A Story of Two Washingtons: The Earliest Electron Microscopes in America

In the history of electron microscope development in North America, the work at Toronto, Canada is well known:

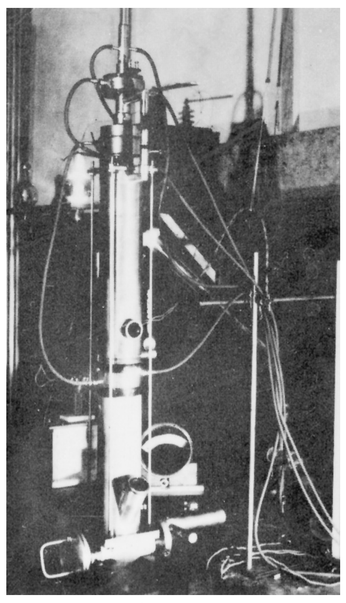
(1) An electrostatic emission electron microscope, using a standard cathode ray tube, was demonstrated in 1934 at the University of Toronto by Walter Kohl, a visiting lecturer from Germany. This was likely the first example of electron microscopy of any kind in North America.
(2) The 1938 microscope of Hillier and Prebus was the first high-resolution TEM in North America, reaching 60 Å resolution in 1939, a bit better than the 100 Å of the Siemens Elmiskop of the time.

Much less well-known were very early efforts in the United States, described here.

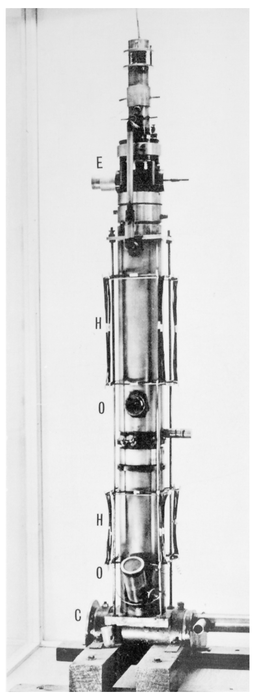
It is interesting to note that the primary intended use of the first electron microscopes was in medicine or biology, and this remained true for many years, with materials science applications gaining prominence only in the last decades.

Washington State University

The honor for the first TEM constructed outside Germany goes to Paul Anderson and Kenneth Fitzsimmons of Washington State University. Anderson had been in Berlin for a year, where he learned of Ruska and Knoll's microscope. Work on the instrument was started in 1935 and completed later that year or in 1936 (accounts differ), and was used until 1938. As was usual for the time, great difficulty was encountered with preparing the specimens of interest (WSU was known for work in plant pathology and cereal genetics), so only images of support grids and wires were obtained. By 1938, work in Germany and Toronto was progressing rapidly, and since Anderson and Fitzsimmons were still obtaining only low-magnification images, they abandoned the project. They were not, in fact, primarily interested in the instrument itself, but rather the uses to which it could be put. General knowledge of the WSU instrument did not surface until 1964, when parts of a second, improved microscope that was never completed were discovered in the attic of the Physics Department building. The parts were assembled, and missing pieces were made, by Edward Steever and Daniel Marlowe. The early EM work was subsequently described by Arthur Cohen at the 1971 EMSA meeting. The microscope is on permanent display near the EM facility at WSU.



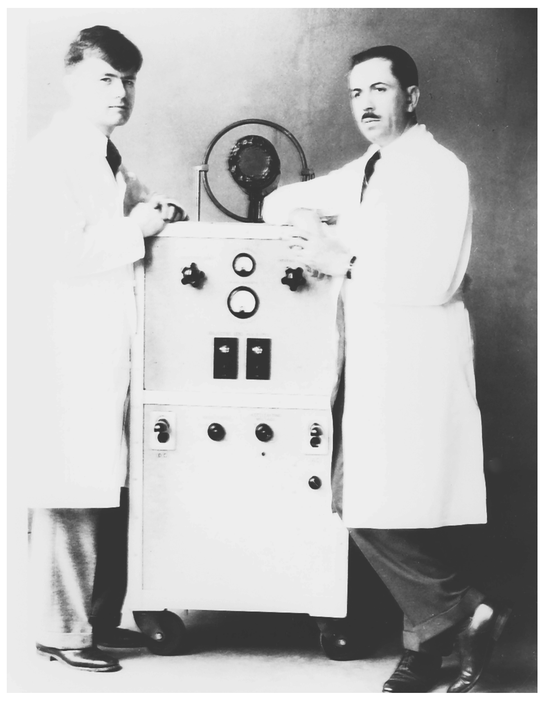
The WSU microscope as originally set up. The Helmholtz coils shown at right were not in place for this photograph.



The restored WSU microscope as currently displayed. Emission chamber (E), Helmholtz coils (H), observation ports (O), camera chamber (C).

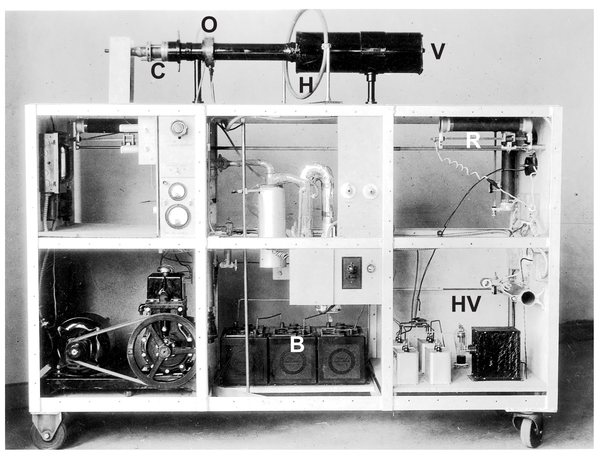
Washington University, St. Louis

Also predating the Toronto microscope was a project started by Gordon H. Scott in 1935 at the Medical School of Washington University in St. Louis. Scott engaged Howard McMillen as Resident Physicist for the microscope project. McMillen was aware of the German work, and constructed a single-lens magnetic emission microscope in 1935. McMillen left for a teaching position at Kent State in 1937, and was replaced with Donald Packer. Packer improved the microscope by adding a second lens, raising the magnification to 150X, and increasing the accelerating voltage from 4 to 6 kV. Packer soon left for the U.S. Public Health Service, and was replaced by Sterling Newberry in 1938. By Spring, 1939 Newberry had constructed a new, much larger, 15kV microscope, that could be used in both emission and transmission modes. Although funding ran out, work continued for a time, and a resolution test specimen of fine wires yielded excellent images at 2500X.



McMillen (l) and Scott with the second Washington University emission microscope. Viewing screen at (V).

Donald Packer



Side view of the second emission microscope. Cathode (C), objective lens (O), Helmhotzs coil (H), diffusion pump (D), Batteries (B), High-voltage supply (HV), rheostat for cathode heater (R), viewing screen (V).

First application of EM microanalysis

Scott was interested in the function and location of soluble salts in tissue. In order to retain the original distribution of the salts, he improved rapid freezing techniques and low-temperature light microscopy. He also improved optical spectroscopy and microincineration techniques. McMillen reasoned that since tissue structure is still visible in microincinerated samples, an emission electron microscope might reveal the location of trace elements such as magnesium, calcium and iron in tissue.

The cathode of the emission microscope consisted of a nickel thimble coated with barium and strontium carbonates. Tissue was freeze-dried and vacuum-embedded in paraffin. A thin section was placed on the cathode. As the temperature was raised, the organic materials burned off, the carbonates were converted to oxides, and the salts were deposited on the cathode. At emission temperature, there was a local increase in emission by about three orders of magnitude at points where the specimen had magnesium, calcium, or iron. Although it was not possible to distinguish between elements if more than one were present, this was the first example of elemental mapping by electron microscopy, many years ahead of its time.

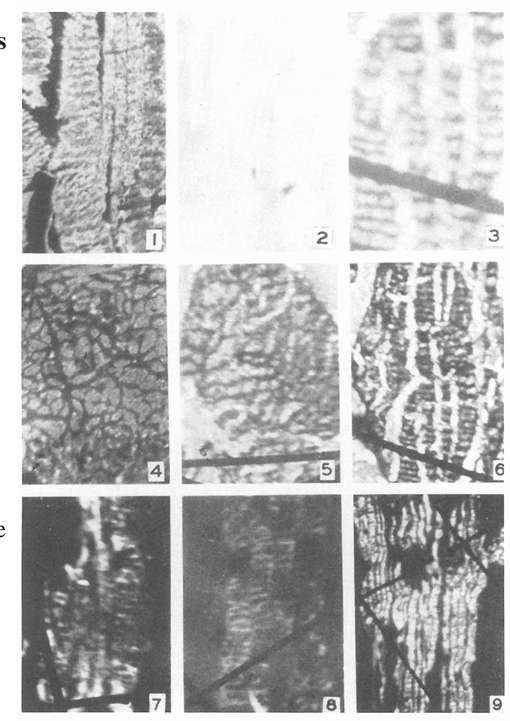
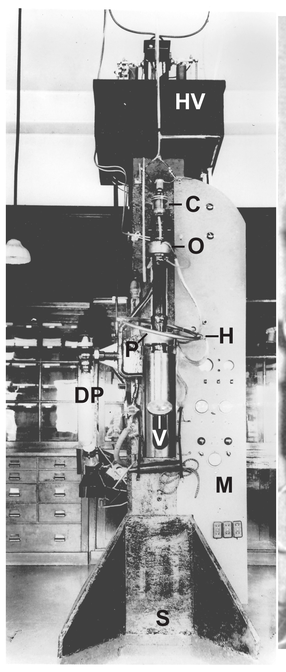
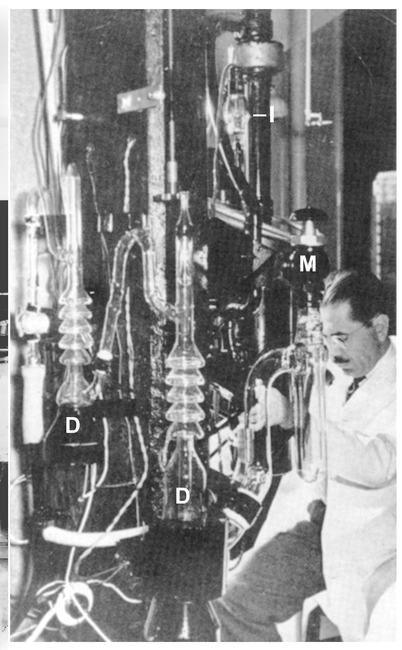


Figure 10. 1-9—Representative electron emission images from the microscope. Copied from the Anatomical record, Scott and Packer (1939). 1. Microincinerated section of skeletal muscle of cat. Note differentiation in amount of ash deposit in the most central muscle fiber, X 150; 2. Photograph of area of cathode surface used to obtain electron microscope picture shown in 3 and 6. There is no detectable optical differentiation on the cathode surface, X 150; 3. Electron microscope picture showing calcium and magnesium in the contraction nodes of skeletal muscle. Compare with 1 in which the total ash is shown, X 150; 4. Electron microscope picture of cross section of frog sartorius muscle showing magnesium and calcium only in the muscle fibers. The "tissue spaces" show little if any of these elements, X 25; 5. Electron microscope picture of cross section of cat skeletal muscle. Compare with 4, X 66; 6. Electron microscope picture of the same area as that in 3 at lower magnification, X 67; 7 and 8. Electron microscope pictures of skeletal muscle fibers showing localization of magnesium and calcium. The light areas represent these elements in the muscle fibers, X 86 and X72; 9. Low power electron microscope pictures of skeletal muscle fibers. Note lack of magnesium and calcium in the "tissue spaces," the deposits being confined almost entirely to the muscle cells, X 32.





A. The third (and final) Washington University microscope, built by Sterling Newberry. High-voltage supply (HV), cathode (C), objective (O) and projector (P) lenses, Helmholtz coil (H), diffusion pump (DP), viewing port (V), concrete support with embedded copper tubing for current leads and water cooling (S), Masonite control panel (M). The instrument was 2 M high. B. Rear view of the microscope in A, with Gordon Scott at the controls, showing both series-connected diffusion pumps (D), main vacuum valve (M), and ionization vacuum gauge (I).

Sterling Newberry, in 1938, in front of Wyman Crow Physics building at Washingtom University.

Sources:

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Cohen, Arthur and Steever, Edward (1971) An Early American Electron Microscope. In: 29th Ann. Proc. Electron Microscopy Soc. Amer., pp.4,5. Claitor's, Baton Rouge.
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