

The lecture notes provide a fairly complete introduction to the principles and practice of transmission electron microscopy, **BUT** they are **NOT** comprehensive. The following optional reading list is meant to guide you to other places to obtain additional and more detailed descriptions of appropriate topics. To maximize the value derived from this course, it is most helpful to supplement the lectures and lecture notes with some outside reading. Those references identified with the '•' symbol are recommended starting points. **Notes:** This list is far from complete: when possible, updates will be posted on the Web site (<http://bilbo.bio.purdue.edu/~baker/>). Check the Book List for full citations for textbooks like Watt, Wischnitzer, Meek, etc..

INTRODUCTORY MATERIAL

- Watt (1985) Chap. 1, pp.1-19 (Chap. 1, pp.1-29 in 1997 edition)
 Wischnitzer (1981) Chap. 1-3, pp.1-37 (pp.1-37 in 1970 edition)
 •Meek (1976) Chap. 1-2, pp.1-59 (pp.1-65 in 1970 edition)
 Agar (1974) Chap. 1, pp.1-37
 Slayter (1970) Chap. 16, pp.341-350
 Sjostrand (1967) Chap. 2-3, pp.15-128
 Hall (1966) Chap. 1-2, pp.1-43

HISTORY OF THE ELECTRON MICROSCOPE

- Wischnitzer (1981) Chap. 2, pp.4-5 (4-5 in 1970 edition)
 •Meek (1976) Chap. 2, pp.55-59 (49-54 in 1970 edition)
 Hall (1966) Chap. 1, pp.1-6
 Burton, E. F. and W. H. Kohl, In The Electron Microscope. 1st ed. 1942, 2nd ed. (1946). Historical accounts of very early electron microscopy. (1942: 578.1 B95; 1946: 578.1 B95e2)
Historical Aspects of Microscopy. S. Bradbury and G. L'E. Turner (eds.). (1967). Contains a chapter by T. Mulvey on the history of the electron microscope. (578.09 H629)
The Beginnings of Electron Microscopy. P. W. Hawkes (ed.). (1985). Contains many chapters devoted to the history of TEM and SEM. *Adv. Elec. Elec. Phys. Suppl. 16* (621.38 Ad9s. v.16; Physics, Eng., MC)
 Cosslett, V. E. (1987) Fifty years of instrumental development of the electron microscope. *Adv. Opt. Elec. Microsc. 10:215-267* (R. Barer and V. E. Cosslett, eds.). (578.405 Ad95)
 Reisner, J. H. (1989) An early history of the electron microscope in the United States". *Adv. Elec. Elec. Phys. 73:133-231* (621.38 Ad9 Physics library)

GENERAL OVERVIEW OF THE MICROSCOPE

- Slayter (1992) Chap. 1, pp.4-5
 Watt (1985) Chap. 2, pp.20-31 (Chap. 3, pp.59-89 in 1997 edition)
 Wischnitzer (1981) xvi-xix, Chap. 3, pp.36-37 (xiv-xv,36-37 in 1970 edition)
 •Meek (1976) Chap. 6, pp.107-111 (97-101 in 1970 edition)
 Agar (1974) Chap. 1, pp.8,14
 Slayter (1970) Chap. 18, pp.377-379
 Sjostrand (1967) Chap. 3, pp.63-66
 Hall (1966) Chap. 7, pp.136-138

ANALOGY BETWEEN ELECTRON AND LIGHT MICROSCOPY

- Slayter (1992) Chap. 1, pp.4-5
 Watt (1985) Chap. 2, pp.20-21 (Chap. 3, pp.59-61 in 1997 edition)
 Wischnitzer (1981) Chap. 3, pp.36-37; Chap. 4, pp.111-112 (36-37,108 in 1970 edition)
 •Meek (1976) Chap. 1, pp.1-38 (1-42 in 1970 edition)
 Agar (1974) Chap. 1, p.8
 Slayter (1970) Chap. 18, pp.377-379

PHOTONS/ELECTRONS: Diffraction/Interference/Coherence/Resolution

- Slyater (1992) Chap. 2, pp.7-22; Chap. 4, pp.39-49; Chap. 9, pp.118-130
 Watt (1985) Chap. 1, pp.6-10 (Chap. 1, pp.7-14 in 1997 edition)
 Wischnitzer (1981) Chap. 3, pp.6-15; Appendix A, pp.290-295; Appendix J, pp.316-321 (6-15,206-211,232-237 in 1970 edition)
 •Meek (1976) Chap. 1-2, pp.23-49 (20-45 in 1970 edition)
 Agar (1974) Chap. 1, pp.2-9; Chap. 3, pp.96-99
 Slyater (1970) Chap. 3, pp.65-71; Chap. 10, pp.233-248; Chap. 16, pp.341-346
 Sjostrand (1967) Chap. 2, pp.24-31; Chap. 4, pp.97-106,112-118
 Hall (1966) Chap. 1, pp.12-18; Chap. 3, pp.55-56; Chap. 7, pp.138-142,154-157; Chap. 9, pp.235-249

OPTICS (Lens Theory)

- Slyater (1992) Chap. 2, pp.10-13; Chap. 6, pp.65-73; Appendix, pp.298-301
 Watt (1985) Chap. 1, pp.1-5 (Chap. 1, pp.1-7 in 1997 edition)
 Wischnitzer (1981) Chap. 3, p.19 (19 in 1970 edition)
 •Meek (1976) Chap. 1, pp.1-23 (1-20 in 1970 edition)
 Agar (1974) Chap. 1, pp.4-9
 Slyater (1970) Chap. 8, pp.153-170,176-185; Chap. 17, pp.364-350
 Sjostrand (1967) Chap. 2, pp.15-24
 Hall (1966) Chap. 1, pp.6-12; Chap. 3, pp.44-57

- HANDOUT: Oriel - Geometrical Optics - A very short course.

Most physics textbooks have a chapter on geometrical optics

ELECTRON BEAMS/OPTICS AND MAGNETIC AND ELECTROSTATIC LENSES

- Slyater (1992) Chap. 6, pp.73-79
 Watt (1985) Chap. 1, pp.10-16 (Chap. 1, pp.14-24 in 1997 edition)
 Wischnitzer (1981) Chap. 3, pp.15-35 (15-35 in 1970 edition)
 •Meek (1976) Chap. 2, pp.49-54; Chap. 4, pp.75-80; Chap. 6, pp.103-107 (45-49,66-71,93-97 in 1970 ed.)
 Agar (1974) Chap. 3, pp.98-99; Chap. 8, pp.277
 Slyater (1970) Chap. 3, pp.70-71; Chap. 16-17, pp.349-363
 Sjostrand (1967) Chap. 2, pp.31-56
 Hall (1966) Chap. 2, pp.26-43; Chap. 4-5, pp.58-117; Chap. 7, pp.154-157

TRANSMISSION ELECTRON MICROSCOPE INSTRUMENTATION**General References**

- Slyater (1992) Chap. 14, pp.192-206
 Watt (1985) Chap. 2, pp.20-32 (Chap. 3, pp.59-85 in 1997 edition)
 Wischnitzer (1981) Chap. 4, pp.38-81,102-103; Appendix E, pp.304-306; Appendix N, pp.335-342.
 Wischnitzer (1970) Chap. 4, pp.38-81,102-103; Appendix E, pp.220-222
 •Meek (1976) Chap. 5, pp.97-99; Chap. 6-8, pp.111-191; Chap. 15, pp.354-355.
 Meek (1970) Chap. 4, pp.87-88; Chap. 5-7, pp.101-176; Chap. 14, pp.372-373.
 Agar (1974) Chap. 1-2, pp.9-82; Chap. 6, pp.168-169,177,186
 Slyater (1970) Chap. 9, pp.187-219; Chap. 17-18, pp.363-397
 Sjostrand (1967) Chap. 2-3, pp.56-92
 Hall (1966) Chap. Chap. 1, pp.6-7; Chap. 6-7, pp. pp.118-166

TRANSMISSION ELECTRON MICROSCOPE INSTRUMENTATION (Cont'd)**A. Electron Gun**

- Slayter (1992) Chap. 14, pp.196-199
 Watt (1985) Appendix 4, pp.276-286 (Appendix 4, pp.432-447 in 1997 edition)
 Wischnitzer (1981) Chap. 4, pp.38-46 (38-46 in 1970 edition)
 •Meek (1976) Chap. 6, pp.111-117 (101-106 in 1970 edition)
 Agar (1974) Chap. 1, pp.15-21; Chap. 2, pp.42-46
 Slayter (1970) Chap. 18, pp.379-383
 Sjostrand (1967) Chap. 3, pp.66-75
 Hall (1966) Chap. 7, pp.145-151

Field Emission Gun Technology

- Brock, J. M., M. T. Otten, and W. M. Coene. (1992) High resolution imaging with a coherent electron source: The field emission gun. *Micron* **23:149-150**.
 Brock, J. M., M. T. Otten, and M. J. C. deJong. (1992) Improved spatial resolution in imaging, diffraction, microanalysis and scanning with a field emission TEM/SEM. *Micron* **23:151-152**.
 Zemlin, F. (1992) Desired features of cryoelectron microscopy for the electron crystallography of biological material. *Ultramicroscopy* **46:25-32**.
 deJong, A. F. and D. VanDyck. (1993) Ultimate resolution and information in electron microscopy II. The information limit of transmission electron microscopes. *Ultramicroscopy* **49:66-80**.
 Delong, A. (1993) Electron sources for electron microscopes. *Microscopy and Analysis* **3:17-19**.
 Otten, M. T. and W. M. J. Coene. (1993) High-resolution imaging on a field emission TEM. *Ultramicroscopy* **48:77-91**.
 Zhou, Z. H. and W. Chiu. (1993) Prospects for using an IVEM with a FEG for imaging macromolecules towards atomic resolution. *Ultramicroscopy* **49:407-416**.
 •Zemlin, F. (1994) Expected contribution of the field-emission gun to high-resolution transmission electron microscopy. *Micron* **25:223-226**.
 Rathkey, D. (1995) Field emission basics: The water bucket analogy. *Microscopy Today* **95 10:20-21**.

B. Condenser Lens

- Slayter (1992) Chap. 14, pp.199-201
 Watt (1985) Chap. 2, pp.23-25 (Chap. 3, pp.63-65 1997 edition)
 Wischnitzer (1981) Chap. 4, pp.46-50,102-103; Appendix E, pp.304-306 (46-50,102-103,220-222 in 1970)
 •Meek (1976) Chap. 6, pp.117-123 (107-113 in 1970 edition)
 Agar (1974) Chap. 1, pp.21-26; Chap. 2, pp.46-50
 Slayter (1970) Chap. 18, pp.388-391
 Sjostrand (1967) Chap. 3, pp.75-78
 Hall (1966) Chap. 7, pp.151-154

C. Lens Aberrations

- Slayter (1992) Chap. 6, pp.79-87
 Watt (1985) Chap. 1, pp.2-5,11-17 (Chap. 1, pp.1-6,18-24 in 1997 edition)
 Wischnitzer (1981) Chap. 4, pp.53-59,64-65 (53-59,64-65 in 1970 edition)
 •Meek (1976) Chap. 4, pp.80-89 (71-80 in 1970 edition)
 Agar (1974) Chap. 1, pp.9-13
 Slayter (1970) Chap. 9, pp.187-219; Chap. 17, pp.363-372
 Sjostrand (1967) Chap. 2, pp.56-62
 Hall (1966) Chap. 6, pp.118-135

TRANSMISSION ELECTRON MICROSCOPE INSTRUMENTATION (Cont'd)

D. Objective Lens/Aperture and Specimen Stage

- Slayter (1992) Chap. 14, pp.201-204
 Watt (1985) Chap. 2, pp.25-27 (Chap. 3, pp.66-68 in 1997 edition)
 Wischnitzer (1981) Chap. 4, pp.50-52,72-75 (50-52,72-75 in 1970 edition)
 •Meek (1976) Chap. 5, pp.97-99; Chap. 6, pp.123-127 (87-88,113-117 in 1970 edition)
 Agar (1974) Chap. 1, pp.26-28; Chap. 2, pp.50-67; Chap. 6, pp.168-169
 Slayter (1970) Chap. 18, pp.391-394
 Sjostrand (1967) Chap. 3, pp.78-80
 Hall (1966) Chap. 7, pp.158-163

E. Projector Lens

- Slayter (1992) Chap. 14, p.204
 Watt (1985) Chap. 2, pp.27-28 (Chap. 3, pp.68-69 in 1997 edition)
 Wischnitzer (1981) Chap. 4, pp.62-68 (62-68 in 1970 edition)
 •Meek (1976) Chap. 6, pp.127-133 (117-123 in 1970 edition)
 Agar (1974) Chap. 2, pp.28-37,69
 Slayter (1970) Chap. 18, pp.394-395
 Sjostrand (1967) Chap. 3, pp.80-81
 Hall (1966) Chap. 6-7, pp.132-135,163-166

F. Camera and Viewing System

- Slayter (1992) Chap. 14, pp.204-206
 Watt (1985) Chap. 2, pp.28-29 (Chap. 3, pp.69-72 in 1997 edition)
 Wischnitzer (1981) Chap. 4, pp.68-71,75 (68-71,75 in 1970 edition)
 •Meek (1976) Chap. 15, pp.354-355 (372-373 in 1970 edition)
 Agar (1974) Chap. 2, pp.69-72; Chap. 6, p.177
 Slayter (1970) Chap. 18, pp.396-397
 Sjostrand (1967) Chap. 3, pp.82-83

G. Vacuum System

- Watt (1997) Chap. 3, pp.76-78; Appendix 1, pp.379-400
 Slayter (1992) Chap. 14, pp.192-196
 Watt (1985) Chap. 2, pp.29-31; Appendix 1, pp.228-241
 Wischnitzer (1981) Chap. 4, pp.76-79; Appendix N, pp.335-342 (76-79 in 1970 edition)
 •Meek (1976) Chap. 7, pp.139-166 (129-155 in 1970 edition)
 Agar (1974) Chap. 2, pp.73-77; Chap. 6, p.186
 Slayter (1970) Chap. 18, pp.383-387
 Sjostrand (1967) Chap. 3, pp.83-91

H. Electrical System

- Wischnitzer (1981) Chap. 4, pp.80-81 (80-81 in 1970 edition)
 •Meek (1976) Chap. 8, pp.167-191 (156-176 in 1970 edition)
 Agar (1974) Chap. 2, pp.78-82

CONTRAST AND IMAGE FORMATION**A. Depth of Field/Focus**

- Slayter (1992) Chap. 16, p.235
 Watt (1985) Chap. 1, pp.8-9 (Chap. 1, pp.10-11 in 1997 edition)
 Wischnitzer (1981) Chap. 4, pp.61-64; Appendix F, pp.307-310 (61-64,223-226 in 1970 edition)
 •Meek (1976) Chap. 4, pp.89-91 (80-82 in 1970 edition)
 Agar (1974) Chap. 1, pp.13-14; Chap. 2, p.72
 Slayter (1970) Chap. 18, pp.413-415
 Sjostrand (1967) Chap. 4, pp.118-122
 Hall (1966) Chap. 7, pp.142-145

B. Elastic/Inelastic Scattering

- Slayter (1992) Chap. 8, pp.102-109
 Watt (1985) Chap. 2, p. 74 (Chap. 2, pp.48-49 in 1997 edition)
 Wischnitzer (1981) Chap. 4, pp.59-61 (59-61 in 1970 edition)
 •Meek (1976) Chap. 5, pp.94-97 (85-86 in 1970 edition)
 Agar (1974) Chap. 3, pp.83-87
 Slayter (1970) Chap. 19, pp.421-430
 Sjostrand (1967) Chap. 4, pp.93-97
 Hall (1966) Chap. 8, pp.200-216

C. Phase/Amplitude Contrast/Contrast Transfer Theory

- Slayter (1992) Chap. 7, pp.88-94; Chap. 8, pp.95-102,109-117
 Watt (1985) Chap. 3, pp.88-91 (Chap. 5, pp.189-192 in 1997 edition)
 Wischnitzer (1981) Chap. 4, pp.59-61; Appendix J, pp.317-321 (59-61,233-237 in 1970 edition)
 •Meek (1976) Chap. 5, pp.97-101 (88-90 in 1970 edition)
 Agar (1974) Chap. 3, pp.87-96,99-110; Chap. 8, pp.277-285
 Slayter (1970) Chap. 19, pp.421,431-441
 Sjostrand (1967) Chap. 4, pp.106-110
 Hall (1966) Chap. 9, pp.262-264

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Thon, F. (1971) Phase contrast electron microscopy. In Electron Microscopy in Materials Science (U. Valdre, ed.) Academic Press, N. Y. **570-625.**

Johansen, B. V. (1973) Bright field electron microscopy of biological specimens. I. Obtaining the optimum contribution of phase contrast to image formation. *Micron* **4:446-472.**

Johnson, H. M. (1973) In-Focus phase contrast electron microscopy. *Princ. Tech. Elec. Microsc.* (M. A. Hayat, ed.) **3:153-198** (578.4 H323p).

Johnson, D. J. and D. Crawford. (1973) Defocusing phase contrast effects in electron microscopy. *J. Microscopy* **98:313-324.**

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Unwin, P. N. T. and R. Henderson. (1975) Molecular structure determination by electron microscopy of unstained crystalline specimens. *J. Mol. Biol.* **94:425-440.**

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Johansen, B. V. (1977) High resolution bright field electron microscopy of biological specimens. *Ultramicrosc.* **2:229-239.**

CONTRAST AND IMAGE FORMATION (Cont'd)**C. Phase/Amplitude Contrast/Contrast Transfer Theory** (Cont'd)

- Misell, D. L. (1978) Contrast enhancement by using two electron micrographs. *Princ. Tech. Elec. Microsc.* (M. A. Hayat, ed.) **8:181-245** (578.4 H323p).
- Misell, D. L. (1978) The phase problem in electron microscopy. *Adv. Opt. Elec. Microsc.* (R. Barer and V. E. Cosslett, eds.) **7:185-279**. (578.405 Ad95)
- Zemlin, F. (1978) Image synthesis from electron micrographs taken at different defocus. *Ultramicrosc.* **3:261-263**.
- Cowley, J. M. and R. E. Bridges. (1979) Phase and amplitude contrast in electron microscopy of stained biological objects. *Ultramicrosc.* **4:419-427**.
- Stewart, M. and G. Vigers. (1986) Electron microscopy of frozen-hydrated biological material. *Nature (London)* **319:631-636**.
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MICROSCOPE DISTURBANCES AND ALIGNMENT

- Slayter (1992) Chap. 16, pp.241-242
- Watt (1985) Chap. 2, pp.24-25 (Chap. 3, pp.65-66 in 1997 edition)
- Wischnitzer (1981) Chap. 4, pp.81-95 (81-95 in 1970 edition)
- Meek (1976) Chap. 6, pp.133-138; Chap. 11, pp.229-233,241-256,276-289
(1970) 123-128,254-258,265-281,298-311
- Agar (1974) Chap. 3, pp.98-99; Chap. 8, pp.277
- Slayter (1970) Chap. 17, pp.370-372; Chap. 18, pp.387-388,399-402,409-413; Chap. 20, pp.453-459
- Sjostrand (1967) Chap. 10-11, pp.311-361
- Hall (1966) Chap. 7, pp.167-171

OPERATION OF THE TRANSMISSION ELECTRON MICROSCOPE**General References**

- Slayter (1992) Chap. 16, pp.238-246
- Wischnitzer (1981) Chap. 4, pp.100-102 (100-102 in 1970 edition)
- Meek (1976) Chap. 11-12, pp.221-297 (246-319 in 1970 edition)
- Agar (1974) Chap. 6, pp.166-190
- Slayter (1970) Chap. 20, pp.458-459

A. Choice of Voltage

- Wischnitzer (1981) Chap. 4, pp.107-111 (none in 1970 edition)
- Meek (1976) Chap. 11, p.228 (252-253 in 1970 edition)
- Agar (1974) Chap. 6, pp.166-167

B. Choice of Apertures

- Wischnitzer (1981) Chap. 4, pp.73-75 (73-75 in 1970 edition)
- Agar (1974) Chap. 6, pp.167-169

C. Specimen Stage

- Watt (1985) Chap. 2, pp.25-26 (Chap. 3, pp.66-67,74-75 in 1997 edition)
- Wischnitzer (1981) Chap. 4, pp.72-73 (72-73 in 1970 edition)
- Meek (1976) Chap. 11, pp.233-235 (258-261 in 1970 edition)
- Agar (1974) Chap. 6, pp.169-171
- Sjostrand (1967) Chap. 3, pp.81-82

OPERATION OF THE TRANSMISSION ELECTRON MICROSCOPE (Continued)**D. Choice of Magnification**

- Meek (1976) Chap. 11, pp.235-238 (260-262 in 1970 edition)
- Agar (1974) Chap. 1, pp.28-30
- Slyater (1970) Chap. 18, pp.395-396

E. Focusing

- Watt (1997) Chap. 3, pp.75-77; Chap. 5, pp.197-199
- Slyater (1992) Chap. 16, pp.238-240
- Watt (1985) Chap. 2, pp.29-30; Chap. 4, pp.169-172
- Meek (1976) Chap. 11, pp.238-241; Chap. 12, pp.271-272,290-296 (263-265,293-294,311-318 in 1970 edition)
- Agar (1974) Chap. 3, pp.106-110; Chap. 6, pp.173-177
- Slyater (1970) Chap. 18, pp.402-409
- Sjostrand (1967) Chap. 4, pp.106-110

F. Magnification Calibration

- Slyater (1992) Chap. 16, pp.242-244
- Watt (1985) Chap. 3, pp.94-95 (Chap. 5, pp.195-197 in 1997 edition)
- Wischnitzer (1981) Chap. 4, pp.101-102 (101-102 in 1970 edition)
- Meek (1976) Chap. 13, pp.317-321 (335-339 in 1970 edition)
- Agar (1974) Chap. 5, pp.159-165
- Slyater (1970) Chap. 18, pp.416-417
- Sjostrand (1967) Chap. 12, pp.362-365
- Hall (1966) Chap. 10, pp.347-356

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- Reisner, J. H. (1965) The determination of magnification in the electron microscope. I. Instrumental Factors influencing the estimate of magnification. *Lab. Invest.* **14, 137-141.**
- Hoskins, G. C., V. Williams, C. L. Smith, and W. K. Thornton. (1967) A method providing precise reproducibility of magnification of electron micrographs. *J. Ultrastruc. Res.* **20:1-5.**
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- Skinner, L. M. (1969) An accurate method for measuring the magnification of an electron microscope. *J. Sci. Instrum.* **2:206-208.**
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- Dunn, R. F. (1978) Calibration of magnification in transmission electron microscopy. *Princ. Tech. Elec. Microsc.* (M. A. Hayat, ed.) **8:156-180 (578.4 H323p).**
- Olson, N. and T. S. Baker. (1989) Magnification calibration and the determination of spherical virus diameters using cryo-microscopy. *Ultramicrosc.* **30:281-297.**
- Belnap, D. M., W. D. Grochulski, N. H. Olson, and T. S. Baker (1993) Use of radial density plots to calibrate image magnification for frozen-hydrated specimens. *Ultramicrosc.* **48:347-358.**

OPERATION OF THE TRANSMISSION ELECTRON MICROSCOPE (Continued)**G. Resolution Tests**

- Slayter (1992) Chap. 16, p.244
 Watt (1985) Chap. 1, pp.16-18 (Chap. 1, pp.25-27 in 1997 edition)
 Wischnitzer (1981) Chap. 4, p.102 (102 in 1970 edition)
 •Meek (1976) Chap. 13, pp.305-317 (324-335 in 1970 edition)
 Agar (1974) Chap. 5, pp.142-150
 Slayter (1970) Chap. 18, pp.417-418
 Sjostrand (1967) Chap. 12, pp.366-369
 Hall (1966) Chap. 10, pp.292-298

H. Image Intensifier/TV Display

- Wischnitzer (1981) Chap. 4, pp.103-104 (103-104 in 1970 edition)
 •Meek (1976) Chap. 17, pp.404-407 (400-402 in 1970 edition)
 Agar (1974) Chap. 7, pp.268-270
 Hall (1966) Chap. 9, pp.275-277
- Reynolds, G. T. (1968) Image intensification applied to microscope systems. *Adv. Opt. Elec. Microsc.* (R. Barer and V. E. Cosslett, eds.) **2:1-40.** (578.405 Ad95)
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I. Microscope Maintenance

- Wischnitzer (1981) Chap. 4, pp.95-96 (95-96 in 1970 edition)
 •Meek (1976) Chap. 15, pp.343-364 (361-382 in 1970 edition)
 Sjostrand (1967) Chap. 3, pp.91-92

J. Photography

- Slayter (1992) Chap. 19, pp.286-297
 Watt (1985) Chap. 2, pp.28-29; Chap. 4, pp.181-183 (Chap. 3, pp.70-72 in 1997 edition)
 Wischnitzer (1981) Chap. 4, pp.100-101 (100-101 in 1970 edition)
 •Meek (1976) Chap. 11, pp.242-243; Chap. 14, pp.325-342 (267-268,343-360 in 1970 edition)
 •Agar (1974) Chap. 7, pp.191-276 (*This is a good, comprehensive description*)
 Slayter (1970) Chap. 18, pp.396-397; Chap. 21, pp.460-479
 Sjostrand (1967) Chap. 5, pp.129-137
 Hall (1966) Chap. 7, pp.171-176
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- Farnell, G. C. and R. B. Flint. (1975) Photographic aspects of electron microscopy. *Princ. Tech. Elec. Microsc.* (M. A. Hayat, ed.) **5:19-61** (578.4 H323p; TSB).
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OTHER MODES OF TRANSMISSION ELECTRON MICROSCOPE OPERATION**A. Electron Diffraction**

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B. Specimen Support Films for TEM

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SPECIMEN PREPARATION TECHNIQUES (Continued)**D. Negative Staining (Continued)**

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- Horne, R. W. and P. Wildy. (1979) An historical account of the development and applications of the negative staining technique to the electron microscopy of viruses. *J. Microscopy* **117:103-122.**
- Hayat, M. A. and S. E. Miller. (1990) In Negative Staining, McGraw Hill Pub. Co., N. Y. (616.0194 H323n in Vet. Med. library and TSB)

E. Metal Shadowing

- Watt (1997) Chap. 4, pp.140-144; Chap. 5, pp.192-195; Appendix 2, pp.400-406
- Watt (1985) Chap. 3, pp.84-87,91-95; Appendix 2, pp.241-247
- Wischnitzer (1981) Appendix L, pp.328-331 (244-247 in 1970 edition)
- Meek (1976) Chap. 15, pp.476-482 (471-477 in 1970 edition)
- Slyter (1970) Chap. 19, pp.430-431,434
- Hall (1966) Chap. 10, pp.298-309
- Abermann, R., M. M. Salpeter, and L. Bachmann. (1972) High resolution shadowing. *Princ. Tech. Elec. Microsc.* (M. A. Hayat, ed.) **3:195-217.** (578.4 H323p)
- Henderson, W. J. and K. Griffiths. (1972) Shadow casting and replication. *Princ. Tech. Elec. Microsc.* (M. A. Hayat, ed.) **3:149-193.** (578.4 H323p)
- Slyter, H. S. (1976) High-resolution metal replication of macromolecules. *Ultramicrosc.* **1:341-357.**
- Smith, P. R. and J. Kistler. (1977) Surface reliefs computed from micrographs of heavy metal-shadowed specimens. *J. Ultrastruc. Res.* **61:124-133.**
- Neugebauer, D. C. and H. P. Zingsheim. (1978) The two faces of the purple membrane: Structural differences revealed by metal decoration. *J. Mol. Biol.* **123:235-246.**
- Smith, P. R. and I. E. Ivanov. (1980) Surface reliefs computed from micrographs of isolated heavy metal shadowed particles. *J. Ultrastruc. Res.* **71:25-36.**
- Tyler, J. M. and D. Branton. (1980) Rotary shadowing of extended molecules dried from glycerol. *J. Ultrastruc. Res.* **71:95-102.**
- Baumeister, W., O. Kubler, and H. P. Zingsheim. (1981) The structure of the cell envelope of micrococcus radiodurans as revealed by metal shadowing and decoration. *J. Ultrastruc. Res.* **75:60-71.**
- Fowler, W. E. and U. Aebi. (1983) Preparation of single molecules and supramolecular complexes for high-resolution metal shadowing. *J. Ultrastruc. Res.* **83:319-334.**

F. Unstained Specimens

To my knowledge, general textbooks have yet to include discussion about the preparation and microscopy of unstained specimens. Hence, to acquire any in-depth knowledge about preparation and imaging such specimens, it is important to read **at least one or two** of the articles listed below.

1. Unstained Specimens (Room Temperature)

- Hart, R. G. (1968) Electron microscopy of unstained biological material: The polytropic montage. *Science* **159:1464-1467.**
- Matricardi, V. R., R. C. Moretz, and D. F. Parsons. (1972) Electron diffraction of wet proteins: catalase. *Science* **177:268-270.**
- Ottensmeyer, F. P. and M. Pear. (1975) Contrast in unstained sections: A comparison of bright and dark field electron microscopy. *J. Ultrastruc. Res.* **51:253-259.**

SPECIMEN PREPARATION TECHNIQUES (Continued)**1. Unstained Specimens (Room Temperature) (Continued)**

- Unwin, P. N. T. and R. Henderson. (1975) Molecular structure determination by electron microscopy of unstained crystalline specimens. *J. Mol. Biol.* **94:425-440.**
- Hui, S. W. and D. F. Parsons. (1978) Electron microscopy and electron diffraction studies on hydrated membranes. In *Advanced Techniques in Biological Electron Microscopy* **2:213-235.**
- Ottensmeyer, F. P., D. P. Bazett-Jones, J. Hewitt, and G. B. Price. (1978) Structure analysis of small proteins by electron microscopy: valinomycin, bacitracin and low molecular weight cell growth stimulators. *Ultramicrosc.* **3:303-313.**
- Kuhlbrandt, W. (1982) Discrimination of protein and nucleic acids by electron microscopy using contrast variation. *Ultramicrosc.* **7:221-232.**
- Akey, C. W. and S. J. Edelstein. (1983) Equivalence of the projected structure of thin catalase crystals preserved for electron microscopy by negative stain, glucose or embedding in the presence of tannic acid. *J. Mol. Biol.* **163:575-612.**
- Cohen, H. A., T. -W. Jeng, R. A. Grant, and W. Chiu. (1984) Specimen preparative methods for electron crystallography of soluble proteins. *Ultramicrosc.* **13:19-26.**

2. Unstained Specimens (Frozen-Hydrated)

- Taylor, K. A. and R. M. Glaeser. (1974) Electron diffraction of frozen, hydrated protein crystals. *Science* **186:1036-1037.**
- Taylor, K. A. and R. M. Glaeser. (1976) Electron microscopy of frozen hydrated biological specimens. *J. Ultrastruc. Res.* **55:448-456.**
- Taylor, K. A. (1978) Structure determination of frozen, hydrated, crystalline biological specimens. *J. Microscopy* **112:115-125.**
- Hax, W. M. A. and S. Lichtenegger. (1982) Transfer, observation and analysis of frozen hydrated specimens. *J. Microscopy* **126:275-284.**
- Lepault, J., F. P. Booy, and J. Dubochet. (1983) Electron microscopy of frozen biological specimens. *J. Microscopy* **129:89-102.**
- McDowall, A. W., J. -J. Chang, R. Freeman, J. Lepault, C. A. Walter, and J. Dubochet. (1983) Electron microscopy of frozen hydrated sections of vitreous ice and vitrified biological samples. *J. Microsc.* **131:1-9.**
- Adrian, M., J. Dubochet, J. Lepault, and A. W. McDowall. (1984) Cryo-electron microscopy of viruses. *Nature* **308:32-36.**
- Jaffe, J. S. and R. M. Glaeser. (1984) Preparation of frozen-hydrated specimens for high resolution electron microscopy. *Ultramicrosc.* **13:373-378.**
- Milligan, R. A., A. Brisson, and P. N. T. Unwin. (1984) Molecular structure determination of crystalline specimens in frozen aqueous solutions. *Ultramicrosc.* **13:1-10.**
- Dubochet, J., M. Adrian, J. Lepault, and A. W. McDowall. (1985) Cryo-electron microscopy of vitrified biological specimens. *Trends in Biochem. Sci* **10:143-146.**
- Chiu, W. (1986) Electron microscopy of frozen, hydrated biological specimens. *Ann. Rev. Biophys. Biophys. Chem.* **15:237-257.**
- Lepault, J. and J. Dubochet. (1986) Electron microscopy of frozen-hydrated specimens: preparation and characteristics. *Meth. Enzym.* **127:719-730.**
- Stewart, M. and G. Vigers. (1986) Electron microscopy of frozen-hydrated biological material. *Nature* **319:631-636.**
- Henderson, R., J. M. Baldwin, K. H. Downing, J. Lepault, and F. Zemlin. (1986) Structure of purple membrane from *Halobacterium halobium*:: Recording, measurement and evaluation of electron micrographs at 3.5Å resolution. *Ultramicrosc.* **19:147-178.**

SPECIMEN PREPARATION TECHNIQUES (Continued)**2. Unstained Specimens (Frozen-Hydrated) (Continued)**

- Kellenberger, E. (1987) The response of biological macromolecules and supramolecular structures to the physics of cryo-specimen preparation. in Cryotechniques in Biological Electron Microscopy, (R. A. Steinbrecht and K. Zierold, eds.), Springer-Verlag, Heidelberg, **pp.35-63.**
- Dubochet, J., M. Adrian, J. -J. Chang, J. -C. Homo, J. Lepault, A. W. McDowell, and P. Schultz. (1988) Cryo-electron microscopy of vitrified specimens. *Quat. Rev. Biophys.* **21:129-228.**
- Stewart, M. (1989) Topical minireview. Transmission electron microscopy of frozen-hydrated biological material. *Elec. Microsc. Rev.* **2:117-121.**

G. Freeze Drying/Etching/Fracture

- Slyter (1992) Chap. 16, pp.231-232
- Watt (1985) Chap. 4, pp.157-158,160-164 (Chap. 4, pp.171-180 in 1997 edition)
- Wischnitzer (1981) Chap. 13, pp.200-201 (196-197 in 1970 edition)
- Meek (1976) Chap. 15, pp.484-485 (479-480 in 1970 edition)
- Sjostrand (1967) Chap. 8, pp.188-221
- Hall (1966) Chap. 10, pp.371-376
- Bullivant, S. (1973) Freeze-etching and freeze-fracturing. In Advanced Techniques in Biological Electron Microscopy (J. K. Koehler, ed.) **1:67-112.**
- Branton, D. and S. Kirchanski. (1977) Interpreting the results of freeze-etching. *J. Microscopy* **111:117-124.**
- Kistler, J., U. Aebi, and E. Kellenberger. (1977) Freeze-drying and shadowing a two-dimensional periodic specimen. *J. Ultrastruc. Res.* **59:76-86.**
- Kistler, J. and E. Kellenberger. (1977) Collapse phenomena in freeze-drying. *J. Ultrastruc. Res.* **59:70-75.**
- Nermut, M. V. (1977) Freeze-drying for electron microscopy. *Princ. Tech. Elec. Microsc.* (M. A. Hayat, ed.) **7:79-117** (578.4 H323p).
- Sleytr, U. B. and A. W. Robards. (1977) Freeze-fracturing: A review of methods and results. *J. Microscopy* **111:77-100.**
- Gross, H., E. Bas, and H. Moor. (1978) Freeze-fracturing in ultrahigh vacuum at -196°C. *J. Cell Biol.* **76:712-728.**
- Sjostrand, F. S. (1979) The interpretation of pictures of freeze-fractured biological material. *J. Ultrastruc. Res.* **69:378-420.**
- Gross, H. (1980) Ultrahigh vacuum freeze-fracturing at -196°C and decoration of specific sites of paracrystalline membranes. In Electron Microscopy at Molecular Dimensions (W. Baumeister and W. Vogell, eds.) Springer-Verlag, Berlin **pp.71-80.**
- Lepault, J. and J. Dubochet. (1980) Freezing, fracturing, and etching artifacts in particulate suspensions. *J. Ultrastruc. Res.* **72:223-233.**
- Smith, P. R. (1980) Freeze-drying specimens for electron microscopy. *J. Ultrastruc. Res.* **72:380-384.**
- Willison, J. H. M. and A. J. Rowe. (1980) Replica, shadowing and freeze-etching techniques. *Pract. Meth. Elec. Microsc.* (A. M. Glauert, ed.) **8:1-282.** (502.8 P881)
- Studer, D., H. Moor, and H. Gross. (1981) Single bacteriorhodopsin molecules revealed on both surfaces of freeze-dried and heavy metal-decorated purple membranes. *J. Cell Biol.* **90:153-159.**
- Wildhaber, I., H. Gross, and H. Moor. (1982) The control of freeze-drying with deuterium oxide. *J. Ultrastruc. Res.* **80:367-373.**
- Miller, K. R., C. S. Prescott, T. L. Jacobs, and N. L. Lassignal. (1983) Artifacts associated with quick-freezing and freeze-drying. *J. Ultrastruc. Res.* **82:123-133.**

SPECIMEN PREPARATION TECHNIQUES (Continued)**G. Freeze Drying/Etching/Fracture (Continued)**

Robarts, A. W. and U. B. Sleytr. (1985) Low temperature methods in biological electron microscopy. *Pract. Meth. Elec. Microsc.* (A. M. Glauert, ed.) **10:1-527**. (502.8 P881)

H. Electron Autoradiography

- Slayter (1992) Chap. 16, pp.233-234
 Watt (1985) Chap. 4, pp.165-166,168 (Chap. 4, pp.156-158 in 1997 edition)
 •Wischnitzer (1981) Chap. 13, pp.186-189 (182-185 in 1970 edition)
 Sjostrand (1967) Chap. 17, pp.413-435
 Hall (1966) Chap. 10, pp.337

Meek does not discuss autoradiography.

- Pelc, S. R. and M. G. E. Welton. (1968) Autoradiography and the photographic process. *Adv. Opt. Elec. Microsc.* (R. Barer and V. E. Cosslett, eds.) **2:151-166**. (578.405 Ad95)
- Salpeter, M. M. and L. Bachmann. (1972) Autoradiography. *Princ. Tech. Elec. Microsc.* (M. A. Hayat, ed.) **2:221-278**. (578.4 H323p)
- Salpeter, M. M. and F. A. McHenry. (1973) Electron microscope autoradiography. In Advanced Techniques in Biological Electron Microscopy **1:113-152**.
- Maraldi, N. M. (1976) Electron autoradiography of free specimens. *Princ. Tech. Elec. Microsc.* (M. A. Hayat, ed.) **6:271-289**. (578.4 H323p)
- Gleuskens, M. (1977) Autoradiographic localization of DNA in nonmetabolic conditions. *Princ. Tech. Elec. Microsc.* (M. A. Hayat, ed.) **7:163-201**. (578.4 H323p)
- Williams, M. A. (1977) Autoradiography and immunocytochemistry. *Prac. Meth. Elec. Microsc.* (A. M. Glauert, ed.) **6, Part I**. (502.8 P881)
- Williams, M. A. (1977) Quantitative methods in electron microscopy. *Prac. Meth. Elec. Microsc.* (A. M. Glauert, ed.) **6, Part II**. (502.8 P881)
- Baker, J. R. J. (1989) Autoradiography: A comprehensive overview. *Roy. Microsc. Soc. Microsc. Handbooks* **18:1-110**. (578 B174a)

RADIATION EFFECTS

- Slayter (1992) Chap. 17, pp.247-250
 Wischnitzer (1981) Chap. 4, pp.96-100 (96-100 in 1970 edition)
 •Meek (1976) Chap. 16, p.367 (387-388 in 1970 edition)
 Agar (1974) Chap. 6, pp.181-186; Chap. 8, p.294
 Hall (1966) Chap. 9, pp.267-275

Most general texts tend to ignore problems associated with radiation induced specimen damage. Consequently, you are encouraged to read **AT LEAST ONE** of the articles marked with the "•".

- Hillier, J., S. Mudd, A. G. Smith, and E. H. Beutner. (1950) The 'fixation' of electron microscopic specimens by the electron beam. *J. Bact.* **60:641-654.**
- Bahr, G. F., F. B. Johnson, and E. Zeitler. (1965) The elementary composition of organic objects after electron irradiation. *Lab. Invest.* **14:377-395.**
- Stenn, K. and G. F. Bahr. (1970) Specimen damage caused by the beam of the transmission electron microscope, a correlative reconsideration. *J. Ultrastruc. Res.* **31:526-550.**
- Williams, R. C. and H. W. Fisher. (1970) Electron microscopy of tobacco mosaic virus under conditions of minimal beam exposure. *J. Mol. Biol.* **52:121-123.**
- Glaeser, R. M. (1971) Limitations to significant information in biological electron microscopy as a result of radiation damage. *J. Ultrastruc. Res.* **36:466-482.**
- Thach, R. E. and Thach, S. S. (1971) Damage to biological samples caused by the electron beam during electron microscopy. *Biophys. J.* **11:204-210.**
- Isaacson, M., D. Johnson, and A. V. Crewe. (1973) Electron beam excitation and damage of biological molecules; its implications for specimen damage in electron microscopy. *Rad. Res.* **55:205-224.**
- Unwin, P. N. T. (1974) Electron microscopy of the stacked disk aggregate of tobacco mosaic virus protein II. The influence of electron irradiation on the stain distribution. *J. Mol. Biol.* **87:657-670.**
- Dubochet, J. (1975) Carbon loss during irradiation of T4 bacteriophages and *E. coli* bacteria in electron microscopes. *J. Ultrastruc. Res.* **52:276-288.**
- Glaeser, R. M. (1975) Radiation damage and biological electron microscopy. In Physical Aspects of Electron Microscopy and Microbeam Analysis (B. Siegel and D. R. Beaman, eds.) John Wiley and Sons, N. Y. 205-229.
- Ottensmeyer, F. P., R. F. Whiting, E. E. Schmidt, and R. S. Clemens. (1975) Electron microtophography of proteins: A close look at the ashes of myokinase and protamine. *J. Ultrastruc. Res.* **52:193-201**
- Salih, S. M. and V. E. Cosslett. (1975) Radiation damage in electron microscopy of organic materials: Effect of low temperatures. *J. Microscopy* **105:269-276.**
- Hahn, M., J. Serebinski, and W. Baumeister. (1976) Inactivation of catalase monolayers by irradiation with 100keV electrons. *Proc. Nat. Acad. Sci. (U.S.A.)* **73:823-827.**
- Cosslett, V. E. (1978) Radiation damage in the high resolution electron microscopy of biological materials: A review. *J. Microscopy* **113:113-129.**
- Glaeser, R. M. and K. A. Taylor. (1978) Radiation damage relative to transmission electron microscopy of biological specimens at low temperature: A review. *J. Microscopy* **112:127-138.**
- Dietrich, I., J. Dubochet, F. Fox, E. Knapek, and R. Weyl. (1980) Reduction of radiation damage by imaging with a superconducting lens system. In Electron Microscopy at Molecular Dimensions (W. Baumeister and W. Vogell, eds.) Springer-Verlag, Berlin **pp.234-244.**
- Fujiyoshi, Y., T. Kobayashi, K. Ishizuka, N. Uyeda, Y. Ishida, and Y. Harada. (1980) A new method for optimal-resolution electron microscopy of radiation-sensitive specimens. *Ultramicrosc.* **5:459-468.**

RADIATION EFFECTS (Continued)

- Herrmann, K.-H., D. Krahl, and H.-P. Rust. (1980) Low-dose image recording by TV techniques. In *Electron Microscopy at Molecular Dimensions* (W. Baumeister and W. Vogell, eds.) Springer-Verlag, Berlin **pp.186-193**.
- Knapek, E. and J. Dubochet. (1980) Beam damage to organic material is considerably reduced in cryo-electron microscopy. *J. Mol. Biol.* **141:147-161**.
- Chiu, W. and T. W. Jeng. (1982) Electron radiation sensitivity of protein crystals. *Ultramicrosc.* **10:63-70**.
- Talmon, Y. (1982) Thermal and radiation damage to frozen hydrated specimens. *J. Microscopy* **125:227-237**.
- Wrigley, N. G., E. Brown, and R. K. Chillingworth. (1983) Combining accurate defocus with low-dose imaging in high resolution electron microscopy of biological material. *J. Microsc.* **130:225-232**.
- Jeng, T. -W. and W. Chiu. (1984) Quantitative assessment of radiation damage in a thin protein crystal. *J. Microsc.* **136:35-44**.
- Henderson, R. and R. M. Glaeser. (1985) Quantitative analysis of image contrast in electron micrographs of beam-sensitive crystals. *Ultramicrosc.* **16:139-150**.
- Berriman, J. and K. R. Leonard. (1986) Methods for specimen thickness determination in electron microscopy. II. Changes in thickness with dose. *Ultramicrosc.* **19:349-366**.
- Talmon, Y., M. Adrian, and J. Dubochet. (1986) Electron beam damage to organic inclusions in vitreous, cubic, and hexagonal ice. *J. Microsc.* **141:375-384**.
- Bullough, P. and R. Henderson. (1987) Use of spot-scan procedure for recording low-dose micrographs of beam-sensitive specimens. *Ultramicrosc.* **21(3):223-230**.
- Dorset, D. L. and F. Zemlin. (1987) Specimen movement in electron-irradiated paraffin crystals - A model for initial beam damage. *Ultramicrosc.* **21:263-270**.
- Jesior, J.-C. and R. H. Wade. (1987) Electron-irradiation-induced flattening of negatively-stained 2D protein crystals. *Ultramicrosc.* **21:313-320**.
- Downing, K. H. (1988) Observations of restricted beam-induced specimen motion with small-spot illumination. *Ultramicrosc.* **24:387-398**.
- Luther, P. K., M. C. Lawrence, and R. A. Crowther. (1988) A method for monitoring the collapse of plastic sections as a function of electron dose. *Ultramicrosc.* **24:7-18**.