaped by the environments they experienced as fetuses, and it is critical to our understanding and treatment of reproductive dysfunction (such as infertility and pregnancy loss) in women today.

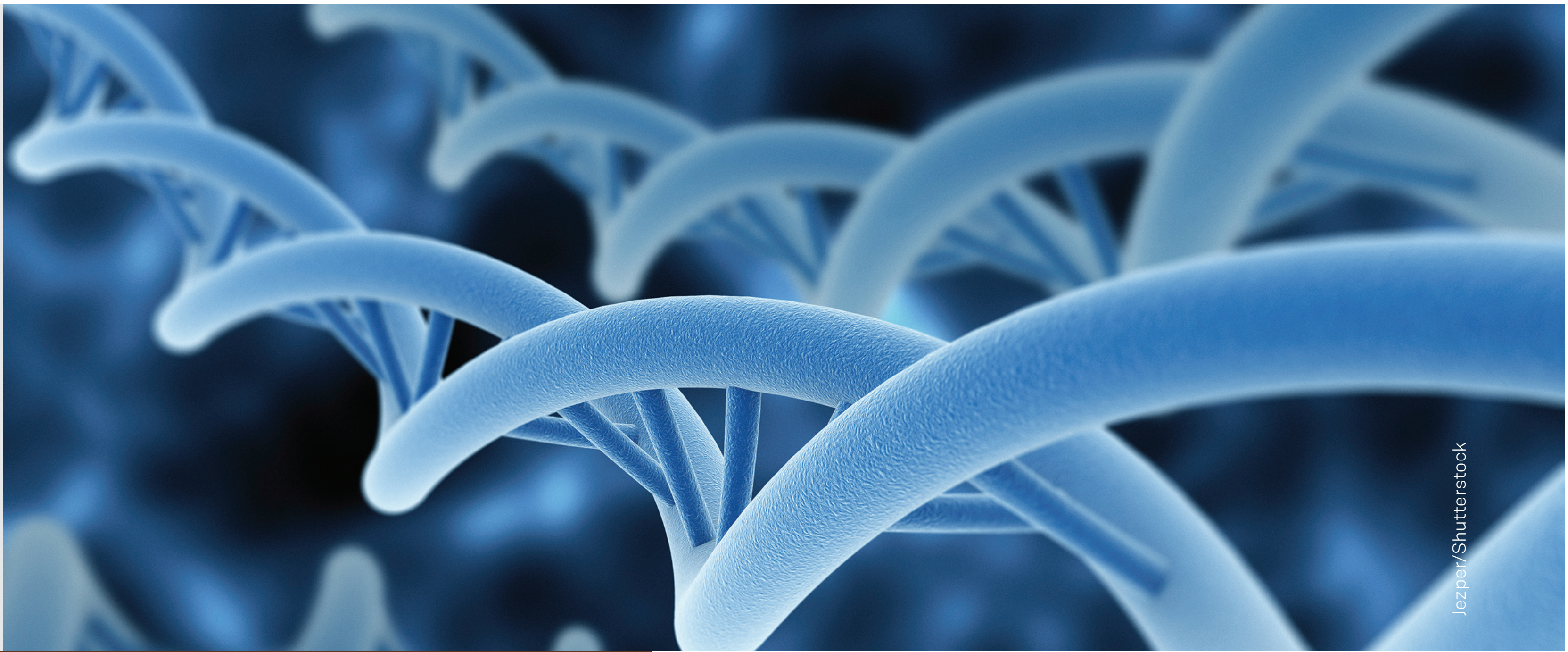
Along with her research interests in biological anthropology, Julienne is deeply passionate about working to eradicate sexual harassment and gender inequity from the sciences. Julienne is one of four co-authors of the Survey of Academic Field Experience (SAFE) studies,[1] who found that sexual harassment and assault are common experiences in field-based sciences (such as anthropology, archaeology, geology, and animal behavior). They found not only that these experiences are common, but also that they contribute directly to the stalling of women's careers. Julienne's research on maternal environments and her work on harassment and gender equity are linked by their shared acknowledgment that nurturing environments early in life, and early in one's career, have lasting consequences for optimal functioning, and both are rooted in premises of social justice.

Julienne's fascinating work requires a strong understanding of human genetics and the processes of inheritance. In Labs 2 and 3, you will get to do your own hands-on work to explore these crucial concepts.

[1]Clancy et al. 2014; Nelson et al. 2017.

Courtesy of Dr. Julienne Rutherford

Dr. Julienne Rutherford prepares a marmoset placenta for microscopic analysis during her doctoral studies at the Southwest National Primate Research Center in San Antonio, Texas.



The genetic code for every organism is housed in its DNA.

Lab Learning Objectives

By the end of this lab, students should be able to:

- describe the basic parts of a cell.
- compare the processes of mitosis and meiosis and describe how meiosis relates to evolution.
- describe the components of chromosomes and DNA and explain the principle of complementary base pairs.
- explain the process of DNA replication.
- explain the process of protein synthesis and compare the transcription and translation stages of that process.

LAB 2

Genetics

It is early March 1953. Researchers have been working off and on for several years on an interesting scientific problem. They have been trying to determine the structure of DNA. So far, scientists have identified the biological compounds adenine, thymine, guanine, and cytosine in DNA, and they recognize that these compounds appear to follow some sort of pattern: the quantities of adenine and thymine are the same, and the quantities of guanine and cytosine are the same. Thanks to the hard work of Rosalind Franklin (**FIGURE 2.1**), many X-ray photographs of DNA have been taken, which show that it has a compact, potentially helical structure. These first steps have made a significant contribution to the understanding of DNA's overall shape and components, but many questions still remain. How is so much information kept in such a tiny package, and what could explain the paired quantities of adenine and thymine and of guanine and cytosine molecules?

After months and months, and a few frustrating missteps, researchers in England are about to answer these questions. The team has a new idea. What if the adenine and thymine bond together in the structure, and the guanine and cytosine also bond together? That idea would certainly explain their similar quantities, but is it real or another false lead?

Science Source

Omikron/Science Source

FIGURE 2.1 DNA Pioneers
Much of what we know about DNA and genetics today is possible because of the work of researchers like (A) Rosalind Franklin whose (B) X-ray photographs of DNA helped reveal its underlying structure.

prokaryote organism (such as a bacterium) that has a cell without a nucleus and is often made of only a single cell

eukaryote organism (such as a plant or animal) that is made of many cells that have cell nuclei

nucleus the area inside a eukaryotic cell that contains most of the cell's DNA

DNA (deoxyribonucleic acid) the chemical that acts as the genetic blueprint for an organism

nuclear DNA the DNA found in the nucleus of a cell

organelle a type of cell part with its own function, like an organ of the body

mitochondria (mitochondrion, singular) cell organelles that produce energy for the cell and that contain their own DNA

Two scientists, Francis Crick and James Watson, get to work building, measuring, and refining a model of DNA based on this idea (and other ideas researchers have pieced together over the past year). The model they construct takes the shape of a double helix with bonded pairs of adenine–thymine and guanine–cytosine running along the core. Their excitement mounts, and over the coming days, weeks, and months, their structure is verified by other scientists and supported by further X-ray photography. This group of scientists has just revolutionized our understanding of life on Earth! Their work, which earns them a Nobel Prize, forms the foundation of our modern understanding of genetics and the passing of traits between generations. Understanding these foundational genetics concepts allows us to better understand how evolution happens, and in this lab we review these concepts with this goal in mind.

INTRODUCTION

We begin this lab with an introduction to cells, the basic building blocks of life. This introduction includes a review of the parts of the cell related to genetics and inheritance and an examination of how cells divide and replicate. We also take a close look at the importance of cell division for evolution. We then focus on DNA—the genetic code passed from one generation to the next. We consider how DNA replicates and how it codes for proteins in the body.

WHAT IS A CELL?

Cells are the most basic units of life. All living organisms are made of cells. Some organisms, such as bacteria, are made of only one cell. The cells of bacteria do not have a cell nucleus, and these organisms are called **prokaryotes**. Other organisms, such as plants and animals, are made of many cells. The cells of plants and animals have a cell nucleus, and these organisms are called **eukaryotes**. We will focus on eukaryotic cells because they are the cells found in humans.

Some of the major parts of eukaryotic cells are the nucleus, the mitochondria, the cytoplasm, and the cell membrane (**FIGURE 2.2**). The **nucleus** contains genetic information in the form of **DNA (deoxyribonucleic acid)**. This **nuclear DNA** holds almost all of the organism's genetic information, which, together with environmental influences, determines the appearance and behavior of an organism. Outside the nucleus, there are various other organelles. **Organelles** are cell parts that have different functions, similar to the special functions of different organs in the body. The *endoplasmic reticulum* is an organelle that holds *ribosomes*, which are important organelles for the production of the body's proteins. **Mitochondria** are organelles that produce "chemical power" for the cell. They take in nutrients and turn them into energy for the cell. Interestingly, mitochondria have their own DNA, separate from the DNA found in the cell nucleus. This DNA is called **mitochondrial DNA (mtDNA)**. This mtDNA has been very useful in attempts to track human lineages and relationships in the past because it is passed directly from a mother to her offspring. The nucleus and the cell organelles, such as mitochondria, are all suspended in the cell in a fluid called *cytoplasm*. Cytoplasmic fluid helps give cells their shape. All of these cell parts are held together by the *cell membrane*. This membrane is a barrier that separates the cell from its surroundings. The

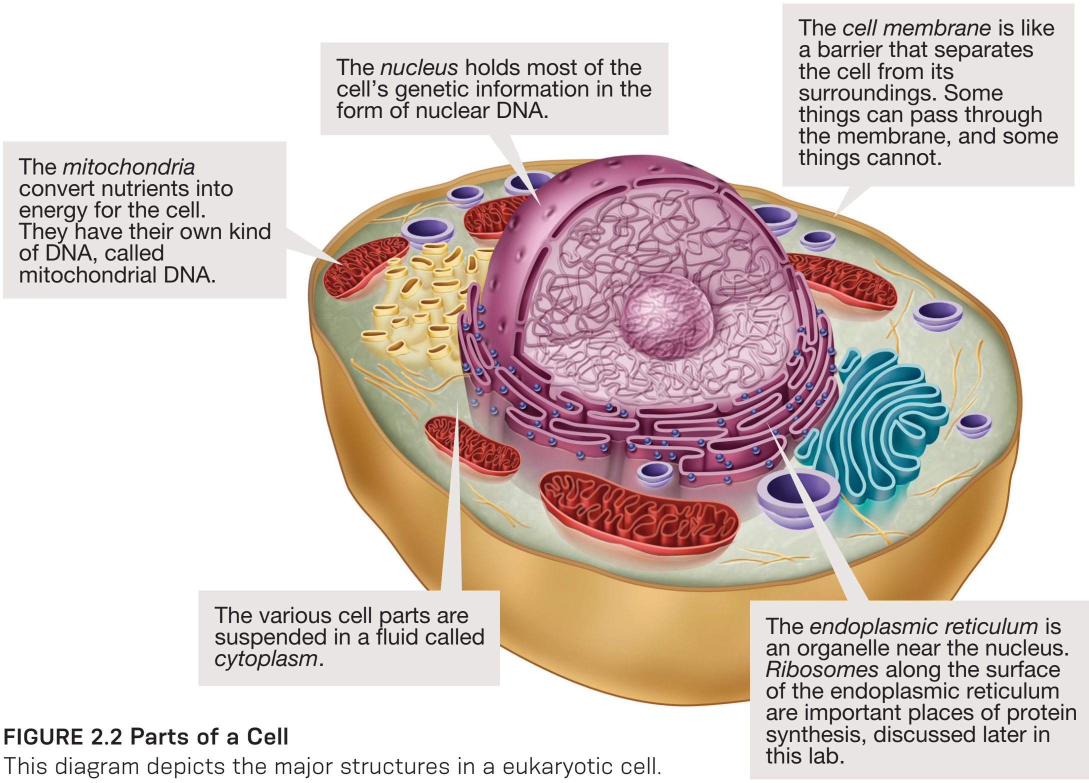


FIGURE 2.2 Parts of a Cell
This diagram depicts the major structures in a eukaryotic cell.

cell membrane is semipermeable, meaning some things can pass through it while others cannot.

THE GENETIC CODE

The DNA found inside the cell nucleus is the genetic information or blueprint for the organism. DNA is a chemical that is organized into **chromosomes** in the nucleus (FIGURE 2.3). These chromosomes are like long threads. A chromosome usually occurs as a single fiber, called a **chromatid**, but chromatids can duplicate and occur in pairs when a cell is about to divide (see below). Chromosomes have an area that is contracted, called a **centromere**. The centromere can be located toward the end of the chromatid or in the middle, depending on the chromosome. This variation makes centromere position a useful tool for identifying chromosomes. Different species have different numbers of chromosomes, but the number of chromosomes found in an organism is not an indicator of an organism's complexity. For example, humans have 46 chromosomes, chimpanzees have 48 chromosomes, and turkeys have 82 chromosomes. None of these organisms is more or less complex than the others.

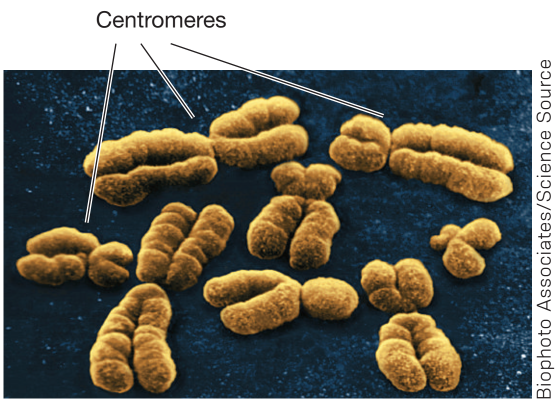


FIGURE 2.3 Chromosomes
These chromosomes, made of paired chromatids, show the diversity of chromosome size and shape. Also, note the different centromere locations on different chromosomes.

Types of Chromosomes

There are two types of chromosomes: the autosomes and the sex chromosomes. The **autosomes**, or non-sex chromosomes, exist in homologous pairs. **Homologous pairs** are sets of matching chromosomes with similar types of genetic

mitochondrial DNA (mtDNA) the DNA found in mitochondria, which is passed from mothers to offspring

chromosome a tightly coiled strand of DNA within the cell nucleus

chromatid a single chromosome fiber that duplicates and occurs in pairs when a cell is about to divide

centromere the contracted area of a chromosome, whose position varies from one chromosome to the next and is therefore useful in distinguishing chromosomes

autosome a chromosome other than one of the sex chromosomes

homologous pair a set of two matching chromosomes with similar types of genetic information, similar lengths, and similar centromere positions

sex chromosome one of the two different chromosomes (X and Y) involved in the determination of an organism's biological sex

X chromosome the larger of the two sex chromosomes, having genetic information related to a wide range of traits

Y chromosome the smaller of the two sex chromosomes, having genetic information that codes primarily for traits related to maleness

nucleotide a set of linked phosphate, sugar, and nitrogen base molecules in DNA

adenine one of the nitrogen bases in DNA; its complement is thymine

thymine one of the nitrogen bases in DNA; its complement is adenine

guanine one of the nitrogen bases in DNA; its complement is cytosine

cytosine one of the nitrogen bases in DNA; its complement is guanine

information, similar lengths, and similar centromere positions. In sexually reproducing organisms, each homologous pair has one chromosome from each of the organism's parents. **Sex chromosomes** are a little different. Although most people have two sex chromosomes, one from each parent, these chromosomes are not truly homologous like the autosomes. The two different sex chromosomes contribute to an organism's biological sex. The **X chromosome** is larger and has genetic information important to both females and males, such as genes that allow for color vision. The **Y chromosome** is smaller and has genetic information that codes primarily for traits related to "maleness." Generally, organisms with two X chromosomes are female, and organisms with one X chromosome from the mother's egg and one Y chromosome from the father's sperm are male. Importantly, only males have Y chromosomes. This means that the father's genetic information, not the mother's, is responsible for determining the sex of offspring. Only the inheritance of the father's Y chromosome can result in a male offspring. This is particularly interesting when considering that in many cultures, in the past and today, women are held responsible for the successful production of male heirs.

DNA Structure

The genetic information on chromosomes is found in their DNA. The DNA has a double-helix shape, similar to that of a twisting ladder or spiral staircase. The sides of the ladder are formed by phosphates and sugars. The rungs of the ladder are made of nitrogen bases. Each set of linked phosphate, sugar, and nitrogen base molecules is called a **nucleotide**. The nucleotides on the two sides of the helix are held together by hydrogen bonds between the nitrogen bases. There are four possible bases in DNA: **adenine**, **thymine**, **guanine**, and **cytosine**. These bases, often abbreviated A, T, G, and C, form complementary base pairs because each one bonds with only one of the other bases. Adenine and thymine always bond together, and guanine and cytosine always bond together (**FIGURE 2.4**).

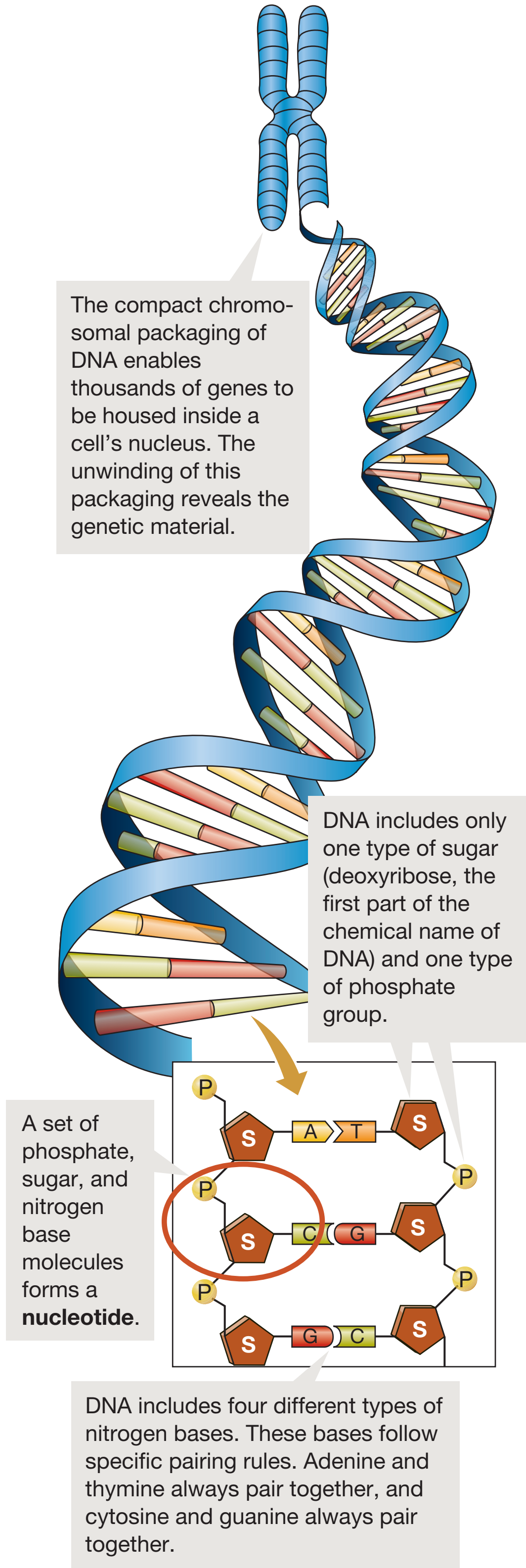


FIGURE 2.4 DNA Structure
DNA has a double helix shape, resembling that of a twisted ladder. The rungs of the ladder are formed by nitrogen bases. The sides of the ladder are formed by phosphates and sugars.

Genes and Alleles

A section of DNA that codes for a particular trait is called a **gene**, and each gene has multiple versions, called **alleles**. For each trait, there are multiple alleles (gene variations). Often, there are even multiple genes for a trait, which multiplies the number of alleles and variations. The genes for particular traits are arranged as part of larger sequences of genes for many traits (FIGURE 2.5). These gene sequences are also interspersed with long sections of nucleotides that do not code for traits but instead act as punctuation marks that separate genes from one another and as regulators that can turn nearby genes on and off. All together, the long strands of twisting genes and other nucleotides make up chromosomes. Chromosomes hold the genetic code that determines how our bodies look and function. The chromosomes act in particular ways during cell division to make sure the right amount of genetic information is passed into the replicated cells.

Representing the Genetic Code: Karyotypes

An individual's or species' chromosomal makeup is often represented in a **karyotype**—a picture of the chromosomes, numbered and laid out in their homologous pairs. Karyotypes are produced by staining chromosomes so that some bases (adenine and thymine) show as different colors than other bases (guanine and cytosine). The chromosomes are then matched to their homologous partners based on similarities in size, centromere location, and dye pattern. The homologous pairs are then arranged and numbered in size order, from largest to smallest. In humans, this treatment results in 23 pairs of chromosomes of different sizes (FIGURE 2.6). The sex chromosomes are often distinguished from the autosomes and placed at the end of the karyotype, despite their relatively larger size. Karyotypes can be used for a variety of purposes, including identifying chromosomal anomalies or comparing chromosomal information across species for classification purposes.

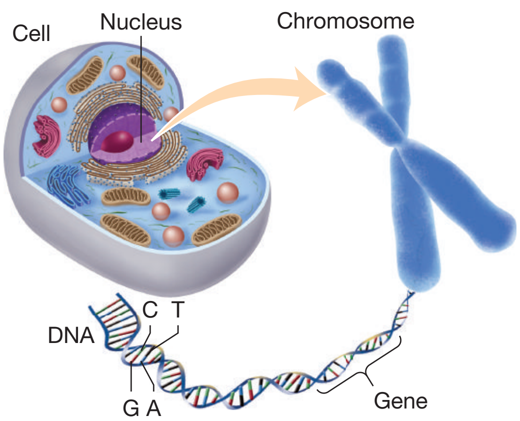
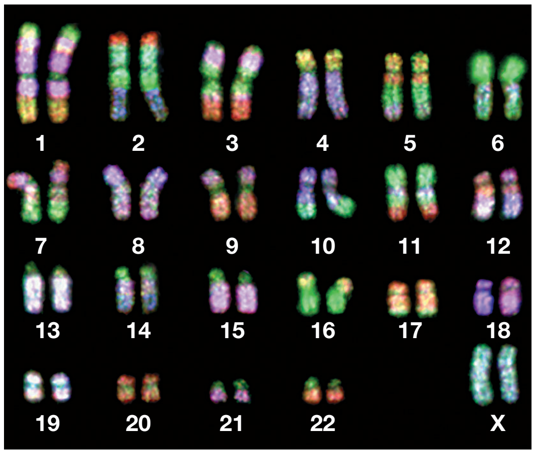


FIGURE 2.5 The Organization of Genetic Material
Sequences of genes form long DNA strands. The DNA strands coil to form the chromosomes in the cell nucleus.



L. Willatt/Science Source

FIGURE 2.6 Human Karyotype
This human karyotype shows 46 chromosomes, arranged in 23 homologous pairs and laid out from largest to smallest. Note that the sex chromosomes are placed at the end of the karyotype. This individual has two X chromosomes, so she is female.

DNA REPLICATION

DNA replication is the process that allows for the duplication of genetic information. It is the important first step in the cell division processes discussed below. During DNA replication, a strand of DNA is copied, resulting in two identical strands where there was previously one. The replication process is very simple (FIGURE 2.7). First, the DNA strand is unzipped by

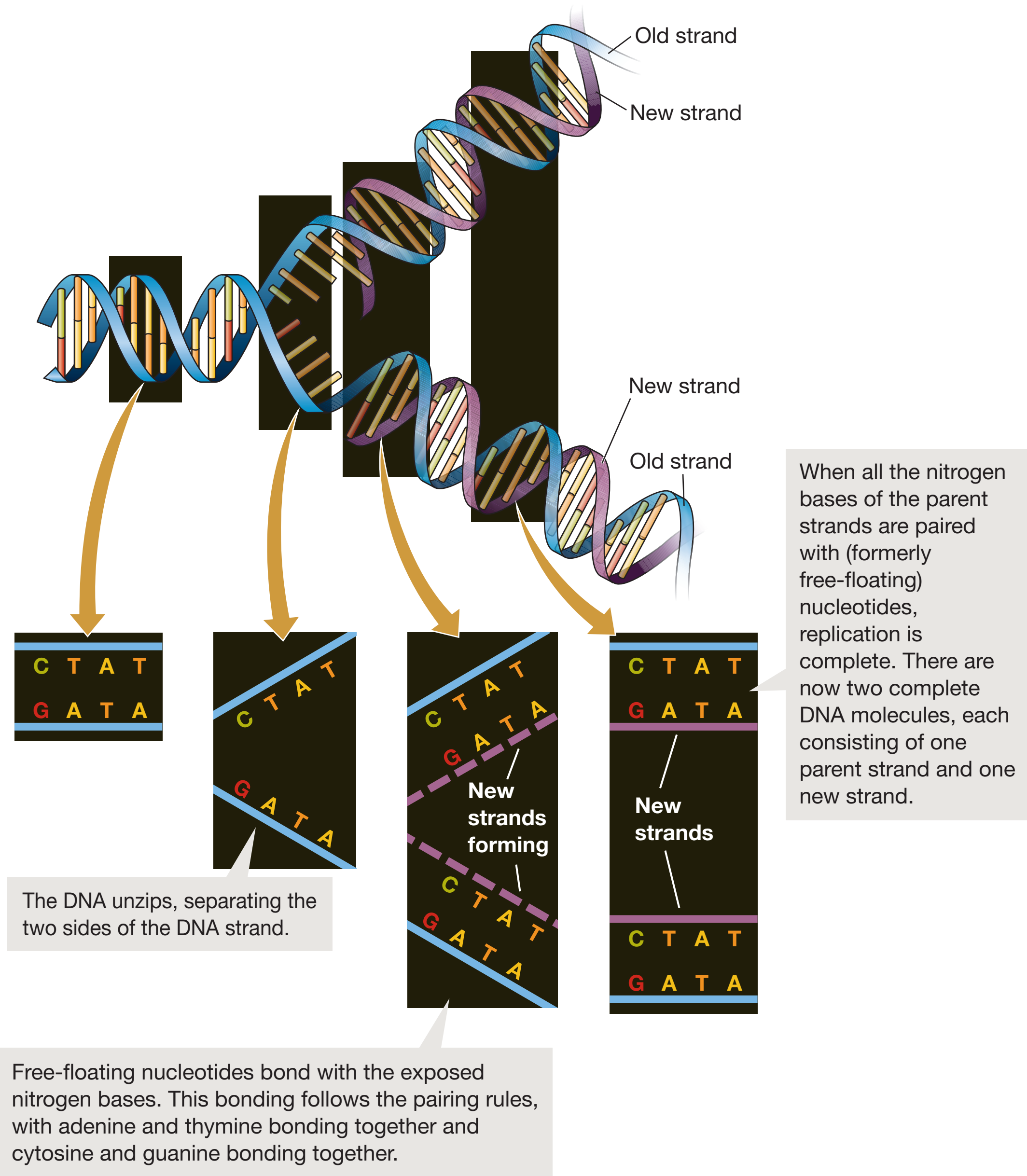
gene a section of DNA that codes for a particular trait

allele an alternative version of a gene

karyotype a picture of an individual's stained chromosomes, arranged in homologous pairs and laid out in order from largest to smallest

DNA replication the process whereby DNA is copied

FIGURE 2.7 DNA Replication
Because all of the bases in a sequence of DNA follow strict pairing rules, one side of a DNA strand can act as the blueprint for a complete strand during DNA replication. The existing nitrogen bases attract complementary free-floating nucleotides.



an enzyme when replication needs to occur. The bonds holding the two sides of the DNA ladder together weaken and allow the two sides to separate. This exposes the nitrogen bases that were previously bonded together. Second, free-floating nucleotides in the cell (sets of phosphates, sugars, and nitrogen bases) line up with the exposed sides of the DNA strand. The nucleotides bond with the nitrogen bases on the strand, making a two-sided strand of DNA.

Because all of the bases in a sequence of DNA follow strict pairing rules, one side of a DNA strand can act as the blueprint for a complete strand. Each base on a side of DNA can determine which free-floating nucleotide is bonded to it. Imagine a DNA strand with a hydrogen bond between adenine and thymine. When this strand separates for replication, the adenine and thymine are exposed and open for bonding with free-floating nucleotides. The exposed adenine can bond only with a free-floating thymine, and the exposed thymine can bond only with a free-floating adenine. When these hydrogen bonds are formed with the free-floating nucleotides, the result is two sections of DNA that both have the same adenine–thymine bond. This structured pairing happens for each of the exposed sets of bases along the DNA strand, and each exposed base matches with its appro-

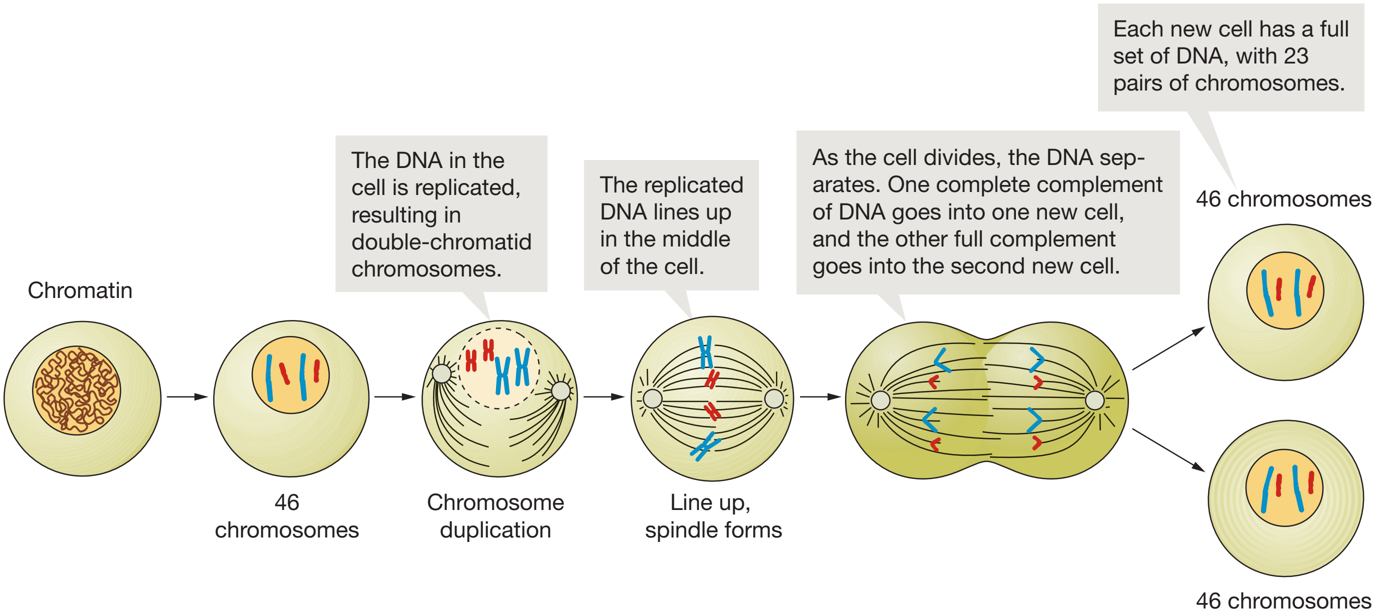


FIGURE 2.8 Mitosis
The process of cell division that takes place in somatic cells is called mitosis. It involves one cell division, and it results in two daughter cells that are exact copies of the original cell.

priate free-floating nucleotide until the strand is duplicated.

CELL DIVISION

Humans have two different types of cells: somatic cells and gametes. **Somatic cells** are also called body cells because they are the cells that make up our different body parts. Hair, organs, bone, fat, and other body parts are made of somatic cells. **Gametes** are called sex cells because they are the cells involved in sexual reproduction. Males have sperm, and females have ova (eggs). New cells are produced through a process called cell division. Generally, cell division in somatic cells occurs through **mitosis**, and cell division in gametes happens through **meiosis**.

In humans, mitosis begins with the 46 single-chromatid chromosomes in a somatic cell. The chromosomes duplicate via DNA replication to form double-chromatid chromosomes. These chromosomes align in the middle of the cell in single file. Then, the chromosomes split apart at their centromeres, and each chromatid goes to a different side of the cell. The cell then pinches in at the middle, leaving two daughter cells that each have a complete set of 46 single-chromatid chromosomes. This process begins with one cell and ends with two daughter cells that are both exact replicas of the original cell (**FIGURE 2.8**). The process of mitosis creates new somatic cells, which allows for growth and repair of damaged tissue in the body.

Meiosis is a little different (**FIGURE 2.9A**). Meiosis begins with a gamete-forming cell containing 46 single-chromatid chromosomes that replicate to form double-chromatid chromosomes. As in mitosis, these chromosomes then line up in the center of the cell, this time with their homologous partners. In this stage of meiosis, each chromosome can exchange genetic information with its homologous partner. This process is called **crossing-over** because genetic information is exchanged between one chromosome and the other (**FIGURE 2.9B**). After crossing-over, the chromosomes separate for the first time. The double-chromatid chromosomes do not split apart, as they do in mitosis at this stage. Instead, the chromosomes remain intact, and the two members of each homologous pair move to different sides of the cell. Then, the cell pinches in and creates two daughter cells. Remember that because of the crossing-over that occurred earlier, some genetic information has been exchanged, leading to new combinations

somatic cell a non-sex cell that makes up different body parts; also called a body cell

gamete a sex cell (in humans, sperm or egg)

mitosis the process of cell division that occurs in somatic cells

meiosis the process of cell division that produces gametes

crossing-over the stage in meiosis during which genetic information is exchanged between the two chromosomes in a homologous pair

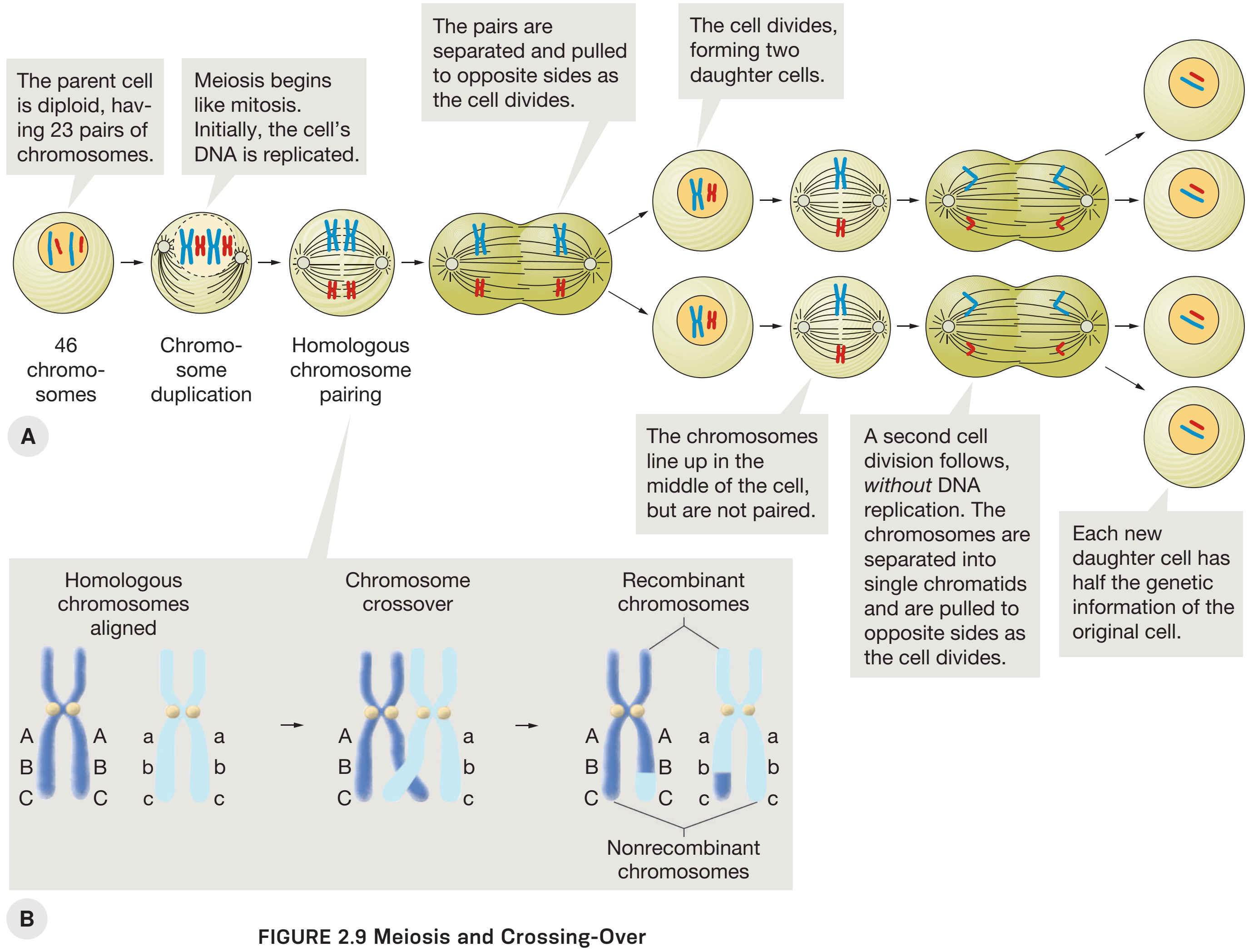


FIGURE 2.9 Meiosis and Crossing-Over
(A) The process of cell division that takes place to make gametes is called meiosis. It involves two cell divisions, and it results in four daughter cells that have half the genetic information of the original cell. (B) Early in meiosis, homologous pairs of chromosomes line up in the middle of the cell and swap genetic information during a process called crossing-over.[1]

of genes that were not present before. This means that the daughter cells are not identical to each other or to the original cell. The two daughter cells then undergo a second division. The double-chromatid chromosomes move to the center of the cell. The double-chromatid chromosomes then split apart at their centromeres, as in mitosis. The now single-chromatid chromosomes move to opposite sides of the cell, and the cell pinches in at the middle, leaving two daughter cells. Because there were two daughter cells after the first division that then divided again, meiosis results in a total of four daughter cells. Each of the four cells has 23 single-chromatid chromosomes (half the genetic information of the original cell) (see Figure 2.9A). The process of meiosis creates gametes (sperm and ova in humans), which are necessary for sexual reproduction.

Meiosis is very important to evolution because it results in **genetic recombination**. This does not mean that entirely new genes are created. It means that the existing genes are mixed up in new combinations. As the chromosomes cross over and the cell is divided, new combinations of genetic information are formed. For example, even if two traits are carried on the same chromosome, they may not necessarily be inherited together. If one of those traits is exchanged with the homologous chromosome during crossing-

genetic recombination the mixing of genetic information into new combinations that occurs during meiosis

[1] Adapted from OpenStax College. 2014. Concepts of biology. OpenStax CNX. cnx.org/contents/b3c1e1d2-839c-42b0-a314-e119a8aafbdd @8.49. Textbook content produced by OpenStax College is licensed under a Creative Commons Attribution License 3.0 license.

over, the two traits become separated. When the cell divides, the two traits will end up in different daughter cells and will not be inherited together. This process leads to genetic variation, and genetic variation plays a key role in evolution. At the same time, each daughter cell created by meiosis carries only half of a parent's possible genes. So, if a person has only one offspring, only half of their genes will be passed to the next generation. If a person has two offspring, there is a greater likelihood of passing on more of their possible genes; however, it is not guaranteed that the parent's entire genome is represented in those two offspring. Remember, the parent's genes are recombined during each meiosis event. There will be some overlap in genes that are passed to both of the offspring, and there will be some genes that are passed to only one offspring and not the other. Even if a person had 100 offspring, some of their genes would never be passed to their children. This variation in genetic recombination and genetic representation across generations is central to evolution.

PROTEIN SYNTHESIS

DNA is the template for proteins in our bodies. Proteins are chemicals that form and regulate tissues in the body, and they are the physical expression of our genetic code. Proteins themselves are made of amino acids, which are produced by the body or obtained through certain foods. The number and combination of amino acids in a protein determine the kind of protein it is. The amino acids that are assembled into a protein are defined by the DNA sequence. So, a sequence of DNA codes for a specific sequence of amino acids, which determines a protein. This process of determining proteins from a DNA sequence is called **protein synthesis**.

There are two primary steps to protein synthesis. The first step is called **transcription**. Nuclear DNA cannot leave the cell nucleus, so the DNA must be transcribed to another form that can leave the nucleus and code for proteins elsewhere (**FIGURE 2.10A**). Transcription, then, is basically a copying process. In fact, it begins very similarly to DNA replication. First, the DNA strand is unzipped, exposing the two sides of the strand. The exposed bases on one side of the strand attract free-floating nucleotides. However, these nucleotides are not DNA nucleotides. They are **ribonucleic acid (RNA)** nucleotides. RNA is similar to DNA, except that its sugar is slightly different and one of its nucleotide bases is different: instead of thymine, RNA has uracil. Uracil in RNA bonds with adenine, just as thymine in DNA bonds with adenine. The cytosine and guanine in RNA bond with each other, as in DNA. The exposed bases on one side of the unzipped DNA strand—called the template strand—bond with the appropriate free-floating RNA nucleotides, following the same base pairing principles seen in DNA replication. This process forms a single strand of RNA called **messenger RNA (mRNA)**. The mRNA separates from the DNA and moves outside the nucleus to the cell cytoplasm, and the original DNA strand stays inside the nucleus and zips back up.

The second step of protein synthesis is called **translation**. During translation, the RNA is translated (or interpreted) to form the sequence of amino acids that makes up a specific protein. Having moved into the cytoplasm, the mRNA now attaches to ribosomes, the organelles where protein synthesis occurs. Inside the cytoplasm, there is another form of RNA, called **transfer RNA (tRNA)**. Each tRNA molecule contains a triplet of bases called an **anticodon**. These free-floating tRNA molecules seek out complementary mRNA triplets, called **codons**. Again, the basic rules of base pairing apply. Each mRNA codon is a series of three bases that will match only the appropriate series of bases in the complementary tRNA anticodon. For example, an mRNA codon of adenine-guanine-uracil will match with a tRNA anticodon of uracil-cytosine-adenine. Each tRNA molecule carries a specific amino acid that corresponds to its anticodon. The mRNA codons are read in order, like you read a line of text on a page. As each mRNA codon is read, the tRNA with the appropriate anticodon and amino acid is brought over. The amino acids are then linked together into long chains to make proteins (**FIGURE 2.10B**).

protein synthesis the process of determining proteins from a DNA sequence

transcription the first step of protein synthesis where nuclear DNA is transcribed into messenger RNA that can leave the cell nucleus

RNA (ribonucleic acid) a chemical that is similar to DNA, except it contains uracil instead of thymine; it plays vital roles in the process of protein synthesis

messenger RNA (mRNA) the RNA formed in the first stage of protein synthesis (transcription) that brings the genetic information from the cell nucleus to the ribosome

translation the second step of protein synthesis where messenger RNA is translated (or read) to form a sequence of amino acids that makes up a protein

transfer RNA (tRNA) a type of RNA that brings amino acids to a ribosome to form the amino acid chains in the second stage of protein synthesis (translation)

anticodon a triplet of bases in transfer RNA

codon a triplet of bases in DNA (or messenger RNA)

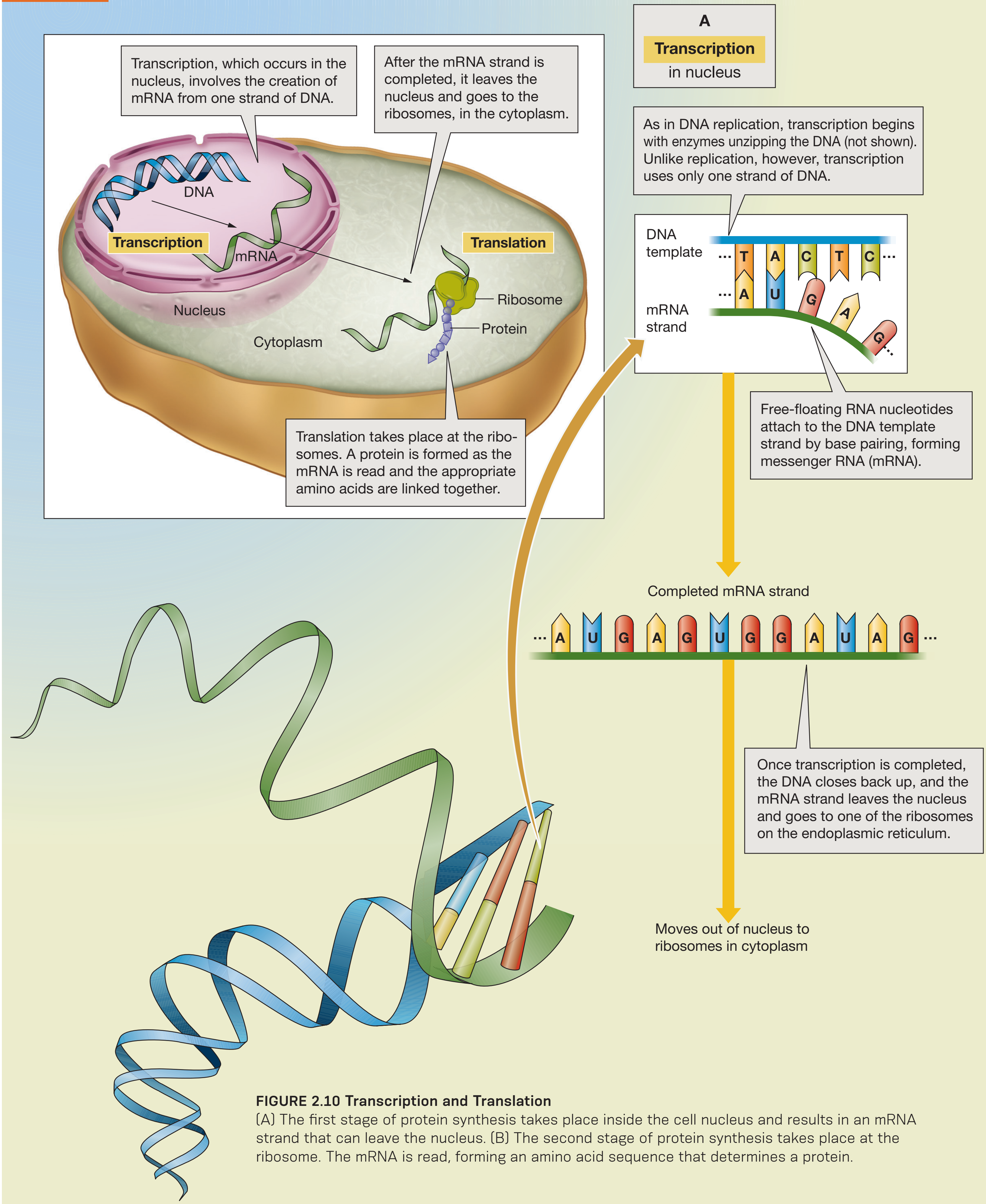


FIGURE 2.10 Transcription and Translation
(A) The first stage of protein synthesis takes place inside the cell nucleus and results in an mRNA strand that can leave the nucleus. (B) The second stage of protein synthesis takes place at the ribosome. The mRNA is read, forming an amino acid sequence that determines a protein.