# GRAY'S ANATOMY

## DESCRIPTIVE AND APPLIED

THIRTY-FIRST EDITION


EDITED BY

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*WITH 1317 ILLUSTRATIONS*
*OF WHICH 615 ARE COLOURED*
*AND 52 ARE X-RAY PLATES*


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THE FIRST EDITION OF THIS BOOK

WAS DEDICATED TO

SIR BENJAMIN COLLINS BRODIE, BART.,

F.R.S., D.C.L.,

IN ADMIRATION OF HIS GREAT TALENTS AND IN REMEMBRANCE OF MANY ACTS OF KINDNESS SHOWN TO THE ORIGINAL AUTHOR OF THE BOOK FROM AN EARLY PERIOD OF HIS PROFESSIONAL CAREER.

# PREFACE

TO

# THE THIRTY-FIRST EDITION

In the preparation of the Thirty-first Edition for the press, we have followed our usual practice of revising all the sections with critical eyes and of rewriting those parts where new knowledge has come to light and has established itself in the past few years. At the same time, since every textbook unavoidably accumulates a slowly increasing amount of ' dead-wood ', we have endeavoured to use the pruning knife wherever we have felt justified in so doing. We hope that, as one of the results, the size of the book has been kept within reasonable bounds.

We have again enjoyed the help of Professor Francis Davies and, in revising the Respiratory and the Digestive Systems, he has expanded the parts dealing with the Rectum and Anal Canal, incorporating in them the now generally accepted views of W. B. Gabriel and others.

Responsibility for the remaining sections rests with the two Editors as in the preceding Edition. The descriptions of the functional areas of the cerebral cortex have been rewritten, and every effort has been made to keep the rapidly changing body of knowledge of the functions of the parts of the Central Nervous System up to date.

We have devoted an unusual amount of time and trouble to the replacement of more than three hundred figures which had become worn or threatened to lose their clarity of definition and, in addition, nearly a hundred new figures have been introduced throughout the text, including many coloured illustrations of microscopical anatomy. For the meticulous care he has taken to ensure that the drawings are anatomically accurate, for the character he has succeeded in impressing on them and for the high degree of artistic skill that he has displayed, the Editors are deeply grateful to Mr. S. W. W. Woods, who has again been responsible for most of this work. To Mr. R. N. Lane and to Mr. Peter Drury, who have played a lesser but important part, we wish to express our appreciation of their willing co-operation and skilled draftsmanship.

We gratefully acknowledge the generous help we have received from many of our colleagues and friends and we wish to thank especially: Mr. Murray A. Falconer, Neurosurgeon to Guy's Hospital and to the Maudsley Hospital: Mr. T. T. Stamm, Orthopædic Surgeon to Guy's Hospital: Dr. R. L. Waterfield, Hæmatologist to Guy's Hospital, for the pains he took to provide us with a smear of normal bone-marrow: Dr. T. H. Hills, Director of the Department of Diagnostic Radiology, and the staff of his department for the selective care taken in the provision of a number of new X-ray photographs: Mr. Eric Peet, of the Churchill Hospital, Oxford, who kindly gave us the auditory ossicles from which new drawings have been made: Dr. J. Joseph, University Reader in Anatomy, Guy's Hospital Medical School, for helpful criticisms and for many valuable suggestions: and Dr. G. A. Thomas, Lecturer in Histology, Guy's Hospital Medical School, for much help in supplying us with material for illustrations. We extend our grateful thanks to all those friends, colleagues and others, who have given us permission to use or to

modify their figures, and especially to Dr. Frances Gardner for permission to reproduce her beautiful angiocardiographs and to Dr. C. H. Tonge, who gave us enlargements of microphotographs showing the early stages of development of teeth, and to the staff of the Department of Photography, King's College, Newcastle-on-Tyne. Appropriate acknowledgment is made in the text wherever any of these borrowed figures appears.

In a textbook such as this, experience shows that it is impossible to avoid the occurrence of typographical and other minor errors, and we are glad to express our thanks to those readers, both at home and abroad, who have drawn our attention to them.

The Index is the work of Dr. B. H. Pentney and we are much indebted to him for all the care and trouble he has bestowed on it.

To the Publishers and to the Printers, both of whom have gone out of their way on many occasions to meet our wishes, we are indeed deeply grateful and we believe that we share our indebtedness with the many regular readers of Gray's Anatomy.

T. B. JOHNSTON
J. WHILLIS
*Editors*

GUY'S HOSPITAL
*March*, 1954

# HENRY GRAY, F.R.S., F.R.C.S.

As the readers of *Gray's Anatomy* may be interested to learn something of its original author, Henry Gray, the following information as to his career has been extracted from an article which appeared in the *St. George's Hospital Gazette* of May 21st, 1908.

Gray, whose father was private messenger to George IV. and also to William IV., was born in 1827, but of his childhood and early education nothing is known.

On the 6th of May, 1845, he entered as a perpetual student at St. George's Hospital, London, and he is described by those who knew him as "a most painstaking and methodical worker, and one who learnt his anatomy by the slow but invaluable method of making dissections for himself."

While still a student he secured, in 1848, the triennial prize of the Royal College of Surgeons for an essay entitled, "The origin, connexions and distribution of the nerves to the human eye and its appendages, illustrated by comparative dissections of the eye in other vertebrate animals."

At the early age of twenty-five he was, in 1852, elected a Fellow of the Royal Society, and in the following year he obtained the Astley Cooper prize of three hundred guineas for a dissertation "On the structure and use of the spleen."

He held successively the posts of demonstrator of anatomy, curator of the museum, and lecturer on anatomy at St. George's Hospital, and was in 1861 a candidate for the post of assistant-surgeon. Unfortunately he was struck down by an attack of confluent smallpox, which he contracted while looking after a nephew who was suffering from that disease, and died at the early age of thirty-four. A career of great promise was thus untimely cut short. Writing on June 15th, 1861, Sir Benjamin Brodie said, "His death, just as he was on the point of obtaining the reward of his labours . . . is a great loss to the Hospital and School."

In 1858 Gray published the first edition of his *Anatomy*, which covered 750 pages and contained 363 figures. He had the good fortune to secure the help of his friend, Dr. H. Vandyke Carter, a skilled draughtsman and formerly a demonstrator of anatomy at St. George's Hospital. Carter made the drawings from which the engravings were executed, and the success of the book was, in the first instance, undoubtedly due in no small measure to the excellence of its illustrations. A second edition was prepared by Gray and published in 1860.

The portrait here given of Gray is a reproduction of one which appeared in the *St. George's Hospital Gazette* of May 21st, 1908, where the original is described as being "a very faded photograph taken by Mr. Henry Pollock, second son of the late Lord Chief Baron Sir Frederick Pollock, and one of the earliest members of the photographic society of London."

**R. H.**

# HUMAN ANATOMY

## INTRODUCTION

THE term *human anatomy* comprises a consideration of the various structures which make up the human body. In a restricted sense it deals merely with the parts which form the fully developed individual, and can be demonstrated to the naked eye by various methods of dissection. Regarded from that standpoint, human anatomy may be studied by two methods: (1) the various structures may be considered as individual entities—*systematic anatomy*; or (2) the organs and tissues may be studied as they lie in relationship with one another in the different regions of the body—*topographical* or *regional anatomy*. The practical value of the knowledge acquired through dissection of the cadaver by either line of study can be greatly enhanced by frequent reference to the living body and the identification of those structures which are susceptible of examination through the skin. This aspect of the subject is termed *surface anatomy*. Additional information on the structure of the living body can be obtained with the aid of radiography and, on account of the steady improvement of radiographical technique, the scope of *radiological anatomy* is constantly increasing. Both surface examination and radiography of the living body are of general application, both in health and disease, and are in daily use in medical practice. In addition certain individual organs can be inspected with the aid of instruments specially devised for the purpose, and the text contains many references to these methods of examination.

It is, however, essential to supplement the facts ascertained by naked-eye dissection by those observed by means of the microscope. In this way two fields of investigation are opened, viz. the study of the minute structure of the various component parts of the body—*histology*; and the study of the human organism in its immature condition, from the fertilisation of the ovum to the birth of the child —*embryology*. The importance of the various tissues and organs depends on the functions which they subserve and a very intimate relationship always exists between structure and function.

The changes through which any organism passes from the fertilisation of the ovum until the fully adult form is reached constitute its *ontogenetic history* or *ontogeny*. *Phylogeny*, on the other hand, comprises the evolutionary history of the group to which the organism belongs. Owing to the difficulty of interpreting many of the features of human development, recourse must be had to observations on the development of lower but allied forms—*comparative embryology*.

In its broader conception anatomy deals with the factors which have influenced and determined the form, structure and functions of the constituent parts of the body, and this aspect of the subject is termed *morphology*. In this branch much valuable information is obtained from the study of the anatomy of other animals, or *comparative anatomy*.

The direct application of the facts of human anatomy to medicine and surgery constitutes the subject of *applied anatomy*.

In the earlier stages of the development of all vertebrates there are abundant signs of their evolution from a segmented invertebrate type. In their simplest forms the segments are identical with one another, save for their topographical position, and the individual structures contained in each segment are repeated in the other segments. The segments are said to be *serially homologous* with one another, and identical individual structures, repeated from segment to segment, provide further examples of *serial homology*.

When two structures occurring in different animals have similar ontogenetic histories, even though they may show individual differences in other ways, they are said to be *homologous* with each other. Thus, the wing of a bird, the fore-limb of a horse and the upper limb of a man are homologous structures, for, although they differ widely in their structure and functions, they all develop from identical cell-groups in the embryo. Structures which fulfil the same functions in different animals are not necessarily homologous with one another. The gills, which constitute the respiratory apparatus of the fish, are not homologous with the lungs, which carry out a precisely similar function in man, because they have different ontogenetic histories. Such organs are said to be *analogous*.

SYSTEMATIC ANATOMY.—The various tissues of which the body is composed are built up in different combinations and in varying proportions into organs and structures, which can be arranged in a number of groups or *systems*, according to the functions which they perform.

1. *Osteology*—the bony system or skeleton.
2. *Arthrology*—the articulatory system or joints.
3. *Myology*—the muscular system.

It may be noted that the bony, articulatory and muscular systems, grouped together, constitute the *locomotor apparatus*.

4. *The Blood Vascular System*—comprising the heart, blood-vessels, lymph vessels and lymph glands.
5. *Neurology*—the nervous system. It is convenient to include the organs of the senses in this system.
6. *Splanchnology*—the visceral system. The heart, a thoracic viscus, is included in the blood vascular system, and the remaining viscera are grouped into: (*a*) the *respiratory system*; (*b*) the *digestive system*; and (*c*) the *urogenital system*.

DESCRIPTIVE TERMS.—*For descriptive purposes the body is always assumed to be in the erect posture*, with the arms hanging by the side, and the head, the eyes and the palms of the hands directed forwards. The position is an unnatural one, for it entails lateral rotation of the humeri at the shoulder joints. The *median plane* is a vertical plane which passes through the centre of the trunk and divides the body into superficially symmetrical right and left halves. This plane cuts the anterior surface of the body along the *anterior median line*, and the posterior surface, along the *posterior median line*. The median plane will pass approximately through the sagittal suture of the skull, and hence any plane parallel to it is termed a *sagittal plane*. Vertical planes at right angles to the median plane pass through or parallel to the central part of the coronal suture of the skull; such planes are termed *coronal planes*. Planes drawn at right angles to both sagittal and coronal planes are termed *horizontal planes*.

The terms *anterior* or *ventral* and *posterior* or *dorsal* are employed to describe the front or back of the body or limbs, and the relations of structures within the body to one another. The terms *superior* and *inferior* are used to indicate the relative levels of different structures, but in the study of embryology it is more convenient to use the terms *cephalic* and *caudal* to denote relationships to the head and tail ends of the embryo. The terms *proximal* and *distal* are frequently used in the description of the limbs in place of the terms *superior* and *inferior*. To denote relative distances from the median plane, the terms *medial* (nearer to) and *lateral* (further from) are employed.

The terms *superficial* and *deep* are confined strictly to descriptions of the relative depth of the various structures from the surface ; *external* and *internal* are reserved, almost entirely, for describing the walls of cavities or of hollow viscera. For example, a rib possesses an external surface, which is directed away from the thoracic cavity, and an internal surface, which is directed towards the thoracic cavity.

Special terms are restricted for use to certain regions of the body. For example, *palmar* is frequently used instead of *anterior* in the palm of the hand, and *plantar* is employed in descriptions of the sole of the foot and *peroneal* in descriptions of the lateral or fibular aspect of the leg.

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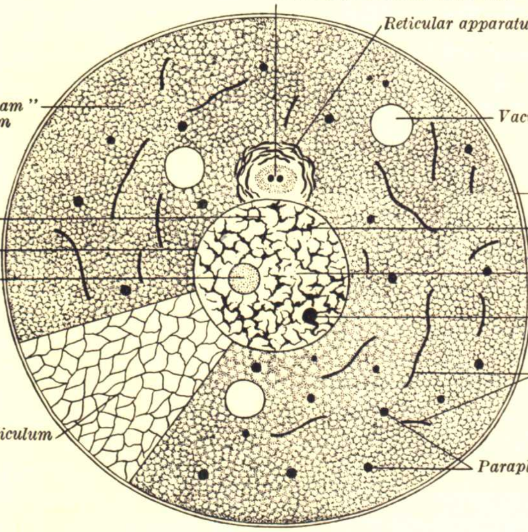
## THE ANIMAL CELL (fig. 1)

ALL the tissues and organs of the body originate from the germ-cell (*ovum*) of the female after it has been fertilised by the germ-cell (*spermatozoön*) of the male. The fertilised ovum divides and subdivides into an enormous number of cells, which become variously modified in size, shape and other characteristics according to their positions and functions. All, however, consist of a viscid, unstable, semifluid substance named *protoplasm*. This is a highly complex material of a colloidal nature, which consists of water and the following substances in solution or suspension, viz. nitrogenous substances (proteins), fatty bodies (lipoids and phospholipins), starches and sugars (carbohydrates), and inorganic and organic salts. When a living cell, healthy and unspecialised, is examined under the

FIG. 1.—A diagram of a cell. (After fixation.)




high powers of the microscope the protoplasm of the cell body (*cytoplasm*) appears to be homogeneous and structureless, save that it contains a small, globular mass, centrally situated, which is termed the *nucleus*. A cell is therefore frequently defined as " a mass of protoplasm containing a nucleus ", but this definition is not altogether satisfactory, because some cells (e.g. red blood-cells of mammals) are non-nucleated, and may carry on their functions for a limited time, while others (e.g. white blood-cells) may be multinucleated.

**The cell-body.**—*After fixation with reagents*, such as mercuric chloride, the protoplasm of the body of the cell appears to consist of a delicate network or *cytoreticulum*, the meshes of which are filled with a more fluid material, named *hyaloplasm*. Granules of fat, pigment or glycogen may be imbedded in the cell-protoplasm, and are collectively spoken of as *paraplasm* ; vacuoles or spherical spaces filled with fluid may also be present. Most cells are surrounded by a thin wall or *plasma-membrane*, formed by a condensation of the cell-protoplasm.

Hitherto there have been two chief views as to the structure of protoplasm : (*a*) that it consists of a *cytoreticulum* the meshes of which are filled with a more fluid material, named *hyaloplasm*, as described above, and (*b*) that it has an *alveolar* or *foam-like* structure consisting of a viscid interalveolar material having the appearance of a honey-comb, and a more fluid substance consisting of separate alveolar spheres suspended in the inter-alveolar material ; when closely packed the spheres assume a more or less angular form. These views were based on the examination of fixed material, but, as already stated, they are not confirmed by the examination of normal living cells.

The **nucleus** is a small, globular structure situated eccentrically within the cell. It contains one or more minute and highly refractile bodies named *nucleoli*, and is readily stained by basic dyes such as carmine or hæmatoxylin. *In fixed and stained preparations* the nucleus exhibits a network (*karyomitome*), the meshes of which are filled with a semifluid substance named *karyoplasm*. The network consists of two constituents, (*a*) a material named *linin*, which stains with acid dyes, and (*b*) a number of more or less discontinuous masses, called *chromatin* because they stain with basic dyes. The karyomitome is condensed around the nucleus to form a distinct *nuclear membrane*.

The **nucleoli** are of two kinds, (*a*) *true nucleoli* or *plasmones*—small, spherical bodies lying in the karyoplasm, and staining readily with acid dyes ; one is usually present but sometimes there are two or three ; and (*b*) *chromatin nucleoli* or *karyosomes*, which consist of localised thickenings of chromatin.

A **centrosome** is present in most cells. It lies near the nucleus, and has the appearance of a small, spherical mass of clear protoplasm. One or two minute particles, named *centrioles* or *central bodies*, are found within it and play an important part in cell-division.

Two other groups of bodies are of general occurrence in animal cells :—

(*a*) The *chondriosomes*, first described in germ-cells undergoing development into spermatozoa, assume the form of small rods, granules or filaments (*mitochondria*). They are soluble in ether and dilute acetic acid, can be stained by iron-hæmatoxylin and other dyes, and are darkened by osmic acid. When the cell divides they are distributed between the two daughter cells.

(*b*) The *reticular apparatus of Golgi*, first described in nerve-cells, consists of a network or a group of granules or rods (*Golgi bodies*) in the neighbourhood of the nucleus or of the centrosome. These bodies are blackened by osmic acid, and are best displayed by Golgi's silver-method. During cell-division the reticular apparatus divides into rods or particles which are distributed between the two daughter cells.

**Reproduction of cells** is effected either by direct or by indirect division.

In *direct division* (*amitosis*) the nucleus becomes constricted in the middle, assuming an hour-glass shape, and then divides into two. This is followed by a cleavage or division of the whole protoplasmic mass of the cell ; and thus two daughter cells are formed, each containing a nucleus. The daughter cells are at first smaller than the original mother cell ; but they grow, and the process may be repeated in them, so that multiplication may take place rapidly. Direct division is said to occur in leucocytes and bone-cells, and in the epithelial cells lining the urinary bladder.

*Indirect division* or *karyokinesis* (*mitosis*) is the common method of division in the higher animals, and the process is characterised by a series of complex changes in the nucleus, leading to its subdivision ; this is followed by cleavage of the cell-protoplasm. The whole process extends over a period of from thirty minutes to two or three hours. Starting with the nucleus in the quiescent or *resting* condition, these changes may be grouped briefly under the four following stages (fig. 2) :

1. *Prophase*.—The nucleolus disappears and a number of wavy filaments, termed *chromosomes*, become apparent. Although present in the living cell and in fixed and stained preparations, they cannot be recognised in the latter before the nucleolus has disappeared. Thereafter they can readily be identified because nucleic acid, liberated from the nucleolus, becomes fixed on them and enables them to be stained. Each chromosome consists of two chromatids or daughter chromosomes lying side by side. The number of chromosomes varies widely in different animals but is constant for all the somatic cells in animals of any given species. In man * the number is forty-eight, of which half are maternal in origin, and half

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