

HUMAN STRUCTURE

- Matt Cartmill
- William L. Hylander
- James Shafland



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Preface

Why study human anatomy? Like other brute facts, the facts of anatomy are not very interesting in themselves. After mere curiosity has been satisfied and the horrid fascination of dissecting a human cadaver has worn off, the study of anatomical facts as an end in itself soon becomes sterile and pedantic. Apart from the purely practical sort of interest that drives artists and surgeons to learn anatomy, there are two chief reasons why the mind is drawn to the scientific study of the body. The first is a wish to understand the body's functioning. The second is a desire to understand why the facts of anatomy should be as they are—that is, to explain human structure.

The two questions are closely related. To understand function is to explain a lot, because there are functional reasons for most anatomical facts. Ears are evidently built to receive sounds, and feet seem to be made for walking on. This sort of straightforward functional explanation was good enough for early scientific anatomists, whose demonstrations of the detailed correspondences between form and function in animal bodies provided theologians with compelling arguments for the existence and wisdom of a divine Creator.

But as knowledge of anatomy and understanding of function accumulated, it became painfully evident that some facts could not be explained in functional terms. It was all very well to invoke the infinite wisdom of the Creator in accounting for the marvelous intricacies of the human hand or eye; but there were other situations where form and function were less perfectly matched, and it seemed inappropriate to blame these on Providence. Some differences between species of animals are apparently just plain arbitrary; for instance, birds have their aorta on the right side and mammals have theirs on the left, but there is no corresponding difference in function. Some organs have no apparent function at all—for example, the little muscles of the external ear in man, which can make the ear twitch slightly in some people, but not in others, and serve no useful purpose

in either case. Finally, and worst of all from the standpoint of natural theology, some organs appear to be downright ill-designed. There is no evident reason, for instance, why the human testicle could not develop in the scrotum; but as a matter of fact it develops just below the diaphragm in the embryo and then creeps down the inside of the belly muscles to slip out into the scrotum, dragging its blood vessels and ducts along with it. As a result of this peculiar arrangement, human males are prone to a variety of painful and occasionally fatal maladies, including inguinal hernia and varicose testicular veins. It is not very satisfying from either a scientific or a religious standpoint to explain this questionable contrivance as the handiwork of God. Evidently, anatomy is subject to constraints of some sort beyond the mere requirements of good design.

As we understand them today, these constraints are those imposed by history, of two sorts: the history of the individual and the history of the individual's ancestors. Neither can be understood without some knowledge of the other. We may think of any organism as a pattern of organization through which matter is continually passing, like an enormously complicated wave or vortex. Eventually such patterns develop instabilities and collapse—waves break, tornados disintegrate, and people die. Simple physical patterns like waves and tornados are endlessly being brought into existence by the forces of nature, but animals and plants are too complicated for that. The long-term survival of a biological pattern of organization depends on that pattern's capacity to incorporate more and more matter into new duplicates of itself. This duplication, or reproduction, is inexact. Random changes accumulate through many duplications. Usually these changes render the altered pattern less stable, so they and their possessors vanish from the scene. When they do not—when hereditary changes persist and spread—the result is long-term historical change: biological evolution.

The evolutionary history, or phylogeny, of a species is the sum of changes in its pattern of ontogeny (the anatomical history of a typical individual) from generation to generation. Because every individual's ontogeny is on the whole like those of its ancestors (with modifications), a developing organism goes through phases and develops organs that it has no use for itself but that were important to its ancestors.

For example, the shoddy design of the human testicle becomes understandable when we know something about its ontogeny and

phylogeny. In early fishes, the testis was an appendage of a kidneylike organ, the mesonephros, which filtered wastes from the blood and dribbled the resulting urine into a long hollow duct leading to the anal end of the gut. The testis lay alongside the mesonephros and ejected its sperm into the same duct. When the ancestors of land-dwelling vertebrates gave up life in the water, they needed a more efficient, water-conserving urinary organ. Eventually an improved auxiliary kidney with its own separate duct evolved. In time, this new kidney replaced the mesonephros. But the mesonephros could not be given up altogether, because its duct was needed by the testis. The mesonephros in a human embryo develops alongside the backbone just below the liver (as it would in a fish or a salamander), stays around long enough for its duct to hook up with the testis, and then regresses and disappears. This leaves the testes sitting up under the liver. In a lizard or a turtle, they would stay in that spot. But the high body temperatures of mammals prevent sperm from maturing; so the testes of fetal mammals must be relocated to a cooler, more external position. In human beings, they descend before birth into the scrotum alongside the penis, drawing their ducts and blood vessels along with them—and creating a line of weakness along which herniating loops of intestine can push their way into the scrotum, too. The testes develop in the abdomen for reasons of ontogenetic necessity, dictated by phylogenetic history. Their descent into the scrotum is a makeshift demanded for physiological reasons, not the best anatomical arrangement that could be imagined. To understand the anatomical facts, one must understand all these factors.

Unfortunately, standard textbooks of human anatomy offer a lot of description and very little explanation. What little explanation they provide is mostly functional, though some textbooks add a smattering of embryology. The phylogenetic aspect of anatomy is almost wholly ignored. This deficiency is not exactly a flaw in the standard textbooks; they are just presupposing a traditional educational background that can no longer be taken for granted. The enormous growth in biological knowledge at the cellular and molecular levels during the last thirty years or so has tended to oust the traditional mudpuppy-and-fetal-pig sort of comparative and developmental anatomy from the preprofessional curriculum in the health sciences. There is nothing wrong with this trend in principle, but it has meant

in practice that students increasingly lack the background in comparative anatomy and embryology that they need to digest a fact-crammed textbook of human gross anatomy.

This book is intended as an aperitif to promote such digestion. It is the product of fifteen years of experience in teaching an abbreviated "core course" in gross anatomy to medical and allied health students at Duke University. Compelled by curriculum reforms to teach human anatomy in one-quarter the time previously allotted to that subject, we hit upon the plan of presenting the anatomical facts as a series of regional variations from a schematic vertebrate ground plan—the typical body segment—in an idealized primitive fish or human embryo.

We begin this book with an exposition of the segmental organization characteristic of vertebrates. We then undertake a description of the most obviously segmented parts of the human body: the bones, muscles, vessels, and nerves of the trunk between the neck and the pelvis. From this, we progress through regions where the basic plan has undergone more and more radical modifications, and we end the book with the ancient and extreme specializations found in the head. At each step, we show how these modifications have been imposed, ontogenetically or phylogenetically, upon simpler precursors. We hope that this kind of analysis will help our readers to grasp the logic of the human body from the outset and to fit each new fact they encounter into a single explanatory picture, so that rote memorization can be reduced to a minimum.

We have found in our teaching experience that some students find thinking more painful than memorizing. Such students shrink from explanations, which for them represent only an additional strain on the memory. This book is intended not for them but only for those students of anatomy who, like the book's authors, welcome any expedient that reduces the number of unexplained brute facts that need to be hammered into memory. We think that most students who approach the study of anatomy in this way not only will find it easier and more enjoyable to assimilate the facts of human anatomy but also will come to understand the fascination that anatomy holds for scientific investigators. That fascination lies, not in the facts of anatomy, but in the interpretation of those facts as a transient stage in a historical process of great beauty and unparalleled complexity.

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The great majority of the illustrations in this book are the work of scientific illustrator Dorothy L. Norton. We are thoroughly indebted to her for executing hundreds of complex drawings with unfailing artistry, intelligence, and good humor in the face of a demanding and erratic schedule. Whatever value this book has for its readers has been greatly enhanced by the elegance and clarity of her work. Figures 1-3, 1-4, 1-6, 1-7C, 1-8, 6-1 through 6-8, 7-1 through 7-10, and 7-12 are from the accomplished pen of Margaret L. Estey, whom we thank for her valuable contribution. Figures 2-4 and 7-11, drawn by Dorothy Norton and the senior author respectively, derive from draft versions by Ms. Estey. The senior author is also responsible for Figures 14-14, 15-1, 17-8, and the labeling of all the figures. Figures 1-7, 9-4, and 10-2 were redrawn after figures in *Medical Embryology* by J. Langman, copyright © 1963; by permission of Williams & Wilkins Company, Baltimore. Figures 5-1, 5-9A, 8-3, 8-9, 10-7, and 19-11 were redrawn after figures in *Grant's Method of Anatomy*, 10th ed., by J. V. Basmajian, copyright © 1980; by permission of Williams & Wilkins Company, Baltimore, and J. V. Basmajian. Figures 6-2, 10-1, 13-12, 19-7, 19-8, and 21-1B were redrawn after figures in *The Vertebrate Body*, 5th ed., by Alfred Sherwood Romer and Thomas S. Parsons; copyright © 1977 by W. B. Saunders Company; by permission of CBS College Publishing. Figure 7-12 was redrawn after a figure in *A New System of Anatomy*, 2nd ed., by Lord Zuckerman, copyright © 1981; by permission of Oxford University Press. Figure 9-16 was redrawn after a figure in *Primary Anatomy*, 7th ed., by J. V. Basmajian, copyright © 1982; by permission of Williams & Wilkins Company, Baltimore, and J. V. Basmajian. Figure 22-5 was redrawn after a figure in *Cunningham's Manual of Practical Anatomy*, 12th ed., by G. J. Romanes, copyright © 1976; by permission of Oxford University Press.

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VERTEBRATE ANATOMY
AND THE
SEGMENTED TRUNK

PART I
