

Letter to the Editor: Key Events in the History of Electron Microscopy

Over the years, I have read with great interest several articles and book chapters about historical aspects of electron microscopy. The report by F. Haguenu et al. about the key events in the history of electron microscopy (*Microscopy and Microanalysis*, Vol. 9, No. 2, April 2003, pp. 96–138) is, to my knowledge, by far the most comprehensive article ever published. The authors did a superb job in first listing chronologically the development of electron optics and instrumentation for the years from 1897 to 2002, and then describing major applications in physics and materials science, as well as life sciences.

I am a microbiologist and epidemiologist with research interests in microbial pathogenesis and carcinogenesis, and I quite frequently use conventional and immunoelectron microscopy (both scanning and transmission electron microscopy) in my research. The authors covered in the life science section numerous applications of the electron microscope, including (a) techniques devised for the study of biological material, (b) the normal cell and its organelles, (c) some specialized cells and cell structures, (d) ultrastructure of viruses, and (e) plants, as well as (f) listed numerous books and surveys related to the use of electron microscopy in the field of life science. However, I noticed that the otherwise excellent review left out the crucial impact of electron microscopic data on the field of microbiology, in particular, bacteriology. Scanning and transmission electron microscopes are invaluable tools for the study of host–pathogen interactions as well as of prokaryotic cell structures of Gram-positive bacteria, Gram-negative bacteria, and *Mollicutes* (also known as mycoplasmas). Without the electron microscope, we would not have the current knowledge about the prokaryotic architecture and pathogenicity of many bacteria. I took the liberty of listing chronologically some historical research articles as well as some helpful

books and book chapters about the use of electron microscopy in bacteriology that, I believe, will complement the list by the authors (see below). For all other applications and academic studies using electron microscopy, the guide provided by F. Haguenu et al. is much appreciated.

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HISTORICAL RESEARCH ARTICLES IN BACTERIOLOGY

Morphological studies about bacteria have greatly benefited from the development of the electron microscope. Early studies were mainly concerned with the electron microscopic visualization of prokaryotic cell structures (Gram-positive and Gram-negative cell walls, capsules, protoplasts, nucleoids, and flagella) and determination of cell shapes and cell sizes.

1938–1942 Early electron microscopic studies on bacteria.

von Borries, B., Ruska, E. and Ruska, H., Bakterien und Virus in übermikroskopischer Aufnahme (Mit einer Einführung in die Technik des Übermikroskops). *Klin. Wochenschr.* **17** (1938) 921–925. [Note that this reference was also cited by the authors F. Haguenu et al. as the earliest publication in the section “Ultrastructure of Viruses.”]

Piekarski, G., Lichtoptische und übermikroskopische Untersuchungen zum Problem des Bakterienzell-

kerns. *Zentralbl. Bakteriolog. Parasitenk. Infektionskrankh.* [1. Abt., Orig.] **144** (1939) 140–148.

Jakob, A. and Mahl, H., Strukturdarstellung bei Bakterien, insbesondere die Kapseldarstellung bei Anaerobiern mit dem elektrostatischen Elektronen-Übermikroskop. *Arch. Exp. Zellforsch. Gewebezücht.* **24** (1940) 87–104.

Marton, L., The electron microscope—A new tool for bacteriological research. *J. Bacteriol.* **41** (1941) 397–413.

Mudd, S. and Lackman, D.B., Bacterial morphology as shown by the electron microscope. I. Structural differentiation within the streptococcal cell. *J. Bacteriol.* **41** (1941), 415–420.

Mudd, S., Polevitzky, K., Anderson, T.F. and Chambers, L.A., Bacterial morphology as shown by the electron microscope. II. The bacterial cell-wall in the genus *bacillus*. *J. Bacteriol.* **42** (1941), 251–264.

Umbreit, W.W. and Anderson, T.F., A study of *Thiobacillus thiooxidans* with the electron microscope. *J. Bacteriol.* **44** (1942) 317–320.

Mudd, S., Polevitzky, K., Anderson, T.F. and Kast, C.C., Bacterial morphology as shown by the electron microscope. III. Cell-wall and protoplasm in a strain of *Fusobacterium*. *J. Bacteriol.* **44** (1942) 361–366.

Improvements in electron microscopic preparation techniques allowed investigators to observe bacterial cells with considerably fewer artifacts (the preparations have been freed of extraneous material and desiccation artifacts). This significantly improved the quality of electron micrographs and facilitated their interpretation. Studies were conducted to determine electron microscopically the effects of antibiotics (penicillin, streptomycin, chloromycetin, aureomycin, and lithium chloride) and physicochemical treatment (sonication and disinfectants) on bacteria, as well as to visualize the effectiveness of bacterial-dense filters. Studies were also aimed at investigating mycoplasmas (small pleomorphic bacteria totally devoid of cell walls).

1948–1964 The electron microscope became an invaluable tool in the field of bacteriology.

Hillier, J., Knaysi, G. and Baker, R.F., New preparation techniques for the electron microscopy of bacteria. *J. Bacteriol.* **56** (1948) 569–576.

Houwink, A.L. and van Iterson, W., Electron microscopical observations on bacterial cytology. II. A study of flagellation. *Biochim. Biophys. Acta* **5** (1950) 10–44.

Bringmann, G., Licht- und elektronenmikroskopische Studien an Antibiotica-Formen von Coli-Bakterien. *Zentralbl. Bakteriolog. Parasitenk. Infektionskrankh. Hyg.* [1. Abt., Orig.] **157** (1951/52) 577–585.

Brauß, W., Elektronenoptische Beobachtungen an Coli-Bakterien. *Zentralbl. Parasitenk. Infektionskrankh. Hyg.* [1. Abt., Orig.] **158** (1952) 339–341.

Freundt, E.A., Morphological studies of the peripneumonia organism (*Micromyces peripneumoniae bovis*). *Acta Pathol. Microbiol. Scand.* **31** (1952) 508–529.

Helmcke, J.-G., Elektronenmikroskopische Untersuchungen der Strukturen verschiedener Membranfilter. *Zentralbl. Bakteriolog. Parasitenk. Infektionskrankh. Hyg.* [1. Abt., Orig.] **159** (1952/53) 308–310.

Henneberg, G. and Haagen-Crodel, B., Elektronenmikroskopische Darstellung von Bakterien in Schnitten von Membranfiltern. *Zentralbl. Bakteriolog. Parasitenk. Infektionskrankh. Hyg.* [1. Abt., Orig.] **161** (1954) 314–323.

Klieneberger-Nobel, E. and Cuckow, F.W., A study of organisms of the pleuropneumonia group by electron microscopy. *J. Gen. Microbiol.* **12** (1955) 95–99.

Ueckert, H., Elektronenmikroskopische Untersuchungen über die normale und die gestörte Morphologie von *Corynebacterium diphtheriae*. *Zentralbl. Bakteriolog. Infektionskrankh. Hyg.* [1. Abt., Orig.] **165** (1956) 135–147.

Kellenberger, E., Ryter A. and Séchaud, J., Electron microscope study of DNA-containing plasma. II. Vegetative and mature phage DNA as compared with normal bacterial nucleoids in different physiological states. *J. Biophys. Biochem. Cytol.* **4** (1958) 671–676.

van Iterson, W. and Ruys, A.C., The fine structure of the *Mycoplasmataceae* (microorganisms of the pleuropneumonia group—P.P.L.O.). I. *Mycoplasma hominis*, *M. fermentans* and *M. salivarium*. *J. Ultrastruct. Res.* **3** (1960) 282–301.

Schyma, D., Gärtner, H., and Moll, G., Elektronenmikroskopische Darstellung der Feinstruktur eines neuartigen Ultrafilters aus Aluminiumalginat. *Zentralbl. Bakteriolog. Parasitenk. Infektionskrankh. Hyg.* [1. Abt., Orig.] **181** (1961) 22–28.

Bladen, H.A. and Hampp, E.G., Ultrastructure of *Treponema microdentium* and *Borrelia vincentii*. *J. Bacteriol.* **87** (1964) 1180–1191.

Domermuth, C.H., Nielson, M.H., Freundt, E.A., and Birch-Andersen, A., Ultrastructure of mycoplasma species. *J. Bacteriol.* **88** (1964) 727–744.

Biology (Barile, M.F. and Razin, S., eds.) pp. 63–102 (Academic Press, London & New York, 1979).

Watson, L.P., McKee, A.E. and Merrell, B.R., Preparation of microbiological specimens for scanning electron microscopy. *Scanning Electron Microscopy II* (1984) 45–56.

Aldrich, H.C. and Todd, W.J., Ultrastructure techniques for microorganisms (Plenum, New York, 1986).

Hoppert, M. and Holzenburg, A., *Electron Microscopy in Microbiology*. (BIOS Scientific Publishers Ltd., Oxford, UK, 1998).

BOOKS AND BOOK CHAPTERS

Boatman, E.S., Morphology and ultrastructure of the *Mycoplasmatales*. In. *The Mycoplasmas*, Vol. I: *Cell*

Response to “Letter to the Editor”

We are most grateful to Dr. Stadtländer for his careful reading of our list of “key articles” and for his generous, appreciative remarks. He is indeed correct in saying that bacteriology was not well covered. We should have pointed out that this was one of the many topics that we unfortunately had to exclude for lack of space and readers will no doubt be able to list many others. As we say in the

introduction, this is a personal selection and we leave readers to complete it in their own specialities.

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