

Helmut Leonhardt

Human Histology, Cytology and Microanatomy

Helmut Leonhardt

Human Histology, Cytology and Microanatomy

Translated by D. P. Winstanley

246 illustrations

(内部交流)



Georg Thieme Publishers Stuttgart 1977

Prof. Dr. med. Helmut Leonhardt
Direktor des Anatomischen Instituts der Universität
2300 Kiel, Federal Republic of Germany

Dr. D. P. Winstanley
Ongar, Essex, England

CIP-Kurztitelaufnahme der Deutschen Bibliothek

Leonhardt, Helmut

Human histology, cytology and microanatomy. —
Stuttgart : Thieme, 1977.

Einheitssacht.: Histologie, Zytologie und
Mikroanatomie des Menschen (engl.).

ISBN 3-13-511401-5

1st German edition 1967

2nd German edition 1969

3rd German edition 1971

1st Japanese edition 1973

4th German edition 1974

1st Italian edition 1975

1st Spanish edition 1975

This book is an authorized translation from the German edition published and copyrighted © 1967, 1969, 1971 and 1974 by Georg Thieme Verlag Stuttgart, Germany, and may not be reproduced in part or in whole without written permission from the publisher. Title of the German edition: Histologie, Zytologie und Mikroanatomie des Menschen.

All rights reserved, in particular the rights of duplicating, distribution and translation. No part of this publication may be reproduced in any form (by photocopying, microfilm or any other process), stored in a retrieval system, duplicated or transmitted without written permission from the publisher.

Georg Thieme Verlag, D-7000 Stuttgart 1, Herdweg 63, P.O.B. 732
Printed by Maisch & Queck, Gerlingen.

ISBN 3-13-511401-5 (Georg Thieme Publishers)

ISBN 91-85342-08-4 (Scientia Bokförlag)

ISBN 0-8151-5375-9 (Year Book Medical Publishers, Inc.)

LCCCN 75-43257

Book Code LH-4

Preface to the 4th German Edition

This new edition of the histology pocketbook contains numerous alterations, some of them extensive. The need for these alterations arose partly from advances in certain fields such as immunology and endocrinology and partly from didactic reasons. The chapters mainly affected are those on cytology, connective and supporting tissues, blood and hemopoietic organs, endocrine glands, nerve tissue, nervous system and skin. Prof. Dr. W. Specht, Homburg (Saar), kindly undertook a thorough revision of large parts of the chapters on connective and supporting tissues and on blood and hemopoietic organs. I am indebted to several specialist colleagues and certain students for useful hints. These have been carefully considered and I am always ready to receive further comments. The list of references has been considerably expanded and subdivided into subjects. It now provides detailed guidance to the literature and is intended for those with special interests, in particular graduates or undergraduates working on theses. I am indebted to Dr. h. c. G. Hauff for making these extensive changes possible. Nevertheless, the text as a whole has been kept within its original length by concentrating on information essential for an understanding of the functional aspects of cytologic and histologic structures. Additional information has been printed in small type. In the sections devoted to special histology more attention has been paid to microanatomy, both in the text and the illustrations, and it seemed justifiable to expand the title of the book. Many illustrations have been replaced with improved ones taken without individual acknowledgement from my volume "Internal organs" of the pocketbook atlas. These illustrations were prepared by Herr G. Spitzer. Frau H. Zuther and Fräulein E. Östermann contributed to the production of the new electron micrographs and Frau A. Schaller assisted in the compilation of the index. I wish to thank them and also the staff of Georg Thieme Publishers.

Homburg (Saar), December 1973

HELMUT LEONHARDT

From the Preface to the 1st German Edition

A short textbook owes its shortness mainly to what is left out; there is no room for full discussion of problems or detailed presentation of evidence. Those who are interested will find exhaustive descriptions and references to the literature in the major textbooks of histology and cytology (see reference list at the end of this book). The text has been still further compressed by extracting as much material as possible from the chapters on special histology and dealing with it in the sections devoted to general histology; nerve tissue and the nervous system, for example, are described together. In order to understand the arrangement of the book it is important to read the introduction. Light microscopic and electron microscopic appearances are described in parallel under the appropriate headings. So far as possible each description begins with an account of what can be seen with the unaided eye and progresses step by step into the higher ranges of magnification.

In drafting the text I received help from many quarters. First of all I wish to thank Prof. Dr. Bargmann, whose encouragement and constructive criticism were of the greatest value. Most of the histologic and microscopic illustrations were drawn from photomicrographs belonging to the teaching material and collections of the Anatomical Institute, University of Kiel. Herr K.-H. Seeber was responsible for the majority of the illustrations. I am also indebted to Dr. med. h. c. G. Hauff who originally proposed that I should write this book, and to Georg Thieme Publishers for valuable assistance. In writing the book I drew on experience gained in working with medical students in lectures and courses, and with my son Matthias.

Kiel, June 1967.

HELMUT LEONHARDT

Contents

Preface to the 4th German Edition	III
From the Preface to the 1st German Edition	IV
Introduction	1
Cytology	2
Techniques and Magnifications Used in Microscopic Study	2
Examination with Naked Eye and Hand Lens	4
Examination by Light Microscopy	4
Examination with the Electron Microscope	9
The Cell	11
History and Definition	11
Examination with the Hand Lens	12
Examination with the Light Microscope	12
Cytoplasm	16
Karyoplasm (cell nucleus)	19
Electron Microscopy	22
Cell membranes (cytomembranes)	22
Cytoplasm	25
Karyoplasm	37
Electron Microscopic Interpretation of the Light Microscope Image of the Cell	39
Vital Activities of the Cell	40
Mitosis (Cell Division)	40
The Phases of Mitosis	42
Chromosomes	44
Chromosome Structure	44
Autoreduplikation (Identical Reduplication, Replication)	47
Meiosis (Reduction Division)	54
Polyploidy, Endomitosis, Amitosis	57
Protein Synthesis	59
Energy Production	63
Motility	63
Ciliary Movement	63
Ameboid Cell Movement	63
Intracellular Protoplasmic Movements	65

VI Contents

Transport of Materials Through the Cell Membrane	65
Ingestion Mechanisms	65
Phagocytosis	65
Micropinocytosis	66
Egestion Mechanisms	67
Secretion and Extrusion	67
Circadian Periodicity	69
Anabolic Processes	70
Catabolic Processes	71
General Histology and Microanatomy	73
Tissues	73
Epithelial Tissues	75
Covering Epithelia	75
Squamous Epithelia	77
Transitional Epithelium	77
Columnar and Cuboidal Epithelia	78
Gland Patterns and Glandular Epithelium	81
Glands	81
Discharge Route	81
Shape of the Secretory Units	82
Quantity and Mode of Discharge	83
Exocrine Glands of the Mucous Membranes	85
Exocrine Glands of the Skin	86
Endocrine Glands	86
Myoepithelial Cells	86
Epithelial Cells as the Parenchyma of Internal Organs	87
Connective and Supporting Tissues	87
Connective Tissue	87
Mesenchyme	88
Reticular Connective Tissue	90
Adipose Tissue	90
Collagen Fiber Connective Tissue	93
I. Constituent Parts	93
Connective Tissue Cells	93
Intercellular Substances	95
Fibers	95
Groundsubstances	99
II. Types of Collagenous Connective Tissue	103
Loose Connective Tissue	103
Dense Connective Tissue	104
Elastic Ligaments	106

Supporting Tissues	106
Cartilage	107
Notochord	111
Bone	111
Woven Bone	112
Lamellar Bone	118
Joints	124
Dentine	125
Blood, Blood-forming Organs and Free Cells of the Connective Tissue (Defense Systems)	126
Blood	126
Red Cells (Erythrocytes)	127
White Cells (Leukocytes)	129
Granulocytes	129
Monocytes	130
Lymphocytes	131
Platelets	132
Hemopoiesis	132
Antenatal and Postnatal Blood Formation	132
Bone Marrow	134
Lymphoid Organs	139
Thymus	141
Tonsils	143
Lymphoid Follicles of Mucous Surfaces	145
Lymph Nodes	145
Spleen	147
Free Cells of Connective Tissue: Defense Systems	150
White Blood Cells as Free Cells of Connective Tissue	151
Defense Systems of the Body	154
1. Nonspecific Defense System	154
Microphages	154
Macrophages (RES)	155
2. Specific Defense System	155
Immunization and Immunity	156
Cellular and Humoral Immunity (Immune Response)	157
The Immune Reaction	157
Muscle	160
Smooth Muscle	162
Striated Muscle	160
Tendon Origins and Insertions	169
Heart Muscle	170
Circulatory System	173
Heart	174

VIII Contents

Myocardium	174
Cardiac Conducting System	175
Endocardium	175
Pericardium	176
Cardiac Nerves	176
Blood Vessels	176
Arteries	177
Capillaries	180
Veins	183
Special Mechanisms for Regulating Blood Flow	184
Lymphatics	187
Nerve Tissue and the Nervous System	188
Subdivisions of the Nervous System	188
Afferent and Efferent Pathways	188
Gray and White Matter	189
Cranial and Spinal Nerves	190
Central and Peripheral Nervous Systems	190
Subdivisions of the Central Nervous System	190
Nerve Tissue and Structural Elements of the Nervous System	191
Nerve Cells	192
Subdivisions of the Nerve Cell	193
Golgi Method: Outline Image (Synapses)	194
Nissl Method: Tigroid Substance (Ergastoplasm), Cell Nuclei	195
Silver Impregnation Methods (Cajal and others): Neurofibrils	195
Conventional Staining Techniques: Cell Organelles and Nucleus	195
The Nerve Cell under the Electron Microscope	196
Nerve Fibers	197
Nerve Fibers under the Light Microscope	198
Nerve Fibers under the Electron Microscope	200
Axon Sheath Formation in Myelinated Peripheral Nerve Fibers	202
Axon Sheath Formation in Nonmyelinated Peripheral Nerve Fibers	204
Synapses	205
Synapses Between Nerve Cells	206
Myoneural Synapses (Motor Endplates)	209
Myoneural Synapses of Autonomic Nerves	210
Transmitter Substances	211
Neuroglia	211
Neuroglia of the CNS	212
Glial Cells of the Peripheral Nervous System	217
Mesoglia	217
Nervous System	218
Neuronal Organization of the Nervous System	218
Methods of Studying Neuronal Connexions	219

Spinal Segment	220
Spinal Nuclei	221
Spinal Tracts	226
Peripheral Nervous System	226
Nerves	226
Ganglia	228
Neuron Chains in the Peripheral Nervous System	230
Neuron Chains in the Autonomic Nervous System	230
Nuclei and Tracts in the Brain	231
Cerebellar Cortex	231
Ganglionic or Nuclear Layer	232
Molecular Layer	233
Granular Layer	234
Cerebral Cortex	234
Isocortex	234
Growth and Aging of the Central Nervous System	241
Meninges and Blood Vessels of the Brain	241
Meninges	241
Cerebrospinal Fluid	242
Cerebral Blood Vessels	243
Sense Organs	245
Organs of Superficial and Deep Sensation	245
Skin Sensation	246
Nerve End Corpuscles	246
Free Nerve Endings	247
Deep Sensation (Proprioceptors)	248
Organs of Visceral Sensation (Visceroreceptors)	249
Pressure Receptors	249
Chemoreceptors	250
Organ of Taste	250
Olfactory Organ	251
Organs of Hearing and Balance	253
Organs of Balance	254
Organ of Hearing	255
Inner Ear	255
Middle Ear	259
External Auditory Meatus and External Ear	260
Organ of Vision	260
Eyeball (Bulbus Oculi)	261
Posterior Segment of the Eye	262
Anterior Segment of the Eye	267
Accessory Structures	270
Skin, Subcutaneous Tissue and Skin Appendages	272
Skin	273
Tissue Components of the Skin Layers	273

X Contents

Regeneration and Age Changes	278
Skin Color	278
Superficial Fascia (Subcutis)	279
Blood Vessels and Lymphatics of the Skin and Subcutaneous Tissues	279
Skin Appendages: Hair, Nails, Glands	280
Hair	280
Nails	282
Female Breast and Mammary Glands	285
Mammary Gland	286
Nipple (Mamilla)	287
Endocrine Glands	288
Hypothalamus and Endocrine Glands	289
Hypothalamic-Pituitary System	289
I. Hypothalamic-Posterior Pituitary System	291
Hypothalamus	291
Posterior Pituitary (Neurohypophysis)	291
II. Hypothalamic-Anterior Pituitary System	294
Hypothalamus	294
Infundibulum	294
Pituitary	296
Adenohypophysis	297
Neural Efferents of the Hypothalamus and Endocrine Glands	299
Pineal (Epiphysis)	299
Adrenals (Suprarenal Glands)	300
Adrenal Cortex	301
Adrenal Medulla	304
Paraganglia	305
Thyroid	305
Parathyroids	307
Pancreatic Islets (Islets of Langerhans)	308
Gonads (Testis, Ovary)	309
Placenta	309
Thymus	310
"Tissue Hormones" and their Formation	310
Endocrine Glands and the Nervous System: Correlation System	310
Serous Membranes	311
Classification and Structure	311
Respiratory Organs	312
Air Passages	312

Basic Structure of the Respiratory Passages	312
Nasal Cavity	314
Pharynx	215
Larynx	316
Trachea and Bronchi	318
Trachea	318
Bronchial Tree	319
Lungs	320
Terminal Subdivisions of the Respiratory Tract	320
Subdivisions of the Lung and its Connective Tissue	320
Terminal Subdivisions of the Blood Vessels and Lymphatics	322
Blood Vessels	322
Lymphatics	322
Alveoli	322
Pleura	324
The Fetal Lung	324
Digestive Organs	325
Foregut	325
Cheeks	326
Lips	326
Palate	326
Tongue	327
Development of the Teeth	329
Teeth	331
Salivary Glands	334
Gut	337
Layers of the Gut Wall	337
Peritoneum	338
Segments of the Gut	339
Esophagus	339
Stomach	340
Small Intestine.	
General Structure of the Small Intestinal Mucosa	343
Duodenum	349
Jejunum	349
Ileum	350
Large Intestine (Colon)	350
Appendix (Vermiform Appendix)	352
Pancreas	353
Liver	354
Bile Ducts	360
Gall Bladder	361
Urinary Tract	363
Kidney	363

XII Contents

Blood Vessels	364
Arteries	364
Veins	366
Glomerulus (Malpighian Corpuscle)	366
Renal Tubules and Collecting Tubules	369
Juxtaglomerular Apparatus	372
Nephron	372
Lower Urinary Tract	374
Renal Pelvis	374
Ureter	374
Urinary Bladder	375
Urethra	375
Reproductive System	377
Male Reproductive Organs	377
Testes	377
Fetal Testis	383
Tunica Vaginalis of the Testis	383
Seminal Passages. Epididymis	384
Vas deferens and Ejaculatory Duct	385
Glands. Seminal Vesicle	386
Prostate	387
Bulbourethral Glands (Cowper's Glands)	388
Semen (seminal fluid)	388
Male External Genital Organs. Penis	389
Scrotum	391
Female Genital Tract	391
Ovary	391
Uterine Tube	397
Uterus	399
Ovarian and Menstrual Cycles	401
Proliferative Phase	401
Secretory Phase	403
Desquamative Phase and Regeneration	404
Pregnancy	404
Placenta	405
Female External Genitals (Vulva) and Glands	412
Notes on Terminology	413
References	417
Index	434

Introduction

The aim of this pocketbook is to build up knowledge **step by step** in the same way as a textbook. It is arranged in such a way that the reader starts from observation and method, each step marking the progress of an investigation which can be seen in **perspective** by consulting the table of contents.

Contents

I. Cytology. The first step is to grasp the degrees of magnification used in microscopic studies. Every finding must be put in its right place in a series of objects arranged in order of magnitude. To guide the reader in case of doubt, light microscopic findings are marked with L and electron microscopic findings (at magnifications up to one hundred times greater) with E. Erythrocytes (diameter $7.5\text{ }\mu\text{m}$) can be used as size standards in sections, and cell nuclei (normally $4\text{--}10\text{ }\mu\text{m}$) also serve as guides to the magnification. Next follows an account of the changes (artefacts) likely to be produced by the technical methods employed. Attention is then turned to the cell, which is studied in three stages:

1. The living cell in tissue culture.
2. The killed cell as seen under the light and electron microscopes.
3. Analysis of the vital phenomena of the cell.

II. General and Special Histology: Tissues and organs are discussed in logical sequence. The section on epithelium leads on to a description of the various kinds of glands, and the account of connective tissue is linked on one side with blood, hemopoiesis and lymphoid organs, and on the other with bone and cartilage. Unless otherwise stated, the illustrations are based on ordinary staining techniques.

Revision: Each section of the text has a heading. When revising the material, these headings should be used as questions to be answered.

The remarks on physiology and biochemistry are incomplete and are simply intended to give the beginner some preliminary concept of the functions of an organ or tissue when he is studying its histology; further information can be obtained from textbooks of physiology and biochemistry.

Cytology

Techniques and Magnifications Used in Microscopic Study

One of the main aims of the biological sciences is to trace back the enormous diversity of living matter to a limited number of laws or principles. In morphology this implies a search for structural units and principles. How far this search can be pursued depends largely on the techniques available.

The *naked eye* can distinguish certain structural elements by their shape, color and surface texture, and by inspection of the cut surface.

Examined in this way, it is obvious that organs are built up from different units. Aristotle developed a theory of this kind around 350 B. C., but the limited resolving power of the human eye precluded further progress.

The *microscope*, introduced in the early years of the 17th century, gives magnifications of several hundred diameters and shows a whole range of new structures. Our current ideas of the structure of biological objects are based mainly on light microscopic investigations carried out during the last hundred years. The discovery of the cell was the key to the understanding of the structure of living organisms.

The development of *electron microscopy* during the past 20-25 years has revealed certain structures never seen before and has disclosed many new details in familiar objects. This has called for wide revision of our ideas of the structure of living matter.

Histologic teaching has to take into account the practical needs of future doctors, and it would be unreasonable to abandon the established orthodoxy of light microscopy. In any case, the only way to acquire an allround knowledge of the organization of living matter is to correlate the pictures obtained at all levels of magnification - hand lens, light microscope und electron microscope.

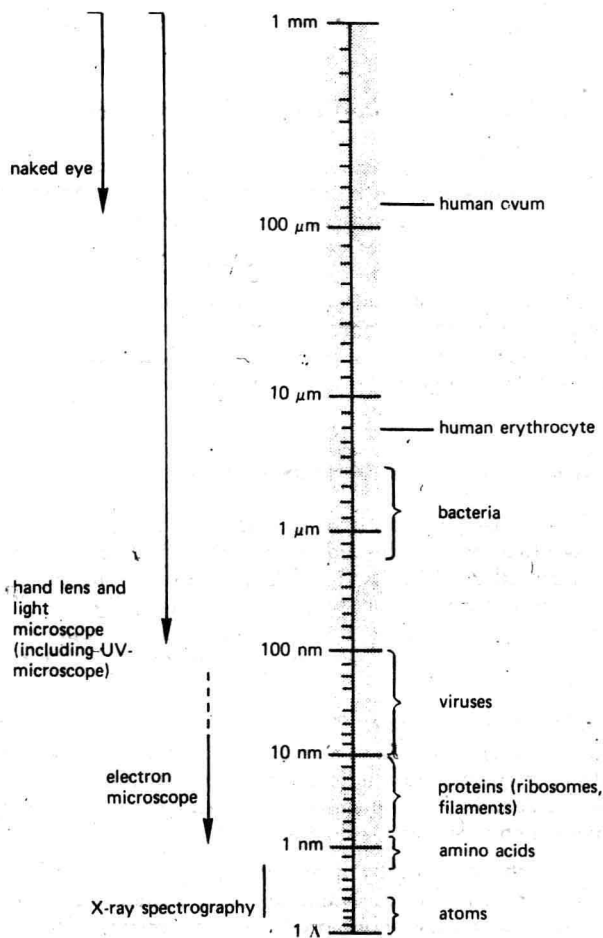
For proper understanding of histologic preparations it is essential to have some knowledge of microscopic and histologic techniques. The next few pages therefore contain a short account of the processes and problems involved in the production and examination of histologic preparations.

Dimensions

1 mm = 1,000 μm (micrometer), sometimes written μ (micron)

1 mm = 1,000,000 nm (nanometer), sometimes written m μ (millimicron)

1 mm = 10,000,000 Å (Ångström unit – now obsolescent)



Scale of microscopic and submicroscopic dimensions (from Bessis)

To convert measurements from one scale of magnification to another it is helpful to remember two equations:

$$10 \text{ \AA} \text{ or } 1 \text{ nm (electron microscopic levels)} = 1/1000 \text{ }\mu\text{m}$$

$$1 \text{ }\mu\text{m (light microscopic levels)} = 1/1000 \text{ mm}$$

Limits of resolving power:

unaided eye approximately 0.1 mm

light microscope approximately 0.1 μm

electron microscope approximately 1 nm = 10 \AA

Examination with Naked Eye and Hand Lens

The only instrument needed is a simple *hand lens*. Major topographical relationships can be recognized. These are often difficult to make out under the microscope and inspection with a hand lens can be of great help. *Low power binocular microscopes* enable structures of this size to be dissected. The lower limit of optical resolution (the smallest separation at which two points can still be perceived as separate) is approximately 0.1 mm for the naked eye. This means that structures such as intestinal villi, central veins of the liver lobules and gastric pits can just be seen.

Examination by Light Microscopy

The **light microscope** consists of a system of lenses by which the final magnification is achieved in two stages. The objective lens produces an enlarged inverted real image which is further enlarged by and viewed through the eyepiece or ocular (Fig. 1). The limit of optical resolution by light microscopy (UV-microscope) is around 0.1 μm . Dark field microscopy enables still smaller objects to be seen.

Vital preparations. Certain thin objects such as the mesentery of a small animal, blood smears, etc., can be observed by transmitted light. For thicker objects it is necessary to illuminate the surface by incident light. Transmitted light can be employed in special ways which offer certain diagnostic advantages:

Ultraviolet light, emitted by a mercury lamp and passed through a filter to remove visible wave-lengths, excites fluorescence in many cell components and metabolic products. This *intrinsic fluorescence* must be distinguished from the fluorescence produced by staining with fluorescent dyes or fluorochromes: *vital fluorochrome staining* (UV-microscopy).