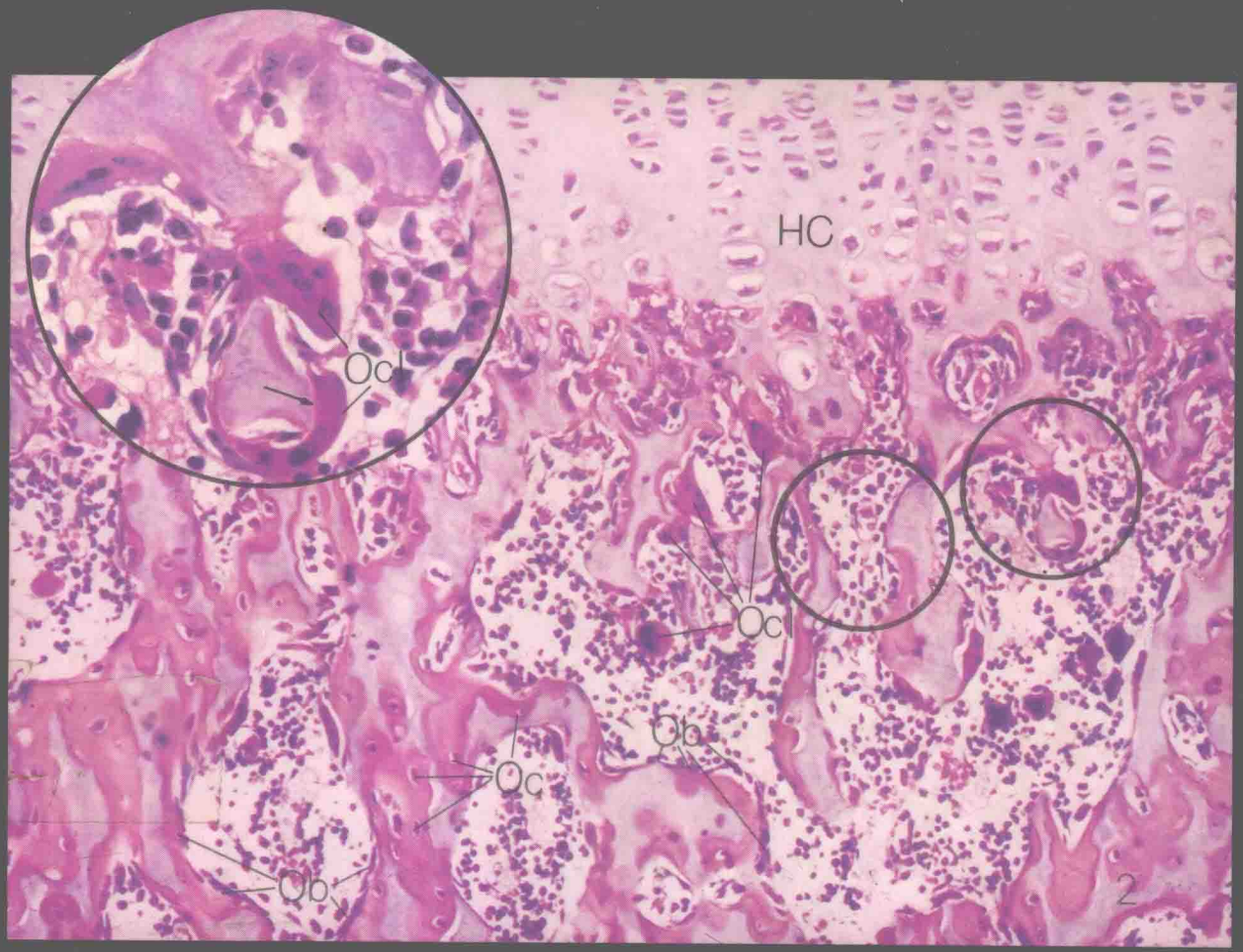
HISTOLOGY

A TEXT AND ATLAS

SECOND EDITION



MICHAEL H. ROSS/LYNN J. ROMRELL

HISTOLOGY

A TEXT AND ATLAS

SECOND EDITION

MICHAEL H. ROSS, Ph.D.

Professor and Chairman
Department of Anatomy and Cell Biology
University of Florida School of Medicine
Gainesville, Florida

EDWARD J. REITH, Ph.D.†

Professor and Chairman
Department of Anatomical Sciences
Temple University School of Dentistry
Philadelphia, Pennsylvania
† *Deceased*

LYNN J. ROMRELL, Ph.D.

Professor
Department of Anatomy and Cell Biology
University of Florida School of Medicine
Gainesville, Florida

With Illustrations by Lydia V. Kibiuk

WILLIAMS & WILKINS
Baltimore • Hong Kong • London • Sydney

Editor: Kimberly Kist
Associate Editor: Victoria M. Vaughn
Copy Editor: Shelley Potler
Design: JoAnne Janowiak
Illustration Planning: Wayne Hubbel
Production: Barbara Felton

Printed in the United States of America

First Edition 1985

Library of Congress Cataloging in Publication Data

Ross, Michael H.
Histology : a text and atlas / Michael H. Ross, Edward J. Reith, and Lynn J. Romrell; with illustrations by Lydia V. Kibiuk. — 2nd ed.
p. cm.
Includes index.
ISBN 0-683-07368-0
1. Histology. 2. Histology—Atlases. I. Reith, Edward J. II. Romrell, Lynn J. III. Title.
[DNLM: 1. Histology—Atlases. QS 516 R825h]
QM551.R67 1989
611'.018—dc19
DNLM/DLC
for Library of Congress

88-20811
CIP

89 90 91 92 93
1 2 3 4 5 6 7 8 9 10

HISTOLOGY

A TEXT AND ATLAS

SECOND EDITION

Dedicated to Edward J. Reith (1925–1985)—and his wife, Addie, and his children, John, Christopher, Mary Ann, and Paul—all of whom contributed to Ed's qualities as a gifted teacher, scientist, and concerned individual.

Preface to the Second Edition

The first edition of *Histology: A Text and Atlas* was conceived at a time when advances in cell and tissue biology were being made in a rapidly moving stream, as continues to be the case today. The question faced was how does one incorporate this burgeoning new knowledge into a text in a manner that enables the student of histology to absorb the "pertinent" new information along with basic information on the microstructure of cells, tissues, and organs. Clearly numerous compromises needed to be made to attain a text of manageable scope for professionals as well as undergraduate students. Moreover, the concept of incorporating a free-standing atlas as an addendum to the text also presented some uncertainty. While an atlas has its place largely in the lab (as well as for review), it was felt that the appending of the atlas to the text, or vice versa, depending on how one wishes to view it, would have considerable value. This enables students to have the text at hand when in the laboratory and, thus, to resolve many questions relating to didactic information.

With respect to the use of color in the Atlas section of the book, other uncertainties emerged, particularly related to the possibility that we were doing a disservice to our students by suggesting to them that color itself is important. We clearly do not feel that students should rely on color as they study and interpret the structure of the cells and tissues of the body. However, we judge the book a success in meeting students' needs on the basis of selling out three substantial printings in less than 3 years. The success of the book and its increasing popularity resulted in its being unavailable for a short period before this new edition published by Williams & Wilkins.

This brings us to two important questions: How does this second edition differ from the first edition, and why a new publisher? The major change that is evident as one peruses this second edition of the book is the addition of text in two chapters where previously only the Atlas section was included. These are the chapters on the Eye and the Ear. Other chapters have been revised to varying degrees; many of the changes were the outcome of suggestions of our colleagues. New figures have been added, other figures were deleted or modified, and, of course, identified errors have been corrected. Pertinent new information has been included. To help make the text manageable, items that can be regarded as significant, but to some extent outside of the direct scope of histology, have been boxed to identify their ancillary significance to the basic information. The least changed area in this new edition is the Atlas section. Here major emphasis has been directed toward simplifying the text while maintaining a concise descriptive account of cell and tissue structure and organization. Because histological structure is not a changing entity, the basic pictorial material in the Atlas section did not require dramatic revision at this time.

With considerable regret we made the decision to leave Harper & Row Publishers. We have had an extremely long and enjoyable association with them. Our departure was based on uncertainties where buy-outs and takeovers in the corporate world can create changes that are not always in the best interest of each of the internal parts. Facing the possibility that the College and Medical Divisions could be divested we felt that problems might arise in the preparation of the second edition of the book. Therefore, we made the decision to go with our new publisher, Williams & Wilkins. The strong interest on the part of Williams & Wilkins led us to believe that an equally good relationship would exist for the production of the second and future editions of *Histology: A Text and Atlas.*

Michael H. Ross
Lynn J. Romrell

January 1989

Preface to the First Edition

In recent years a variety of new histology textbooks have been published. In many ways these books are in contrast with the more traditional texts that had been the mainstay for teaching the subject matter of histology over the decades. The impetus for this new generation of books—though they are varied in approach, content, and design—appears to have one common denominator, which is to provide for the student the kind of basic information that can be assimilated in a reasonable but shortened time frame. In a sense we are faced with a paradox, for, on the one hand, there has been a major growth of information in all areas of histology and, at the same time, these newer books are reduced in length; and, unfortunately, explanations of important background material are often omitted.

In writing this book an attempt has been made to present the student with the pertinent subject matter of histology and, at the same time, to focus on many of the newer salient findings of cell biology as they relate to the understanding of cell, tissue, and organ structure and function. In effect, we too have presented a condensation of what is found in many of the larger textbooks, but every attempt has been made to create a condensation of information that will fulfill the student's needs in histology. In addition, we have made an attempt to present the information so that it will serve as an effective building block for understanding the cellular basis of pathology, physiology, endocrinology, and other basic sciences.

An attempt has also been made to maximize the number of photographs and other illustrations to complement the general text material. To this end, color has also been used lavishly. This has been done with the realization that color has become an increasingly stronger element in the way that we learn. Indeed, we are firmly entrenched in media color. In effect, the color that is used here is simply an extension of another mode of color in communication.

The present book departs from previous histology texts in that it has been combined with an atlas. To this end, we have attempted to incorporate the positive aspects of our previous book, *Atlas of Descriptive Histology*. The one major change relating to the atlas material that is included in this book is, as we have mentioned, the utilization of color. The authors preach just as vehemently as before that it is structure that is important in the understanding of histology, and consequently there is no need to excuse black and white as a basis for learning. However, it is clearly evident that color captures a reality, perceived or otherwise, that is more consistent with the mode of learning of most of today's students. With the patience of the instructor, the student can still be taught the value of basic structure in the learning of histology and at the same time benefit from the new dimension of color which is so much a part of learning in other fields.

The reader will also note that there is a certain repetition between the text and the atlas sections that follow most chapters of the book. It is hoped that this repetition will create a reinforcement in learning. However, it should also be recognized that the text portion of the book restricts itself in large part to theoretical aspects of cells, tissues, and organs, whereas the atlas section restricts itself to the identification of structure and the reasoning that should go into learning how to identify structures.

In summary, it is hoped that this book will satisfy the student's need in learning and, despite its brevity, create sufficient stimulation so that the learning process is enhanced, not diminished.

Acknowledgments

As we publish this second edition of *Histology: A Text and Atlas,* we again express our appreciation to those individuals who have made this work possible through their help, advice, and inspiration. We are particularly grateful for the opportunity to have known and worked with Dr. Edward J. Reith. His excellence in teaching, passion for discovering the essence of things around him, and enthusiasm for science and life, in general, continue to be an inspiration to us and to all those who had the opportunity to know him.

The impetus to write the first edition grew from our positive experiences with students and colleagues with whom we have worked in teaching and in a variety of other roles. We wish to acknowledge the many kind and supportive words of former students who used the *Atlas of Descriptive Histology* in their study of histology and also of colleagues who recommended the *Atlas of Descriptive Histology* to their students. We are also grateful to those who have responded positively to the first edition of *Histology: A Text and Atlas* and especially to those who have offered suggestions for improving the book. These suggestions have been extremely helpful in the preparation of this second edition.

We again thank Carl Zeiss Inc. for providing a grant, which defrayed much of the cost of producing the photomicrographs, Ernst Keller of Carl Zeiss Inc., U.S.A., and Heinz Gundlack of Carl Zeiss, Oberkochen, West Germany, provided technical assistance and invaluable information. The section on the proper use of the microscope written by Mr. Keller is also acknowledged. Finally, with respect to color photomicrographs, the quality of these reproductions is due to the efforts, patience, and technical skill of Denny Player. His contribution in preparing the enlarged positive transparencies from which the color separations were made is evident throughout the book.

A major contribution was made by Dr. Kyle Rarey of the Department of Anatomy and Cell Biology, University of Florida College of Medicine. He contributed the text and many of the illustrations and micrographs in Chapter 24. His expertise on the anatomy and physiology of the ear will be appreciated by all who read this chapter. We also appreciate the efforts of Dr. Christopher West whose critical reading and suggestions on the first seven chapters of the text have been extremely helpful in updating this section of the text which covers various aspects of cell and molecular biology.

Special thanks also go to a number of our colleagues. We appreciate the suggestions and other contributions of Drs. Johannes Rhodin, George Pappas, Gordon Kaye, Bernard Tandler, Tom Hollinger, Kelly Selman, John Terzakis, Ernest Kallenbach, Bryce Munger, Dorothy Zucker-Franklin, Carl Feldherr, Albert Farbman, Toichero Kuwabara, Craig Tischer, and Wilhelm Kriz. We thank them and other unnamed colleagues for their positive impact on this book.

We are also indebted to Lisa Booher and Christi Hughes who played an important role in the preparation and review of the manuscript. Their careful attention to detail has made possible the efficient preparation of the manuscript for this edition. Finally, we acknowledge the advice and assistance provided by the staff of Williams & Wilkins; special thanks are due to Vicki Vaughn, Bob Och, Wayne Hubbel, and Barbara Felton.

Michael H. Ross
Lynn J. Romrell

Contents

1 Methods

Most of the materials examined on a firsthand basis by students taking a histology course are routine paraffin sections stained with hematoxylin and eosin (H&E). These specimens are on the "slides" handed out during laboratory sessions; they are examined with the light microscope and they represent a major part of the histology course. The subject matter of histology, however, goes far beyond what can be learned by the examination of routine H&E paraffin sections. Indeed, it is the objective of histology to understand not only the microanatomy of cells, tissues, and organs, but also to learn as much as possible about their function in structural terms. The methods employed by histologists are extremely diversified and, while much of the histology course content can be framed in terms of light microscopy, the more detailed interpretation of microanatomy rests with the electron microscope, both transmission and scanning, because of its greater useful magnification, that is, its greater resolving power.

Histologists also utilize specialized procedures such as histochemistry and autoradiography, specialized methods for examining tissues such as cell, tissue, and organ culture, and specialized microscopic techniques to visualize the specimen. The student might feel removed from such procedures because direct experience with them may not be available in a busy curriculum. Nevertheless, it is important to know something about specialized procedures and the data that they yield. This chapter provides a survey of methods and offers an explanation of how the data provided by these methods can help the student acquire a sound appreciation of histology.

TISSUE PREPARATION FOR HEMATOXYLIN AND EOSIN STAINED PARAFFIN SECTIONS

The preparation of a stained tissue section on a slide is described in greater detail than other topics presented in this chapter, because this is the type of specimen examined most often by the student and because the methods involve certain basic principles that also apply to other methods.

The first step in preparing a tissue sample for examination with the light microscope is fixation. This step preserves the structure of the tissue and prepares it for future treatments. Numerous chemicals and mixtures of chemicals are used as fixatives; one of the most widely used is formaldehyde. This fixative, a solution of which is called ***formalin,*** may be used simply with buffers or it may be used in combination with other fixatives. Formaldehyde reacts with amino groups of proteins and, thus, is a good fixative for preserving the general structure of the cytoplasm and the nucleus because of their protein content.

After the tissue has been fixed, the fixative is washed out of the sample and the tissue is dehydrated so it can be embedded in a hard substance, such as paraffin, for slicing it into thin sections. Dehydration is typically accomplished by passing the tissue through a graded series of alcohol solutions up to 100 percent. This step removes the water from the tissue and permits it then to be placed in a nonaqueous liquid, such as xylene, which is miscible with melted paraffin. Next, the tissue is infiltrated with melted paraffin and allowed to cool and harden. The hardened paraffin, containing