PHYSIOLOGY
and
ANATOMY

BY

ESTHER M. GREISHEIMER
B.S. IN EDUCATION, M.A., PH.D., M.D.

PROFESSOR OF PHYSIOLOGY, TEMPLE UNIVERSITY SCHOOL OF MEDICINE, PHILADELPHIA; FORMERLY PROFESSOR OF PHYSIOLOGY, WOMAN'S MEDICAL COLLEGE OF PENNSYLVANIA, PHILADELPHIA; FORMERLY ASSOCIATE PROFESSOR OF PHYSIOLOGY, THE UNIVERSITY OF MINNESOTA, MINNEAPOLIS

478 ILLUSTRATIONS, OF WHICH 52 ARE IN COLOR

FIFTH EDITION

PHILADELPHIA LONDON MONTREAL
J. B. LIPPINCOTT COMPANY

FIFTH EDITION

Second Impression

Under Government regulations for saving paper during the war, the thickness of this book has been reduced below the customary peacetime standards. The text is complete and unabridged.

PRINTED IN THE UNITED STATES OF AMERICA

This Book
is affectionately dedicated to
those innumerable nurses
whom it has been my privilege
and joy to teach

PREFACE TO THE FIFTH EDITION

The principal changes in the present edition are the revision of the anatomy of the nervous system and the re-arrangement of the physiology of the nervous system, the revision of the chapter on temperature regulation, and the addition of a new chapter on the physiology of aviation.

The chapters on the nervous system are placed rather early in the text, as in the previous editions; this is deemed essential since the nervous system enters into the discussion of the control of all the other systems.

The chapter on temperature regulation includes the work of the last few years on the partition of heat loss under different conditions.

The physiology of aviation is included because nurses are playing such an important part in military aviation; a former student, Dr. G. W. Holt, who is contributing so much in the training of Flight Surgeons, suggested the inclusion of this subject.

Numerous minor changes have been made throughout the text in response to the needs in teaching.

An attempt has been made to bring the vitamins and internal secretions up to date.

Thanks are due to Mrs. Kathleen Weston, who kindly read the revised manuscript, and to the J. B. Lippincott Company for their ever-splendid cooperation.

THE AUTHOR

Philadelphia

PREFACE

This book represents an attempt to present the essentials of anatomy and present-day physiology logically, simply and graphically. It is abundantly supplied with illustrations which should prove an aid, as they have been carefully selected with this in mind. A glossary is added, which may prove of value to many students.

So far as arrangement is concerned, the anatomy of a system is presented first, and then the physiology of the same system. The study of structure is essential to an understanding of the function, and it is natural to most of us to wish to know how something works, once we have seen how it is made. In a few cases, such as the special senses, the reproductive system and the glands of internal secretion, it seemed advisable to present both the anatomy and physiology in one chapter.

At the end of most of the chapters, practical considerations are presented. These are not to be considered a part of the regular required course; they are added because they are of general interest, and they may help to clear up a few of the pathologic conditions which one meets in everyday life. They have developed as a result of the inevitable questions asked by alert students over a great many years of teaching. It is earnestly hoped they will never be studied, but merely read by the interested student. Including them seems justified since the normal structures and functions of the human body have often an added significance when considered in the light of the deviations from the normal.

It will be found that occasionally material is included which one might expect to be covered in other courses, such as chemistry or physics. Some students may not have had these supporting courses, and such material is included for them. As much or as little as may be desired may be selected for study. Surely there are some students who do not need to study the skeletal system in detail. The anatomy of the muscular system is most important to students of physical education, but less important to other groups. The muscles are considered not only in groups, but also according to the joints across which they act, since the physical education student is especially interested in joints and the muscles which move them. Other students may omit this without loss of continuity. The teacher must select the material essential to her particular group, and omit such as may not be needed.

This must be considered as an introductory course, whether given as one aspect of a general education or as a basis for further study of the human body in health and disease. It is hoped that it contains much which should prove of value and interest to all students, and that it is a worth-while addition to any student's general knowledge, for whatever career he pursues. It is intended to help explain things which one is constantly meeting at every turn.

It should be kept in mind that physiology is a young science in comparison with anatomy. The problems of human disease, especially disorders of internal secretions and vitamin deficiency, have necessitated an investigation of the normal functions of the body. So physiology is a growing subject, in answer to demands; new knowledge is constantly added and old theories must be either discarded or re-interpreted in the light of recent experimental results. The physiologist must keep abreast of these rapid changes in medical science which make the present age such a fascinating one. It is earnestly hoped that the student may enjoy this glimpse of how the body is made and of how it functions, and that he may develop an interest in the growing medical science.

THE AUTHOR

CONTENTS

UNIT ONE

THE BODY AS AN INTEGRATED WHOLE

UNIT TWO

THE ERECT AND MOVING BODY

UNIT THREE

INTEGRATION AND CONTROL OF THE BODY BY THE NERVOUS SYSTEM

UNIT FIVE
THE REPRODUCTIVE SYSTEM

AVIATION

PROLOGUE

WHAT HAPPENS TO THE BODY IN CLIMBING STAIRS

In order to emphasize the correlation between the various systems of the body, an analysis of the part played by each system as one climbs stairs will be made.

The skeletal system, of course, is moved upward step by step. It takes no active part except to furnish places of attachment for muscles and to serve as levers.

The muscular system (striated muscles) is brought into play in its entirety. In moving from one step to the next some muscles are contracting and their antagonists are relaxing or being inhibited. In addition, other muscles are acting as synergists and still others as fixation muscles. Practically every striated muscle is brought into play for some purpose. The burden of lifting the body depends on these muscles. In moving the body up a flight of stairs a great amount of work is done. Chemical changes go on in the muscles to furnish the necessary energy.

Let us consider the reason we find a difference between slow climbing and running up the stairs. If we climb slowly enough, we can breathe in sufficient oxygen to take care of the requirements of the active muscles from moment to moment. The lactic acid which is formed in the muscles is disposed of almost as rapidly as it appears. In other words, our muscles recover completely after each step is taken before the next one is attempted. So if we go up slowly enough we do not get out of breath and we can climb for quite a time.

Suppose, however, that we are in a hurry and we climb the stairs rapidly or even run up. We will find that we cannot run up many flights without being entirely out of breath. Such severe exercise as running up stairs can be carried out for only a short period of time even by those of us who are in excellent physical condition. The amount of oxygen which we can breathe in is much less than we need at the time. Lactic acid accumulates, since it is formed in amounts far greater than the maximum oxygen intake can cope with. We can do work far in excess of the greatest oxygen supplies which the heart and lungs can provide at the time, due to the ability to accumulate lactic acid. In other words, we run into debt for oxygen.

After the exercise is over, or after we reach the top of the stairs, we find that we are quite out of breath and it is several minutes before we can breathe normally again. The oxygen debt can be measured by the amount of oxygen used after the cessation of the exercise in excess of the resting oxygen use for the same time. The largest oxygen debt possible seems to be between 15 and 18 liters. This extra oxygen we breathe in after the cessation of the exercise is used to oxidize the lactic acid which has accumulated. In strenuous exercise the recovery of the muscles lags behind. The lactic acid escapes into the blood stream and is found in much greater amounts than during rest. The ability to accumulate lactic acid makes possible the oxygen debt, but the debt is limited and must be paid promptly after the brief period of strenuous exercise is over. The phosphocreatine and glycogen stores are depleted; they are restored during recovery.

The nervous system is most important. Impulses go out over each motor neuron to the muscles involved. All the branches in each active motor unit are used; the number of impulses in each fiber is great. So in active muscles, the muscle fibers are all in use and the numerous impulses bring about a tetanic form of contraction. In antagonistic muscles even the tone is inhibited, so few or no impulses are reaching these muscle fibers over the efferent nerves.

The afferent fibers from the muscles, tendons and joints are just as important as the efferent ones. They tell us the amount and duration of contraction; we could not move the proper amount if these were lacking.

The afferent nerves whose receptors lie in the walls of the great veins are important. These receptors are stimulated by distention of the great veins due to the increased venous pressure during exercise. The afferent fibers, which travel with the vagus nerve, carry impulses to the cardio-accelerator center which in turn sends out impulses to increase the heart rate.

The changes in the circulatory system are important. There is a redistribution of the blood which brings about a greater supply to the active muscles. In the active muscles themselves there are more capillaries opened than during rest, and all are widely open. These changes in the active muscles are due to the increased production of metabolites, such as carbon dioxide. The increase in carbon dioxide brings about another important change; it stimulates the vasoconstrictor center. The end result of this stimulation is a constriction in the vessels of the skin and viscera; with a decrease in size of these vessels more blood becomes available for the muscular circulation. The carbon dioxide has still another important effect; it dilates the coronaries and assures a greater supply to cardiac muscle. The blood pressure rises and the increase in pressure in itself improves the supply to the active muscles.

With the increase in cross-sectional area of capillaries in the active muscles, there is a slowing of the linear velocity of blood flow. The blood takes longer to traverse any particular muscular capillary and this allows more time for the giving up of oxygen. The active tissues are consuming oxygen at a very rapid rate.

The venous return to the heart is increased. This is due chiefly to two factors. One is the squeezing effect of the contracting muscles; each contraction pushes blood along through the veins and the valves in the veins prevent its return, so it is forced along to the heart faster than usual. The other factor which aids venous return is the deeper movements of respiration; these have a greater suction effect in the thorax.

The increased venous return is responsible for two important changes. The one change is the acceleration of the heart rate due to stimulation of the pressor fibers in the great veins by increased pressure or distention. The other change is the effect of better filling of the heart or the effect of stretching the muscle fibers of the ventricles. The greater the initial length or stretch of the fibers the more forceful the contraction. With an increase in rate to 150 or more beats per minute and with an increase in stroke volume to 150 cc. or more, the cardiac output is greatly increased. Six to eight times the entire blood volume may pass through each ventricle per minute. The maximal minute volume of the heart in very strenuous exercise is about 40 liters. Of course, in running up the stairs, only a trained athlete would show such a great increase in cardiac output. Most of us are not capable of such an increase.

We have already mentioned some of the changes in the respiratory system. There is an increase in the rate and depth of the respiratory movements. In addition to getting in more oxygen and getting out more carbon dioxide, these movements favor the venous return, as stated previously. Impulses from the active muscles stimulate the respiratory center and aid in increasing the respiratory movements. The pulmonary ventilation may increase to 50 or more liters per minute. The oxygen consumption increases from about 250 cc. per minute to four liters or more, if we run up the steps very fast. The low oxygen tension in the active muscles and the high carbon-dioxide tension, together with the higher temperature, favor the dissociation of the oxyhemoglobin. The blood gives up much more of its oxygen in passing through the capillaries of the active muscles than it does during rest, or there is a higher coefficient of utilization of oxygen during activity. We have called attention to the oxygen debt we may take on and to the prompt payment of this debt as the exercise ceases.

The digestive system seems to rather suspend its activities during strenuous exercise. The movements and secretions are temporarily decreased. There is a mobilization of liver glycogen; if the exercise is carried to exhaustion, the blood sugar falls. Under ordinary circumstances, running up one flight of stairs would not be accompanied by a fall in blood sugar; it is only when one exercises to the point of exhaustion that this occurs. But if one is called upon to keep up physical exertion, it is well to fortify one's self with candies or readily available glucose.

Of course the excretory system plays a minor role. The urine flow is temporarily decreased during exercise. The elimination of perspiration for purposes of regulating the body temperature is noted.

The endocrine system is involved to some extent. Even trivial exercise is accompanied by the secretion of epinephrine. This in turn aids in the redistribution of the blood, increases the rate and force of the heart beat, dilates the coronaries, mobilizes the liver glycogen, in some unknown way tends to diminish fatigue in striated muscles, relaxes the bronchioles, and helps to increase the number of red blood corpuscles in circulation by causing contraction of the smooth muscle of the capsule and trabeculae of the spleen.

The body temperature may rise during the strenuous exercise; this in itself increases the rate of respiration and the rate of the heart. It also favors dissociation of the oxyhemoglobin. Reflexes are set up which tend to prevent a great increase in temperature; the blood vessels of the skin secondarily dilate and the sweat glands are stimulated. In both these reflexes, the body gets rid of heat.

The special senses play a very valuable part. The eyes are important; if you doubt this, try to run up rapidly with the eyes closed. There will surely be a difference in your rate of speed. The hand on the banister may aid. Impulses are pouring in from the soles of the feet and from every active muscle, the tendons and joints. Even the ears may function; to determine their part, try stuffing the ears with cotton and see if there is a difference in the speed of climbing. All of these incoming impulses from the receptors over the entire