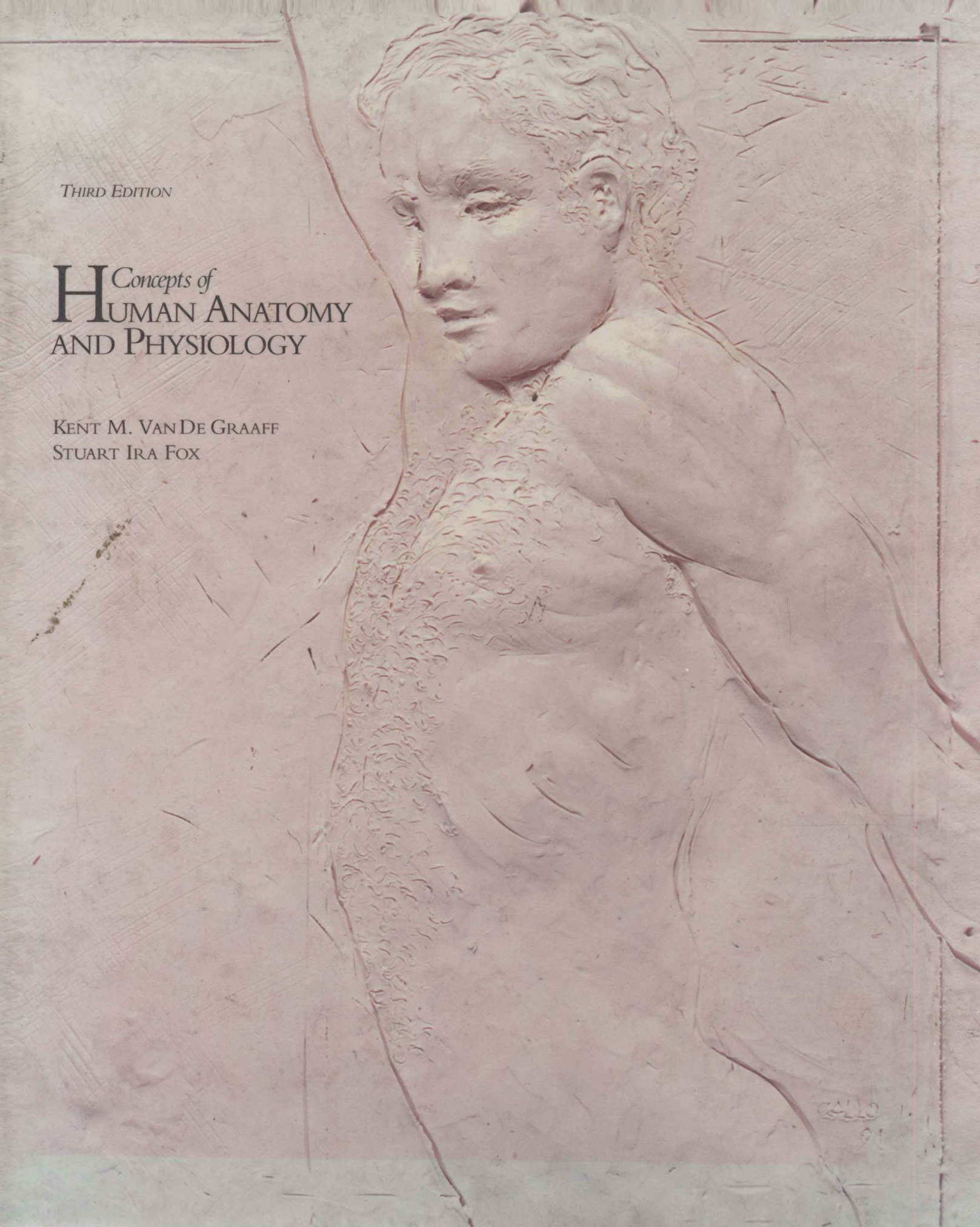
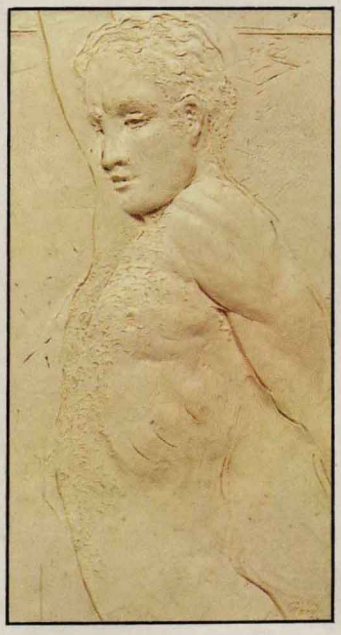
THIRD EDITION

Concepts of HUMAN ANATOMY AND PHYSIOLOGY

KENT M. VAN DE GRAAFF
STUART IRA FOX





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Concepts of HUMAN ANATOMY AND PHYSIOLOGY

KENT M. VAN DE GRAAFF
Brigham Young University

STUART IRA FOX
Pierce College

WCB Wm. C. Brown Publishers

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Concepts of HUMAN ANATOMY AND PHYSIOLOGY

This book could not have been written without the enduring patience and support of our wives, Karen Van De Graaff and Ellen Fox, to whom this book is gratefully dedicated.

Preface

In the third edition of *Concepts of Human Anatomy and Physiology,* we have continued to present the facts of anatomy and physiology around unifying concepts and learning objectives. Complete descriptions and clear explanations, carefully rendered and attractive illustrations, and numerous pedagogical devices help students learn the material in each conceptual unit. The way in which the material is presented promotes understanding, not simply memorization, of the information required in the anatomy and physiology course. The organization of the text also enables instructors to tailor the required text readings to their course needs.

This textbook is designed for students who do not have extensive science backgrounds but who plan to enter health and other careers that require extensive knowledge of anatomy and physiology. Therefore, the chapters in the first unit present basic chemical, cellular, biological, and anatomical concepts. The chapters in the remaining four units then present in detail the anatomy and physiology of organs and systems. Furthermore, descriptions of the frontiers of knowledge, as well as explanations of the experimental basis for the information presented, heighten the excitement of learning. Also, the third edition is scientifically current, containing many new and revised concepts and clinical information that reflect ongoing research efforts.

Organization

The thirty chapters in this text are grouped into five units.

Unit 1: Orientation and Organization of the Human Body. Introductory material containing information about the history of anatomy and physiology, the scientific method, and anatomical concepts and terminology is presented in chapter 1. Chapters 2–6 provide necessary background information on chemistry, cell structure and function, and tissues. Students are shown how this basic knowledge will apply to concepts studied later in the course. These chapters emphasize the fundamental importance of homeostasis in understanding body function.

Unit 2: Support and Movement of the Human Body. The structures and functions of the integument and musculoskeletal systems are described in chapters 7–13. Most of the illustrations within this unit have been rendered new for this edition, with the objective in mind to present clear, informative, and accurate visual depictions of the bones, joints, and muscles of the body.

Unit 3: Integration and Control Systems of the Human Body. The nervous system, sensory organs, and endocrine system are described in chapters 14–19. Likewise many new pieces of color art were rendered in this unit to facilitate student learning.

Unit 4: Regulation and Maintenance of the Human Body. In chapters 20–27, the structure and function of the circulatory, immune, respiratory, urinary, and digestive systems are discussed within the overall theme of homeostasis. Since these systems are of great clinical importance, their basic anatomy and physiology is explained in sufficient detail to allow students to understand important pathological processes. The clincial applications presented in these chapters, in turn, reinforce the basic concepts presented.

Unit 5: Continuance of the Human Species. Chapters 28–30 describe the male and female reproductive systems, prenatal development, human development, inheritance, and aging. The important concepts of these chapters are presented in sufficient depth to promote understanding.

Third Edition

The narrative and illustrations in each chapter have been revised in response to reviewers' and users' comments as well as to new scientific findings. Therefore, students will find the text very readable and visually appealing, and instructors will find that it is scientifically current and accurate. Some of the changes in the third edition include, but are not limited to, the following:

1. All chapters have been reorganized to some extent to improve the flow of information and to enhance understanding. Homeostasis, for example, is presented as a major concept in anatomy and physiology much earlier in the first unit than it was in previous editions.
2. The outstanding illustration program has been greatly improved with this edition and now includes many new pieces, more full color, careful attention to placement near text reference, and the color-coded learning system initiated in previous editions. Where appropriate, illustrated tables have been included for the students to more easily visualize narrative information.
3. Clinical investigations are presented at the beginning of each body system chapter to entice the students into the excitement of learning because of the application of the information that is to be presented. The solution of the clinical investigation appears at the end of the chapter.

4. The information on prenatal development of each body system has been condensed and placed as boxed information with its accompanying illustrations at appropriate intervals of each body system chapter. This makes the information more accessible and uniformly presented throughout the text.
5. The illustrations for this edition have been greatly improved, particularly those of the skeletal, articulations, musculature, and nervous system chapters.
6. An additional chapter has been added to the skeletal system to discuss more adequately the development and physiology of bone.
7. In this edition, the muscular system is covered in two separate chapters: one on muscle tissue and muscle physiology, and one on the skeletal muscle body system.
8. The topic of blood has been added as a separate chapter within Unit 4 on the regulation and maintenance of the human body.
9. Much of the clinical information at the end of each chapter has been updated.
10. The glossary has been expanded to provide a complete listing of pronunciations and definitions of anatomical and physiological terms and processes used in the text.

Pedagogical Aids

This edition of *Concepts of Human Anatomy and Physiology* is organized to maximize students' ability to locate information, associate facts in a conceptual framework, and test their mastery of the material. The wide variety of pedagogical devices within the text further assist students. These devices are described in detail under the heading Student Aids on page xix.

Supplementary Materials

Supplementary materials accompany the text and are designed to aid students in their learning activities and to help instructors plan course work and presentations. These supplementary materials include:

1. A *Laboratory Manual* to accompany *Concepts of Human Anatomy and Physiology,* third edition, by Stuart I. Fox, Kent M. Van De Graaff, and Larry Thouin. The laboratory manual includes information required for each laboratory exercise and requires that students read relevant background information in the textbook before attempting and completing the laboratory exercises. It provides the laboratory experience required to support the lecture portion of the course and includes exercises that have been classroom-tested for a number of years.
2. The *Instructor's Manual for the Laboratory Manual* provides the answers to the questions contained in the laboratory reports in the *Laboratory Manual.*
3. A *Student Study Guide* to accompany *Concepts of Human Anatomy and Physiology,* third edition, by Kent M. Van De Graaff. This study guide aids students in their mastery of the material presented in the course and helps them test their knowledge by taking sample quizzes, answering clinical questions, working crossword puzzles, and adding labels to figures.
4. An updated set of *70 color slides,* which depict important pathological conditions, helps support information given in the text and is free to adopters of this textbook. A narrative describing each slide is provided in the *Instructor's Manual.*
5. A set of *100 acetate transparencies* is available to instructors who adopt this text. The transparencies are made from selected illustrations in the text and have been chosen for their value in reinforcing lecture presentations.
6. *Customized transparencies* are also available. For more information, ask your local WCB sales representative.
7. An *Instructor's Manual and Test Item File* by Kerry Openshaw provides instructional support in the use of the textbook. It also contains a test item file with approximately fifty items for each chapter to aid instructors in constructing examinations.
8. A *Computer Review of Human Anatomy and Physiology* by S. Scott Zimmerman, Thomas V. Davis, and Kent M. Van De Graaff is contained in a thirteen-disk set designed for Apple® II- or IBM®-compatible computers. This computer disk set provides a graphic and innovative way to learn and review human anatomy and physiology.
9. *Knowledge Map of Human Anatomy Systems* by Craig Gundy is a computer tutorial developed for the Macintosh. The computer disk set provides an anatomical review of all the body systems.
10. *Study Cards for Anatomy and Physiology* by Kent M. Van De Graaff, R. Ward Rhees, and Christopher H. Creek. This boxed set of more than three hundred 3-by-5-inch cards presents a well-organized and illustrated synopsis of the structure and function of the human body. Clinical information is presented as it applies to specific body organs and systems or physiological processes. The Study Cards present a quick and effective way for students to review human anatomy and physiology.
11. wcb *TestPak,* a free, computerized testing service for generating examinations and quizzes, is available to instructors who adopt this text.
12. The WCB Anatomy & Physiology Video Series consists of:
    —*Introduction to the Human Cadaver and Dissection* (30 min.; color)
    —*Introduction to Cat Dissection: Musculature* (55 min.; color)
    —*Dry Lab of Blood Drawing/Typing Projects* (30 min.; color)
    —*Internal Organs and the Circulatory System* (58 min.; color)
    —*Human Skeletal System* (51 min.; color)
    These exceptional videotapes are available free to adopters.
    —*Human Skeletal Musculature System* (90 min.; color) Free to qualified adopters.

13. *Anatomy and Physiology of the Heart Videodisc* and *"Slice of Life, vol. V," Anatomy and Physiology Videodisc.*
14. *The Coloring Review Guide to Human Anatomy* by Hogin McMurtrie and James Krall Rikel. This spiral-bound book emphasizes the connections between facts and structures through specific student activities—most notably learning through the process of color association. The Coloring Guide provides a thorough review of anatomical concepts.
15. *Atlas of the Skeletal Muscles* by Robert J. Stone and Judith A. Stone. This book is a guide to the anatomy and actions of human skeletal muscles. The illustrations aid in visual orientation and understanding of the action of the muscles.

Student Aids

The organization and pedagogical devices of this text are designed to help you learn anatomy and physiology. Don't just read this text as you would read a novel. Interact with it. Use the pedagogical tools provided. For example, check off the objectives as they are achieved, and write out the flowcharts and essays asked for at the ends of the sections. The more active you are in your studies, the better you will learn and the more enjoyable the study will become.

The following information about the organization and pedagogical devices in the text will help you use this book to the best advantage.

Unit Introduction

The chapters of this text are grouped into five units, each beginning with an introduction that succinctly summarizes the concepts presented in the unit and lists the chapters in the unit. Read these unit introductions for a general orientation to the topics presented in the units and to learn the common characteristics of the chapters that allow them to be grouped together as a unit.

Chapter Introductions

The opening page of each chapter contains an overview, in outline form, of the contents of the chapter.

Concepts and Objectives

One of the unique attributes of this text is the way in which major headings are introduced. Each major heading begins with a succinct summary of the primary organizing concept in that section, and a list of learning objectives. Read the concepts and the objectives before starting the section, and then check back as you read the section to assure that you have fulfilled the learning objectives.

Study Activities

Each major heading in the chapter ends with a box containing study activities: pictures and flowcharts to draw, essays to answer, and other activities. The more you actually perform these activities, the better you will understand the material presented in the sections. Write these out, rather than just think about them.

Understanding Terminology

Where each technical term first appears in the narrative, it is set off by boldface or italic type and followed by a phonetic pronunciation in parentheses. You should pause in your readings when these appear, and learn the correct pronunciation of the words (you will not be able to remember a term if you can't pronounce it). Then go back and reread the sentence for understanding.

Word Derivations

The derivation of some of the terms in the text are provided in footnotes at the bottom of the page. These are often interesting in themselves, and if you know how a word was derived, it becomes more meaningful and is easier to remember.

Clinical Commentaries

Following a discussion of a basic concept of anatomy or physiology, you may find indented text. These are short discussions of the clinical or practical applications of the preceding information. You will find it enjoyable, as well as instructive, to see how your newly acquired basic science knowledge is applied to clinical and practical problems.

Illustrations and Tables

This text contains abundant tables and illustrations to support the concepts presented. Carefully studying the tables will help you to understand the text more completely, and the summary tables will be useful when you review for examinations. Though many of the figures are visually beautiful, they are constructed with one primary purpose—to illustrate concepts presented in the text. Therefore, analyze and try to understand each figure as it is referenced in the text. This will probably require rereading of sentences, but it is the only way to derive maximum benefit from the information presented.

Chapter Summaries

At the end of each chapter the material is summarized for you in outline form. This outline summary is organized by major headings followed by the essence of textual information. Read the summary after studying the chapter to be sure that you have not missed any points, and use the chapter summaries to help you review for examinations.

Acknowledgments

The third edition of *Concepts of Human Anatomy and Physiology* was greatly improved by comments that the authors have received from the many users of the previous editions. Though there are too many to acknowledge individually, we are deeply grateful to each one. As in the past, our colleagues at our respective institutions have been very supportive and helpful. In particular, we would like to thank professors H. Duane Smith, Lawrence H. Thouin, R. Ward Rhees, James Rikel, William M. Hess, and Ferron L. Andersen.

We also wish to thank friends who have assisted in specific ways. Drs. J. Phillip Freestone, Douglas W. Hacking, and Charles H. Stewart provided professional advice. Dr. Brent C. Chandler provided many of the X rays used in the text. Drs. James N. Jones and Paul Urie assisted in updating the clinical information.

Quality illustrations for this text were provided by a number of talented artists. We are especially grateful for their tremendous contributions.

The editorial and production staffs at Wm. C. Brown have inspired, guided, and shaped this enormous project. We owe a large debt of gratitude to Editor-in-Chief Edward G. Jaffe, Associate Acquisitions Editor Colin H. Wheatley, Developmental Editor Elizabeth M. Sievers, Production Editor Sherry Padden, and many other talented people at Wm. C. Brown Publishers.

Reviewers

We were very fortunate to have a knowledgeable and hard working panel of reviewers, whose forthright criticisms and helpful suggestions added immeasurably to the quality of the final text. The review panel for the third edition included:

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University of California, San Francisco
and Kern Medical Center, Bakersfield, California

Nobel Laureates in Physiology/Medicine

Tobb Wilmoth

Nobel Laureate	Country*	Year of Award	Accomplishment
Emil A. von Behring	Germany	1901	Development of serum therapy for diphtheria
Sir Ronald Ross	England	1902	Studies on the cause and transmission of malaria
Niels Ryberg Finsen	Denmark	1903	Treatment of lupus vulgaris with concentrated light rays
Ivan Petrovich Pavlov	Russia	1904	Work on the physiology of digestion
Robert Koch	Germany	1905	Cultivation of the tubercle bacillus
Camillo Golgi Santiago Ramon Y Cajal	Italy Italy	1906	Structure of the nervous system
Charles Louis Alphonse Laveran	France	1907	Role of protozoa in causing disease
Paul Ehrlich	Germany	1908	Theories on the development of immunity
Elie Metchnikoff	France (USSR)		Description of phagocytosis
Theodor Kocher	Germany (Switzerland)	1909	Work on the physiology, pathology, and surgery of the thyroid gland
Albrecht Kossel	Germany (Switzerland)	1910	Biochemistry of the cell
Allvar Gullstrand	Sweden	1911	Work on the dioptrics of the eye
Alexis Carrel	France	1912	Work on vascular ligature and the grafting of blood vessels and organs
Charles R. Richet	France	1913	Investigations on anaphylaxis
Robert Barany	Austria	1914	Understanding the physiology and pathology of vestibular organs
No Award		1915–1918	
Jules Bordet	Belgium	1919	Discoveries in regard to immunity
August Krogh	Denmark	1920	Discovery of the motor mechanism of capillaries
No Award		1921	
Archibald Vivian Hill Otto Meyerhof	England Germany	1922	Physiology of muscle
Frederick Grant Banting John James Richard Macleod	Canada Canada (Scotland)	1923	Discovery of insulin
Willem Einthoven	Netherlands	1924	Mechanism of the electrocardiogram
No Award		1925	
Johannes Fibiger	Denmark	1926	Discovery of the spiroptera carcinoma
Julius Wagner-Jauregg	Austria	1927	Discovery of the therapeutic value of malaria inoculation in the treatment of dementia paralytica
Charles J. H. Nicolle	France	1928	Studies on the cause and transmission of epidemic typhus
Christiaan Eijkman	Netherlands	1929	Discovery of the antineuritic vitamin
Frederick Gowland Hopkins	England		Discovery of the growth-stimulating vitamins
Karl Landsteiner	United States (Austria)	1930	Discovery of the human blood groups
Otto Warburg	Germany	1931	Discovery of the nature and mode of action of the respiratory enzyme
Charles Scott Sherrington Edgar Douglas Adrian	England England	1932	Functions of neurons
Thomas Hunt Morgan	United States	1933	Function of chromosomes in the transmission of heredity
George Hoyt Whipple George Richards Minot William Parry Murphy	United States United States United States	1934	Discoveries concerning liver therapy against anemias
Hans Spemann	Germany	1935	Discovery of the organizer effect in embryonic development
Henry Dale Otto Loewi	England Germany	1936	Chemical transmission of nerve impulses
Albert Szent-Györgyi von Nagyrapolt	Hungary	1937	Discoveries on biological combustion
Corneille Heymans	Belgium	1938	Discovery of the role played by the sinus and aortic mechanisms in the regulation of respiration
Gerhard Domagk	Germany	1939	Discovery of the chemotherapeutic effects of prontosil
No Award		1940–1942	
Henrik Dam Edward A. Doisy	Denmark United States	1943	Discovery of vitamin K
Joseph Erlanger Herbert Spencer Gasser	United States United States	1944	Functions of nerve fibers
Sir Alexander Fleming Ernst Boris Chain Sir Howard W. Florey	England England (Germany) England (Australia)	1945	Discovery and development of penicillin
Hermann Joseph Muller	United States	1946	Discovery of the production of mutations by means of X-ray irradiation
Bernardo Alberto Houssay Carl F. Cori Gerty T. Cori	United States United States (Hungary) United States (Hungary)	1947	Discovery of how glycogen is catalytically converted
Paul Muller	Switzerland	1948	Discovery of the insect-killing properties of DDT
Walter Rudolf Hess Egas Moniz	Switzerland Portugal	1949	Research on brain control of body
Edward Calvin Kendall Philip Showalter Hench Tadeus Reichstein	United States United States Switzerland (Poland)	1950	Discoveries concerning the suprarenal cortex hormones
Max Theiler	United States (South Africa)	1951	Development of a vaccine for yellow fever
Selman A. Waksman	United States	1952	Discovery and development of streptomycin

*Country of birth is in parentheses.

Nobel Laureate	Country*	Year of Award	Accomplishment
Fritz A. Lipmann	United States (Germany)	1953	Studies on the metabolism of carbohydrates in cells
Hans Adolph Krebs	England (Germany)		
John F. Enders	United States	1954	Cultivation of polio viruses in cell culture
Thomas H. Weller	United States		
Frederick C. Robbins	United States		
Hugo Theorell	Sweden	1955	Studies on oxidation enzymes
Dickinson W. Richards, Jr.	United States	1956	Techniques in treating heart disease
Andre F. Cournand	United States (France)		
Werner Forssmann	Germany		
Daniel Bovet	Italy (Switzerland)	1957	Investigations on antihistamines
Joshua Lederberg	United States	1958	Studies on the biochemistry of microbial genetics
George W. Beadle	United States		
Edward L. Tatum	United States		
Severo Ochoa	United States (Spain)	1959	Discoveries of the mechanisms of synthesis of DNA and RNA
Arthur Kornberg	United States		
Sir R. Macfarlane Burnet	Australia	1960	Studies on immunologic tolerance
Peter Brian Medawar	England (Brazil)		
George von Bekesy	United States (Hungary)	1961	Studies on the function of cochlea
James D. Watson	United States	1962	Determination of the structure of DNA
Francis H. C. Cricks	England		
Maurice H. F. Wilkins	England		
Alan Lloyd Hodgkin	Australia	1963	Research on nerve cells
Andrew Fielding Huxley	England		
John C. Eccles			
Konrad Emil Bloch	Germany	1964	Regulation of cholesterol and fatty acid metabolism
Feodor Lynen	Germany		
Francois Jacob	France	1965	Studies on the regulation of gene activity in the cell
Jacques Monod	France		
Andre Lwoff	France		
Charles Brenton Huggins	United States (Canada)	1966	Treatment of prostate cancer
Francis Peyton Rous	United States		Discovery of tumor-producing viruses
Haldan Keffer Hartline	United States	1967	Research on the function of the eye
George Wald	United States		
Raynar Arthur Granit	Sweden (Finland)		
Robert Holley	United States	1968	Discovery of the genetic codes for amino acids
Har Gobind Khorana	United States (India)		
Marshall W. Nirenberg	United States		
Max Delbruck	United States (Germany)	1969	Studies on the mechanism of the viral infection of cells
Alfred D. Hershey	United States		
Salvadore E. Luria	United States (Italy)		
Julius Axelrod	United States	1970	Studies on the mechanism of neural transmission
Ulf S. Von Euler	Sweden		
Sir Bernard Katz	England (Germany)		
Earl W. Sutherland, Jr.	United States	1971	Research on how hormones work; discovered cyclic AMP
Gerald M. Edelman	United States	1972	Elucidation of the nature and structure of antibody molecules
Rodney R. Porter	England		
Karl von Frisch	Austria	1973	Studies of individual and social behavior patterns
Konrad Lorenz	Austria		
Nikolaas Tinbergen	Netherlands		
George E. Palade	United States (Romania)	1974	Studies on cellular physiology
Christian de Duve	United States (England)		
Albert Claude	United States (Belgium)		
David Baltimore	United States	1975	Studies on the transformation of cells by tumor viruses
Howard Temin	United States		
Renato Dulbecco	United States (Italy)		
Baruch Blumberg	United States	1976	Discovery of the Australia antigen
D. Carleton Gajdusek	United States		Description of slow virus diseases
Rosalyn Yalow	United States	1977	Development of the radioimmunoassay procedure
Roger C. L. Guillemin	United States (France)		Synthesis of peptide hormones
Andrew V. Schally	United States (Poland)		
Daniel Nathans	United States	1978	Studies on restriction enzymes and their use in genetic engineering
Hamilton Smith	United States		
Werner Arber	Switzerland		
Allen M. Cormack	United States (South Africa)	1979	Developing CAT scan technique
Godfrey N. Hoursfield	England		
Baruj Benacerraf	United States	1980	Discovery of the histo-compatibility antigens used in tissue typing
George D. Snell	United States		
Jean Dausset	France		
Roger W. Sperry	United States	1981	Organization and function of the brain
David H. Habel	United States		
Tursten N. Wiesel	United States		
John R. Vane	England	1982	Function of prostaglandins
Sune K. Bergstrom	Sweden		
Bengt I. Samuelsson	Sweden		
Barbara McClintock	United States	1983	Jumping-genes
Ce'sar Milstein	Argentina	1984	Fusion of tumor cells with antibody cells creating hybrids, which have rapid production of pure antibodies
Georges Köhler	West Germany		
Neils Jerne	Switzerland		
Michael S. Brown	United States	1985	Regulation of cholesterol metabolism
Joseph L. Goldstein	United States		
Rita Levi-Montalcini	Italy	1986	Discovery of growth factors: proteins that guide development of immature cells
Stanley Cohen	United States		
Susumu Tonegawa	United States (Japan)	1987	Research, which determined that fragments of genes combine to make millions of different antibodies
Gertrude B. Elion	United States	1988	Discoveries of nucleic acid metabolism that established important principles used in drug treatment
George H. Hitchins	United States		
Sir James W. Black	England		
J. Michael Bishop	United States	1989	Discovery of the cellular origin of retroviral oncogenes
Harold E. Varmus	United States		
Joseph E. Murray	United States	1990	Pioneering organ and bone marrow transplants
E. Donnall Thomas	United States		
Erwin Neher	Germany	1991	Developed techniques to study the physiology of cell membranes.
Bert Sakmann	Germany		

*Country of birth is in parentheses.

Brief Contents

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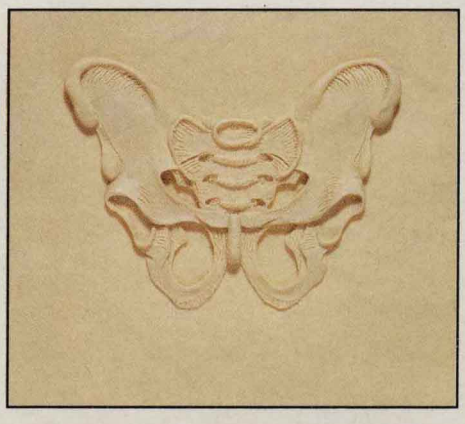
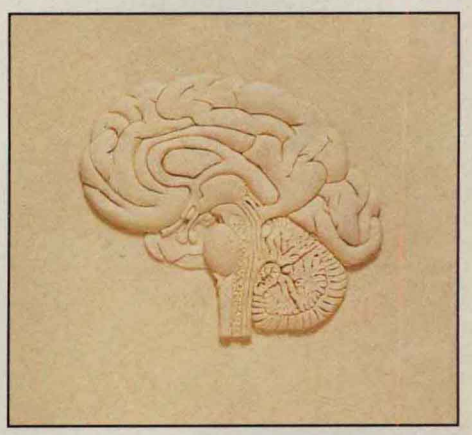
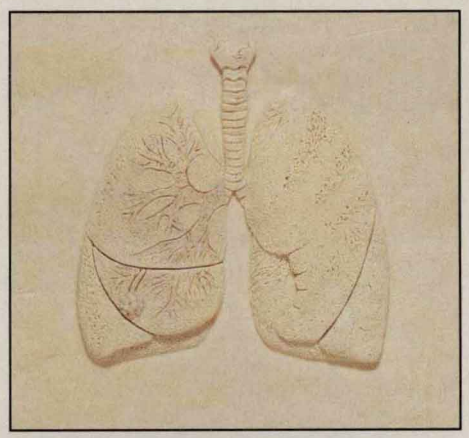




UNIT 3

Integration and Control Systems of the Human Body 334



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