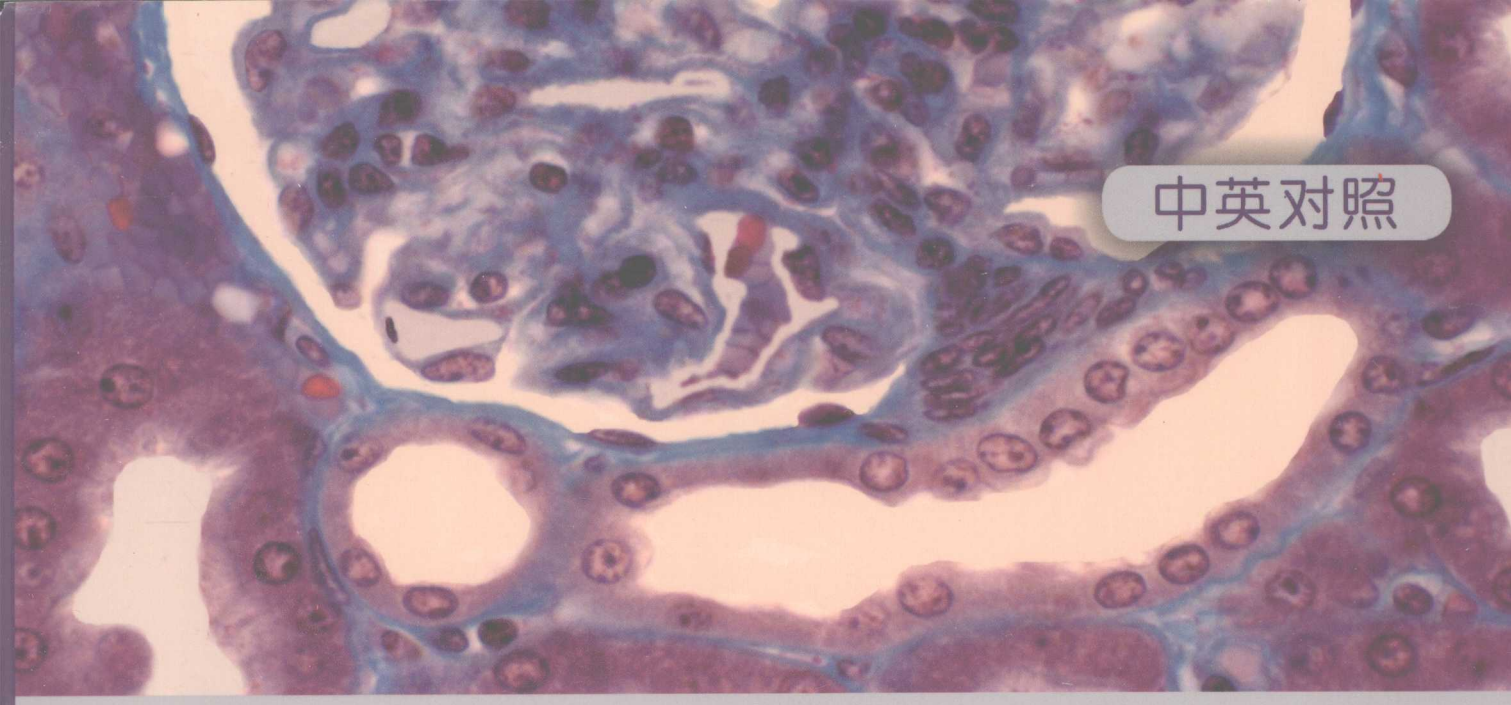
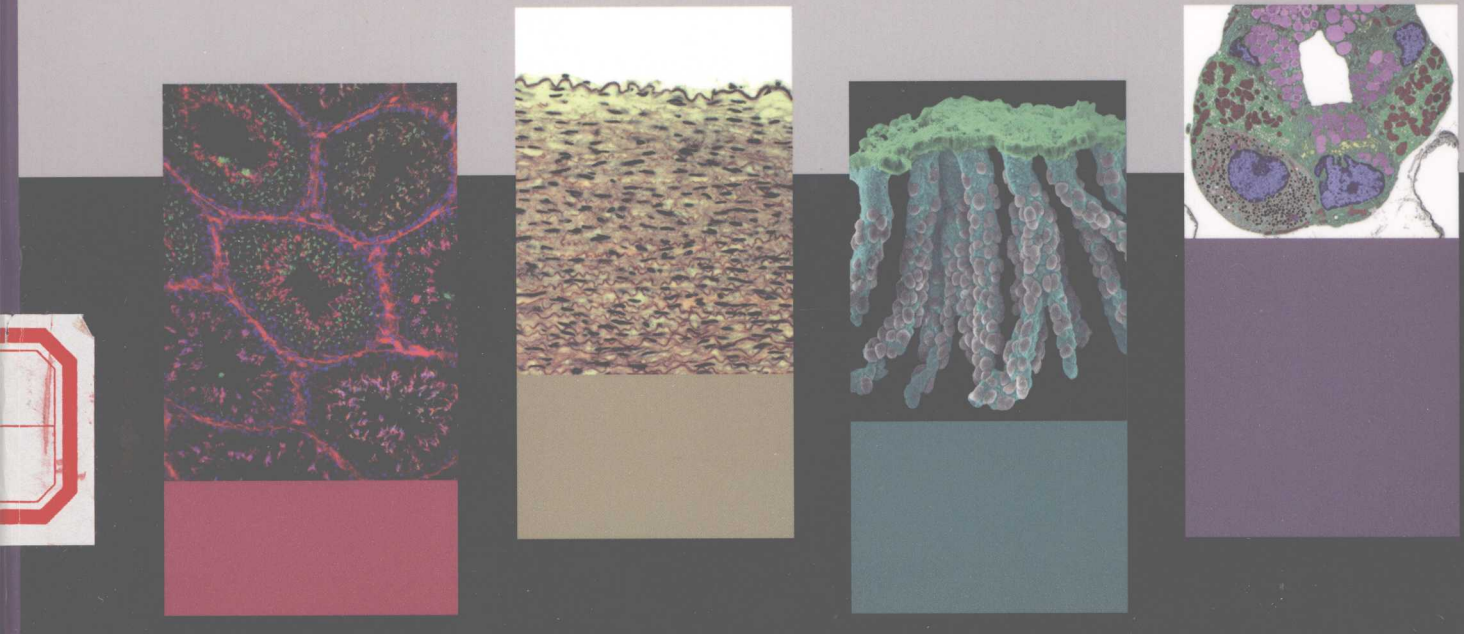


中英对照

Atlas of
Medical Histology
医学组织学图谱

Ronald W. Dudek
罗娜
编著

人民卫生出版社
PEOPLE'S MEDICAL PUBLISHING HOUSE



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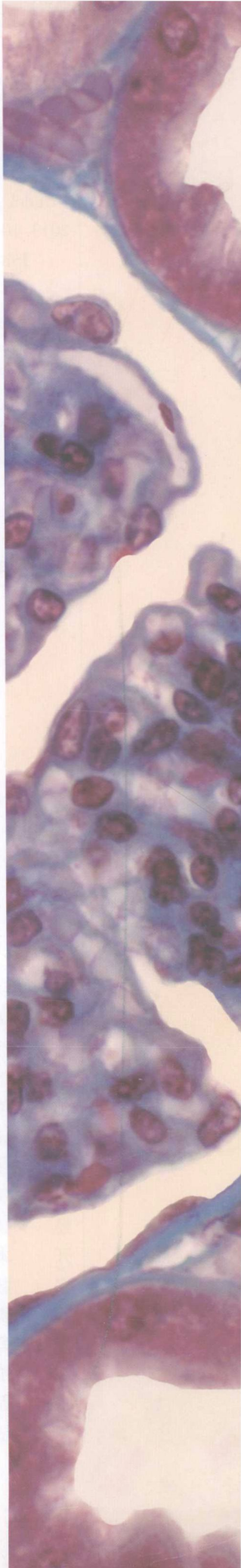

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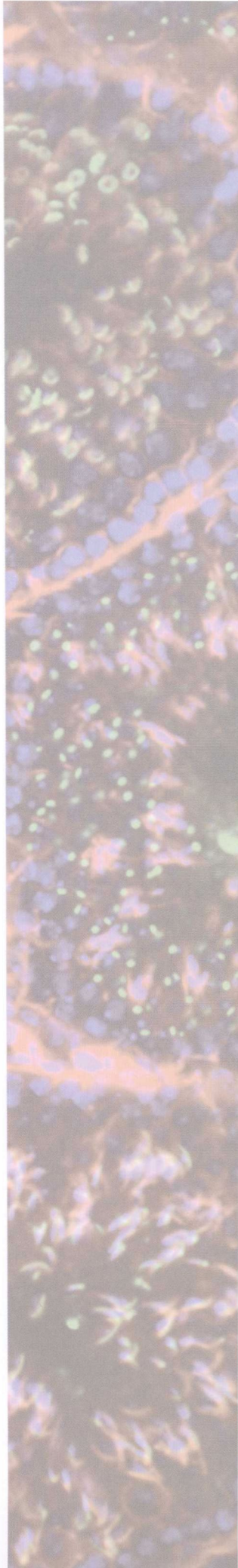
Dedication

此书献给我的父亲罗德武和母亲王凤云，谢谢他们一直以来的关心、支持和爱护。

I also would like to dedicate this book to little Ronny for his unconditional love and companionship.

罗　娜



致　谢

我们要感谢参与这本组织学图谱出版的许多人。首先，我们要追谢 Stanley Erlandsen 博士（明尼苏达大学，遗传学、细胞生物学和发育学系），Dr. Ron W. Dudek 研究生期间的组织学和电镜的导师。Erlandsen 博士是一位充满热情的透射电镜和扫描电镜学家。我们非常感谢可以得到准许，在这本组织学图谱中使用许多他的显微图片。Erlandsen 博士是一位真正的学者。我们确定对于他的显微图片能够继续被努力学习组织学的学生所用，他会感到高兴的。我们要感谢 Robert Sorenson 博士（明尼苏达大学，遗传学、细胞生物学和发育学系）让我们可以使用 Erlandsen 博士的显微图片集，以及分享一些他自己的显微图片。我们要感谢 Todd Clark Brelje 博士（明尼苏达大学，遗传学、细胞生物学和发育学系），制作了许多电脑绘色的透射电镜和扫描电镜图片。电脑绘色的应用极大地帮助了学生理解电镜图片。我们要感谢 Elbert Kennard 先生（视觉艺术专家，布罗迪医学院）花费大量的时间和精力来数字化电镜图片，整合光镜图片，以及指导 Photoshop 技术。我们要感谢负责本科生的电子显微镜技术课程的 Tim Charles 先生（东卡罗莱纳大学，生物学系）。多年来，Charles 先生收集了大量本科生拍的电镜图片。由于图片上的记录模糊，我们没有给予单独的引用。但是，我们要对 Charles 先生和制作这些电镜图片的本科生表示衷心的感谢。我们要感谢 George Sigounas 博士（布罗迪医学院，血液学系），拍了造血过程中的一系列血细胞的图片。我们要感谢 Life Technologies Corporation（Carlsbad，CA）的协助和敬业，准许我们使用他们许多的免疫荧光图片。这些免疫荧光图片对于现代的组织学图谱是重要的贡献。最后，我们要感谢所有对这本组织学图谱提供显微图片的科学家，书后备注中都有详细引用。

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Acknowledgement

We would like to thank the many people involved in the production of this Histology Atlas. We would like to thank posthumously Dr. Stanley Erlandsen (Department of Genetics, Cell Biology, and Development, University of Minnesota) who mentored Dr. Ron W. Dudek as a graduate student in both Histology and Electron Microscopy. Dr. Erlandsen was an avid transmission and scanning electron microscopist and We are appreciative for permission to use many of his micrographs in this Histology Atlas. Dr. Erlandsen was a true academic and We are sure he would be pleased that his micrographs will continue to serve students endeavoring to learn Histology. We would like to thank Dr. Robert Sorenson (Department of Genetics, Cell Biology, and Development, University of Minnesota) for getting us access to Dr. Erlandsen micrograph collection and sharing some of his light micrographs. We would like to thank Dr. Todd Clark Brelje (Department of Genetics, Cell Biology, and Development, University of Minnesota) who produced many of the computer-colorized transmission and scanning electron micrographs. The use of computer-colorization provides significant assistance for the student who is learning to interpret electron micrographs. We would like to thank Mr. Elbert Kennard (Visual Arts Specialist, Brody School of Medicine) for the large amount time and effort he gave in digitizing the electron micrograph negatives, fusing light micrographs to produce photomontages, and for his tutelage in Photoshop techniques. We would like to thank Mr. Tim Charles (Biology Department, East Carolina University) who ran an electron microscopy techniques course for undergraduate students. Over the years, Mr. Charles amassed a huge collection of electron micrographs that were taken by these undergraduate students. Although We cannot give an individual citation to each student since the records are not clear on this issue, We would like to give a general acknowledgement to the efforts of Mr. Charles and these undergraduate students who produced some beautiful electron micrographs. We would like to thank Dr. George Sigounas (Department of Hematology, Brody School of Medicine) who photographed all the cells in the hematopoietic series. We would like to thank Life Technologies Corporation (Carlsbad, CA) for their cooperation and professionalism in granting us permission to use many of their immunofluorescent images that are a valuable contribution to a modern-day Histology Atlas. Finally, We would like to thank all the scientists that contributed their micrographs to this Histology Atlas. We have given each scientist a citation at the index of the Histology Atlas.

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前　言

组织学是一门形态学课程，内容以大量的形态学描述为主，概念繁多，容易混淆。因而，在学习过程中采用大量的图片加以辅助，势必得到事半功倍的效果。这就是这本《医学组织学图谱》的编写目的，即采用高质量的图片，进行清晰的标注和简单的解释，以澄清医学组织学教科书中的重点难点问题。

早在2001年，教育部就已经明确提出了要积极推动双语教学。为此，这本《医学组织学图谱》采用中、英文两种语言。为了使本书中的医学组织学专业术语更加规范，特请来在美国东卡罗莱纳大学布罗迪医学院执教了30多年的Dr. Ronald W. Dudek教授对本书英语相关内容进行编写和审核。

本书设计合理，编排清晰，书中的图片经过了精心筛选，内容结合了与最新医学相关的基础科学知识。除了彩色的光镜图片和电镜图片，书中也包含了最新的免疫荧光染色图片。此外，在每个章节的前面，有关于重点知识的精要介绍。本书为教师的教学和学生的学习提供了丰富的辅助资料。

最后，由于水平有限，书中难免存在不尽如人意之处。因此，非常期待老师和同学们的批评和建议，如有需要，请发email到 dudekr@ecu.edu. 或 luon11@nankai.edu.cn。

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Foreword

The "*Atlas of Medical Histology*" provides medical school students with a histology atlas containing high quality micrographs that are clearly labeled and explained with concise, easy-to-understand figure legends. These micrographs address and clarify the basic concepts and topics involved in both tissue and organ systems histology. The "*Atlas of Medical Histology*" allow students to master basic histological concepts along with the latest up-to-date information concerning various histological topics.

The "*Atlas of Medical Histology*" is bilingual, well-designed, and the micrographs carefully selected. The "*Atlas of Medical Histology*" combines the latest, up-to-date basic science information with clinical relevance when appropriate. The micrographs include light microscopic images stained with hematoxylin and eosin (H&E), other special tinctorial stains, and immunocytochemical techniques (e. g., immunofluorescence). In addition, the micrographs also include transmission and scanning electron microscopic images some of which are computer-colored. A brief introduction at the beginning of each chapter covers the essential important points for each histological topic.

We would appreciate any comments or suggestions concerning the "*Atlas of Medical Histology*". You may contact us at dudekr@ecu.edu or luon11@nankai.edu.cn.

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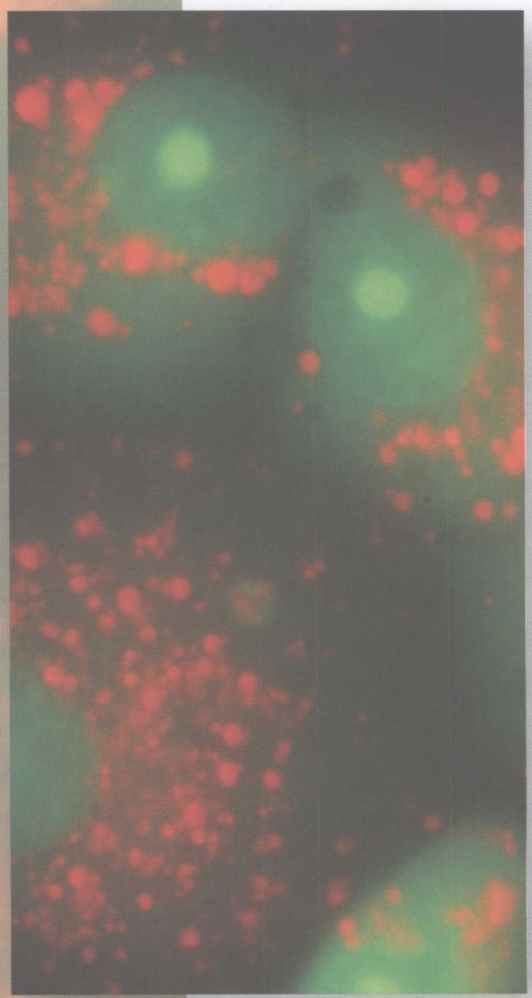
Chapter 1
Cellular Structures



细胞核

染色质是与组蛋白和非组蛋白相关联的双螺旋 DNA。常染色质是处于伸展状态的染色质，大约占总染色质的 90%。在这 90% 的常染色质中，大约 10% 的常染色质具有转录活性，而 80% 的常染色质不具有转录活性。具有转录活性的常染色质，DNA 与组蛋白的结合不紧密，组蛋白的乙酰化程度降低。异染色质是处于聚缩状态的染色质，不具有转录活性。异染色质的一个例子是雌性细胞中的巴氏小体，为不具有转录活性的 X 染色体。异染色质大约占总染色质的 10%。组成型异染色质为总是处于聚缩状态的染色质（不具有转录活性），由着丝粒周围和特定区段的重复 DNA 序列构成。功能型异染色质或处于聚缩状态（不具有转录活性），或处于伸展状态（具有转录活性）。功能型异染色质的一个例子是 XY 小体，它是 X 和 Y 染色体在雄性细胞进行减数分裂时，失活大约 15 天形成的。

核膜为双层膜结构，将细胞核与细胞质分隔开来。核内膜与核纤层相联系。核纤层为纤连蛋白 A、B、C 构成的中间纤丝网，在有丝分裂的前中期核膜的破裂以及有丝分裂末期核膜的重新形成过程中起重要的作用。核外膜表面附着有核糖体，与粗面内质网相通连。核内膜和核外膜由核周腔相分隔。核膜上有许多核孔，介导细胞核和细胞质之间的物质交换（如：离子、mRNA、tRNA、rRNA、基因调节蛋白、DNA 聚合酶、RNA 聚合酶）。核孔与核孔复合体相联系。核孔复合体是由许多不同的蛋白排列成的八面对称结构包绕中央孔道所形成。

核仁由第 13，14，15，21 和 22 对染色体上存在的核仁组织区 DNA 所组成。单倍体基因组的核仁组织区 DNA（也称纤维中心）含有大约 200 个拷贝编码核糖体 RNA 的基因。核仁纤维区含有核糖体 RNA 的初级转录产物（如 45S rRNA）。核仁颗粒区含有成熟的核糖体（核糖体 RNA 和核糖体蛋白）。

Nucleus

Chromatin is double-helical DNA associated with histones and nonhistone proteins. Euchromatin is dispersed chromatin and comprises ~90% of the total chromatin. Of this 90%, ~10% is transcriptionally active and ~80% is transcriptionally inactive. When chromatin is transcriptionally active, there is weak binding and acetylation of histone proteins. Heterochromatin is condensed chromatin and is transcriptionally inactive. An example of heterochromatin is the Barr body which is found in female cells and represents the inactive X chromosome. Heterochromatin comprises ~10% of the total chromatin. Constitutive heterochromatin is always condensed (i. e., transcriptionally inactive) and consists of repetitive DNA found near the centromere and other regions. Facultative heterochromatin can be either condensed (i. e., transcriptionally inactive) or dispersed (i. e., transcriptionally active). An example of facultative heterochromatin is the XY Body which forms when both the X and Y chromosome are inactivated for ~15 days during male meiosis.

The nuclear envelope is a two membrane structure that separates the nuclear compartment from the cytoplasmic compartment. The inner membrane is associated with a network of intermediate filaments (lamins A, B, C) called the nuclear lamina, which plays a role in the dis-assembly of the nuclear envelope during prometaphase of mitosis and re-assembly of the nuclear envelope during telophase. The outer membrane is studded with ribosomes and is continuous with the rough endoplasmic reticulum. The inner and outer membranes are separated by a perinuclear cisterna. The nuclear envelope contains many nuclear pores that allow passage of molecules between the nucleus and cytoplasm (e. g., ions, mRNA, tRNA, rRNA, gene regulatory proteins, DNA polymerases, RNA polymerases). The pores are associated with a nuclear pore complex which consists of many different proteins arranged in octagonal symmetry with a central channel.

The nucleolus consists of portions of five pairs of chromosomes (i. e., 13, 14, 15, 21, and 22) called the nucleolar-organizing DNA. The nucleolar-organizing DNA (also called the fibrillar center) contains ~ 200 copies of ri-

bosomal RNA (rRNA) genes per haploid genome which code for rRNA. The pars fibrosa consists of primary transcripts of rRNA (e. g. ,45S rRNA). The pars granulosa consists of maturing ribosomes (rRNA + ribosomal proteins).

核糖体

核糖体为由40S和60S的核糖体亚单位组成的,大的核糖体RNA和蛋白质的复合物。40S核糖体亚单位与mRNA和tRNA结合,识别起始密码子AUG。60S的核糖体亚单位具有肽基转移酶的活性,与40S核糖体亚单位结合。核糖体为mRNA转译成氨基酸序列(也就是蛋白质的合成)提供结构框架。核糖体可串联附着在mRNA上形成多聚核糖体,参与到细胞质蛋白(如:肌动蛋白、血红蛋白)的合成。如果新合成的蛋白质在其氨基端含有疏水信号序列,核糖体也可被介导到膜性网状结构以形成粗面内质网。

Ribosomes

The ribosomes are large rRNA-protein complexes that consist of a 40S subunit and a 60S subunit. The 40S subunit binds to mRNA and tRNA and finds the start codon AUG. The 60S subunit binds to the 40S subunit and has peptidyl transferase activity. Ribosomes provide the structural framework for the translation of mRNA into an amino acid sequence (i. e. ,protein synthesis) to occur. Ribosomes may cluster along a strand of mRNA to form a polyribosome (or polysome) that is involved in the synthesis of cytoplasmic proteins (e. g. ,actin,hemoglobulin). Ribosomes may also be directed to a membrane network to form rough endoplasmic reticulum (rER) if the nascent protein contains a hydrophobic signal sequence at its amino terminal end.

粗面内质网

粗面内质网为一膜性网状结构,其朝向细胞质的一面上分布着大量的核糖体。通过60S亚单位与内质网膜上的核糖体结合蛋白Ⅰ和Ⅱ相结合,核糖体附着在粗面内质网的膜上。粗面内质网是分泌蛋白(如:胰岛素)、细胞膜整合蛋白(如:受体)和溶酶体酶的合成场所。粗面内质网也是蛋白质共转译修饰的场所。蛋白质的共转译修饰包括:a)N-连接糖基化(天冬酰胺糖基化起始于粗面内质网,终止于高尔基复合体);b)胶原合成过程中脯氨酸和赖氨酸的羟基化;c)信号序列的切除;d)新合成的蛋白质折叠成三维结构;e)蛋白亚单位聚合成多聚复合物。

Rough Endoplasmic Reticulum (rER)

The rough endoplasmic reticulum (rER) is a membrane network that has ribosomes attached to the cytoplasmic surface of the rER in a long linear array. This attachment occurs by the binding of ribophorin Ⅰ and Ⅱ located on the membrane to the 60S subunit of the ribosome. The rER is the site of synthesis of secretory proteins (e. g. ,insulin),cell membrane proteins (e. g. ,receptors),and lysosomal enzymes. The rER is also the site of co-translational modification of proteins which includes: a) N-linked glycosylation (addition of sugars to asparagine begins in the rER and is completed in the Golgi complex), b) hydroxylation of proline and lysine during collagen synthesis, c) cleavage of the signal sequence, d) folding of the nascent protein into three-dimensional configuration, and e) association of protein subunits into multimeric complex.

高尔基复合体

高尔基复合体为一极性的膜性网状结构,分为凸面(顺面)和凹面(反面)。凸面(顺面)接收来自粗面内质网的新合成蛋白质的囊泡,凹面(反面)释放转译后加工修饰的蛋白质浓缩小泡。高尔基复合体是蛋白质转译后加工修饰的场所。蛋白质的转译后加工修饰包括:a)完成从粗面内质网起始的N-连接糖

基化;b)O-连接糖基化;c)硫酸化;d)磷酸化;e)甲基化;f)乙酰化;g)羧基化;h)糖脂的加成;i)豆蔻酰化;j)棕榈酰化;k)焦磷酸化;l)香叶酰香叶酰化。高尔基复合体也参与到蛋白质的分选和包装。分泌蛋白(如:胰岛素、胰凝乳蛋白酶原)包装到小窝蛋白包被的小泡中,小泡聚合为分泌颗粒,以释放到血液(内分泌)或导管中(外分泌)。细胞膜整合蛋白(如:受体)包装到非小窝蛋白包被的小泡中。溶酶体酶在甘露糖磷酸化为6-磷酸甘露糖后包装到小窝蛋白包被的小泡中。高尔基复合体也参与到细胞膜的循环。

Golgi Complex

The Golgi complex is a membrane network with a convex cis-face that receives vesicles containing newly synthesized proteins from the rER and a concave trans-face that releases condensing vacuoles of posttranslationally modified proteins. The Golgi complex is the site of post-translational modification of proteins which includes: a) completion of N-linked glycosylation that began in the rER, b) O-linked glycosylation, c) sulfation, d) phosphorylation, e) methylation, f) acetylation, g) carboxylation, h) addition of glycolipids, i) myristoylation, j) palmitoylation, k) farnesylation, l) geranylgeranylation. The Golgi complex is also involved in protein sorting and packaging. Secretory proteins (e. g., insulin, chymotrypsinogen) are packaged into clathrin-coated vesicles which coalesce into secretion granules for secretion into the blood (endocrine) or into a duct (exocrine). Cell membrane proteins (e. g., receptors) are packaged into nonclathrin-coated vesicles. Lysosomal enzymes are packaged into clathrin-coated vesicles after phosphorylation of mannose to form mannose-6-phosphate. The Golgi complex is also involved in cell membrane recycling.

滑面内质网

滑面内质网为一膜性网状结构,朝向细胞质的一面上无核糖体的分布。滑面内质网参与以下过程:a)细胞膜磷脂、胆固醇和神经酰胺的合成;b)类固醇激素的合成;c)通过细胞色素 P_{450} 单加氧酶和葡萄糖醛酸基转移酶进行药物的解毒;d)糖原的降解;e)脂肪酸的延伸;f)脂解作用;g)脂蛋白的组装;h)肠上皮细胞中甘油三酯的重新合成,i)肌肉收缩相关的钙离子的流动。

Smooth Endoplasmic Reticulum (sER)

The smooth endoplasmic reticulum is a membrane network that contains no ribosomes attached to its cytoplasmic surface. The sER is involved in the following: a) synthesis of membrane phospholipids, cholesterol, and ceramide, b) synthesis of steroid hormones, c) drug detoxification using cytochrome P_{450} monooxygenase and glucuronyl transferase, d) glycogen degradation, e) fatty acid elongation, f) lipolysis, g) lipoprotein assembly, h) resynthesis of triglycerides in enterocytes, and i) calcium fluxes associated with muscle contraction.

线粒体

线粒体由外膜、膜间隙、内膜和基质组成。线粒体的外膜上含有孔蛋白(一种转运蛋白)、磷脂酶 A_2、乙酰辅酶A合成酶和单胺氧化酶。膜间隙中含有氢离子、肌酸激酶和腺氨酸激酶。大多数细胞(如:蛋白质分泌细胞)中,内膜折叠成板层状的嵴,含有电子传递链中的酶类、ATP合成酶、多种转运或转位蛋白、心磷脂和细胞色素c(与凋亡相关)。基质含有:a)三羧酸循环酶类;b)脂肪酸β-氧化酶类;c)氨基酸氧化酶类;d)丙酮酸脱氢复合物;e)氨甲酰磷酸合成酶和鸟氨酸氨甲酰转移酶(尿素循环的一部分);f)碳链裂解酶、18-羟甲基化酶、11β-羟化酶(参与类固醇的合成);g)DNA、mRNA、tRNA、rRNA;h)含有 Ca^{2+} 和 Mg^{2+} 的颗粒。

Mitochondria

Mitochondria consist of an outer membrane, intermembrane space, inner membrane, and matrix compartment. The outer membrane contains porin (a transport protein), phospholipase A_2, acetyl CoA synthase, and monoamine oxidase. The intermembrane space (not shown at this magnification) contains hydrogen ions (H^+ ions), creatine kinase, and adenylate kinase. The inner membrane folds into shelf-like cristae in most cells (e. g., protein-secreting cells) and contains the electron transport chain of enzymes, ATP synthase, various transporter or translocator proteins, cardiolipin, and cytochrome c (involved in apoptosis). The matrix compartment contains: a) tricarboxylic acid (TCA) enzymes, b) fatty acid β-oxidation enzymes, c) amino acid oxidation enzymes, d) pyruvate dehydrogenase complex, e) carbamoylphosphate synthetase and ornithine transcarbamoylase (part of the urea cycle), f) desmolase, 18-methyloxidase, 11β-hydroxylase (involved in steroid synthesis), g) DNA, mRNA, tRNA, rRNA, and h) granules Ca^{2+} and Mg^{2+}.

过氧化物酶体

过氧化物酶体为一膜性结构，其内含物由细胞质中游离的核糖体合成。含有输入受体的过氧化物酶体的前体小泡出芽于内质网，或与另一个前体小泡或已存在的过氧化物酶体发生融合。输入受体将过氧化物酶体的内含物从细胞质转入过氧化物酶体。过氧化物酶体的内含物包括：a）氨基酸氧化酶和羟基酸氧化酶，氧化有机物质，产生过氧化氢（$R\text{-}H_2+O_2 \rightarrow R+H_2O_2$）；b）催化酶和其他过氧化物酶，分解过氧化氢，产生水和氧气（$H_2O_2 \rightarrow H_2O+O_2$）；c）脂肪酸 β 氧化酶，氧化长链脂肪酸（>20 个碳），产生短链脂肪酸；d）胆汁酸合成相关的酶类；e）尿酸氧化酶，分解嘌呤。

Peroxisomes

Peroxisomes are membrane-bound organelles whose contents are synthesized on free ribosomes within the cytoplasm. Peroxisome precursor vesicles that contain import receptors bud from the endoplasmic reticulum and fuse either with each other or existing peroxisomes. The import receptors import the peroxisomal contents from the cytoplasm into the peroxisome. The contents of peroxisomes include: a) amino acid oxidase and hydroxyacid oxidase that use molecular O_2 to oxidize organic substances, producing hydrogen peroxide ($R\text{-}H_2+O_2 \rightarrow R+H_2O_2$), b) catalase and other peroxidases that decompose hydrogen peroxide to water and oxygen ($H_2O_2 \rightarrow H_2O+O_2$), c) fatty acid β-oxidation enzymes that oxidize long-chain fatty acids (>20 carbons) to short-chain fatty acids, d) enzymes for bile acid synthesis, and e) urate oxidase that breaks down purines.

溶酶体

溶酶体为一含有酸性水解酶，在 pH 5 的条件下发挥作用的膜性结构。溶酶体由含有未活化的酸性水解酶的小泡从高尔基体上出芽形成。这些水解酶小泡首先与核内体相融合。核内体的细胞膜上含有 H^+-ATP 酶，从而产生 pH 5 的微环境，形成内吞溶酶体（或初级溶酶体）。内吞溶酶体或与吞噬小泡融合，形成吞噬溶酶体（或次级溶酶体），以降解细胞吞噬的物质；或与自噬泡融合，形成自噬溶酶体（或次级溶酶体），以降解细胞器。含有未降解物质的残余体或发生积聚，形成脂褐素。

Lysosomes

Lysosomes are membrane-bound organelles that contain acid hydrolase enzymes that function at pH 5. Lysosomes form when Golgi hydrolase vesicles that contain inactive acid hydrolase enzymes bud from the Golgi. These vesicles fuse with an endosome, which contains an H^+-ATPase in its membrane that produces a pH 5 environment

forming an endolysosome (or primary lysosome). An endolysosome may fuse with a phagocytic vacuole forming a phagolysosome (or secondary lysosome) which degrades material phagocytosed by the cell. Or, an endolysosome may fuse with an autophagic vacuole forming an autophagolysosome (or secondary lysosome) which degrades cell organelles. Residual bodies contain undigestible material and may accumulate within a cell as lipofuscin pigment.

细胞骨架

细胞骨架主要由三种结构组成:肌动蛋白丝/微丝、微管和中间纤维。

丝状肌动蛋白是直径为6nm的微丝,由球形肌动蛋白螺旋状排列聚合而成。丝状肌动蛋白与细胞质中的球形肌动蛋白维持一种动态的平衡,所以每一条微丝都含有聚合端(正极)和解聚端(负极)。丝状肌动蛋白的作用包括:a)胞吐;b)胞吞;c)胞质分裂;d)形成板状伪足的细胞运动;e)细胞膜整合蛋白的运动。

微管的直径为25nm,由13个环形排列的α微管蛋白和β微管蛋白组成。微管与细胞质中的α微管蛋白和β微管蛋白维持一种动态的平衡,所以每一条微管上都含有聚合端(正极)和解聚端(负极)。微管总是和微管相关蛋白相关联。微管相关蛋白包括:a)驱动蛋白Kinesin,具有ATP酶的活性,负责沿着微管向正极运送小泡(顺面运输);b)动力蛋白Dynein,具有ATP酶的活性,负责沿着微管向负极运送小泡(逆向运输);c)发动蛋白Dynamin,具有ATP酶的活性,负责神经轴突的延伸。微管的功能包括:a)维持细胞的形状(极性);b)有丝分裂过程中染色体的运动;c)分泌颗粒和神经分泌小泡的运动;d)纤毛和鞭毛的摆动;e)细胞吞噬和溶酶体的作用。

中间纤维的直径为10~12nm,起着联系细胞外基质、细胞质和细胞核的作用。中间纤维显示出特定细胞或肿瘤的特异性,因此可作为病理分析的标记分子。例如:细胞角蛋白对于上皮细胞和上皮肿瘤显示出特异性;波形蛋白对于成纤维细胞、成软骨细胞和血管平滑肌细胞显示出特异性;结蛋白对于骨骼肌细胞和非血管平滑肌细胞显示出特异性;神经原纤维对于神经元和神经元肿瘤显示出特异性;胶质纤维酸性蛋白对于星形胶质细胞和神经胶质瘤显示出特异性;以及核纤层蛋白对于核内膜显示出特异性。

Cytoskeleton

The cytoskeleton of a cell comprises three major structures: actin filaments, microtubules, and intermediate filaments.

Filamentous actin (F-actin) is a 6nm diameter microfilament arranged in a helix of polymerized globular monomers of actin (G-actin). F-actin is in dynamic equilibrium with a cytoplasmic pool of G-actin such that a polymerization end (plus end) and a depolymerization end (minus end) exist on each actin filament. The functions of F-actin include: a) exocytosis, b) endocytosis, c) cytokinesis, d) locomotion of cells forming lamellipodia, and e) movement of cell membrane proteins.

Microtubules are 25nm diameter tubules that consist of 13 circularly arranged proteins called α-and β-tubulin. Microtubules are in dynamic equilibrium with a cytoplasmic pool of α-and β-tubulin such that a polymerization end [plus end] and a depolymerization end [minus end] are present on each microtubule. Microtubules are always associated with microtubule-associated proteins (MAPs). MAPs include: a) Kinesin which has ATPase activity for movement of vesicles along microtubules toward the plus end (anterograde transport), b) Dynein which has ATPase activity for movement of vesicles along microtubules toward the minus end (retrograde transport), and c) Dynamin which has ATPase activity for elongation of nerve axons. The functions of microtubule include: a) maintenance of cell shape (polarity), b) movement of chromosomes (karyokinesis), c) movement of secretory granules and neurosecretory vesicles, d) beating of cilia and flagella, and e) phagocytosis/lysosomal function.

Intermediate filaments are 10-12nm diameter filaments. Intermediate filaments function as a cytoplasmic link

between the extracellular matrix, cytoplasm, and nucleus. Intermediate filaments demonstrate specificity for certain cell types/tumors, and therefore can be used as markers for pathologic analysis. For example, cytokeratin shows specificity for epithelium and epithelial tumors; vimentin for fibroblasts, chondroblasts and vascular smooth muscle; desmin for skeletal muscles and non-vascular smooth muscle; neurofilaments for neurons and neuronal tumors; glial fibrillar acidic protein (GFAP) for astrocytes and gliomatous tumors; and lamins for the inner membrane of nuclear envelope.