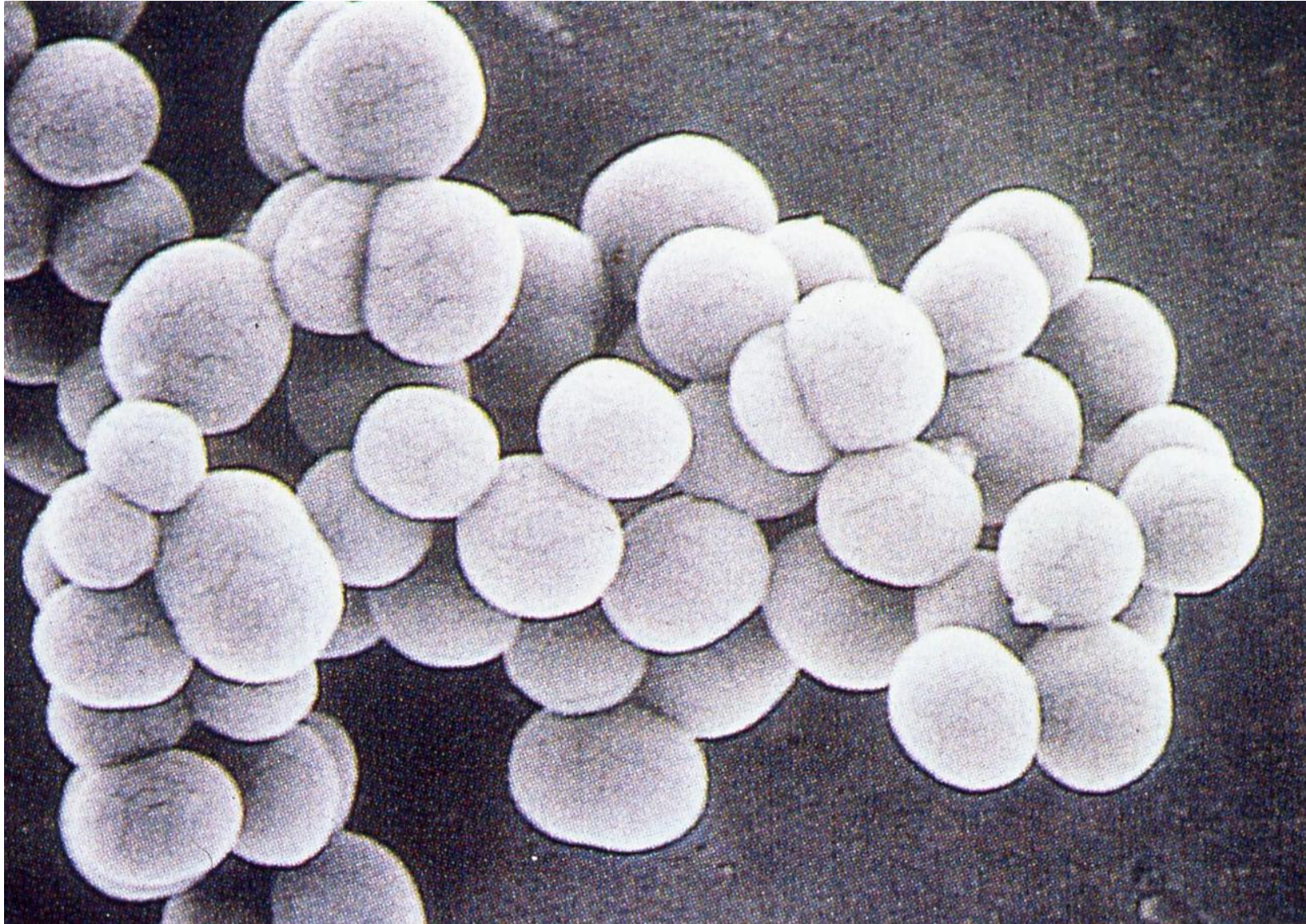
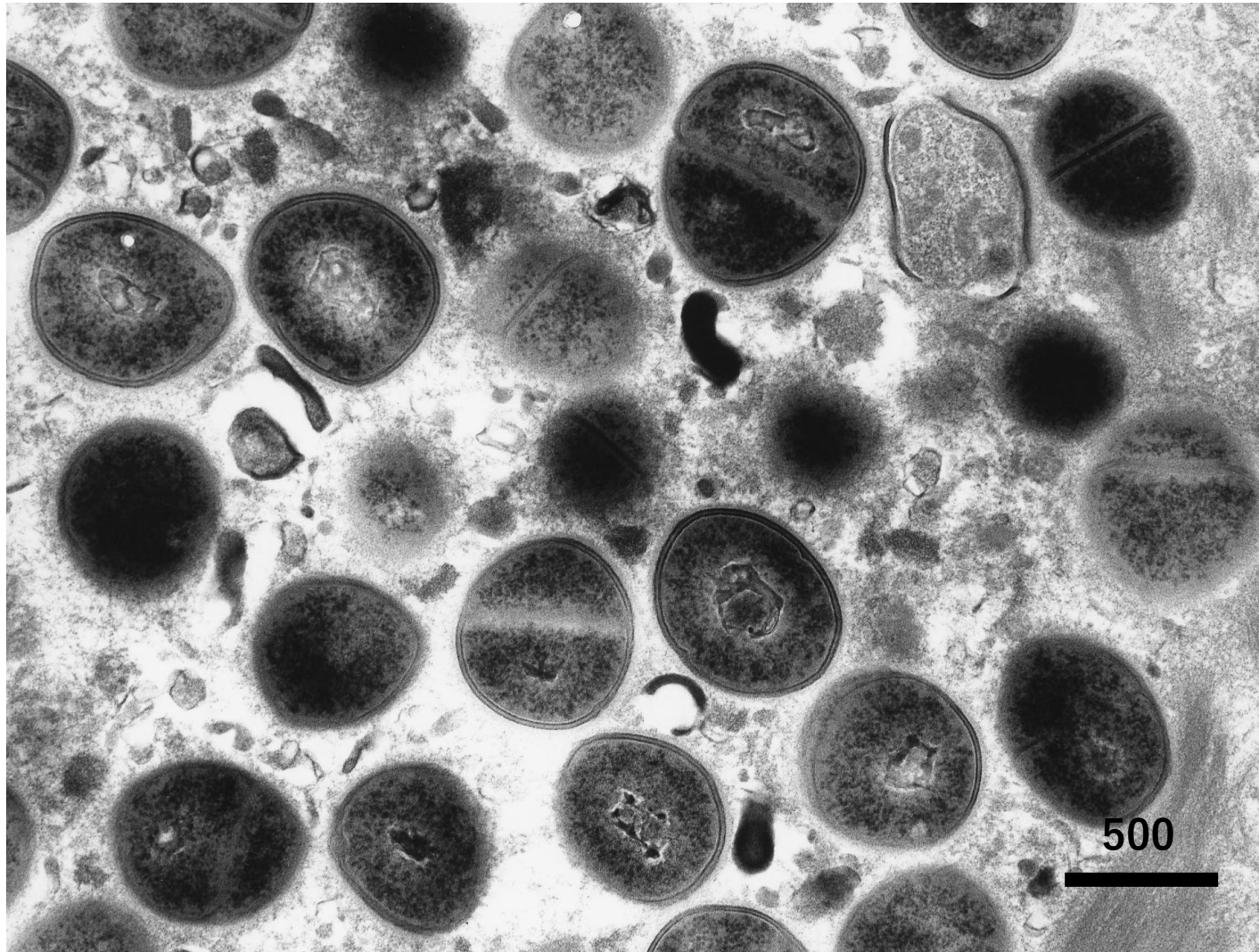


Ultrastructure of bacteria

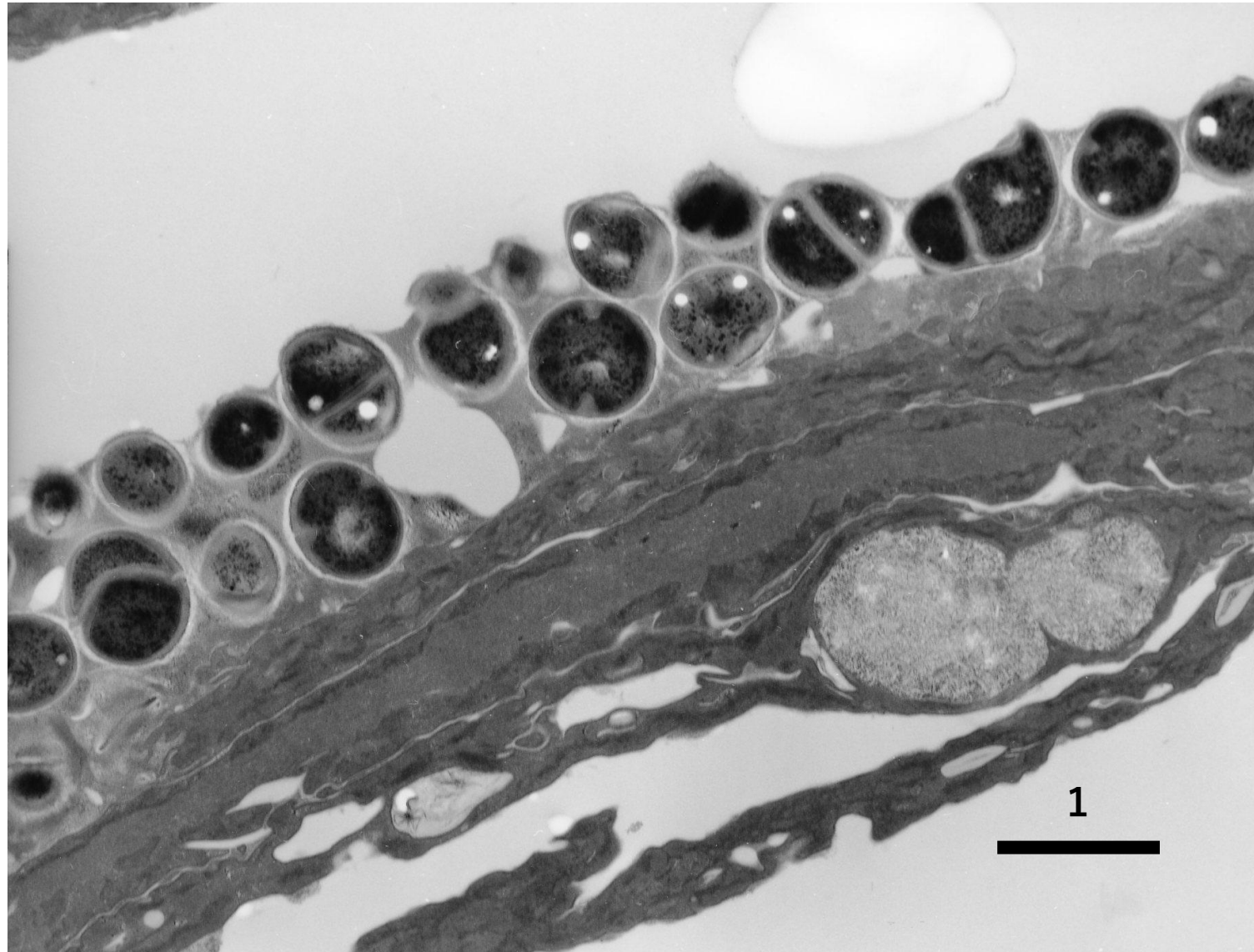
A variety of electron microscopic features of bacteria and bacterial infections are shown here. In addition to conventional transmission electron microscopy (TEM) and scanning electron microscopy (SEM), immunostaining and *in situ* hybridization for pathogens at the ultrastructural level are presented. Please enjoy the variety.



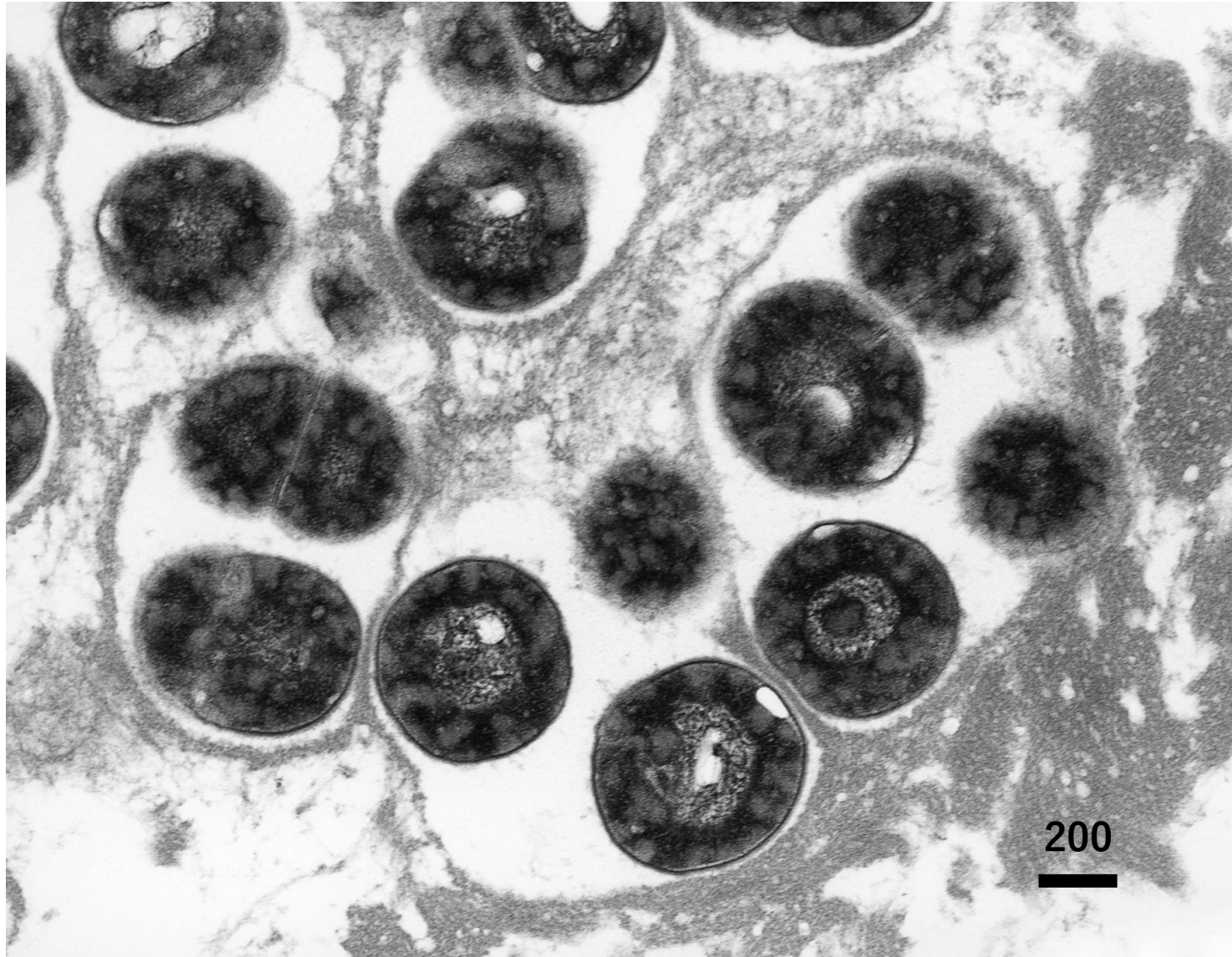
Staphylococcus aureus (SEM). The term “Staphylo” means a bunch of grapes in Latin. The cocci grow with a binary fission.



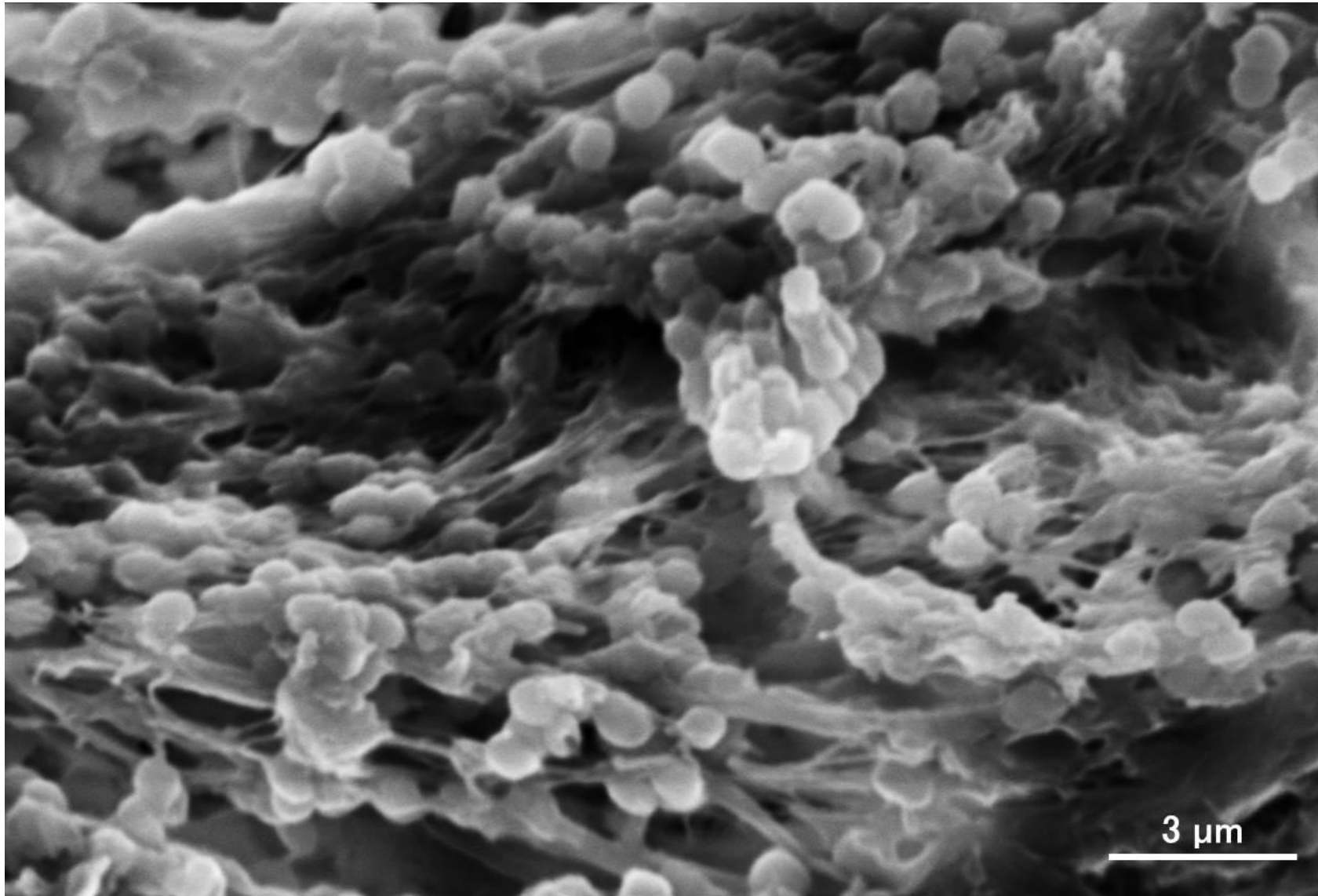
Impetigo contagiosum, a highly contagious infection of *Staphylococcus aureus* (TEM). Biopsy was taken from the occipital skin of a newborn girl.



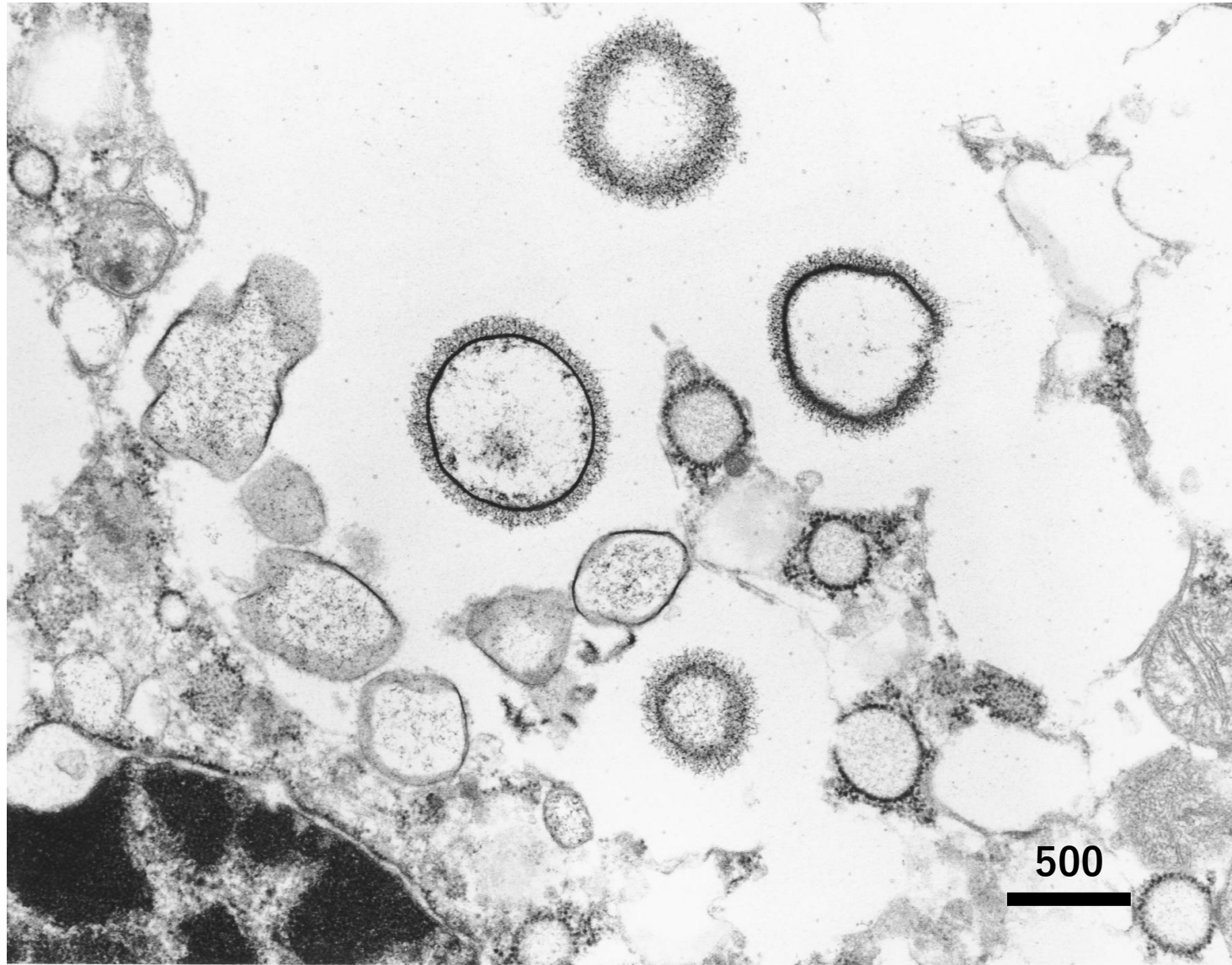
Secondary infection of *Staphylococcus aureus* on the surface of the epidermis in congenital ichthyosiform erythroderma (TEM). Biopsy was taken from a 55 y-o male patient.



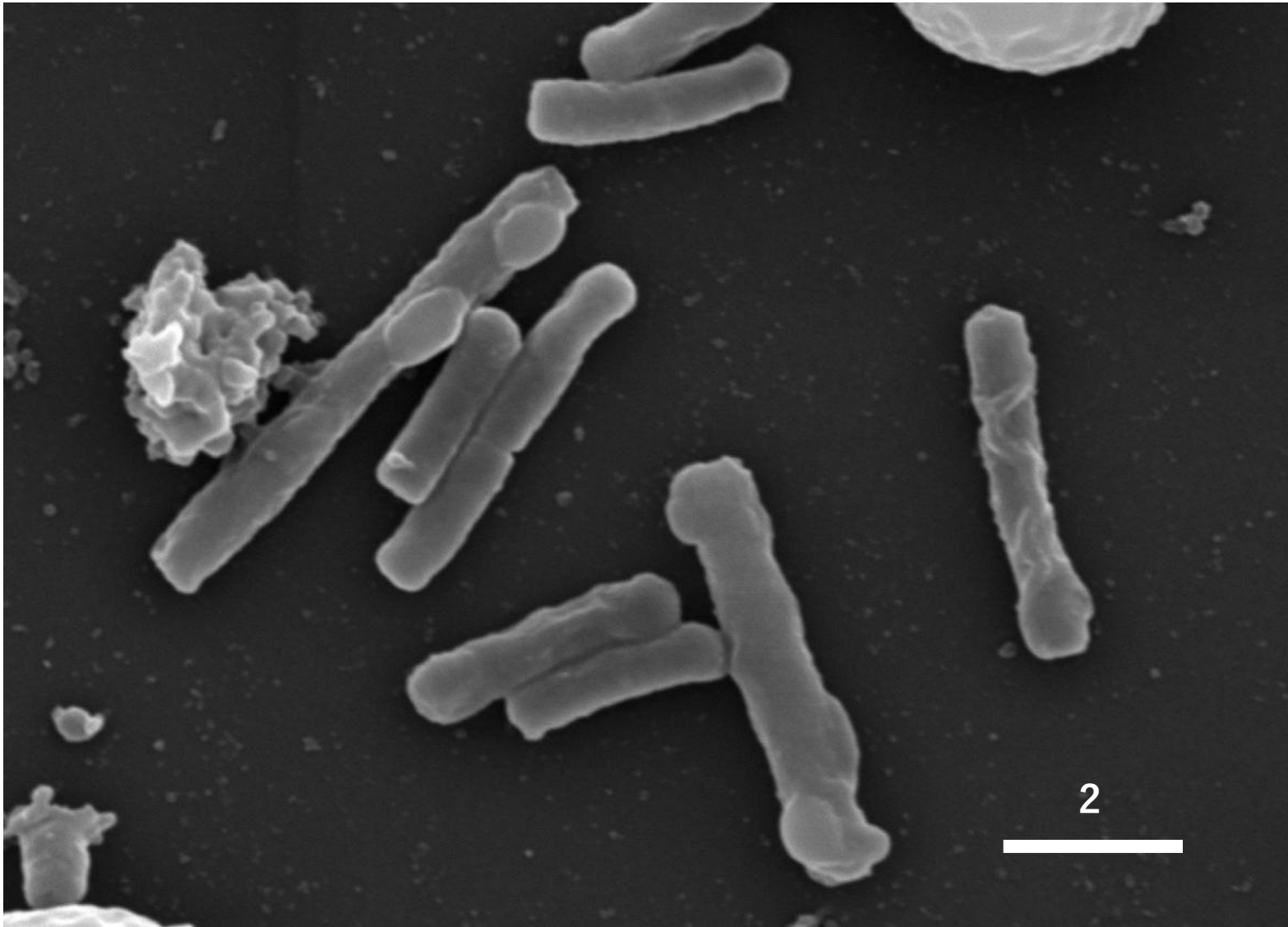
Secondary infection of *Streptococcus viridans*, normal flora of the oral cavity, on the surface of the tongue mucosa (TEM). Biopsy was taken from a 66 y-o male patient.



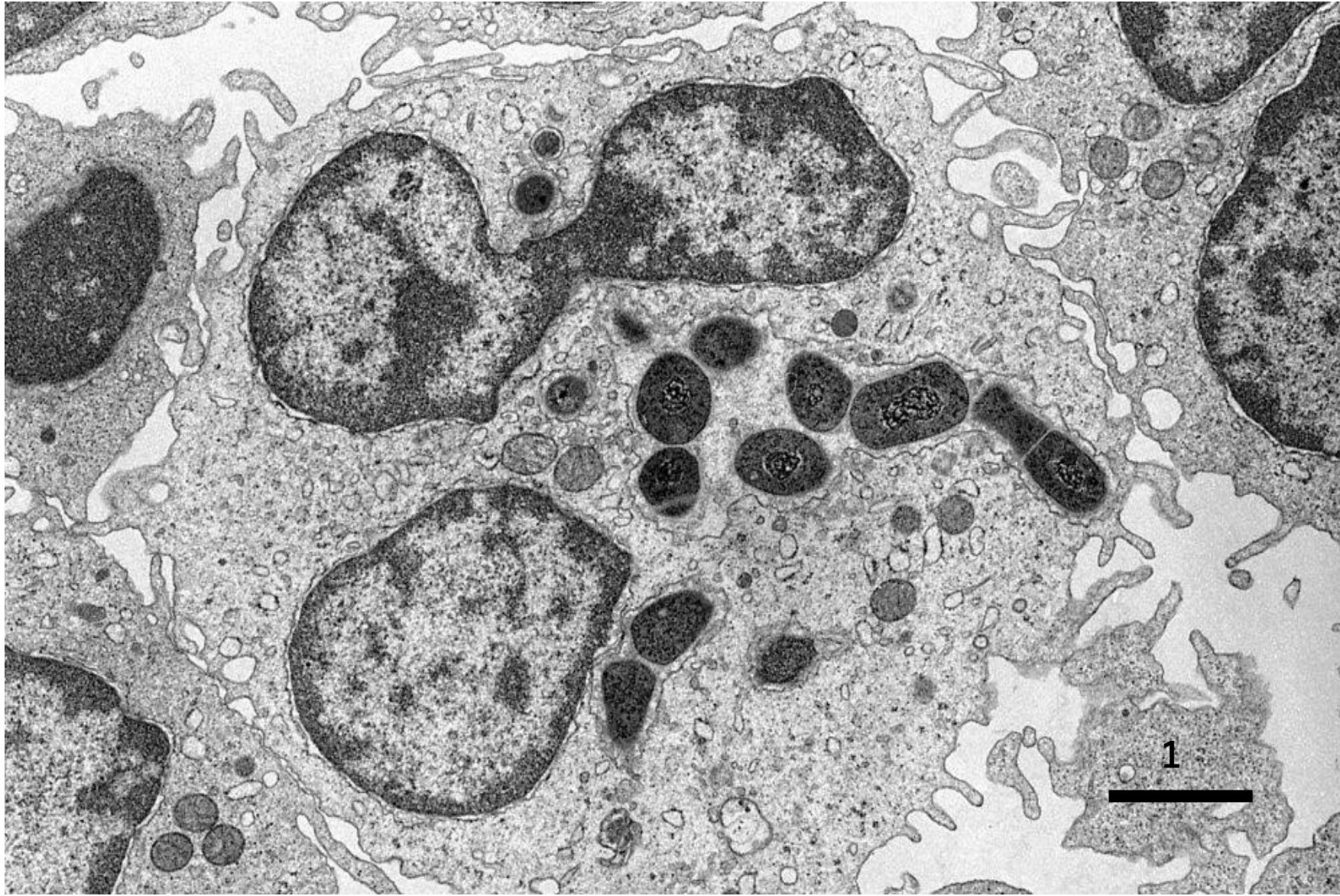
Enterococcus faecalis infection causing perforating cholangitis of the common bile duct of a male adult (SEM).



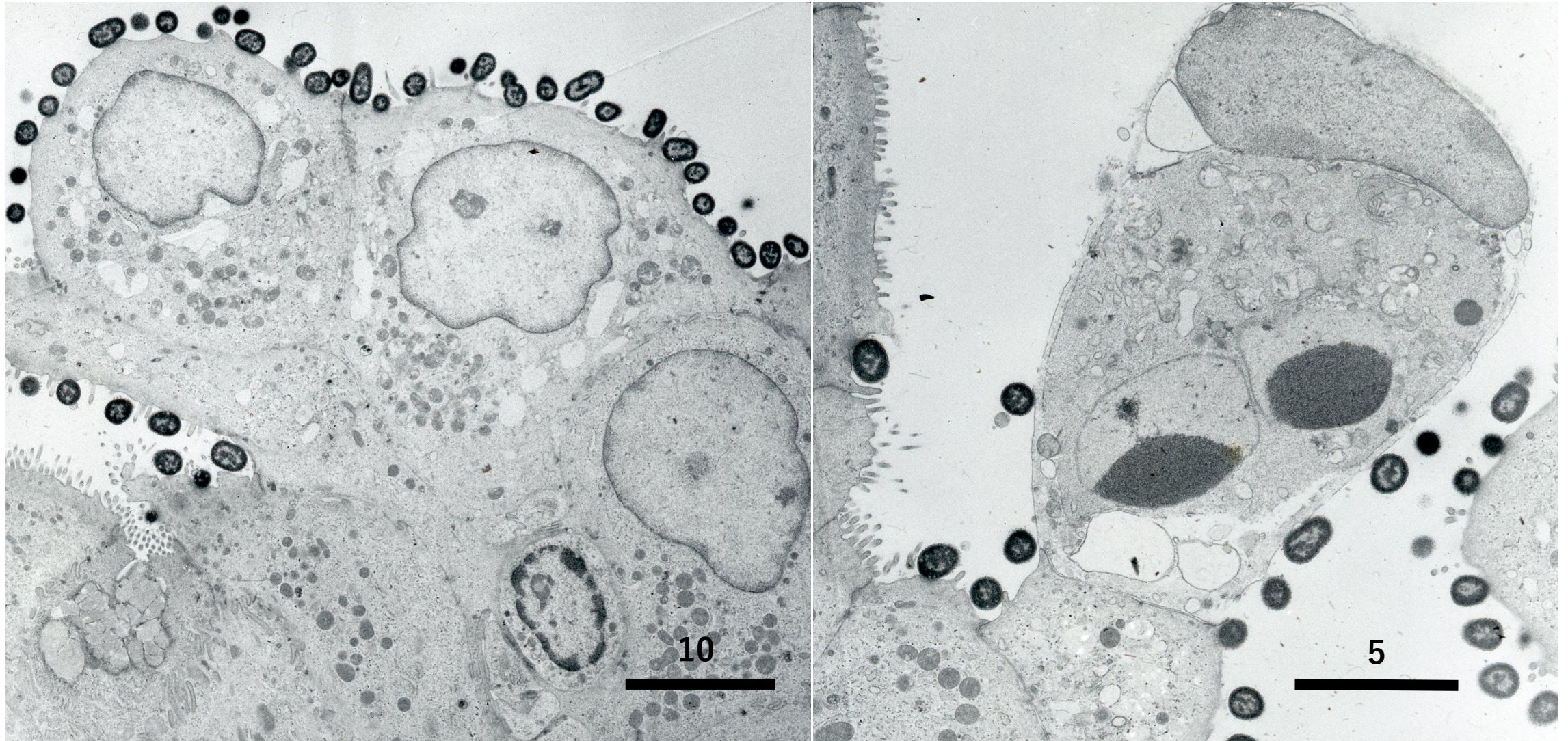
Pneumococcal lobar pneumonia seen in an 84 y-o male patient at autopsy (TEM). The coccal bodies of *Streptococcus pneumoniae* show distinct capsule formation.



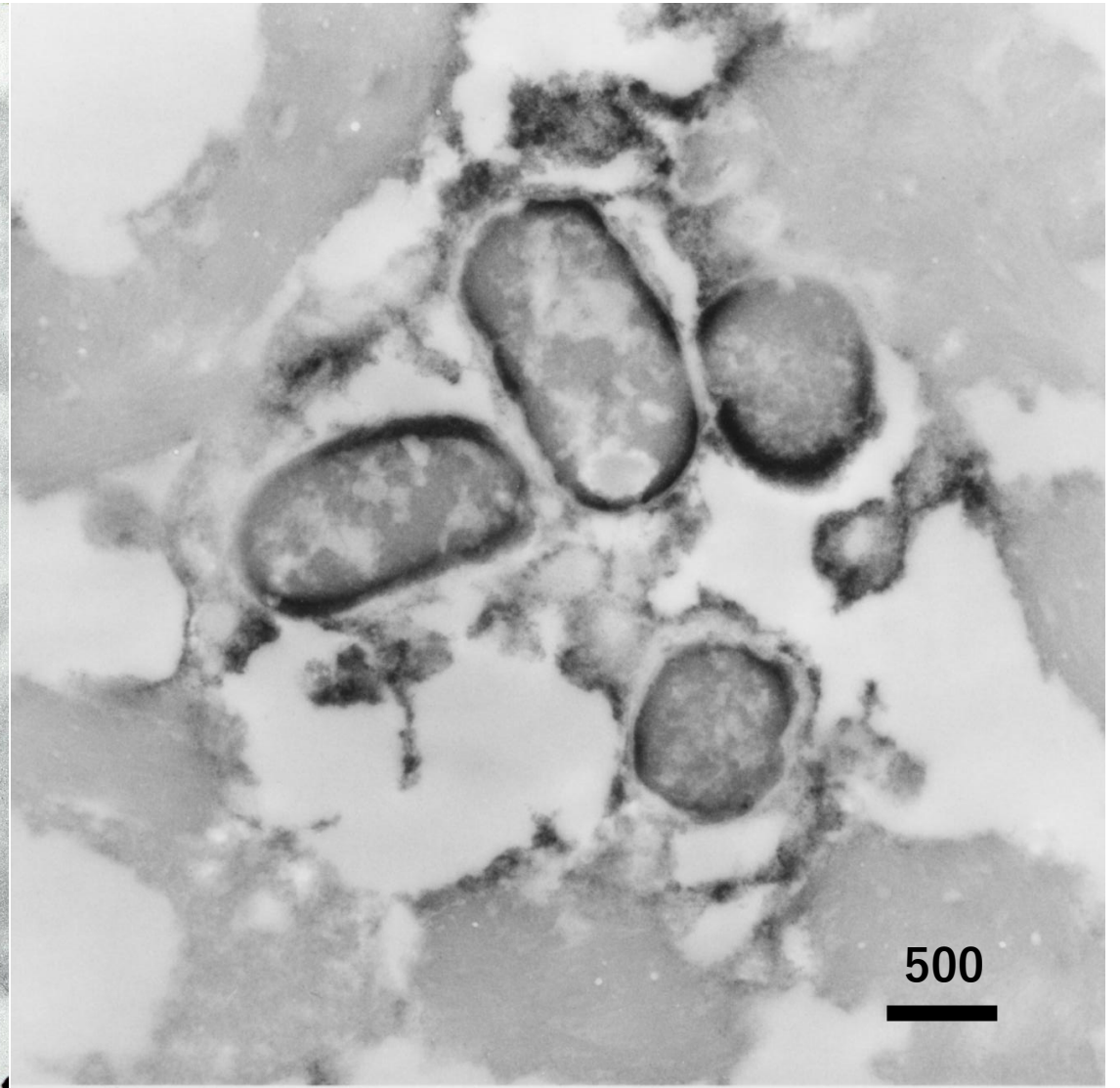
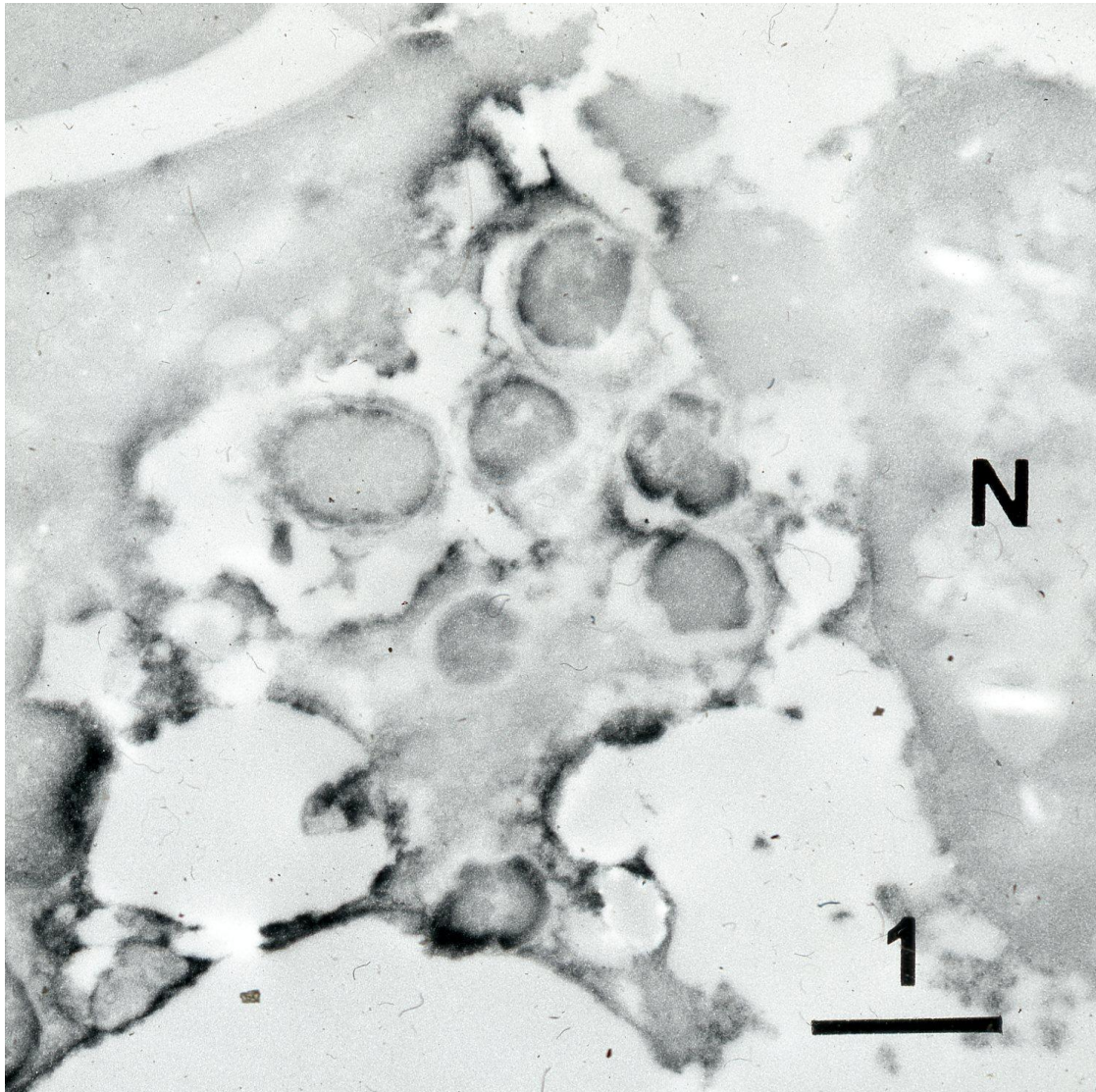
Lactobacillus delbrueckii subsp. *bulgaricus* seen in yogurt (SEM).
Lactobacillus is a non-flagellated Gram-positive bacillus to produce lactic acid.



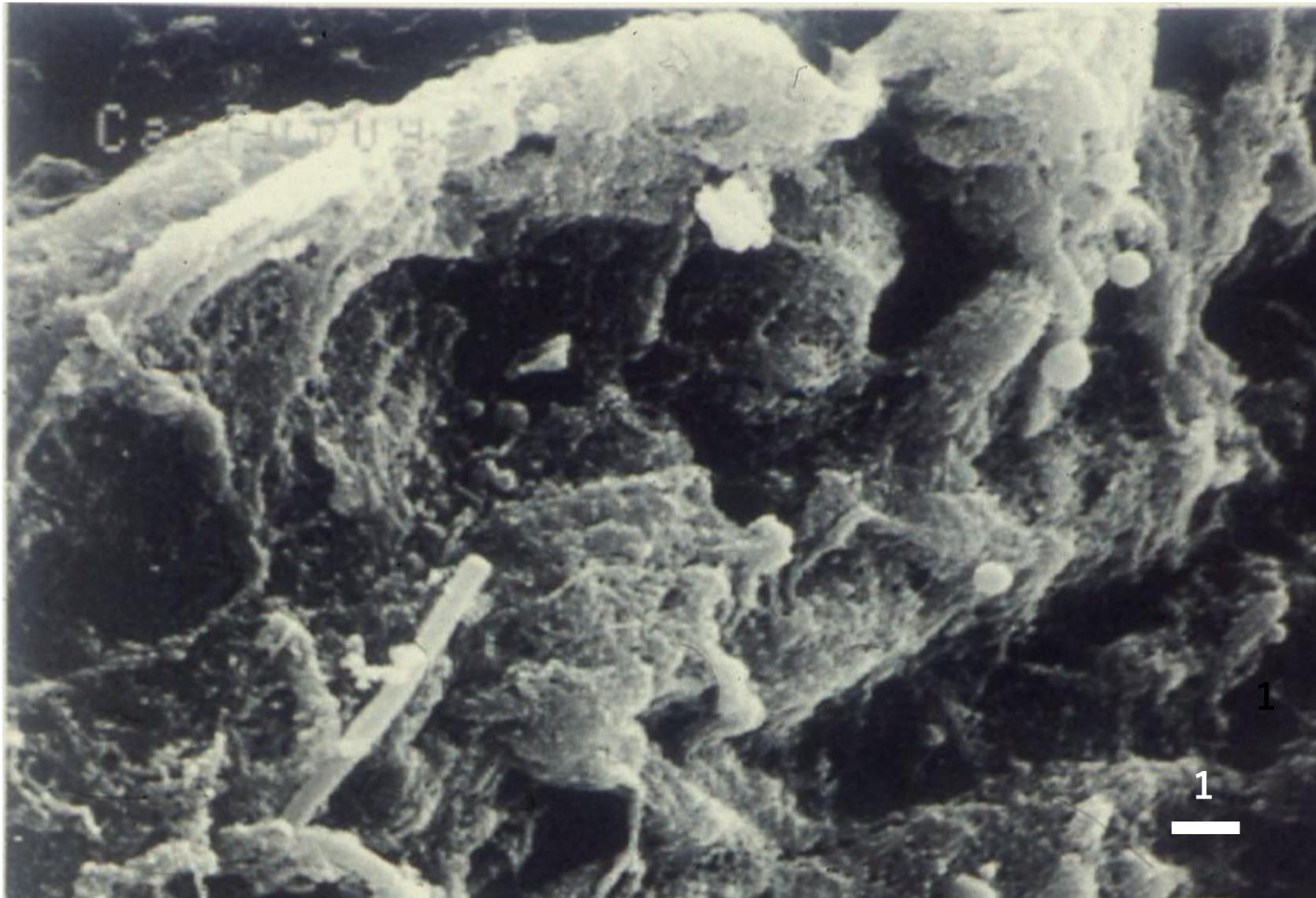
A neutrophil phagocytizes rods (TEM). The rods are seen in lysosomal lumina.



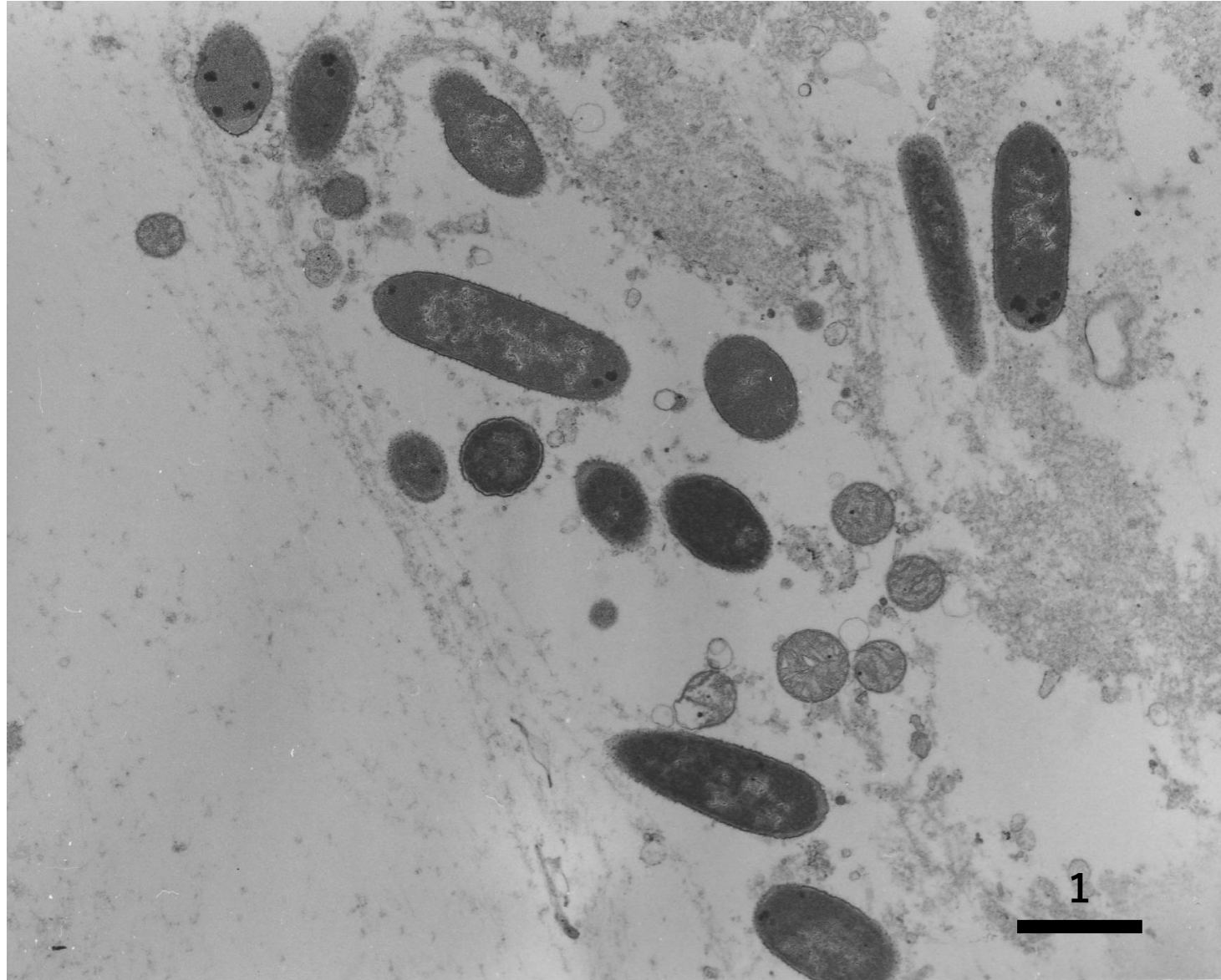
Enteroadhesive *E. coli* (O-5) experimentally infected on the surface of rabbit colonic mucosa (TEM). The pathogenic *E. coli* has provoked intraluminal protruding of the infected epithelial cells. Apoptotic change is seen in the right panel.



E. coli-induced epididymitis (epididymal abscess) seen in an aged male patient. Pre-embedding immunoelectron microscopy with *E. coli* antiserum. Observation using a formalin-fixed, paraffin-embedded section.



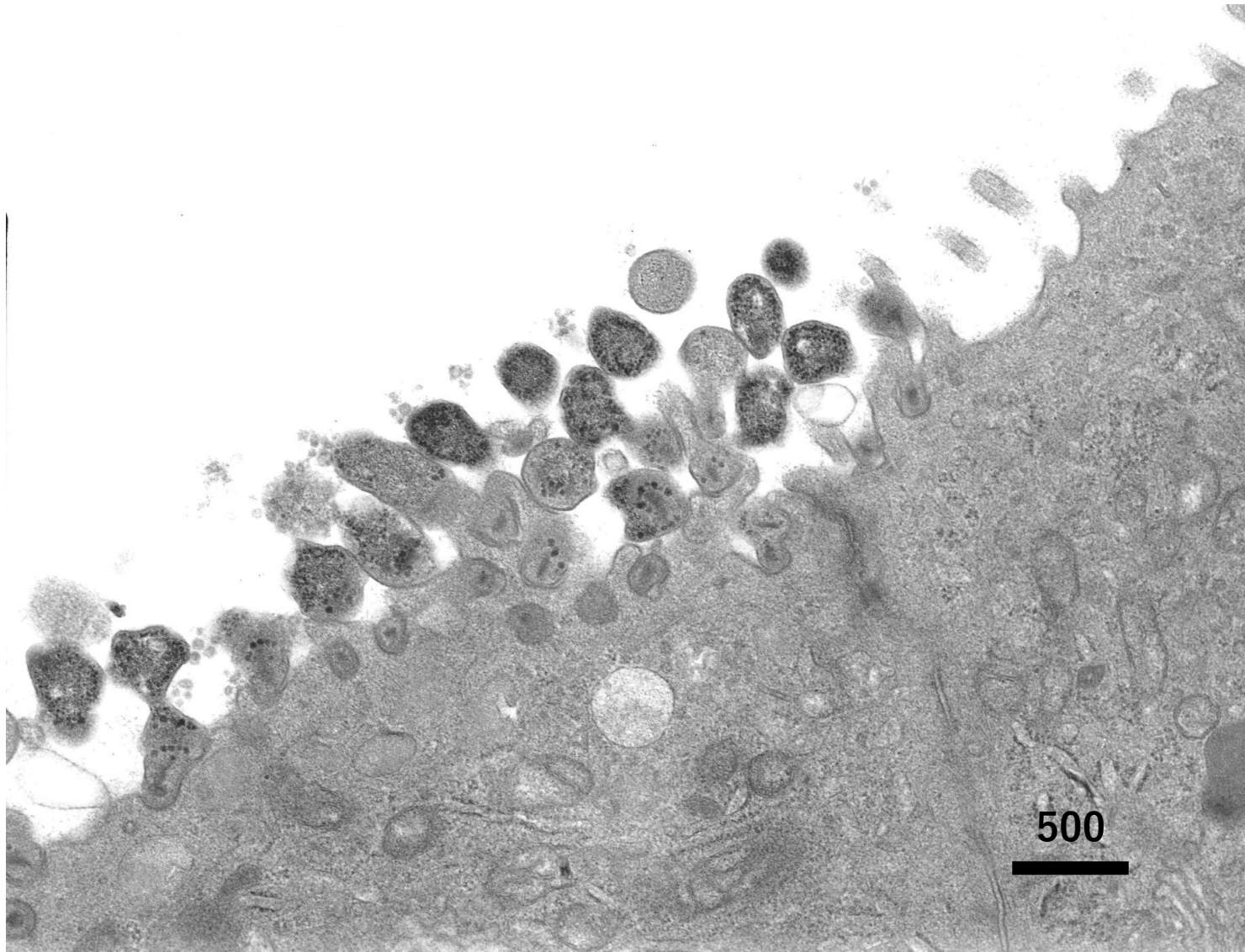
Rods colonized on the base of ulcer caused by tongue cancer (SEM).



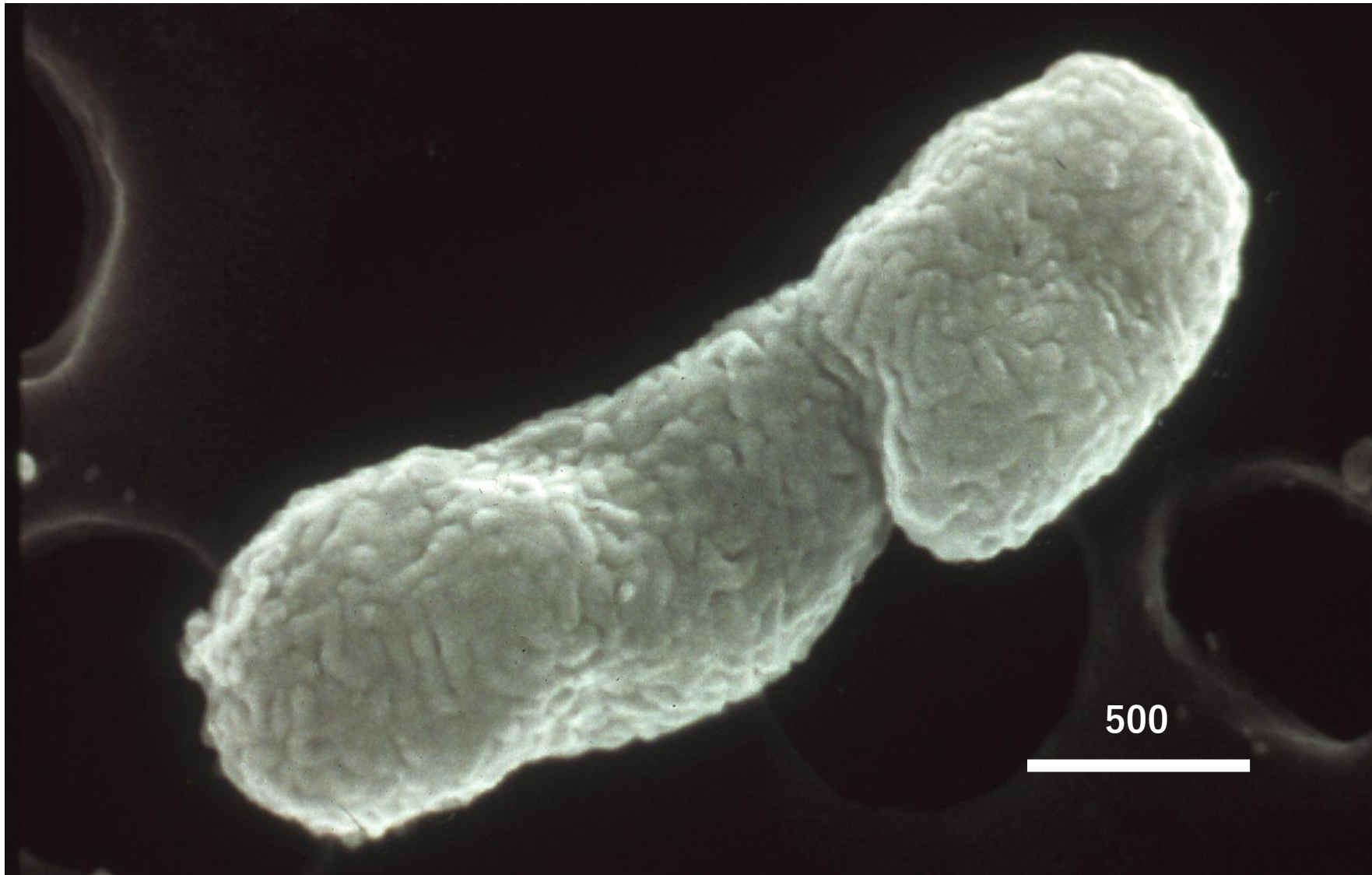
Secondary colonization of Enterobacteria (rods) on the eroded duodenal mucosa seen in a 74 y-o male patient (TEM).



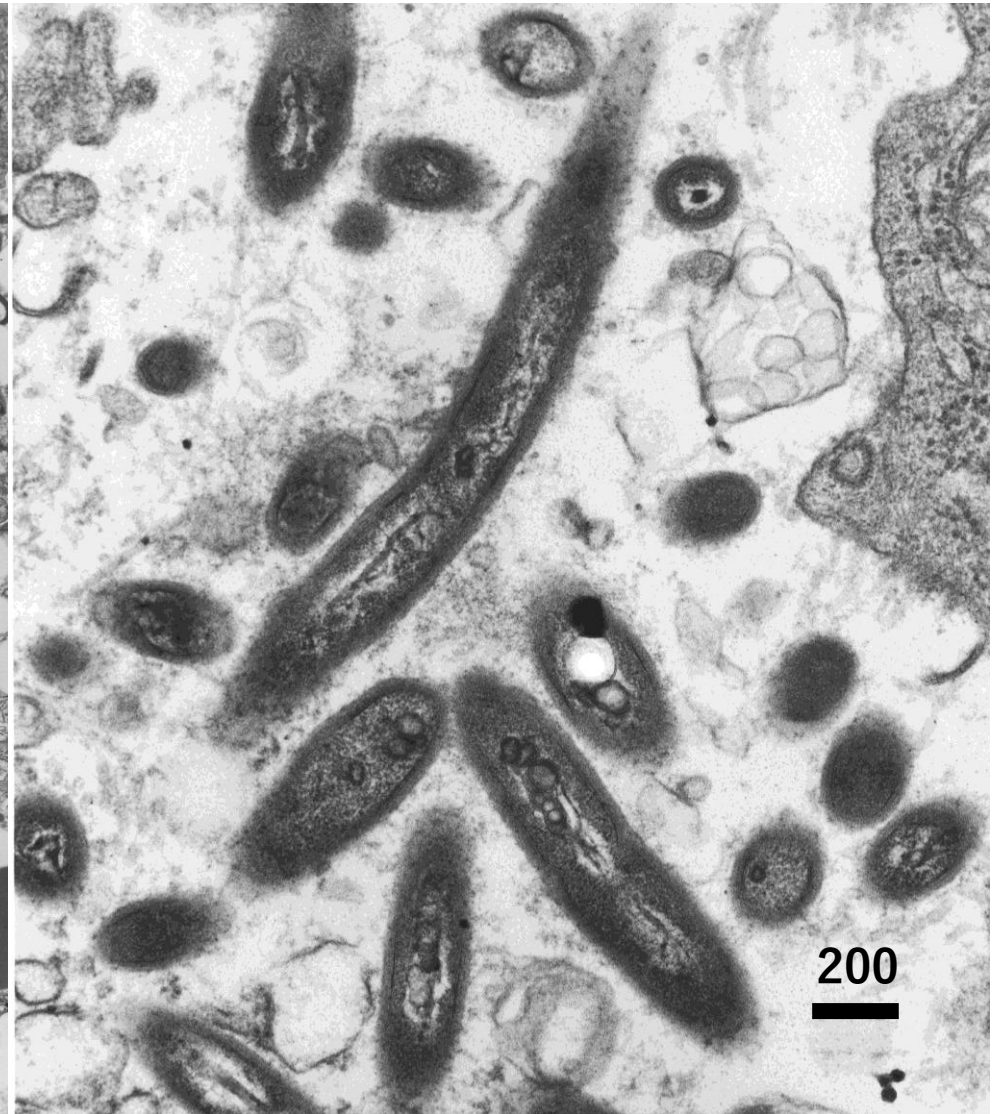
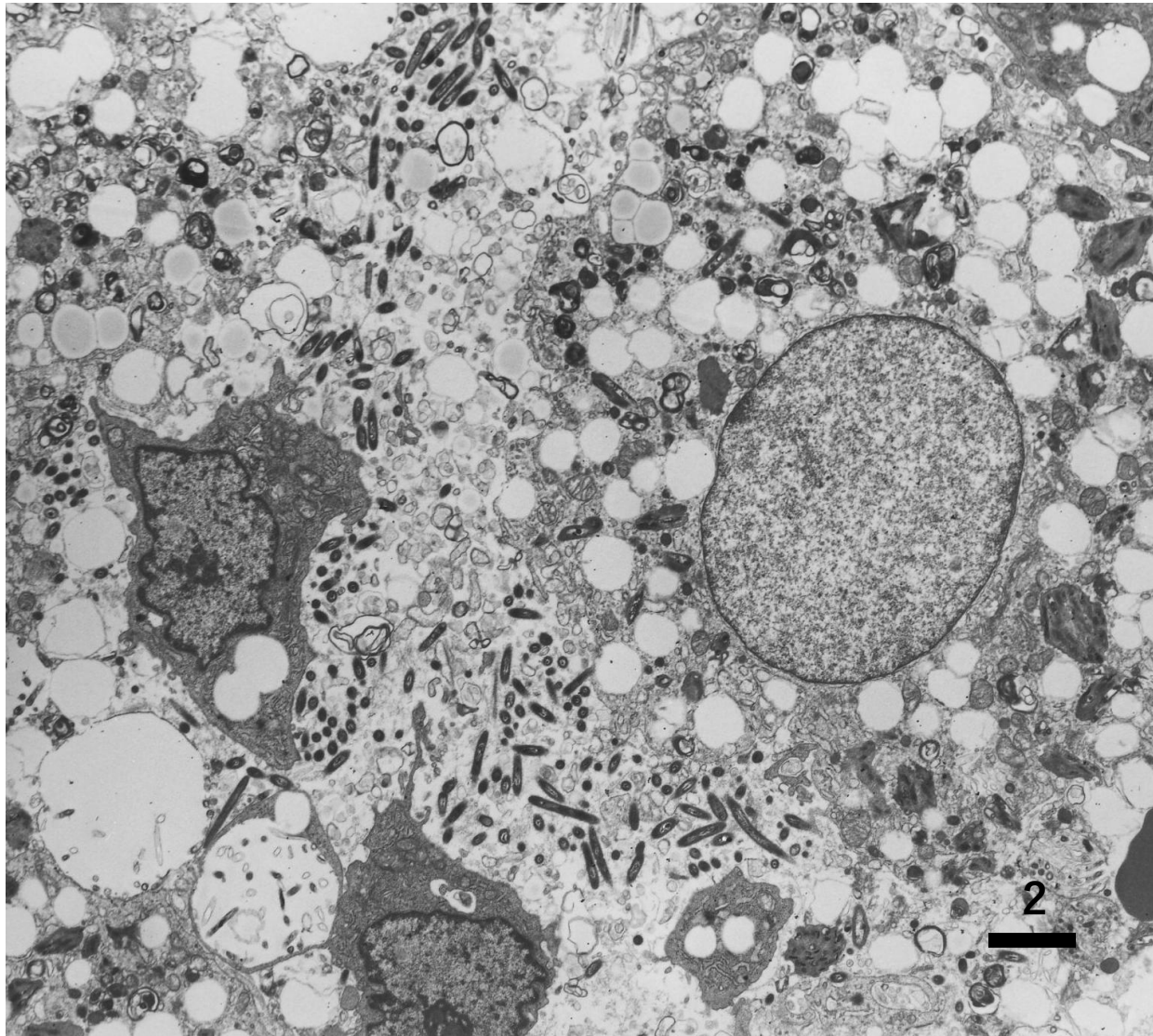
Secondary colonization of rods on the ulcerated surface of pharyngeal cancer (TEM). Biopsy was taken from a 52 y-o male patient.



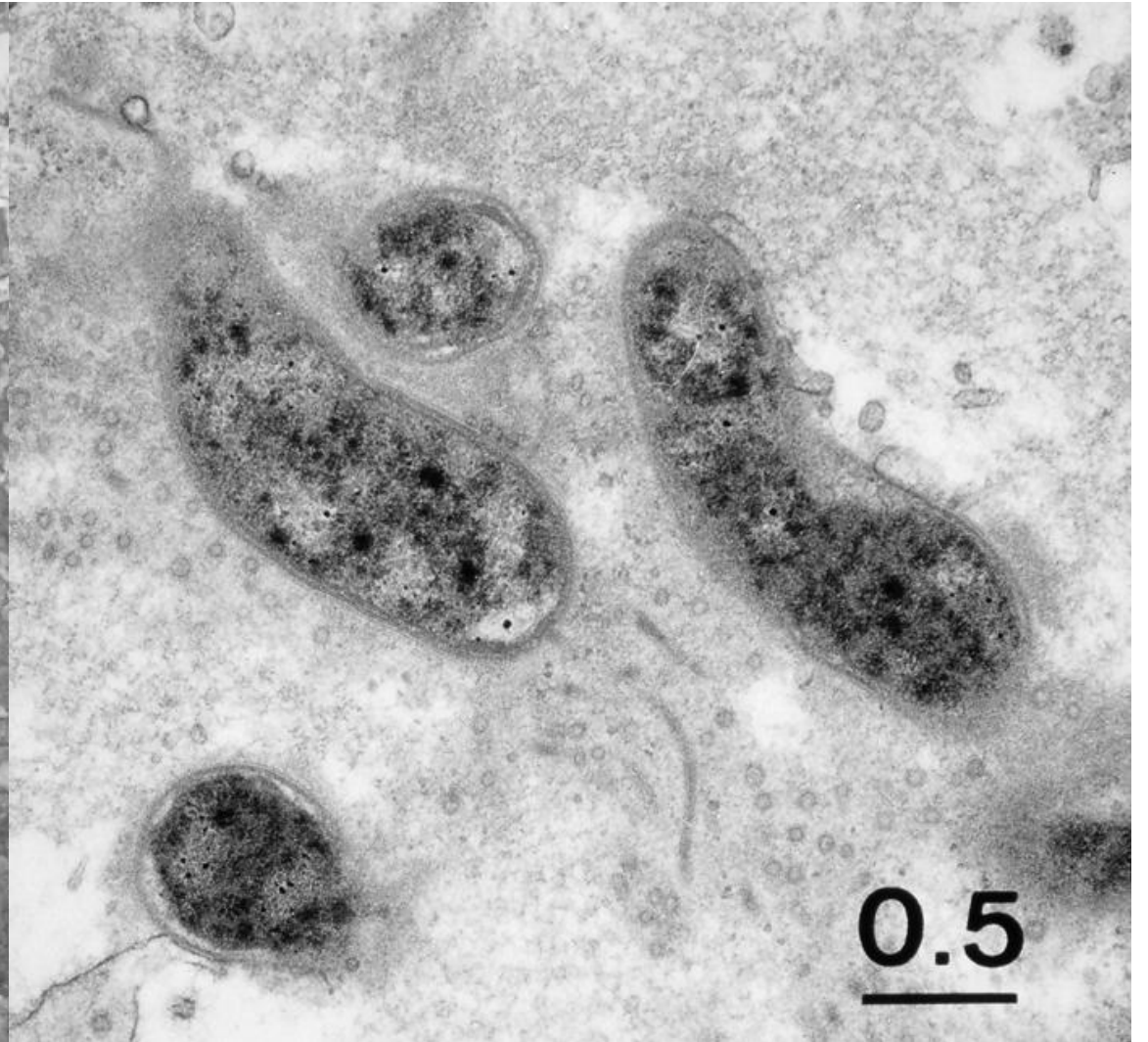
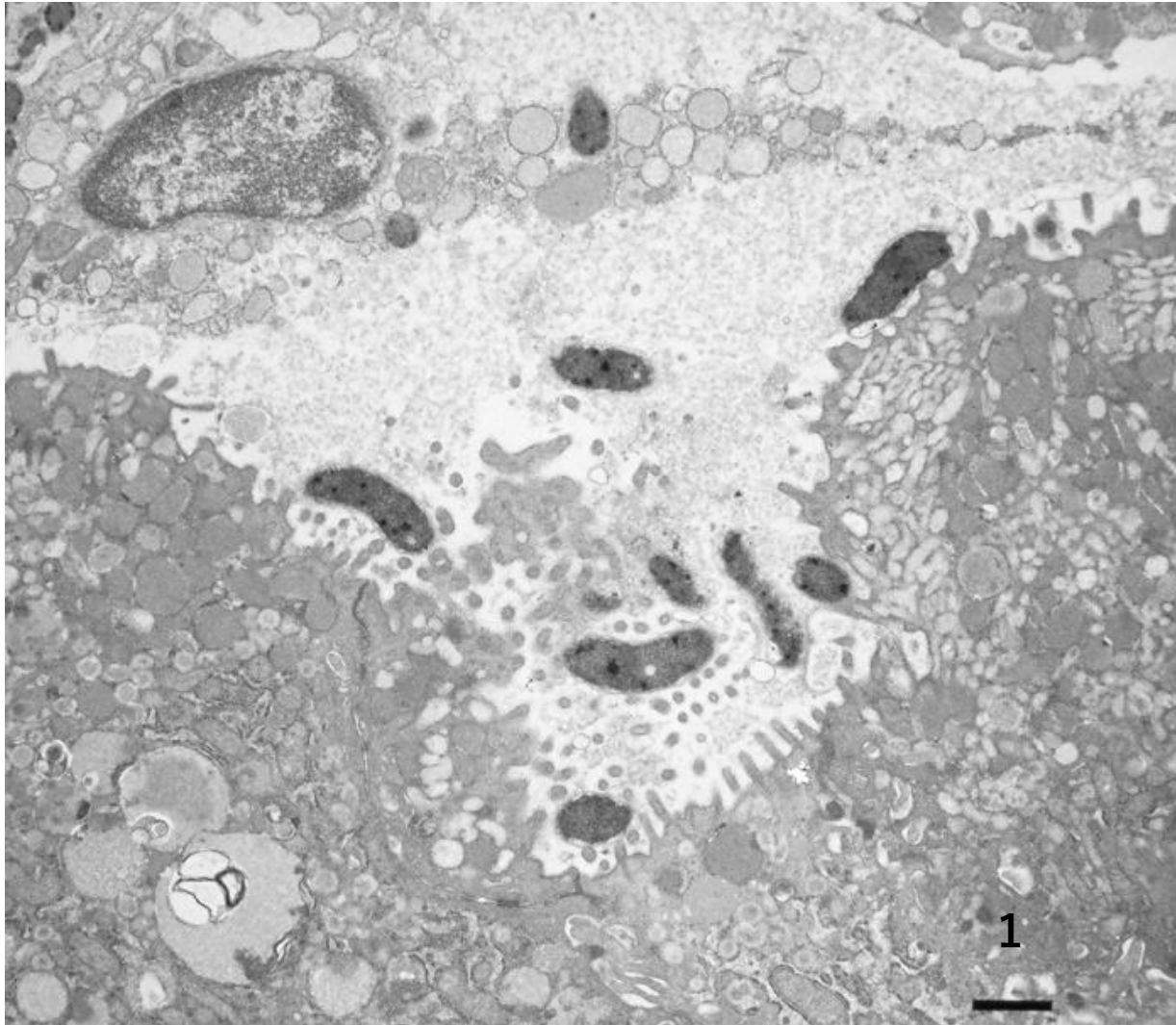
Rods colonized on the non-ciliated nasal mucosa of a 38 y-o male patient (TEM). The rods are adhesive onto the epithelial surface.



Corynebacterium diphtheriae (SEM). A non-flagellated and club-shaped rod is identified from formalin solution soaked with biopsied pharyngeal mucosa of a patient with lethal diphtheria.



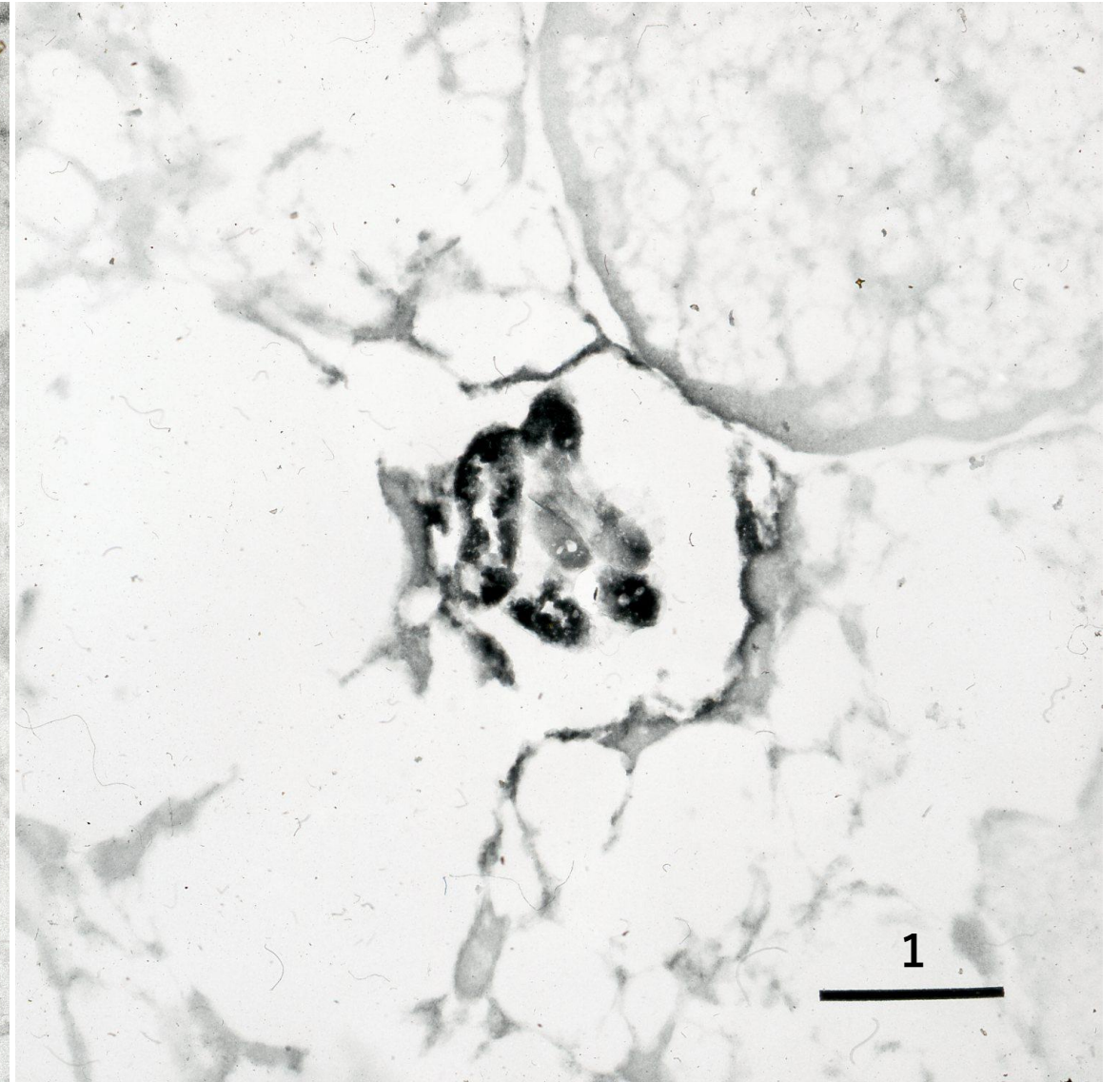
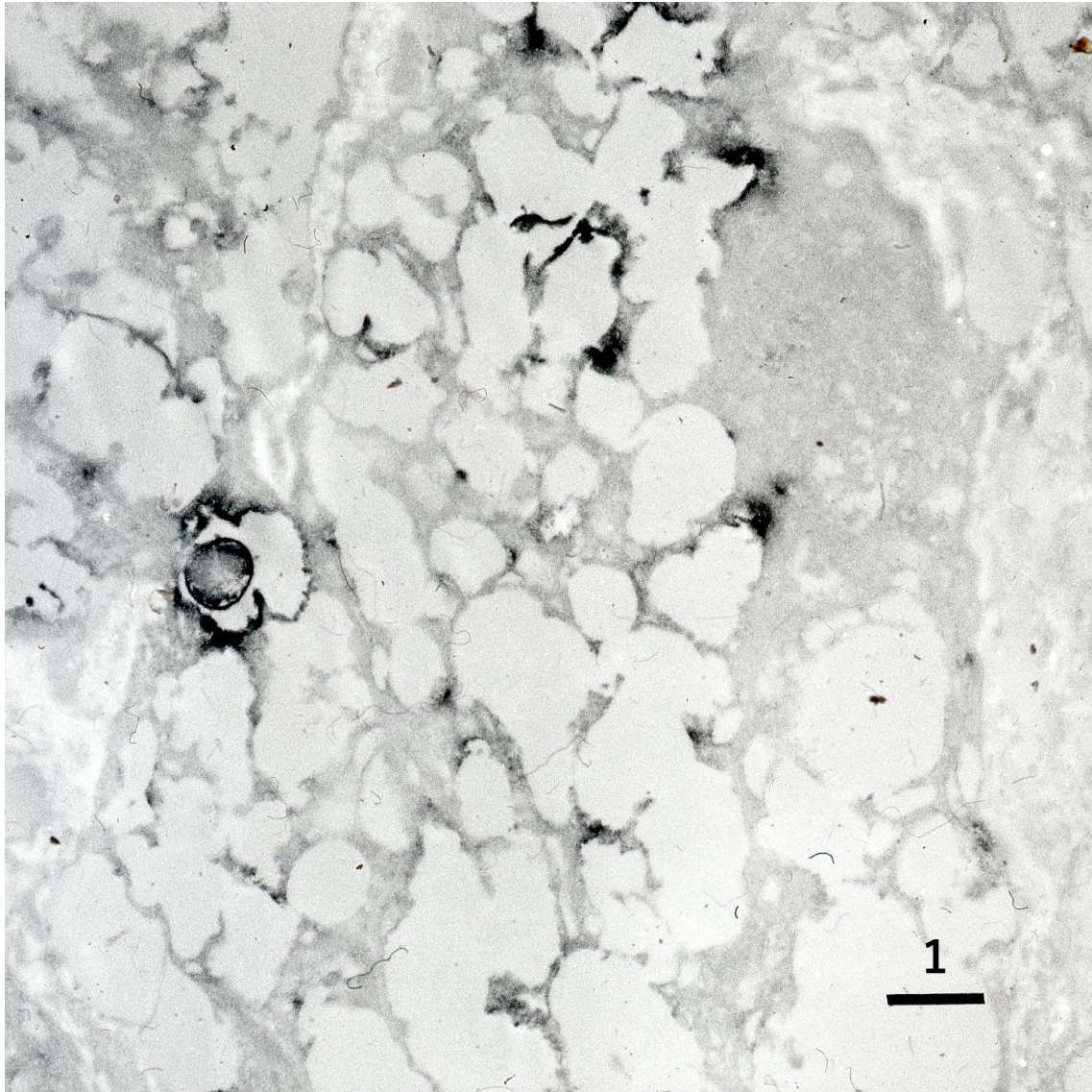
Whipple's disease seen in the biopsied ileal mucosa of a 75 y-o male patient (TEM). Long rods, *Tropheryma whipplei*, are seen both inside and outside of foamy macrophages in the lamina propria mucosae.



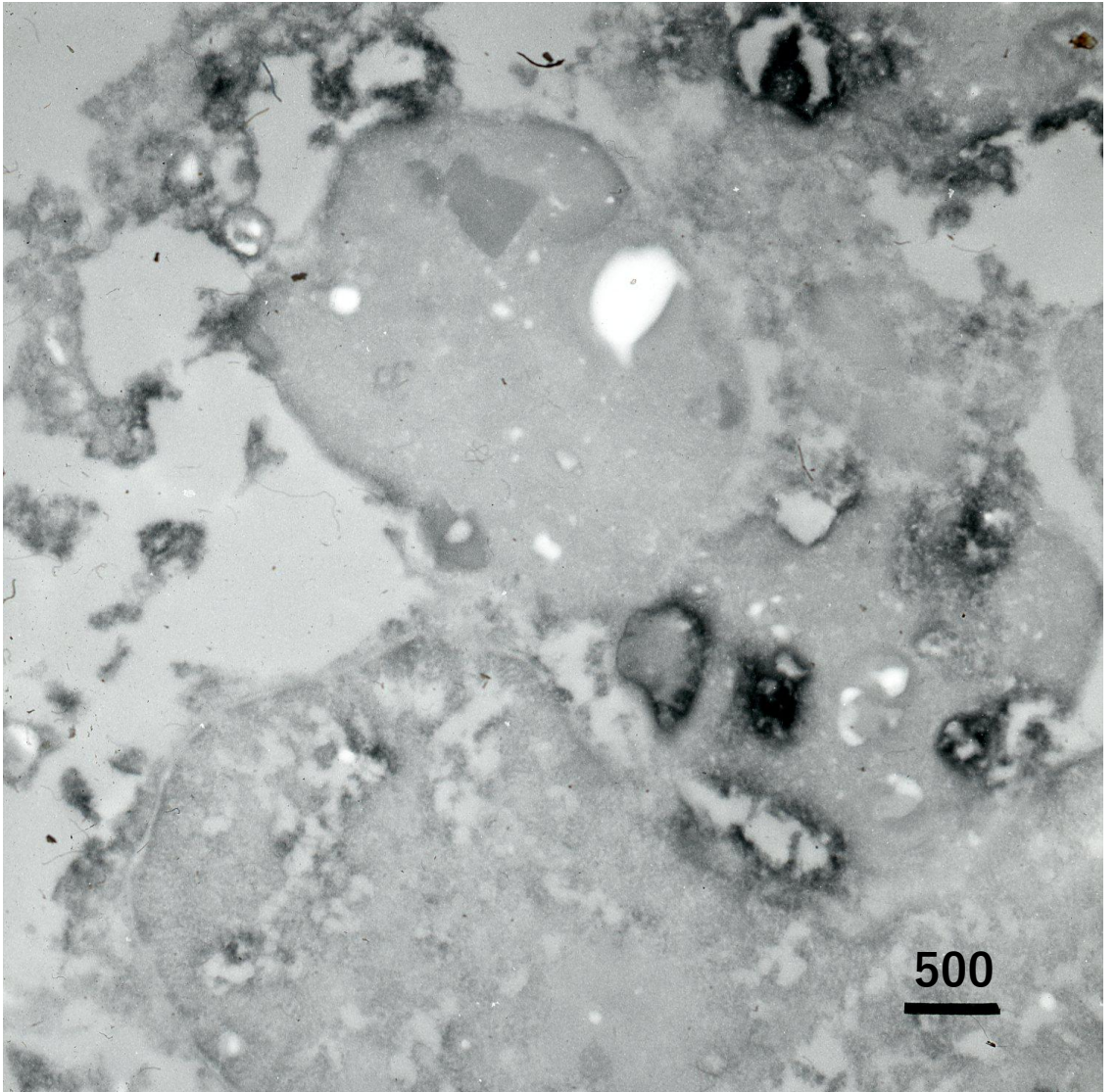
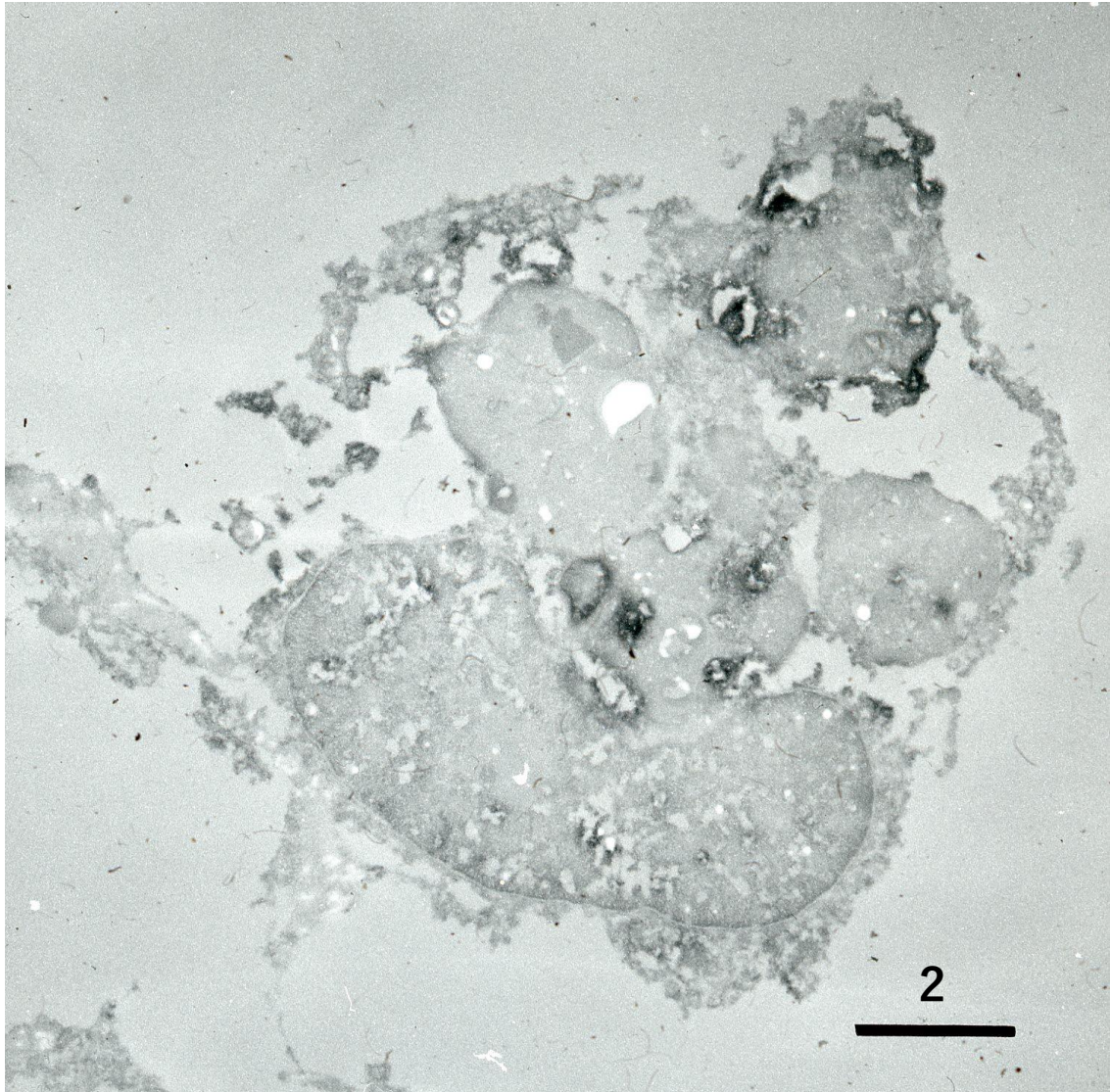
Helicobacter pylori-infected chronic active gastritis biopsied from a male patient aged 40's (TEM). Spiral-shaped bacteria infect the microvillous surface of the gastric foveolar epithelial cells. Cut surfaces of the flagella are seen in the right panel.



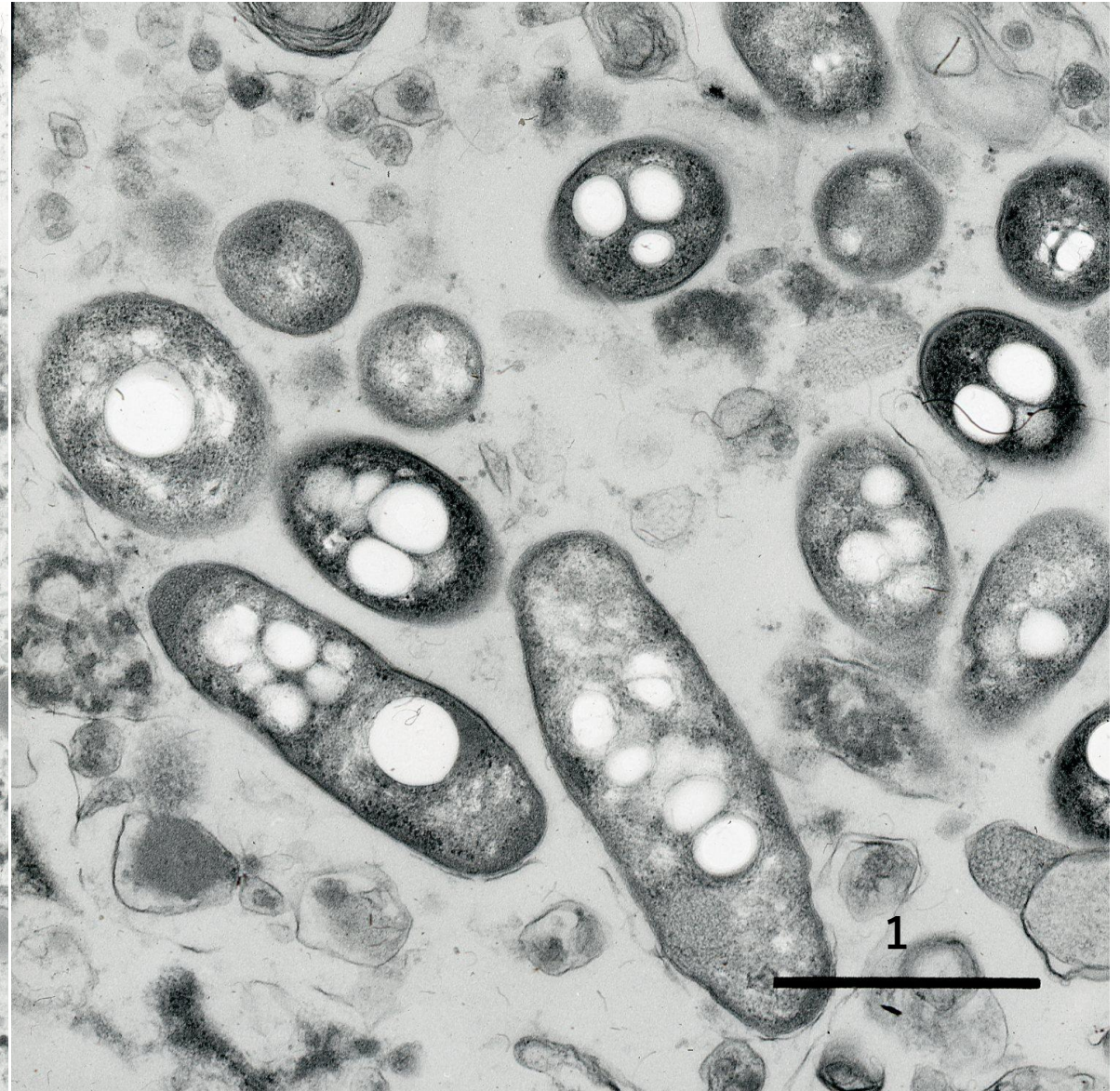
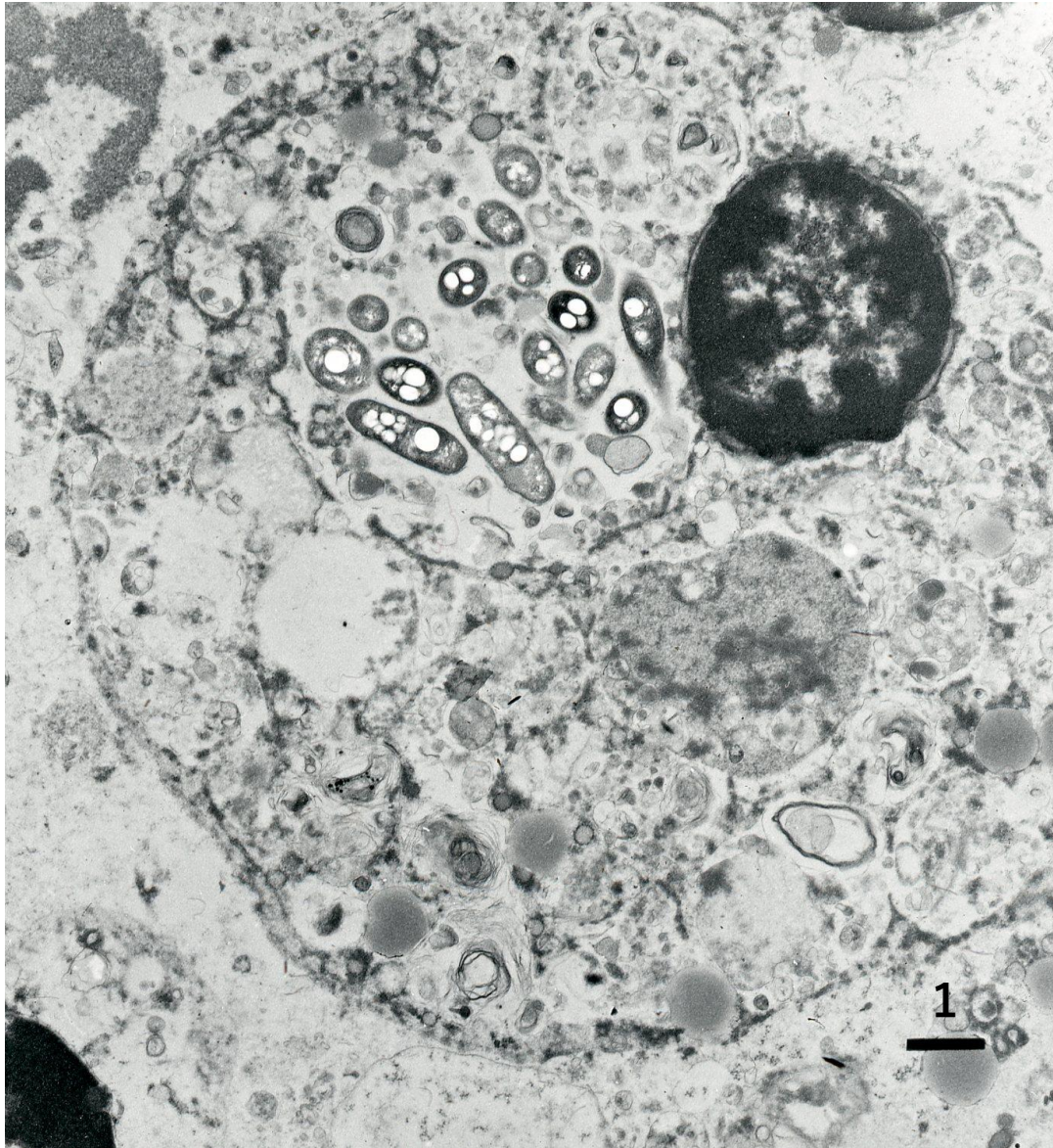
Helicobacter pylori seen on the surface of the gastric mucosa (SEM). Negative staining clearly identified plural flagella anchored at one pole of the bacterium.



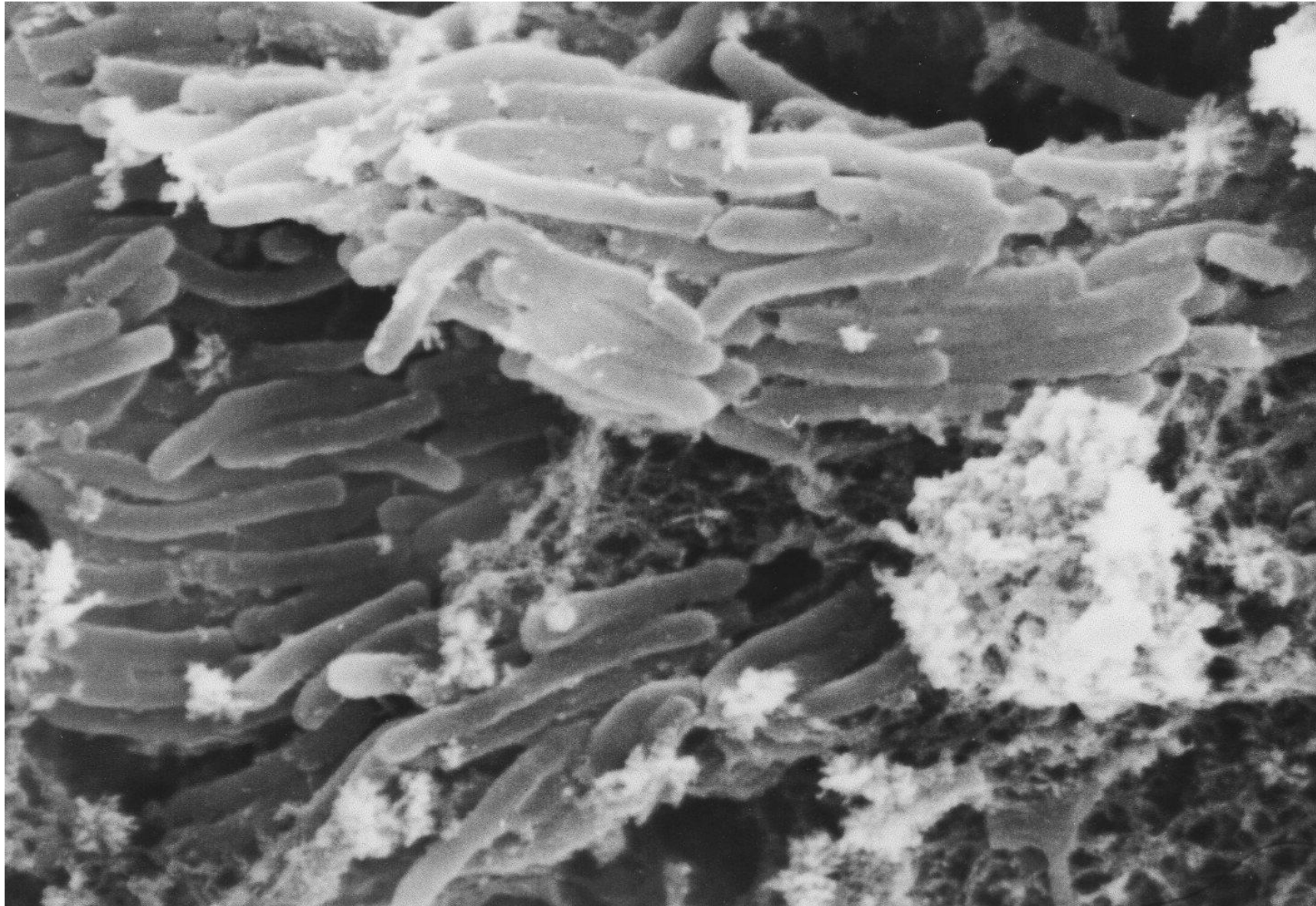
Helicobacter pylori phagocytized by a foamy macrophage seen in gastric xanthoma. Pre-embedding immunoelectron microscopy with *H. pylori* antiserum. Formalin-fixed, paraffin-embedded section was evaluated. Immunoreactive elongated bacteria are observed in the cytoplasm of the macrophages.



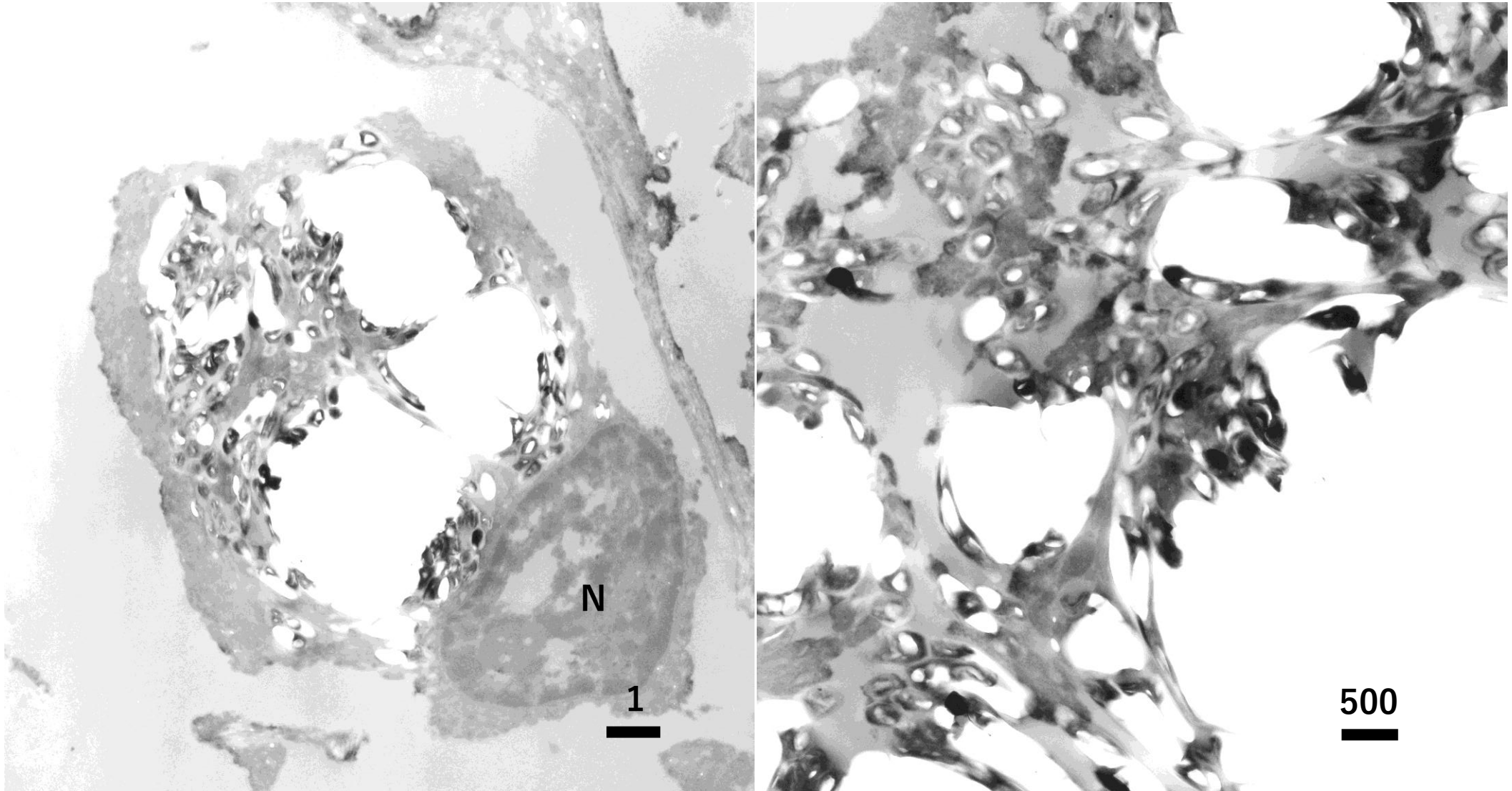
Listeria monocytogenes meningitis. Pre-embedding immunoelectron microscopy with *L. monocytogenes* antiserum. Immunoreactive rods are actively phagocytized by a macrophage in the formalin-fixed, paraffin-embedded cytospun preparation of the aspirated cerebrospinal fluid.



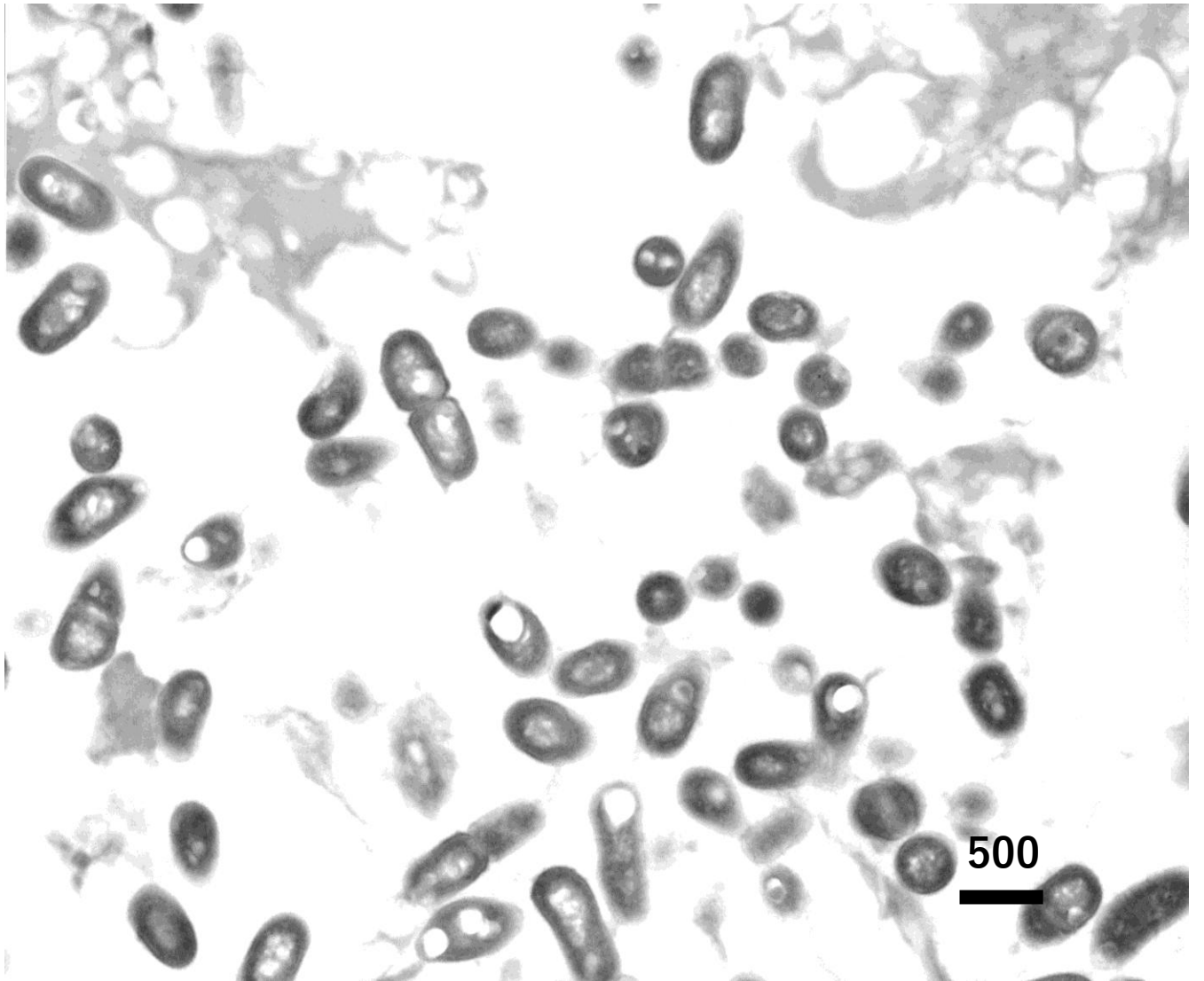
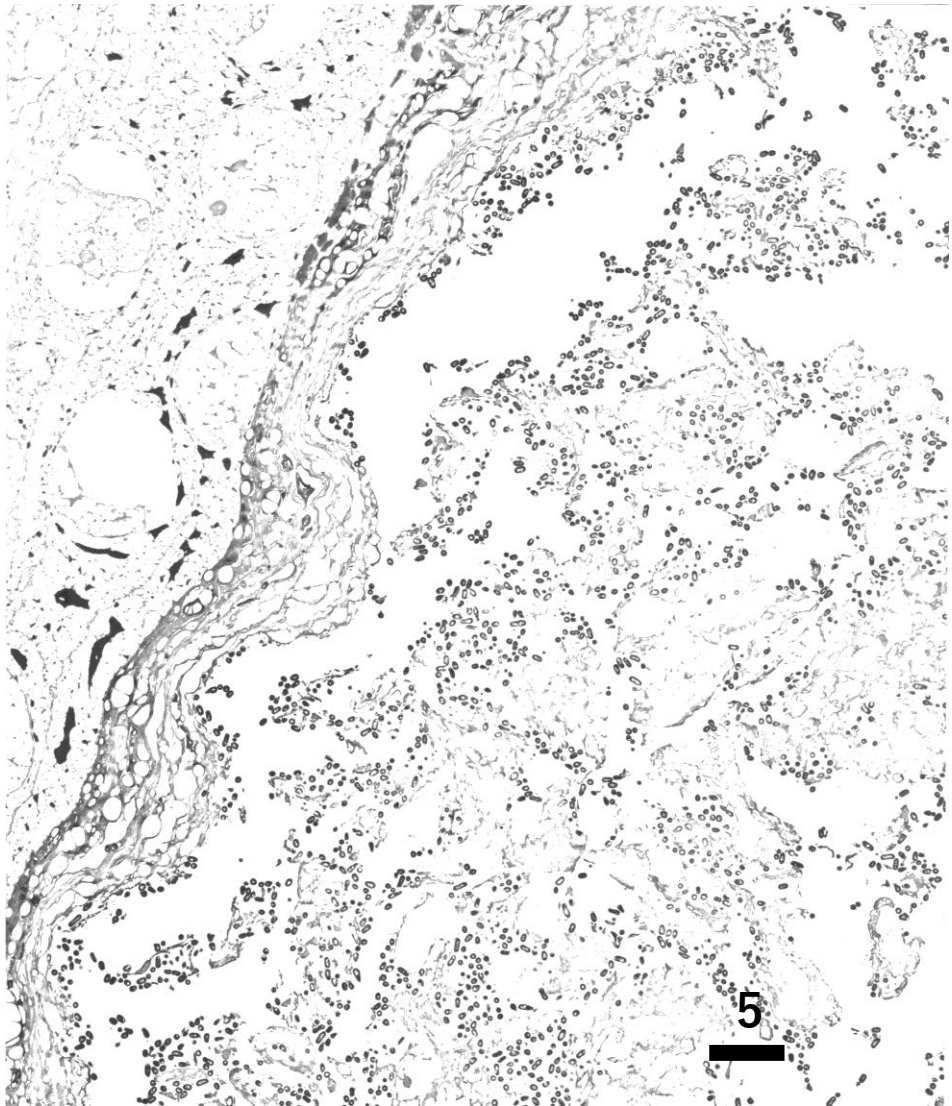
Legionella pneumophila, provoking lethal lobar pneumonia seen in a male patient aged 70's (TEM). Macrophages in the alveolar space in the autopsied lung actively phagocytize rods.



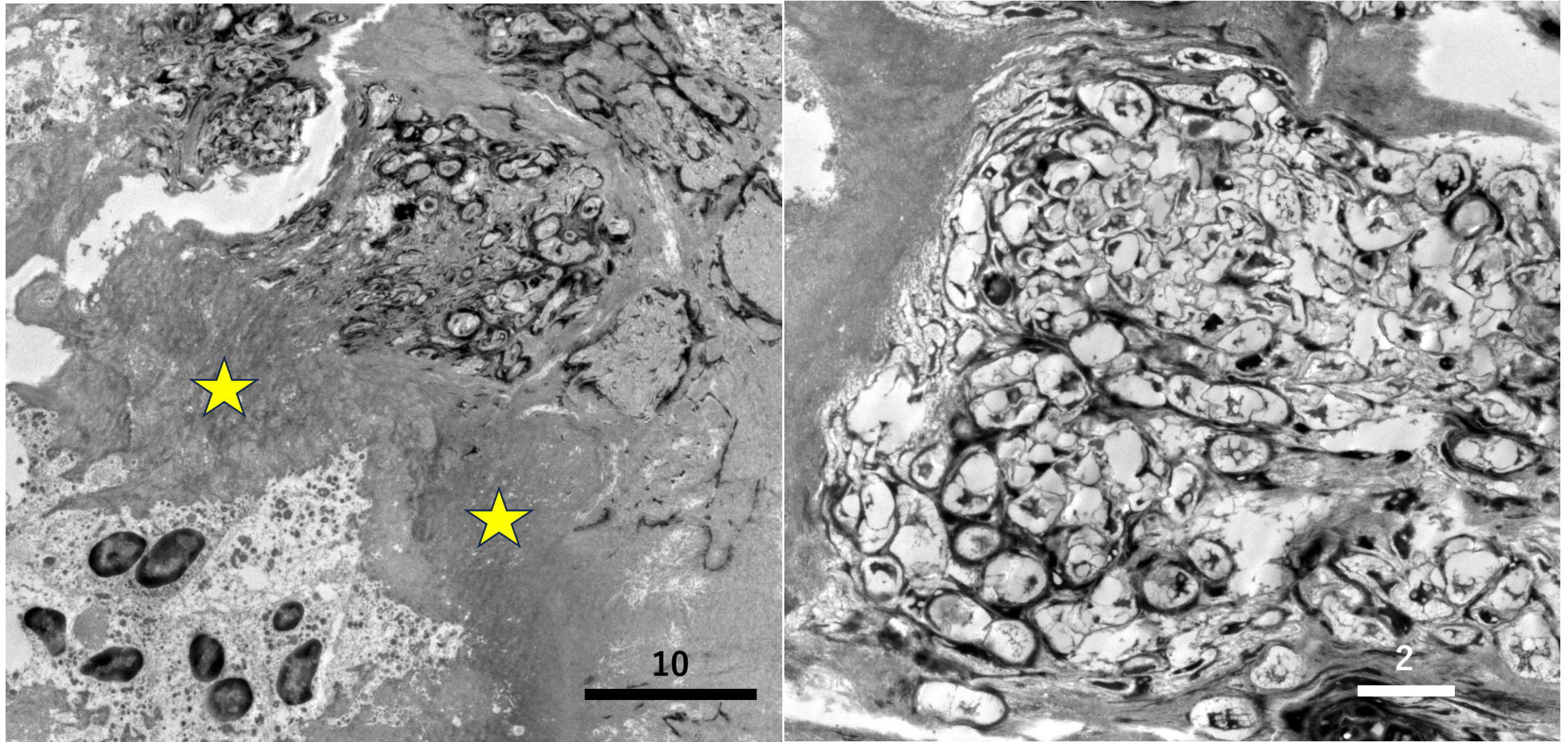
Mycobacterium tuberculosis grown on the culture medium (SEM). Non-flagellated long rods are clustered in a fagot-like fashion.



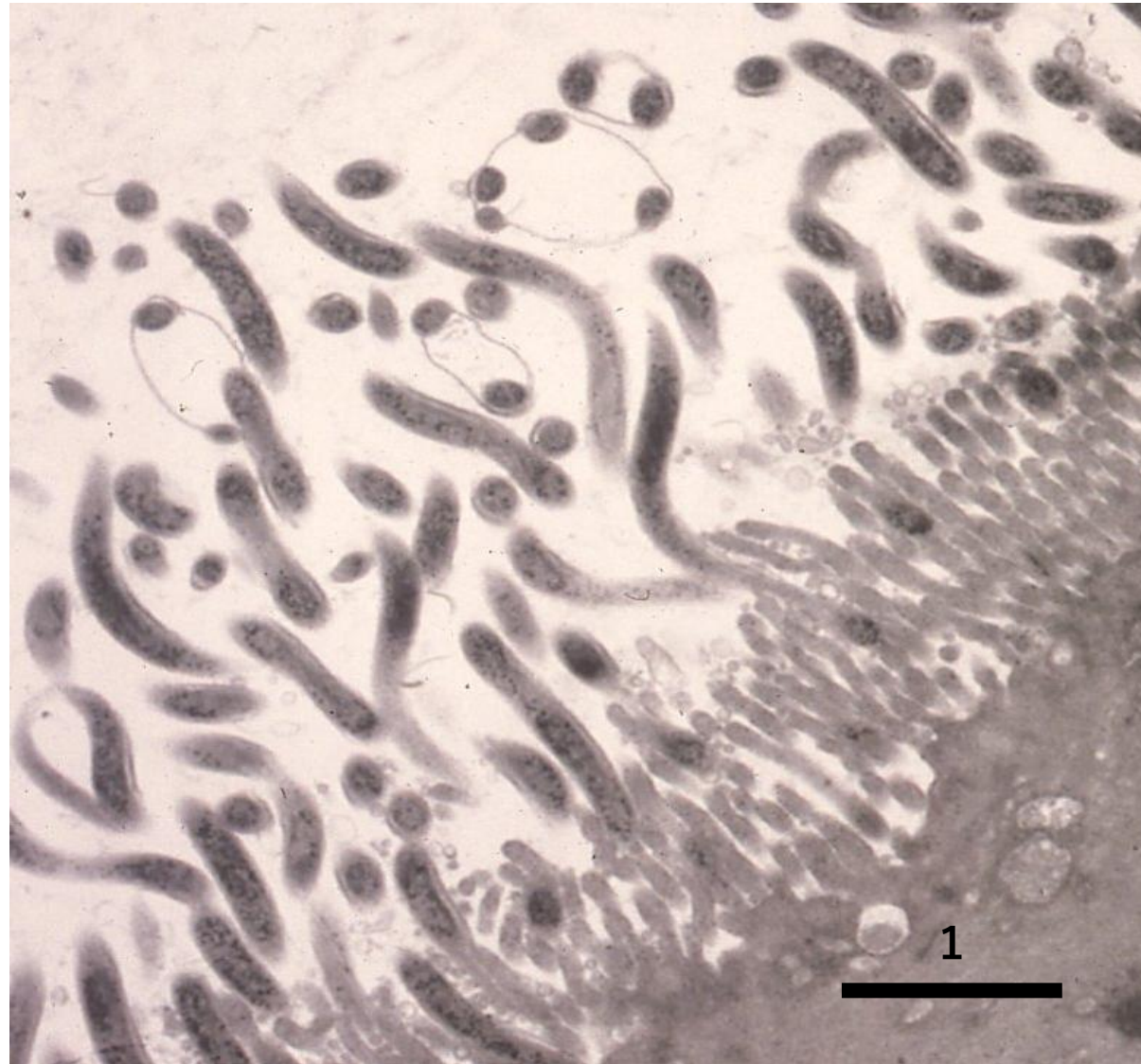
Mycobacterium avium-intracellulare infection in the lung hilar lymph node in an AIDS patient. Pre-embedding immunoelectron microscopy with BCG antiserum. The immunoreactive rods actively grow in the cytoplasm of the macrophage. Opportunistic infection of non-tuberculous Mycobacteria is accelerated in AIDS.



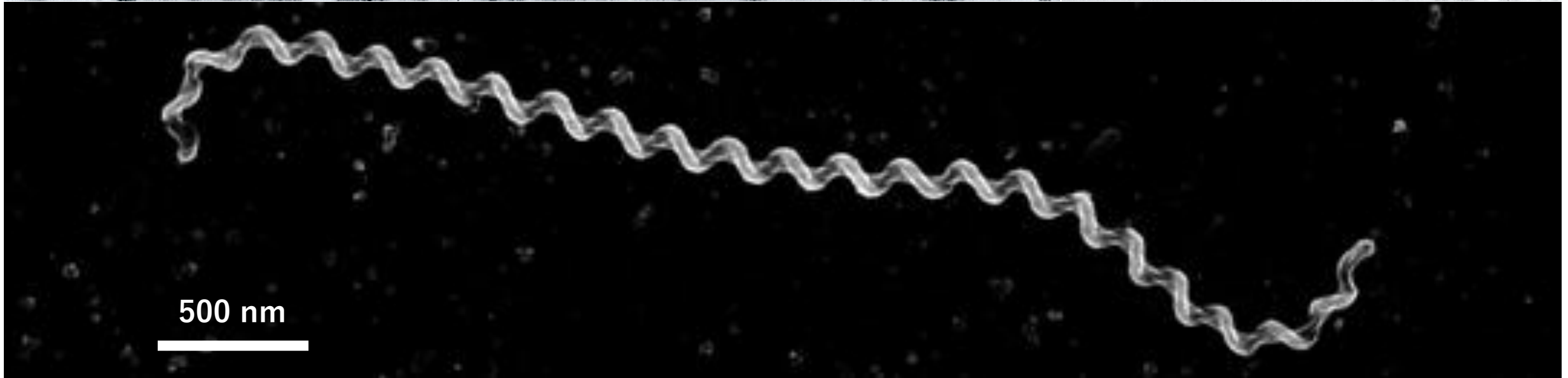
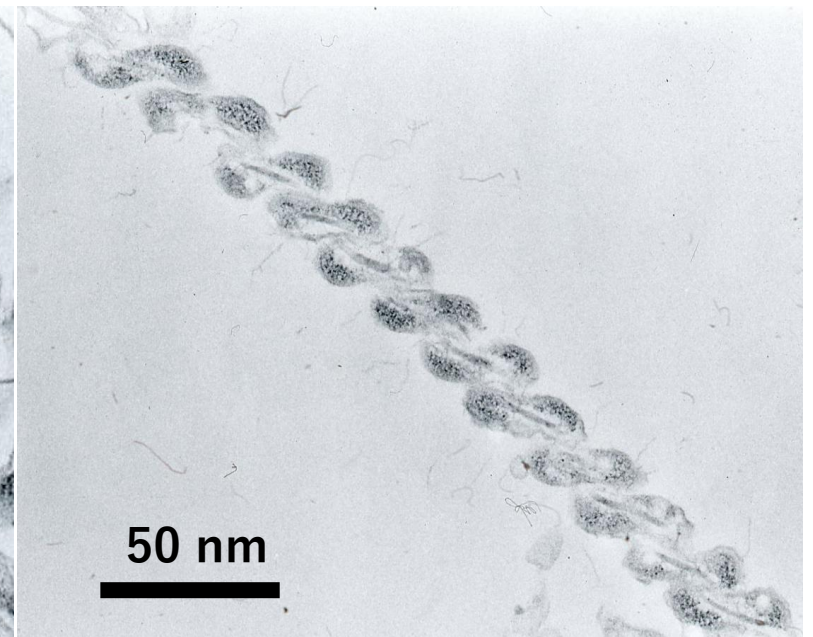
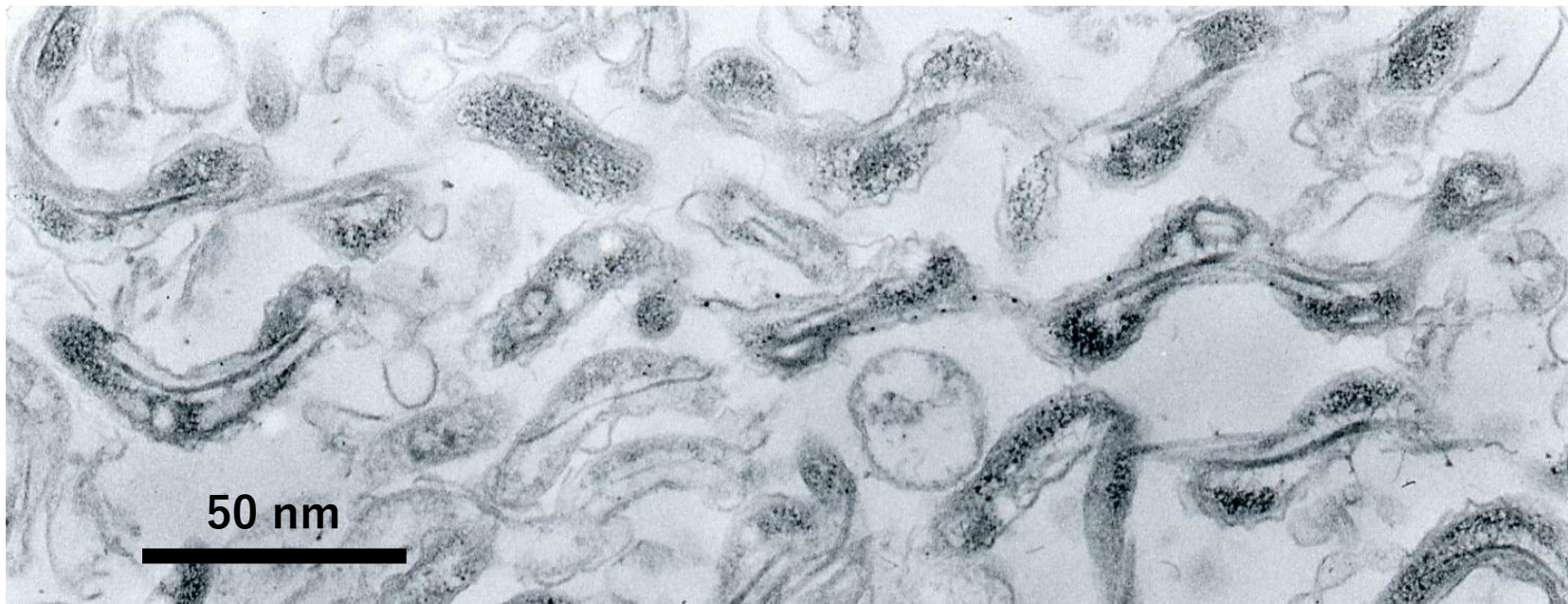
Mycobacterium leprae in lepromatous leprosy. Pre-embedding immunoelectron microscopy with BCG antiserum. Skin biopsy from a middle-aged male Japanese Pruvian. The immunoreactive rods actively grow in the lepromatous (foamy) macrophage.



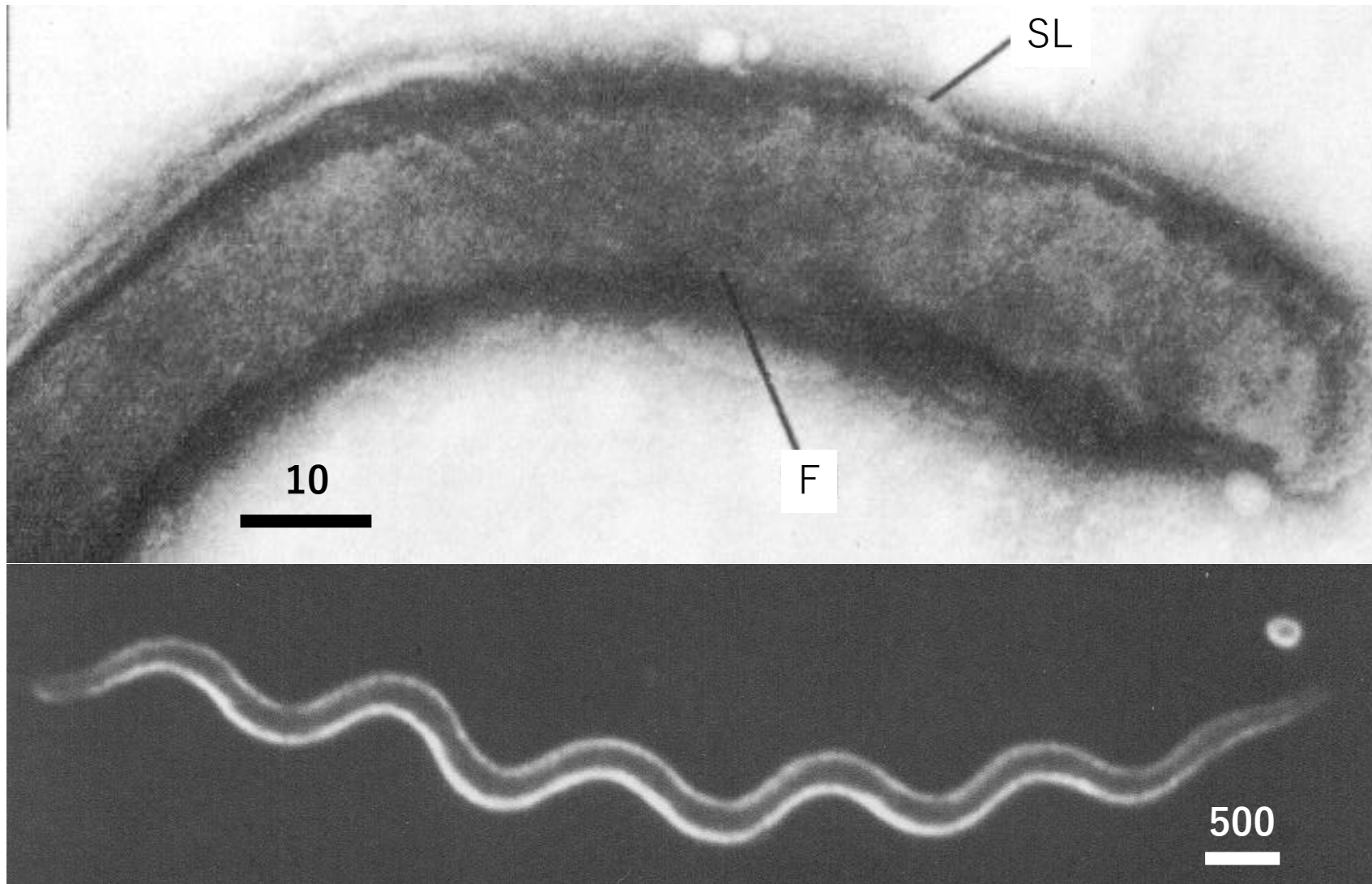
Skin actinomycosis caused by infection of *Gordonia* spp., seen in an 85 y-o female patient (TEM). The growing bacteria are embedded in the Splendore-Hoeppli material (asterisks). Ref.: Miyachi H, Tsutsumi Y. Diagnosis of *Gordonia*-induced cutaneous actinomycetoma using immunostaining and real-time polymerase chain reaction on formalin-fixed paraffin-embedded specimen. *Int J Dermatol* 2023; 62(12): e635-e636. doi: 10.1111/ijd.16843



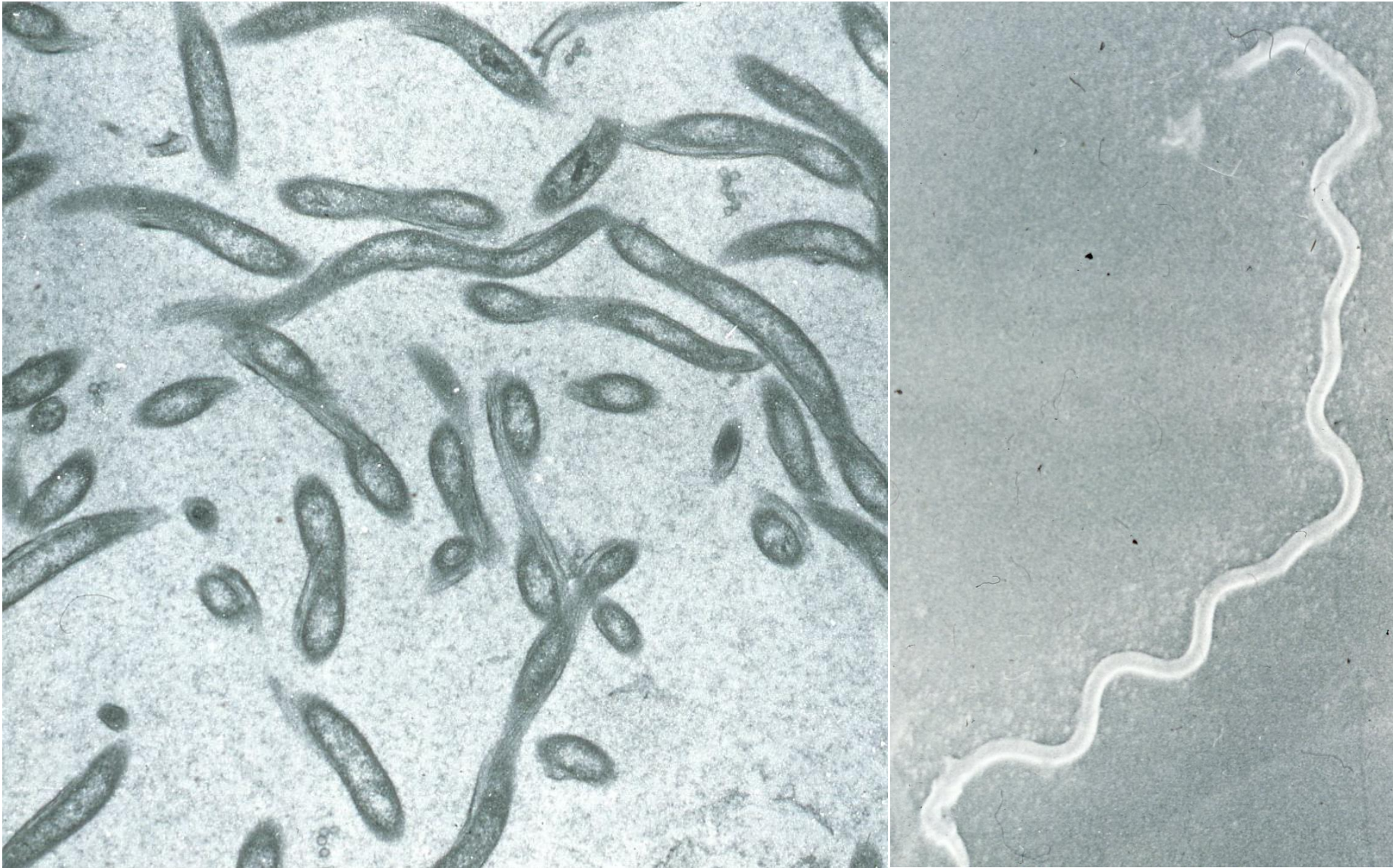
Intestinal spirochetosis (TEM). Biopsy was taken from the cecum of a male patient aged 60's. *Brachyispira aalborgi* densely colonizes the microvillous surface of the colonic epithelial cell.



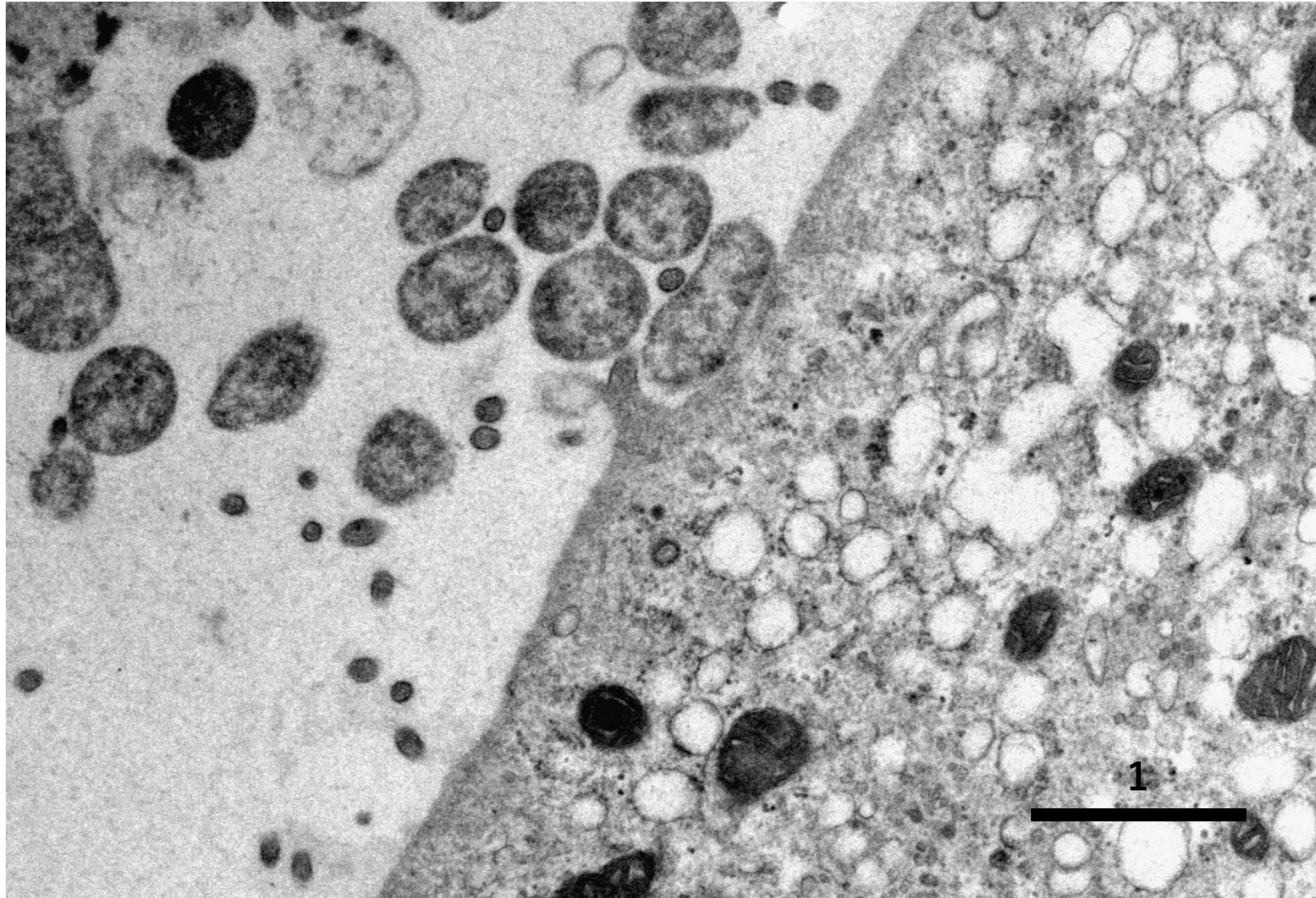
Cultured *Leptospira interrogans* (AC37 strain). TEM figures (top panels) reveal tightly coiled pathogens with a long flagellum along the cell body. The SEM figure (bottom) clearly demonstrates the highly coiled appearance.



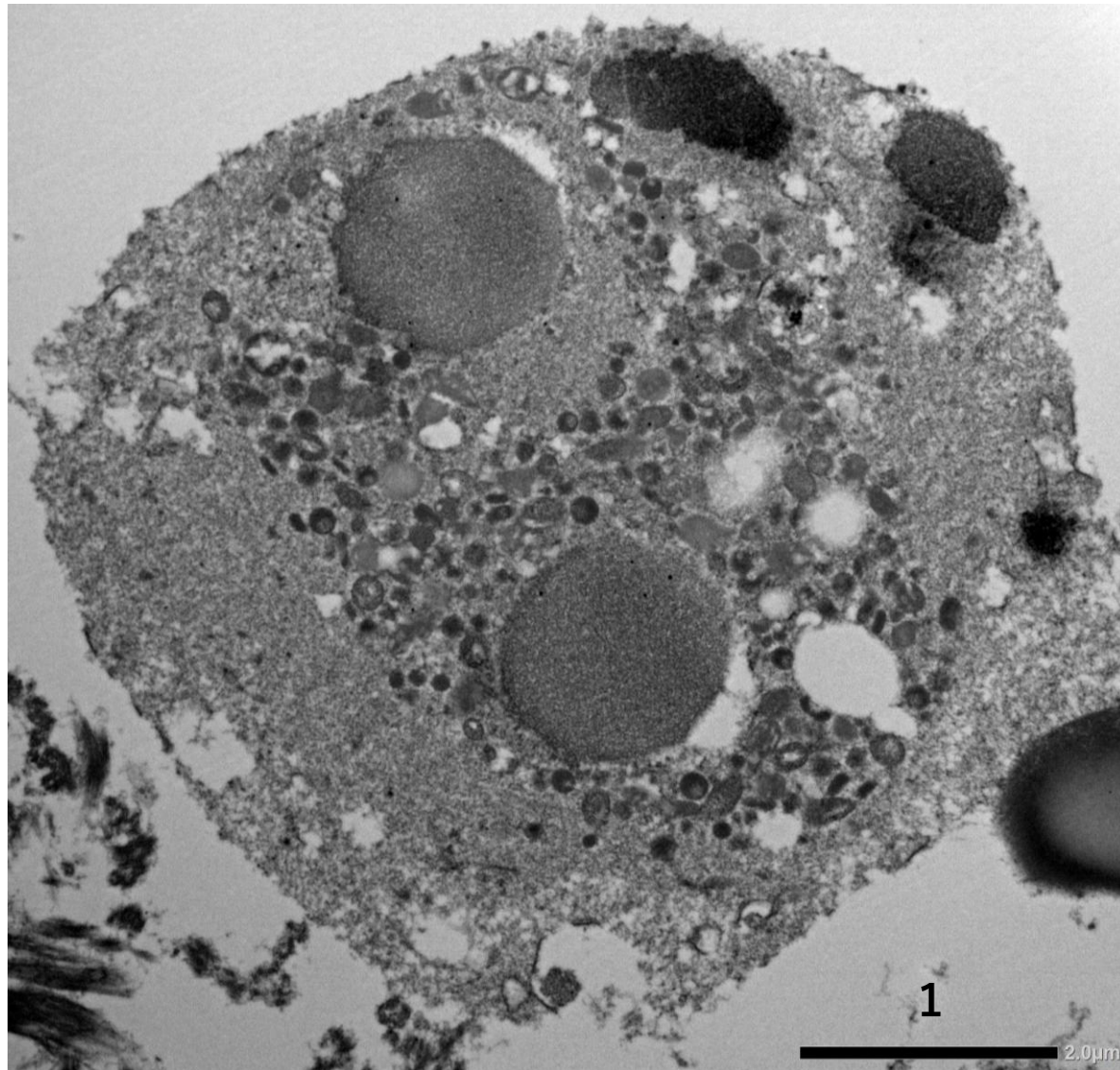
Treponema pallidum causing syphilis (top: TEM, bottom: SEM).
F: filament (flagella), SL: envelop (slime layer). *T. pallidum* coils
gently. Compare with the tightly coiled *Leptospira interrogans*.



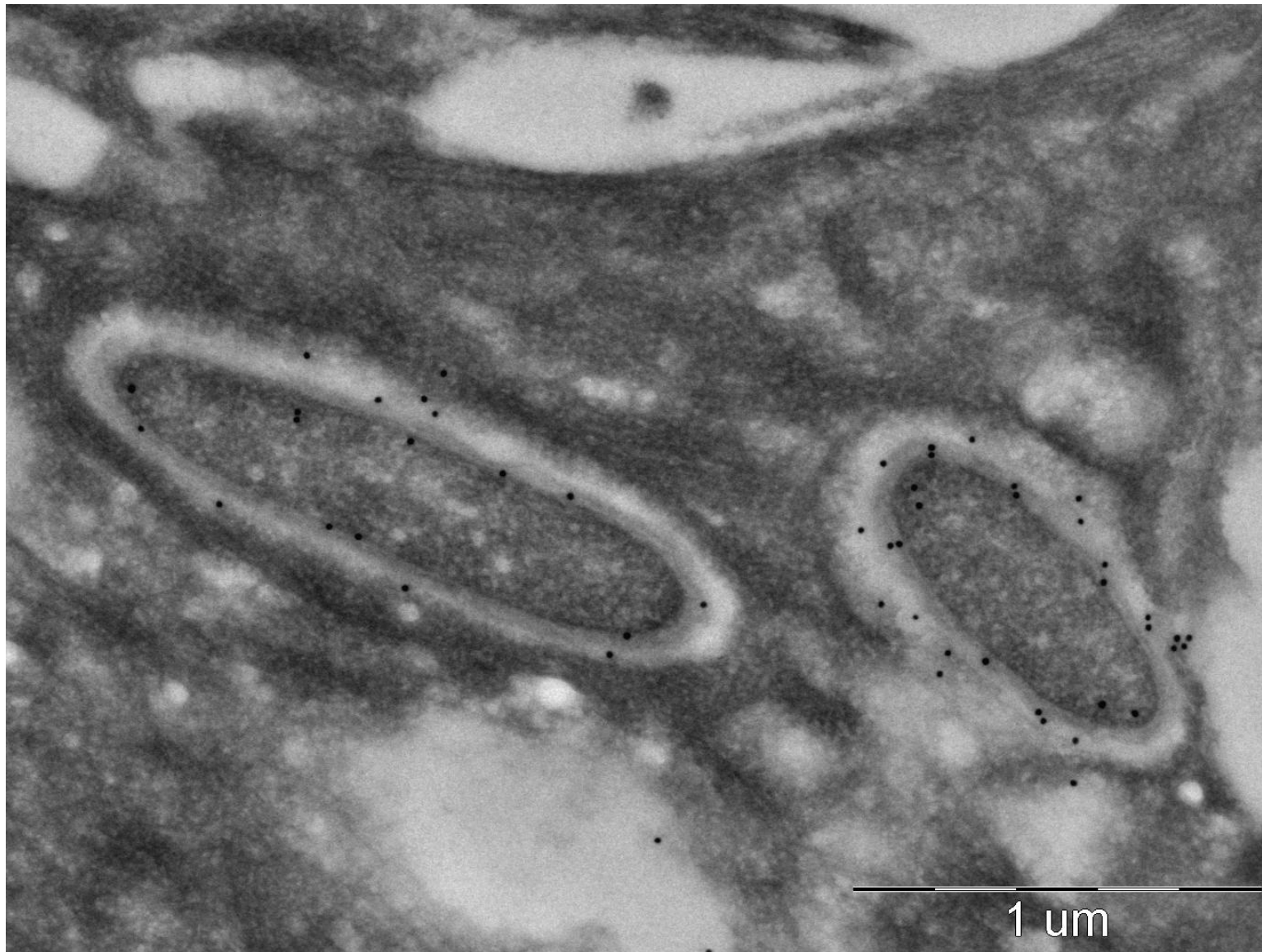
Borrelia burgdorferi (cultured B31 strain). Left: TEM, right: SEM (negative stain). The tick bite mediated infection causes Lyme disease. The gently coiled pathogen possess a long flagellum along the coiled body.



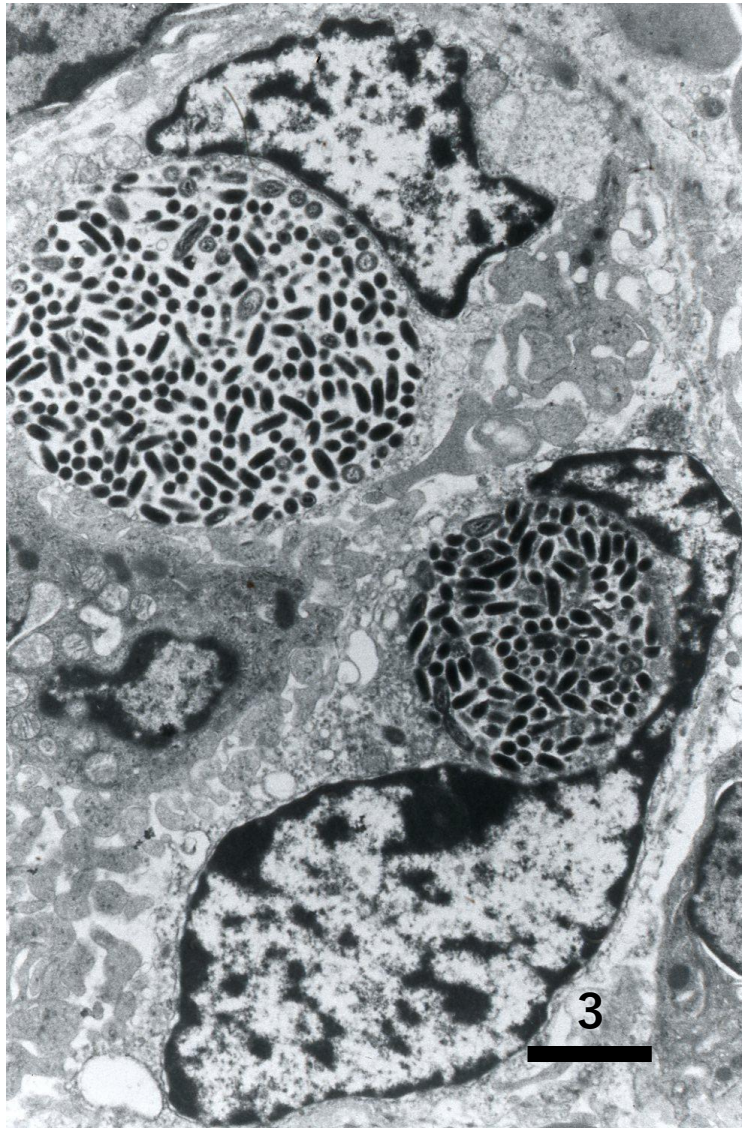
Mycoplasma spp. Incidentally contaminated in the cultured cell (TEM). Mycoplasma is the smallest free-living organisms known. Different shapes have been observed varying from coccoid cells to filaments and irregularly shaped structures. The small coccoid cells are shown here.



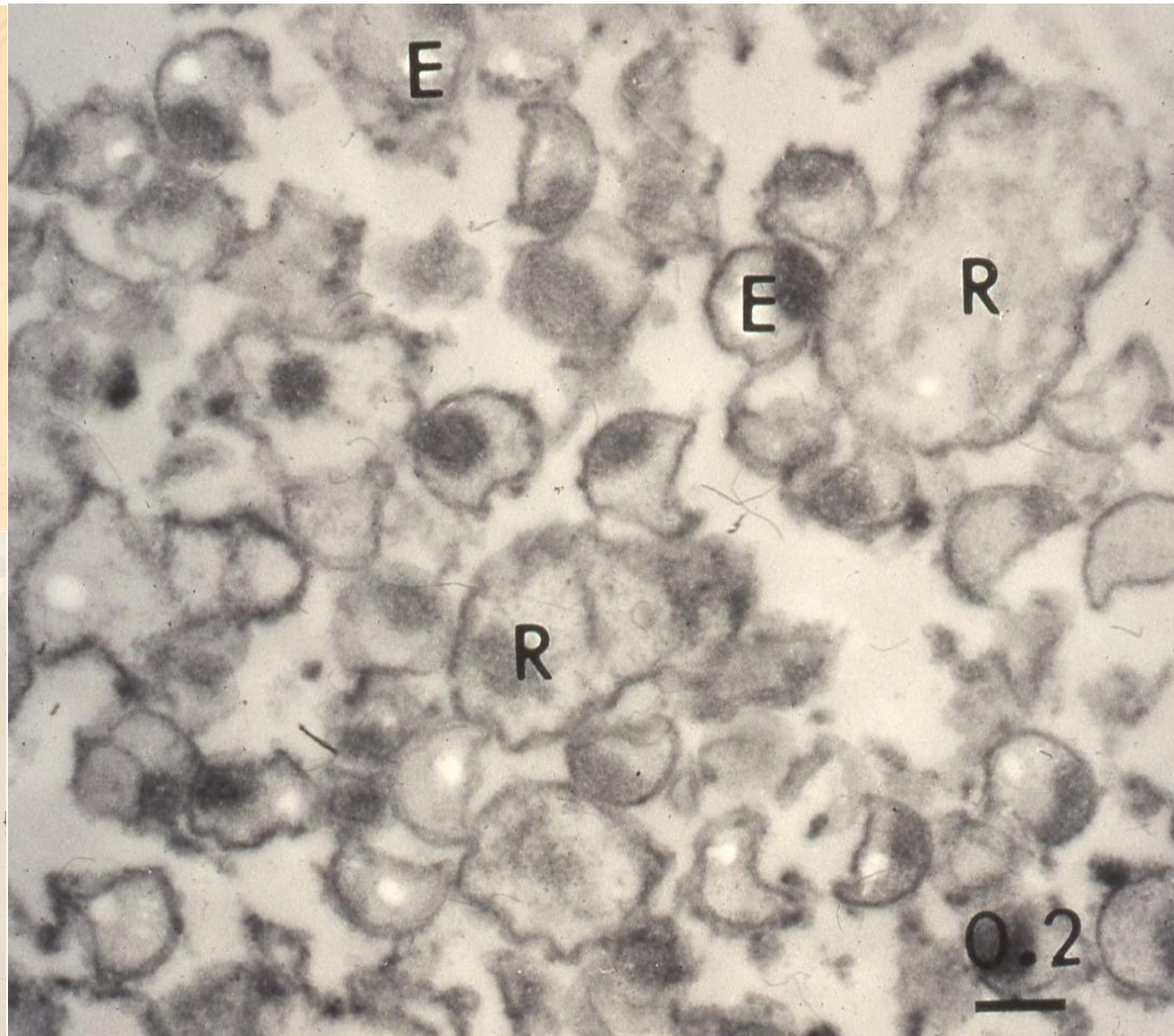
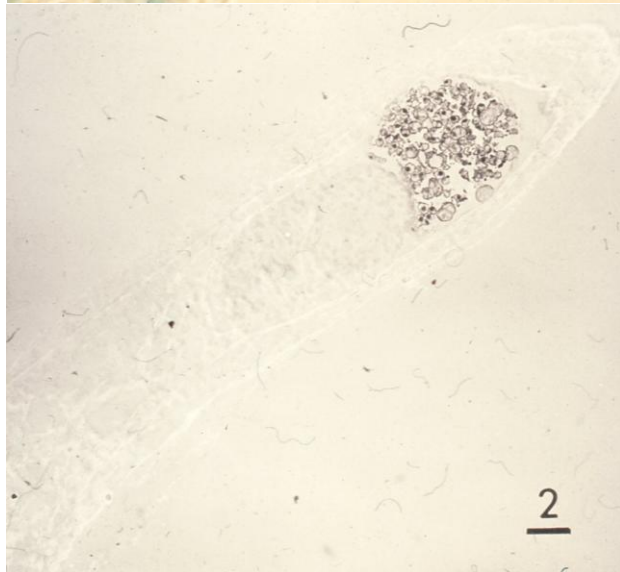
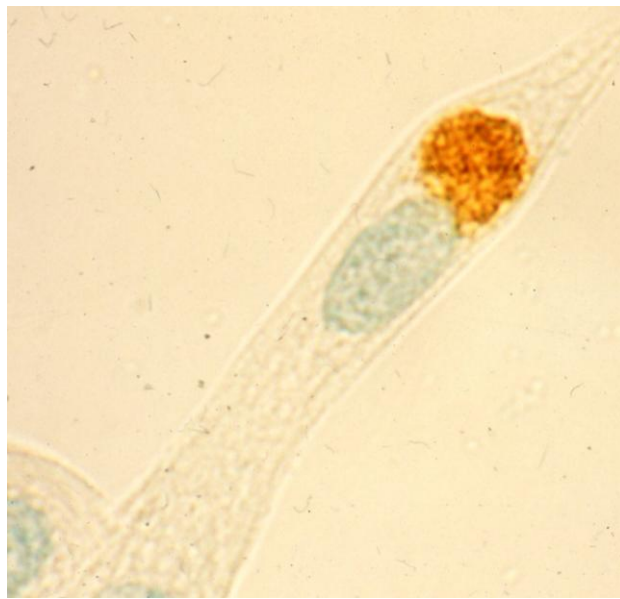
Mycoplasma synovitis of the hip joint (TEM). *Mycoplasma hominis* infection seen in a 48 y-o male patient. A neutrophil contains small coccoid form pathogens in the cytoplasm. **Ref.:** Muramatsu E, et al. Periprosthetic joint infection due to *Mycoplasma hominis* in a multiple sclerosis patient treated with fingolimod. J Infect Chemother 2022; 28(12): 1672-1676. doi: 10.1016/j.jiac.2022.08.020



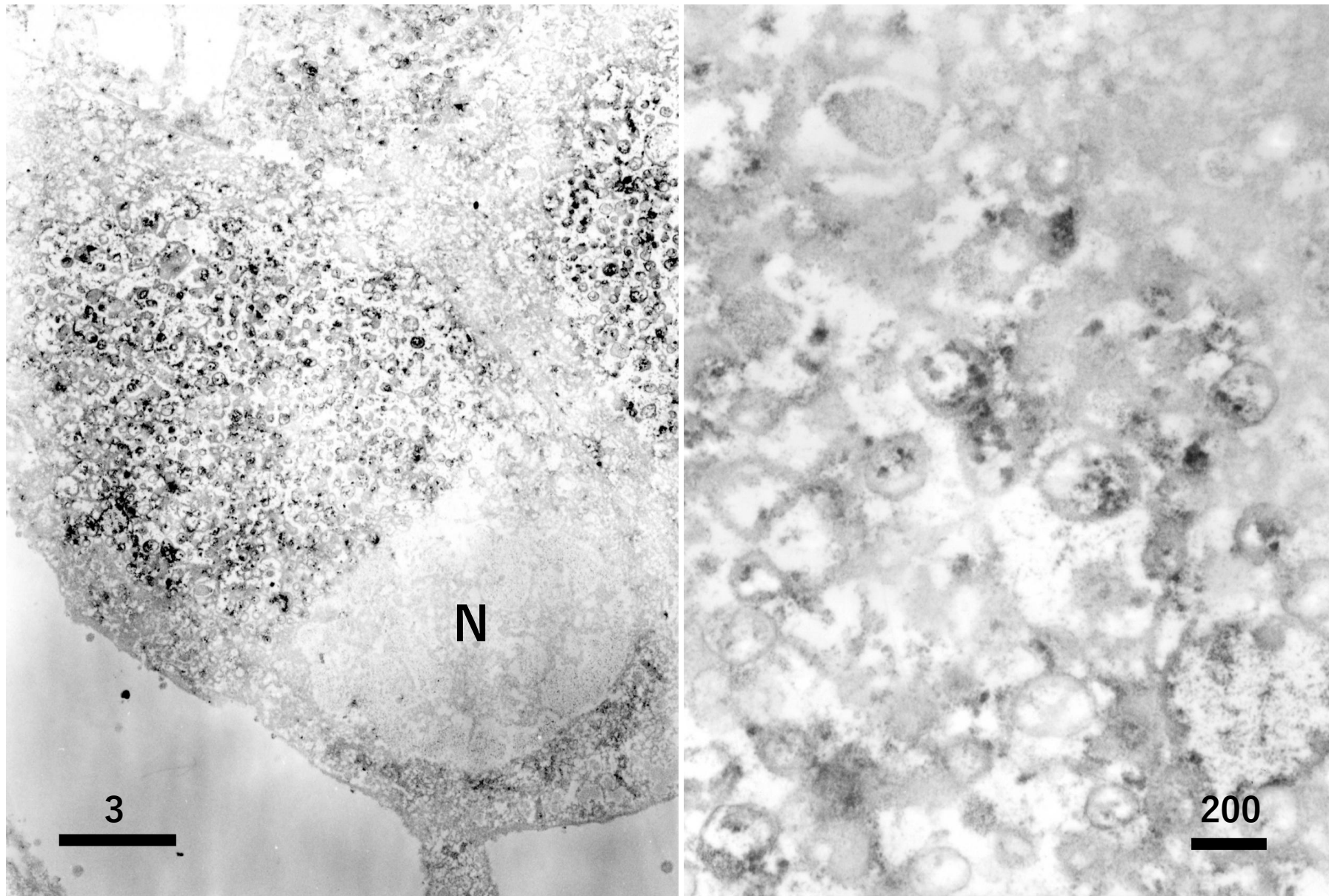
Rickettsia japonica-infected L929 cells (TEM). Post-embedding immunoelectron microscopy using a mouse monoclonal antibody X-1. Small bacillary form rickettsial pathogens are colloidal gold-labeled in the cytoplasm of the cultured cell.



Coxiella burnetii experimentally infected in the mouse spleen (TEM). *C. burnetii* causes Q fever. Cytoplasmic inclusions are formed in the infected macrophages. Small bacillary-form pathogens are observed.



Chlamydia trachomatis infection in the ethanol-fixed cytology specimen of the uterine cervix from a 20 y-o female patient. The chlamydial cytoplasmic inclusion in one metaplastic cell is visualized with immunocytochemistry. Both infective elementary bodies (E) and proliferative reticulate bodies (R) are immunolabeled. Ref. Hori S, Tsutsumi Y. Acta Cytol 1995; 39: 834-835.



Chlamydial epididymitis. The cytoplasmic chlamydial inclusions are filled with *Chlamydia trachomatis* particles. *In situ* hybridization at the EM level demonstrates chlamydial DNA within the particles. Formalin-fixed, paraffin-embedded sections were evaluated herein.