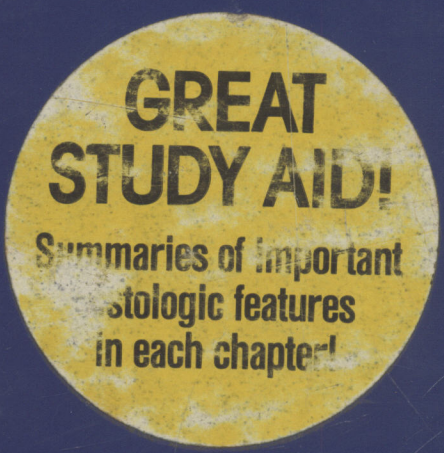
ATLAS OF HISTOLOGY



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ATLAS OF HISTOLOGY

Dedicated to our wives
Roseann and Nancy
and to our children
Jennifer, and Drew, Beth and Kurt

Preface

This atlas was written for students, being mindful of the fact that most enter the study of histology without the realization that the two-dimensional structure they see in their microscope slides is representative of a three-dimensional tissue. It is a concept that is difficult to grasp and even more to apply. Usually, without previous experience, the mental reconstruction of two dimensions into a three-dimensional structure takes several weeks of laboratory work. But then, for most, things begin to fall into place, and with the recognition of histologic features, the laboratory experience becomes a valuable learning tool. Moreover, the student also comes to the realization that the colors of a particular collection of slides appear different from those of classmates' slides and perhaps much different from those the instructor elects to use on practical examinations.

Furthermore, the student also comes to accept the fact that to gain the most from the laboratory aspect of histology, one must study the morphology of the cells, the association of cells and intercellular materials within a tissue, and, to a great extent, learn to disregard colors. It is for these important reasons that the authors elected to produce an *Atlas of Histology,* composed of black and white photomicrographs.

This atlas was designed to provide the student with a laboratory experience that will facilitate learning the material at hand. Each chapter begins with a discussion of the structure and function of the tissue or organ system, providing a capsule description of the material being studied. The photomicrographs are arranged in a logical sequence where low power overviews are followed by higher magnifications, zooming in on significant aspects of the subject matter. Pertinent electron micrographs have also been included to illustrate points of special significance. Finally, 18 of the 19 chapters close with a summary of histologic features, which may be utilized as a review in studying and preparing for practical examinations. It is here that key words are presented in boldface type, which should help to conjure up a sequence of images in the student's mind, providing instant feedback information as to which aspects of the material need to be reviewed before taking an examination.

The photomicrographs in this atlas are of tissues stained with hematoxylin and eosin, unless otherwise noted. Each figure is supplied with the final magnification, which takes into consideration the photographic enlargement as well as that achieved by the microscope. Many of the sections were prepared from plastic embedded specimens, as noted. Many of the exquisite electron micrographs included in this atlas were kindly provided by our colleagues throughout the world as identified in the legends.

Unlike most atlases of histology which are used primarily in the laboratory, this atlas is designed to assist the student in preparing for both practical and didactic examinations. While we have endeavored to be accurate and complete, we realize that shortcomings, errors, and omissions arise in an undertaking of this type. Therefore, we welcome criticisms, suggestions, and comments that will assist us in improving this atlas.

Acknowledgments

We would like to thank Gary Miller for his painstaking work in the dark room; Leslie McLeary for printing our electron micrographs; Jerry Gadd for his excellent illustrations of blood cells; Sangok Yim, Janet Levitas, Mary Eccleston, and Liz Tinnel for their careful typing of the manuscript; members of our department for their support; and our many colleagues who provided us with electron micrographs. A special note of thanks is extended to Mr. Whit Fowler and the Nikon Corporation for generously providing us with a Nikon Optiphot microscope equipped with an HFX automatic microflex photographic system. We would also like to thank our many friends at Williams & Wilkins, including Maryalice Ditzler and Debbie Tourtlotte for their copy editing; Wayne Hubbel and Lorraine Wrzosek for their careful handling of the illustrations; Joanne Janowiak for her designs; Ray Reter for his excellent attention to the details in production; Pamela Caras for her guidance; and especially Vicki Vaughn, our Associate Editor, who was always there when we needed her. A special thanks also to Linda Napora, our Managing Editor and John Gardner, Editor-in-Chief, for having the faith.

Finally, we wish to thank our families for their enthusiastic support of our endeavor, and whose unflagging presence made it all worthwhile.

Baltimore

Leslie P. Gartner
James L. Hiatt

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Chapter 1

The Cell

The cell is the basic structural and functional unit of complex organisms. Although cells assume a myriad of morphologic characteristics and may become specialized to perform one or a number of particular functions, they possess enough common properties that they may be described in a general fashion.

All cells possess a limiting membrane, the plasmalemma, within which is the semifluid protoplasm. The protoplasm is subdivided into two compartments, the cytoplasm, which houses organelles and inclusions, and the nucleus, which contains the genetic information necessary for the coordination of many cellular activities.

CYTOPLASM

The cytoplasm houses numerous organelles, many of which are composed of membranes, microtubules, microfilaments, and granular accretions of proteinaceous materials. These structures will be described as they are observed with the electron microscope.

The cytoplasm is surrounded by an external limiting membrane, the plasmalemma (cell membrane), a bimolecular phospholipid layer in association with various integral and peripheral proteins. The plasmalemma acts as a selective barrier, and it also functions in transport of materials in and out of the cell; cellular recognition phenomena; intercellular adhesion and communication; as the site of receptor-mediated reactions; and transmission of impulses.

Mitochondria

Membranes also form many of the organelles required for cellular functions. Mitochondria, composed of an outer and a folded inner membrane, produce energy for intracellular use. The folds of the inner membrane, known as cristae, provide sites for many of the biochemical enzyme systems, such as the citric acid cycle and the electron transfer system, which participate in the synthesis of ATP via oxidative phosphorylation. Mitochondria may also function in steroid synthesis and the regulation of intracellular ion concentrations.

Endoplasmic Reticulum

Most cells possess a series of anastomosing, membrane-bound tubules and cisternae, and associated vesicles, known as the endoplasmic reticulum. Some of these structures are studded with ribosomes, which impart to it a granular appearance when viewed with the electron microscope; thus, these are referred to as rough endoplasmic reticulum. In contrast, another type without the attached ribosomes is known as smooth endoplasmic reticulum. The rough endoplasmic reticulum functions in the synthesis and modification of proteins destined for delivery to the Golgi apparatus, while the smooth endoplasmic reticulum is utilized by certain cells in steroid synthesis, detoxification, and control of calcium ion concentrations.

Ribosomes

Ribosomes are bipartite proteinaceous structures possessing high concentrations of ribosomal RNA. These organelles are found free in the cytosol as well as attached to the surfaces of the rough endoplasmic reticulum and the outer membrane of the nuclear envelope. Ribosomes and mRNA form a complex known as polysomes, which are responsible for protein synthesis. The formation of a signal peptide indicates that the polysomes must become attached to the rough endoplasmic reticulum, producing a protein that is to be packaged by the Golgi apparatus. However, proteins that are to remain unpackaged are synthesized on polysomes floating free in the cytosol.

Golgi Apparatus

The Golgi apparatus is a system of flattened vesicles stacked in such a fashion that they

present a convex and a concave surface. The peripheral extent of these vesicles, from which secretory granules arise, is dilated. The convex, or forming (cis), face of the Golgi apparatus receives transfer vesicles, derived from the rough endoplasmic reticulum, bringing the newly synthesized proteins to be glycosylated and/or sulfated. Subsequent to these modifications, the proteins are concentrated, packaged, and released at the concave, or maturing (trans), face as secretory granules, condensing vesicles, or primary lysosomes and peroxisomes.

Lysosomes and Peroxisomes

Primary lysosomes are small, spherical, membrane-bound vesicles containing a variety of hydrolytic enzymes utilized by the cell for lysis of particulate matter. The material to be digested may be defunct organelles, foreign bodies (phagosomes) phagocytosed by the cell, or the entire cell itself. Primary lysosomes fuse with phagosomes, forming secondary lysosomes, wherein digestion occurs. The undigestable remnants may remain within the cell as residual bodies.

Peroxisomes are similar to lysosomes, but contain oxidases and catalases. The precise function of these organelles is not known, although it has been suggested that they participate in fatty acid and amino acid oxidation.

Microtubules and Microfilaments

The cytoplasm also contains microtubules and microfilaments, structures which act in the capacity of a cytoskeleton and impart the ability for movement not only of structures within the cytoplasm but also of the entire cell itself. Microtubules, hollow rod-like structures of indeterminate length, are composed of tubulin dimers, associated with each other to form long polymers which lengthen and shorten according to the particular conditions present within the cell. During cell division, microtubules form the spindle apparatus necessary for chromosomal movement. Microtubules also associate with each other in particular configurations to form centrioles and the axoneme of cilia and flagella.

Microfilaments are of three types: thin, thick, and intermediate. These are responsible for motility of the cell and its extensions. Thin filaments (7 nm in diameter) are mostly actin, while thick filaments (14–16 nm in diameter) are myosin. The interaction between these two filaments is especially evident in muscle cells. Intermediate filaments (10 nm in diameter) are composed of a number of different but related polypeptide chains in various cell types. The functions of intermediate filaments are being vigorously investigated.

Inclusions

Cytoplasmic inclusions, such as lipids, glycogen, secretory granules, and pigments, are also consistent constituents of the cytoplasm. Many of these inclusions are transitory in nature, although some pigments, e.g., lipofuscin, are permanent residents of certain cells.

NUCLEUS

The nucleus, a round to ovoid structure that usually occupies the center of the cell, is composed of a nuclear envelope which encloses the nucleoplasm, chromatin, and nucleolus. These structures will be described as they appear in the electron microscope.

The nuclear envelope is composed of closely apposed parallel unit membranes, the inner and outer nuclear membranes. The space between the two membranes is the perinuclear cistern which communicates with the lumina of the rough endoplasmic reticulum. The cytoplasmic aspect of the outer nuclear membrane usually bears ribosomes. Frequently, along the nuclear surface the inner and outer nuclear membranes fuse in circular profiles, forming a nuclear pore complex, composed of eight subunits, through which material may pass between the nucleoplasm and the cytoplasm. Each nuclear pore is spanned by a diaphragm, a proteinaceous structure that is thinner than a unit membrane.

The nucleoplasm is the fluid constituent of the nucleus. It is composed of ions, proteins, and other substances in solution, as well as proteins that are present in the form of fine fibrils constituting the nuclear matrix, whose importance in the functioning of the nucleus is presently being investigated.

Chromatin

Chromatin, strands of DNA and associated histones, is present in clumps as heterochromatin, or dispersed as euchromatin. The latter is in the process of being transcribed, while the former is in the inactive state. A particularly large clump of heterochromatin present in cells of females is known as the sex chromatin (Barr body), which represents the inactive second X chromosome.

Nucleolus

The nucleolus, a more or less spherical

structure, is the region of RNA and ribosome formation. Although the nucleolus maintains its morphology, it is not a membrane-bound structure. The nucleolus presents three regions. One is that portion of the genome which codes for the formation of RNA, known as the nucleolus-associated chromatin; the other two regions are the pars fibrosa and pars granulosa, composed of ribonucleoproteins that are in various stages of being assembled into ribosomes.

CELL DIVISION

Somatic cells that undergo the process of division replicate themselves via the mechanism of mitosis, while germ cells utilize a modification of this process, known as meiosis.

Mitosis was described by light microscopists to occur in several stages; however, it should be realized that these are artificial subdivisions of a continuous process.

Early light microscopists described the first phase, interphase, as the period when the cell was resting. It has since been determined that the cell is actively preparing for division, and, therefore, the actual process of mitosis is only one part of the cell cycle. The interphase stage, no longer considered to be a part of mitosis, has been subdivided into G_1, S, and G_2, where S is the synthesis of DNA, and G_1 and G_2 are intervals during which the cells synthesize proteins and other substances necessary for cell division to occur.

During prophase, the first stage of mitosis, chromatin threads appear, and the nuclear envelope and nucleolus disappear. Also, the centrioles replicate themselves and begin to migrate away from each other to opposite poles of the cell. The spindle apparatus and astral rays make their appearance.

The condensed chromosomes line up along the equatorial plane of the cell during metaphase. Homologous chromosomes (sister chromatids) are attached to each other and to the spindle apparatus at the centromere.

As the sister chromatids are being pulled apart to migrate to opposite poles, the cell is said to enter the next stage of mitosis, known as anaphase.

The final stage of mitosis, telophase, is characterized by the separation of the cell into two daughter cells, the dispersal of chromosomes, and the reappearance of the nuclear envelope and the nucleolus.

PLATE 1.1. The Cell

Figure 1. **Cells. Monkey. Plastic section.** × 1323. The typical cell is a membrane-bound structure that consists of a **nucleus** (N) and **cytoplasm** (C). Although the cell membrane is too thin to be visualized with the light microscope, the outline of the cell approximates the cell membrane (arrowheads). Observe that the outline of these particular cells more or less approximates a square shape. Viewed in three dimensions, these cells are said to be cuboidal in shape, with a centrally placed nucleus. The **nucleolus** (n) is clearly evident, as are the chromatin granules (arrows) that are dispersed around the periphery as well as throughout the nucleoplasm.

Figure 2. **Cells. Monkey. Plastic section.** × 540. Cells may possess tall, thin morphologies, as those of a collecting duct of the kidney. Their **nuclei** (N) are located basally, and their lateral cell membranes (arrowheads) are outlined. Since these cells are epithelially derived, they are separated from **connective tissue elements** (CT) by a **basal membrane** (BM).

KEY

BM	basal membrane	De	dendrite	N	nucleus
C	cytoplasm	E	epithelium	n	nucleolus
CT	connective tissue	L	lumen	PC	Purkinje cell

Figure 3. **Cells. Monkey. Plastic section.** × 1000. Cells come in a variety of sizes and shapes. Note that the **epithelium** (E) that lines the **lumen** (L) of the bladder is composed of numerous layers. The surfacemost layer consists of large, dome-shaped cells, some occasionally displaying two **nuclei** (N). The granules evident in the cytoplasm (arrowhead) are glycogen deposits. Cells deeper in the epithelium are elongated and narrow, and their nuclei (arrow) are located in their widest region.

Figure 4. **Cells. Monkey. Plastic section.** × 540. Some cells possess a rather unusual morphology, as exemplified by the **Purkinje cell** (PC) of the cerebellum. Note that the **nucleus** (N) of the cell is housed in its widest portion, known as the soma (perikaryon). The cell possesses several cytoplasmic extensions, **dendrites** (De) and axon. This nerve cell has the capability of integrating the numerous digits of information that it receives from other nerve cells that synapse on it.

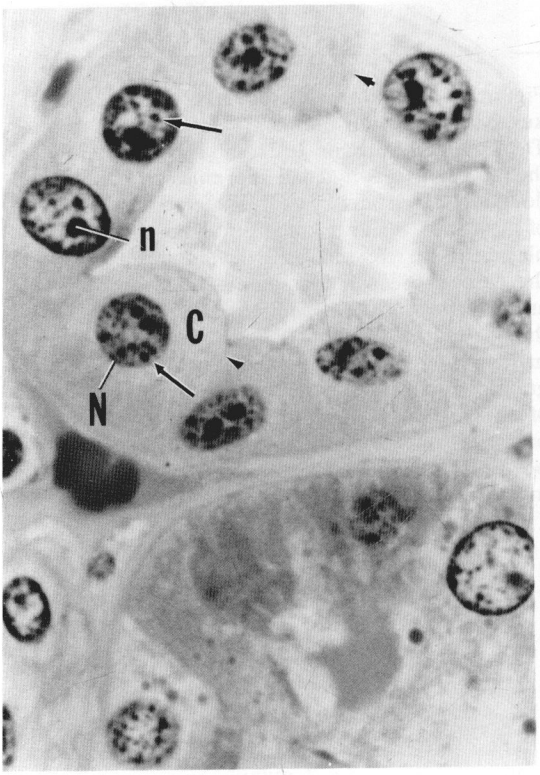

Figure 1

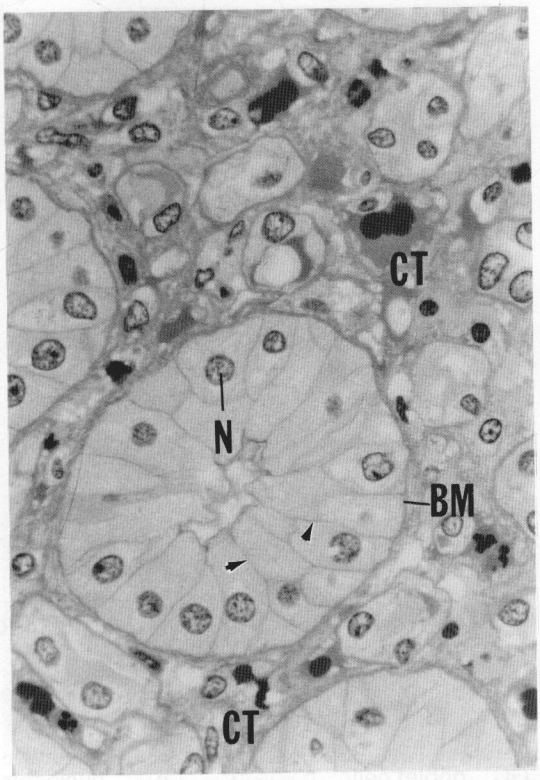

Figure 2

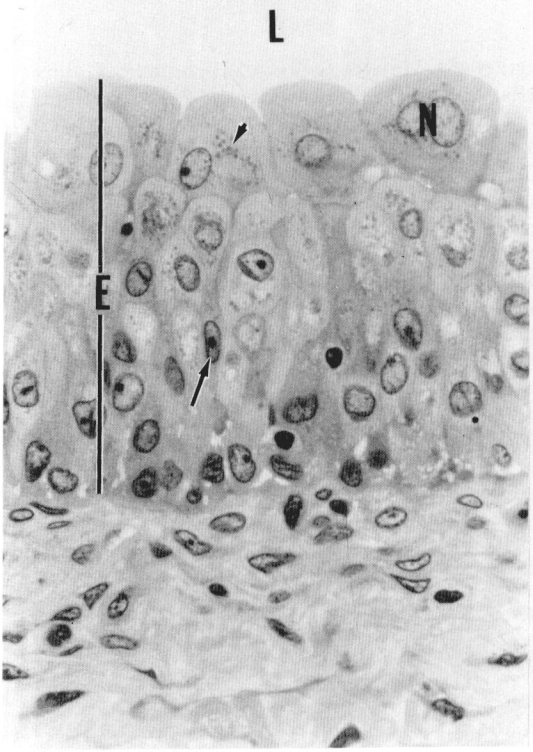

Figure 3

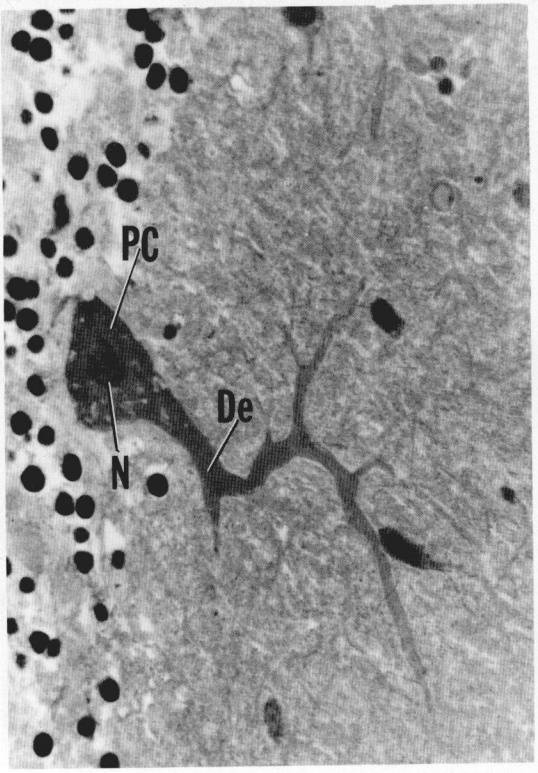

Figure 4

PLATE 1.1