

THIEME FLEXIBOOKS

# Human Histology, Cytology and Microanatomy

*Chin*

by Helmut Leonhardt

Translated by D. P. Winstanley

Year Book Medical Publishers, Inc.  
Georg Thieme Publishers

Dr. Edwin Chin, Jr.  
821 Richmond Avenue  
San Jose, CA 95128

Helmut Leonhardt

# Human Histology, Cytology and Microanatomy

Translated by D.P. Winstanley  
246 illustrations



1977

Year Book Medical Publishers, Inc. Chicago  
Georg Thieme Publishers

Dr. Edwin Chin, Jr.  
821 Richmond Avenue  
San Jose, CA 95128

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

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

Distributed in Continental North, South and Central America, Hawaii, Puerto Rico,  
and the Philippines by Year Book Medical Publishers, Inc.

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
<b>Cytology</b> . . . . .	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

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
<b>General Histology and Microanatomy . . . . .</b>	<b>73</b>
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



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 (Visceroceptors) . . . . .	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

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

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 17<sup>th</sup> 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.

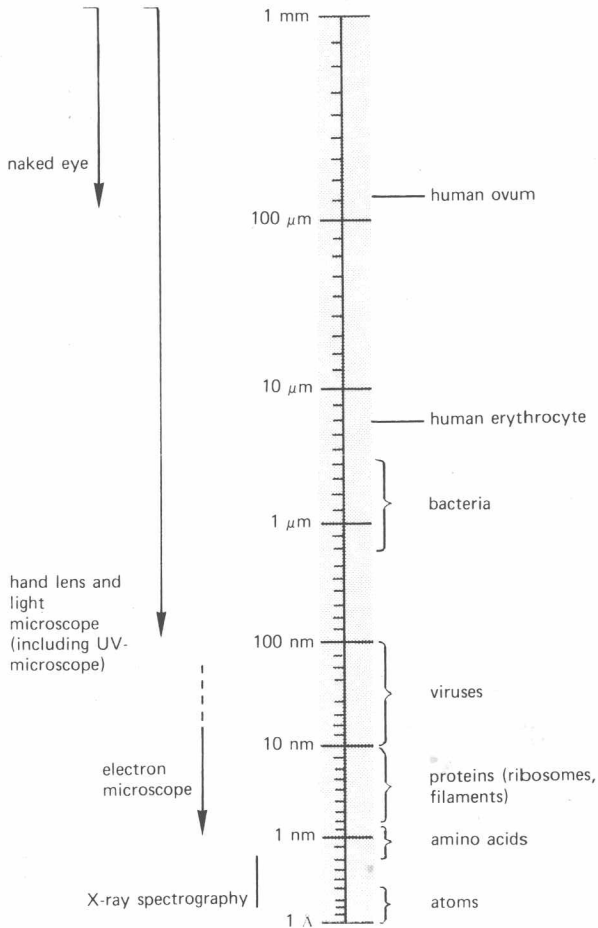
For proper understanding of histologic preparations it is essential to have some knowledge of microscopic and histologic techniques. The next few pages therefore contain a short account of the processes and problems involved in the production and examination of histologic preparations.

## Dimensions

1 mm = 1,000  $\mu\text{m}$  (micrometer), sometimes written  $\mu$  (micron)

1 mm = 1,000,000 nm (nanometer), sometimes written m $\mu$  (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  $\mu\text{m}$

electron microscope . . . . . approximately 1 nm = 10  $\text{\AA}$

## 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  $\mu\text{m}$ . 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)*.