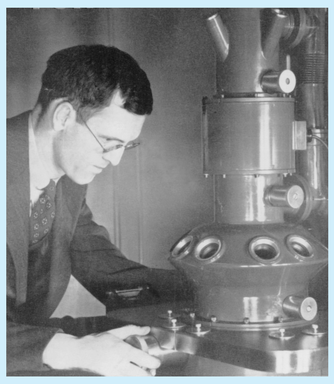
# Ernest F. Fullam 1910 - 2002



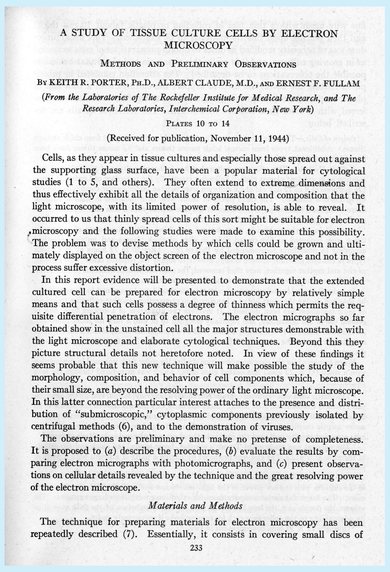
Ernest F. Fullam, a charter member of the Electron Microscope Society of America (predecessor of MSA) was born in Parlin, NJ, son of a noted chemist. He received a bachelors in chemistry from Cornell University in 1936. From 1936 to 1939 he did graduate work at Cornell, the University of Pennsylvania, and Columbia University, studying advanced chemical microscopy, high-resolution photomicrography and theoretical electron optics. In 1939 he married Barbara Jewell of Summit, NJ.

From 1940 to 1945 he worked at Interchemical Corporation in New York City, a manufacturer of printing inks and pigments. He and a colleague convinced the management to purchase one of the first American-made electron microscopes, an RCA EMB. When America entered WWII, , he became involved in the Manhattan Project, studying barrier materials used in the gaseous diffusion plant at Oak Ridge TN. He also collaborated with Rockefeller Institute scientists on biological applications of electron microscopy. By 1050, Fullam already had 14 papers on electron microscopy to his credit.

Fullam moved to Schenectady in 1945 to work in electron microscopy at the General Electric Research and Development laboratories. One of his early studies for GE led to the discovery of deep casting cracks as a cause of failure in steam turbine blades. Using money from an inheritance, he soon purchased his own electron microscope, an RCA EMU-2B and set up an informal consulting business in his home in Schenectady, NY. He organized Ernest F. Fullam, Inc. in October 1953.

Fullam was a president of the Board of Trustees of the Dudley Observatory in Albany, NY and he endowed the annual Ernest F. Fullam award in support of research in astronomy and astrophysics. He was a fellow and life member of the American Association for the Advancement of Science, a member of the scientific honorary society Sigma XI, and was listed in American Men of Science.

## The early years



A STUDY OF TISSUE CULTURE CELLS BY ELECTRON MICROSCOPY

METHODS AND PRELIMINARY OBSERVATIONS

BY KEITH R. PORTER, PH.D., ALBERT CLAUDE, M.D., AND ERNEST F. FULLAM

*(From the Laboratories of The Rockefeller Institute for Medical Research, and The Research Laboratories, Interchemical Corporation, New York)*

PLATES 10 TO 14

(Received for publication, November 11, 1944)

Cells, as they appear in tissue cultures and especially those spread out against the supporting glass surface, have been a popular material for cytological studies (1 to 5, and others). They often extend to extreme dimensions and thus effectively exhibit all the details of organization and composition that the light microscope, with its limited power of resolution, is able to reveal. It occurred to us that thinly spread cells of this sort might be suitable for electron microscopy and the following studies were made to examine this possibility. The problem was to devise methods by which cells could be grown and ultimately displayed on the object screen of the electron microscope and not in the process suffer excessive distortion.

In this report evidence will be presented to demonstrate that the extended cultured cell can be prepared for electron microscopy by relatively simple means and that such cells possess a degree of thinness which permits the requisite differential penetration of electrons. The electron micrographs so far obtained show in the unstained cell all the major structures demonstrable with the light microscope and elaborate cytological techniques. Beyond this they picture structural details not heretofore noted. In view of these findings it seems probable that this new technique will make possible the study of the morphology, composition, and behavior of cell components which, because of their small size, are beyond the resolving power of the ordinary light microscope. In this latter connection particular interest attaches to the presence and distribution of "submicroscopic," cytoplasmic components previously isolated by centrifugal methods (6), and to the demonstration of viruses.

The observations are preliminary and make no pretense of completeness. It is proposed to (*a*) describe the procedures, (*b*) evaluate the results by comparing electron micrographs with photomicrographs, and (*c*) present observations on cellular details revealed by the technique and the great resolving power of the electron microscope.

*Materials and Methods*

The technique for preparing materials for electron microscopy has been repeatedly described (7). Essentially, it consists in covering small discs of

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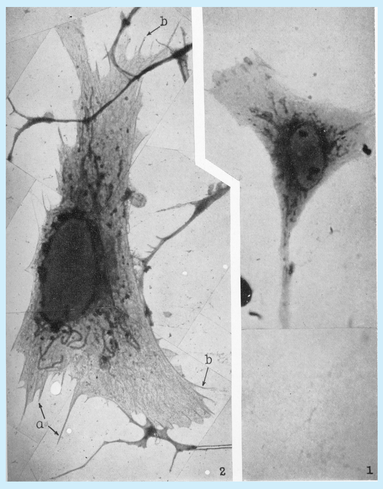
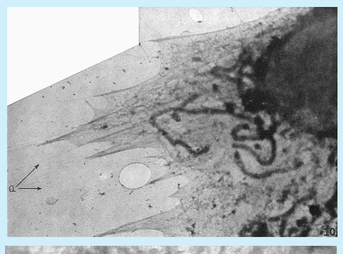
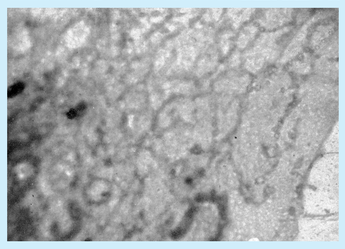
In 1944, while at Interchemical Corp., Fullam did the work that led to his most famous paper, shown here [1], in collaboration with two very well known biologists at the then Rockefeller Institute (now Rockefeller University).

Albert Claude won a Nobel Prize in Medicine for his pioneering work that ushered in modern cell biology, by identifying the components of the cytoplasm using differential centrifugation combined with microscopy. Fullam took electron micrographs of isolated cytoplasmic organelles [2] as well as whole-cell mounts and sections for the Rockefeller group.

Keith Porter, a legendary figure in biological electron microscopy (also EMSA President and founder of the Boulder HVEM facility), developed a technique for preparing whole-mounts of cultured cells. Fullam's images showed, for the first time, fine internal structure of the cytoplasm in an intact cell.



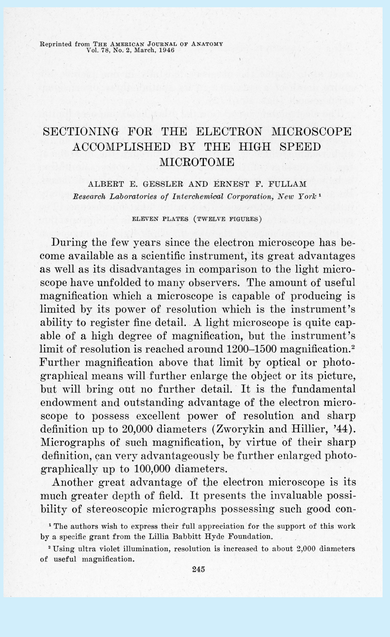



EM montage image of a chick fibroblast-like cell (left, original magnification 1600X) compared to a similar cell by light microscopy. The cell was grown on a formvar film, fixed with osmium vapor, washed, transferred to an EM grid, and air-dried. The paper details several different preparation techniques that were tried, with the osmium fixation method (developed earlier by H. B. Fell) being by far superior.

Photographic enlargement of image on far left, showing intermediate filaments (unknown at the time) and many "filamentous" mitochondria.

Higher-magnification image of another fibroblast (original magnification 4500X). Original caption: "Thinner portion of cell at right of figure shows a granular background and details of a darker lace-like reticulum which in places appears to be made up of chains of 'vesicles'". This presages Porter's naming of the endoplasmic reticulum.



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SECTIONING FOR THE ELECTRON MICROSCOPE ACCOMPLISHED BY THE HIGH SPEED MICROTOME

ALBERT E. GESSLER AND ERNEST F. FULLAM
*Research Laboratories of Interchemical Corporation, New York*[1]

ELEVEN PLATES (TWELVE FIGURES)

During the few years since the electron microscope has become available as a scientific instrument, its great advantages as well as its disadvantages in comparison to the light microscope have unfolded to many observers. The amount of useful magnification which a microscope is capable of producing is limited by its power of resolution which is the instrument's ability to register fine detail. A light microscope is quite capable of a high degree of magnification, but the instrument's limit of resolution is reached around 1200–1500 magnification.[2] Further magnification above that limit by optical or photographical means will further enlarge the object or its picture, but will bring out no further detail. It is the fundamental endowment and outstanding advantage of the electron microscope to possess excellent power of resolution and sharp definition up to 20,000 diameters (Zworykin and Hillier, '44). Micrographs of such magnification, by virtue of their sharp definition, can very advantageously be further enlarged photographically up to 100,000 diameters.

Another great advantage of the electron microscope is its much greater depth of field. It presents the invaluable possibility of stereoscopic micrographs possessing such good con-

[1] The authors wish to express their full appreciation for the support of this work by a specific grant from the Lillia Babbitt Hyde Foundation.

[2] Using ultra violet illumination, resolution is increased to about 2,000 diameters of useful magnification.

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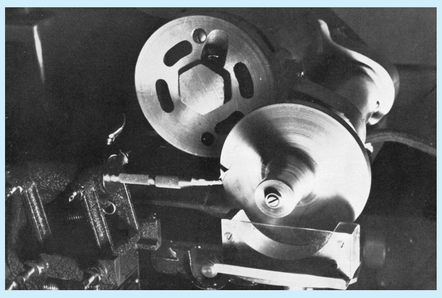
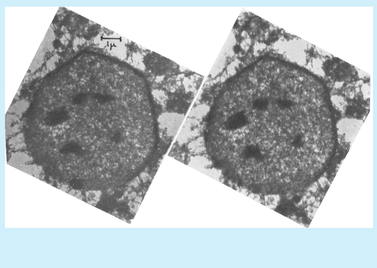
Although the micrographs of cultured cells were the most-detailed yet, it was clear that ultramicrotomy had to be developed for electron microscopy to be a truly general technique for biology. In 1945, Fullam and Albert Gessler constructed a series of high-speed ultramicrotomes [3], inspired by the initial trials of O'Brien and McKinley [4]. Full technical details of the Fullam microtomes were described in an accompanying paper [5]. Sections from this microtome were shown in another paper with Albert Claude [6].

Remarkably, Gessler and Fullam tried vitreous freezing of tissue in liquid propane cooled by liquid nitrogen, then sectioning with the microtome wheel and chamber cooled to below -30°C (they were already aware that crystalline ice cannot be sectioned). The sections were freeze-dried at low temperature before examination in the EM. However, this line of research did not get very far before Fullam left for GE. It would be decades before cryo-sectioning for the EM was finally developed.



High-speed ultramicrotome. The principle of these microtomes was that the high speed (about 50,000 rpm!) causes a fracturing or chipping action, even with fairly soft material, and thus avoids distortion due to plastic deformation. Sections were successfully cut down to 100nm in thickness. The rotating knife--a section of a razor blade--was surrounded by a shield (not shown) on the inside of which was mounted a mesh coated with a formvar film. After sectioning, the mesh was examined with a light microscope and EM grids were punched out where good sections were seen. The whole machine was designed to be put in a vacuum chamber to reduce air turbulence, but this did not seem to be necessary.




Stereopair of guinea pig liver perfusion-fixed with 2% osmium tetroxide (original magnification 5000X). Knowledge of the internal structure of the nucleus had long been sought, and these results looked very promising. Fullam's co-worker Mary Schuster Jaffe (who also was the first to make "holey" grids as test specimens, and one of the most accomplished early electron microscopists) developed a special embedding medium that sublimes at just above room temperature, yet provides sufficient support for good sectioning. This was a eutectic of camphor and naphthalene that could be used just as paraffin in conventional histological embedding protocols. Sublimation produced much less tissue distortion than drying from a liquid phase. Stereopairs were very popular with early electron microscopists, since the depth of field was much greater than in the light microscope. At that time, even using 60kV, the ideal section thickness for biological sections was judged to be 300nm, otherwise the sense of 3-D would be excessively diminished.


1. Porter, K., Claude, A. and **Fullam, E.F.** (1945) A study of tissue culture cells by electron microscopy *J. Exp. Med.* 81:223-246.
2. Claude, A. and **Fullam, E.F.** (1945) An electron microscope study of isolated mitochondria. *J. Exp. Med.* 81:51-62.
3. Gessler, A.E. and **Fullam, E.F.** (1946) sectioning for the electron microscope accomplished by the high speed microtome. *Am. J. Anat.* 78:245-279.
4. O'Brien, H.C. and McKinley, G.M. (1943) New microtome and sectioning for electron microscopy. *Science* 98:455-456.
5. **Fullam, E.F.** and Gessler, A. (1946) A high speed microtome for the electron microscope. *Rev. Sci. Instr.* 17:23-35.
6. Claude, A. and **Fullam, E.F.** (1946) The preparation of sections of guinea pig liver for electron microscopy. *J. Exp. Med.* 83:499-504.


## Ernest F. Fullam, Inc.

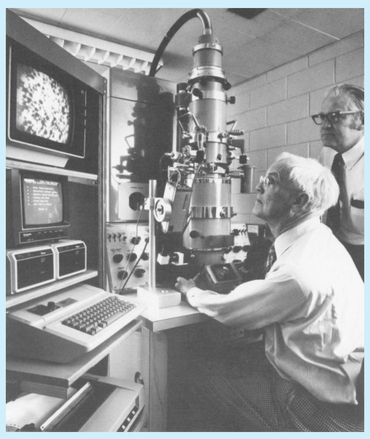
Barbara Jewell Fullam was the co-founder of Ernest F. Fullam, Inc. She earned a bachelor's in anthropology at Radcliffe and did graduate work at Smith College. She served as the secretary and treasurer of the company until retirement in 1986.

There are several parallels between Ernest Fullam and William Ladd, who were good friends. They were both pioneering electron microscopists, both developed a high-speed ultramicrotome, both started private EM consulting companies, and both found they could be of great service by selling instrumentation and supplies to the, at first, very small and very specialized EM community.


One of Fullam's first products, represented on the cover of this early brochure, was a diffraction grating replica for use as a magnification standard. In the mid 1940's only one person, Prof. R.W. Wood, could make diffraction gratings fine enough for EM calibration, and Fullam's replicas were a popular item.

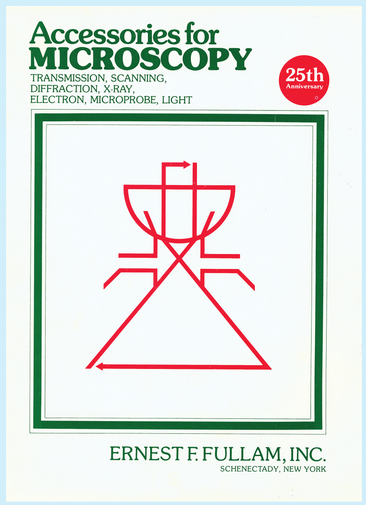

Design and construction of prototype--and production--instruments has been a major part of the Fullam business since the beginning, and is a very important part of the business today. It was this activity that finally drove the business from the family home to a modern facility in 1958, which has been expanded several times since.

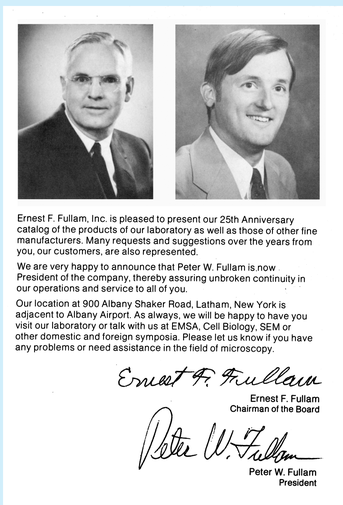

One of the most popular microscopy supply items sold by Fullam is the EFFA duster, introduced at the 1960 EMSA meeting. The idea came from Barbara Fullam, who adapted it from a boat foghorn. The original duster is shown on the left, and a current version is shown on the right.

The company early on offered comprehensive consulting services. In addition to light microscopy, TEM, electron diffraction and SEM, x-ray diffraction and microprobe analysis were available. In the 1960's the company built its own microprobe, and one for a customer.

Here, Ernest Fullam, with Doug Hallgren looking on, is operating an early version of his TV camera system for TEM. An up-to-date version of this item is still offered.




In 1978 the company celebrated its 25th anniversary, and Peter Fullam became President. Ernest continued active involvement in the company unitl 1990, and attended the 50th anniversary EMSA meeting in Boston in 1992, with many of his fellow charter members of the Society. The family tradition continues with daughter-in-law Dianne Fullam, joining the company in 1979 and grandson Richard Fullam in 2001.

Next year Ernest F. Fullam, Inc. will celebrate its own 50th anniversary, as the oldest company engaged in laboratory accessories and supplies for electron microscopy.

Sources: Newberry, S.P. (1992) *EMSA and its people: The first fifty years.* published by EMSA; Peter and Dianne Fullam, personal communication; Items from the MSA archives