AN ELECTRON MICROSCOPE FOR THE RESEARCH LABORATORY

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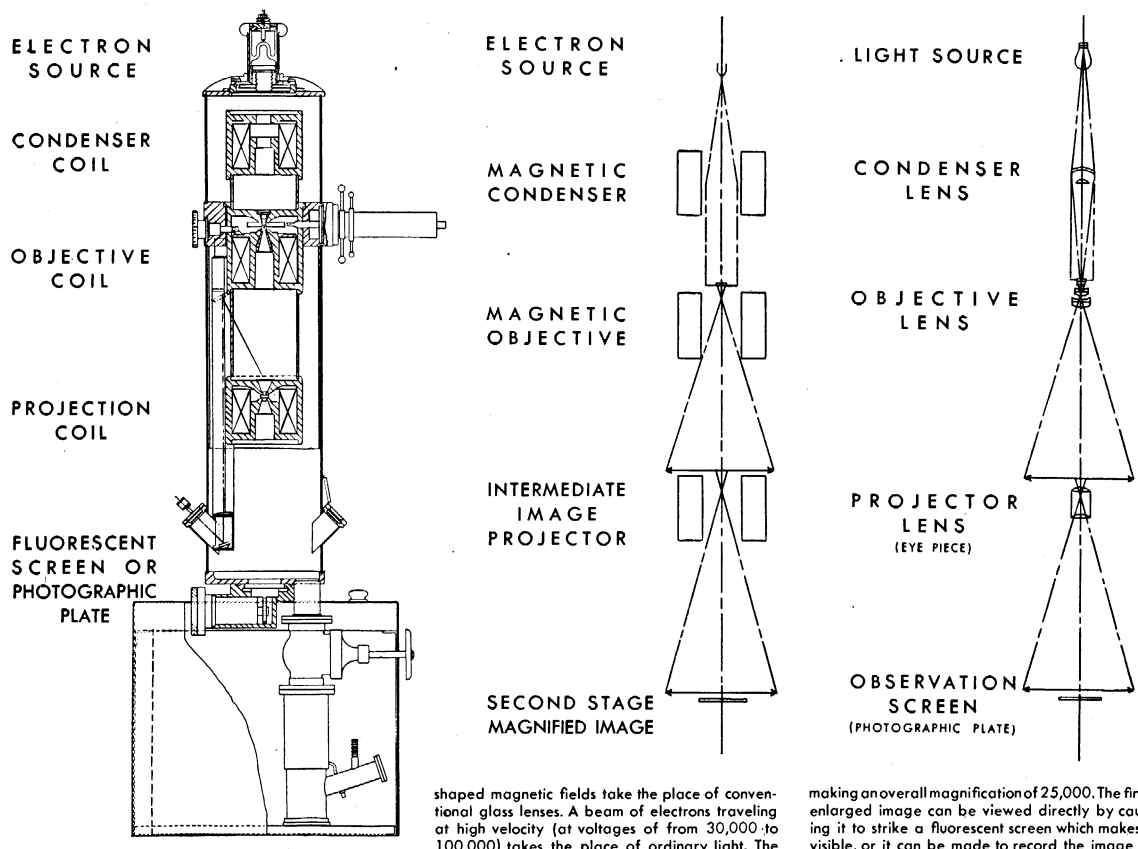
FOR some time scientists have been aware that a considerable increase in the resolving power of microscopes could be obtained if it should prove possible to substitute for light a medium of much shorter wavelength which, like light, could be "focused"—*i.e.*, used to form images. High velocity electrons, having wavelengths one-one hundred thousandth that of light and capable of being focused by axially symmetric magnetic and electric fields, constitute just such a medium. Certain fundamental peculiarities of these electron lens fields appear to prevent, it is true, an approach to an improvement in resolution corresponding to the ratio of the wave-lengths of these electrons and of light. Nevertheless, workers both here and abroad have demonstrated beyond doubt an increase in resolution by a factor of twenty to a hundred times.

There could be no question that an instrument having resolution capabilities one or two orders of magnitude greater than is possible with the ordinary microscope would be of incalculable value in countless researches both of a purely scientific and of an industrial nature. On the other hand, the construction and installation of an "electron microscope" introduces problems quite outside of the sphere of either the optician or the conventional microscopist. This situation caused the RCA laboratories, with their accumulated experience in electronics, electron optics and vacuum technique, to undertake the task of construct-



Simplified sketch of the electron microscope developed in the RCA Laboratories at Camden, New Jersey. Diagram in center shows how closely the operation of the electron microscope is analogous to the conventional light microscope. (right.) Suitably shaped magnetic fields take the place of conventional glass lenses. A beam of electrons traveling at high velocity (at voltages of from 30,000 to 100,000) takes the place of ordinary light. The electron rays are converged by condenser lens onto the specimen. After passing through the specimen, the objective lens coil forms a first image, enlarged about 100 times. The projection lens coil then magnifies the image again about 250 times, making an overall magnification of 25,000. The final enlarged image can be viewed directly by causing it to strike a fluorescent screen which makes it visible, or it can be made to record the image on a photographic plate for permanent record. The RCA electron microscope has such enormous resolving power that the final photograph can be usefully magnified by photographic enlargement up to 100,000 diameters.

FIG. 1. Simplified sectional view of the RCA Electron Microscope.

ing an electron microscope suitable for all types of research problems.

The microscope[1] was designed by L. Marton in cooperation with other staff members. Emphasis has been placed not only on attaining the highest resolution possible, but also on ease of operation, insensitivity to disturbances and safety. A simplified sectional view of the instrument is shown in Fig. 1.

At the top, some eight feet from the floor level, is the electron source, a hairpin filament of tungsten surrounded by a guard cylinder. It is the only part of the microscope at a high potential—30 to 100 kilovolts —above ground. Electrons leaving the filament are accelerated by the strong electric field between the cathode (filament and guard cylinder) and anode, pass through a hole in the latter and enter the magnetic field of the condenser lens. This, as in a light microscope, serves to concentrate the beam on the object, which, itself, is placed within the lens field of the objective, a position favorable from the point of view of minimizing the lens aberrations. The electrons which pass through the object are guided by the magnetic field of the objective so as to form an image of the object enlarged by a factor of about 100 on the fluorescent screen immediately above the projection coil. A central portion of this intermediate image corresponding to a free aperture in the middle of the fluorescent screen is enlarged once more by the projection coil, forming the final image on an interchangeable photographic plate or fluorescent screen below. This final image has a magnification of up to 25,000. Added detail may be brought out on the plates thus obtained by photographic enlargement, bringing the total magnification up to 100,000.

The body of the microscope is made up of two large brass cylinders. This construction lends it rigidity and makes it insensitive to mechanical shock. Magnetic shielding is provided for the entire path of the electrons from the object to the final image.

The lenses consist of coils of magnet wire provided with soft iron shields so shaped as to give a desirable magnetic field distribution along the axis of the microscope. As the entire body of the microscope is evacuated, the coils are sealed into copper cans, the leads being brought out through glass-to-metal seals.

A suitable technique for the preparation of specimens and for their introduction into the evacuated microscope was first worked out by Dr. Marton. In the microscope under discussion the object is placed on a nitrocellulose film less than a millionth of an inch in thickness, which is stretched over a small disk of fine wire cloth. This disk is clamped between two apertures in a pair of blades. After the object holder has been introduced into the forechamber of an air-lock, this chamber is evacuated. Thereupon an inner gate is opened with the aid of an externally operated crank and the object is moved into position within the objective. Further screws and gears, manipulated externally, translate the object horizontally and ver-

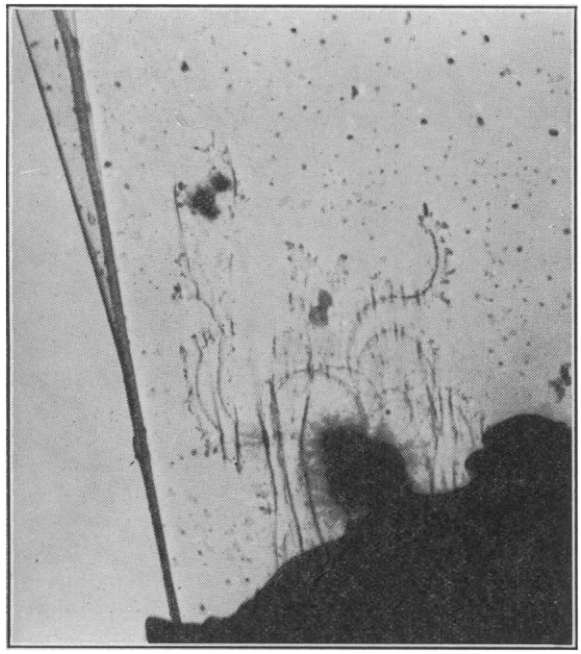


FIG. 2. Typhoid bacillus. Magnification 10,000×.

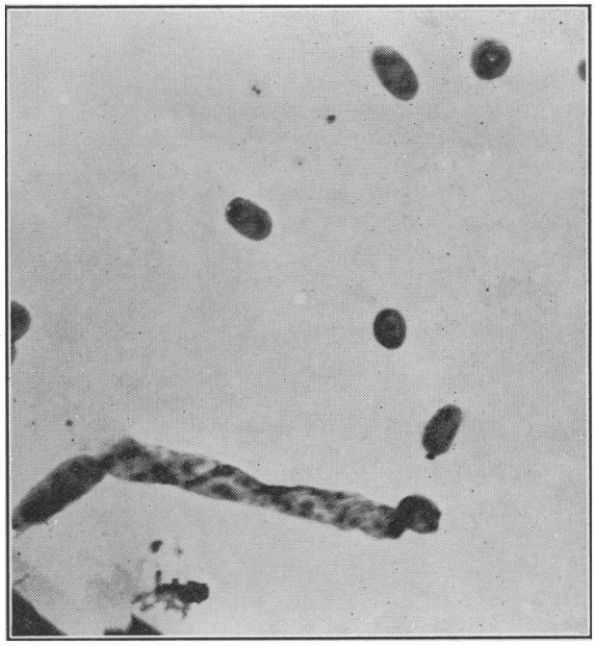


FIG. 3. Whooping cough bacteria. Magnification 9,000×.

[1] For a more detailed description see L. Marton, "A New Electron Microscope," *Physical Review* (in press).

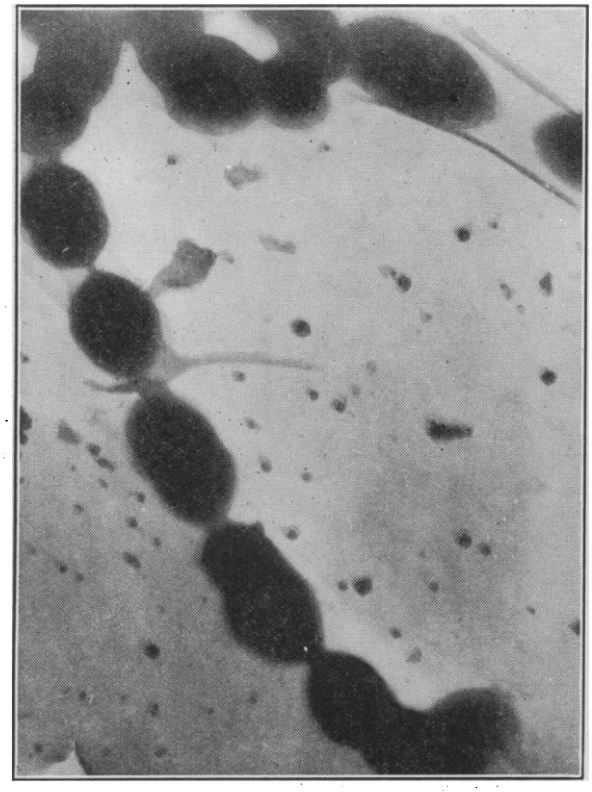


FIG. 4. Streptococcus germs. Magnification 20,000×.

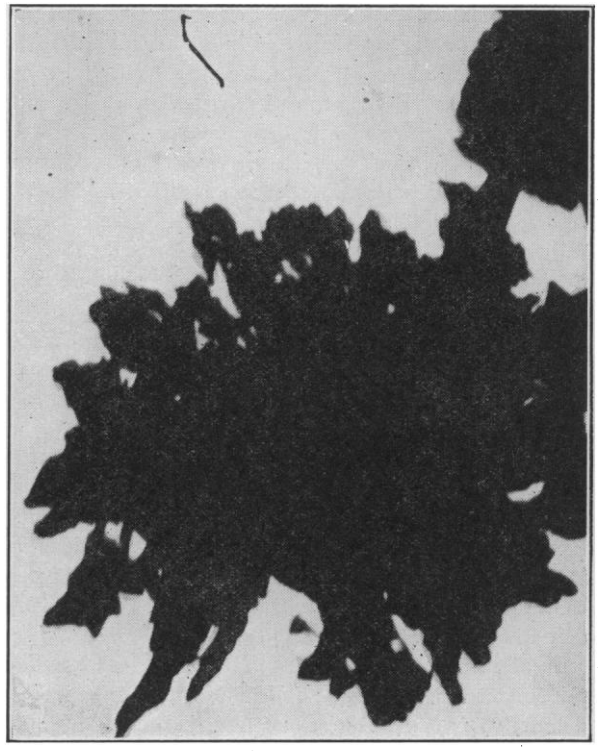


FIG. 5. Iron-oxide powder (rouge). Magnification 15,000×.

tically relative to the objective. This arrangement makes it an easy matter to explore the specimen by manipulating controls from the observer's position.

In studying the object the observer is seated in front of the microscope and views the final image through one of the large rectangular windows provided for that purpose, with the current and voltage controls within easy reach. A periscope at the left end of the window permits the observation of the less highly magnified intermediate image from the same position.

If a photograph is to be taken, a photographic plate is introduced through a second airlock, the fluorescent screen is swung aside and an exposure made. The airlock mechanism opens and closes the plate holder automatically as the plate is introduced and again withdrawn.

To illustrate some possibilities of application of this electron microscope, a few pictures obtained with it are reproduced in Figs. 2 to 5. The first three represent various pathogenic bacteria. Here the long curved flagella of the typhoid germ and the interior structure visible in the whooping cough bacteria are particularly interesting. The last picture, showing a sample of polishing rouge, indicates the usefulness of the instrument for determining the size and shape of particles beyond the reach of the light microscope.

A conservative estimate based on the examination of pictures so far obtained makes the resolving power of the present electron microscope twenty times that of the best light microscopes with oil immersion. There is every probability that research now being carried on will greatly increase this factor. The significance of this newly found sight, extended to the range of the larger organic molecules, in all branches of science—biology, medicine, metallurgy, etc.—can scarcely be gauged. Once again, an apparently insurmountable obstacle to the progress of science has been overcome.

SCIENTIFIC EVENTS

THE HARVARD SCHOOL OF DENTAL MEDICINE

A NEW plan of dental education made possible by contributions amounting in all to $1,300,000 has been inaugurated at Harvard University. The gifts were made by: The Carnegie Corporation, $650,000 in addition to a gift of $350,000 made in 1937; the Rockefeller Foundation, $400,000; and the John and Mary R. Markle Foundation, $250,000. This foundation had contributed previously the sum of $25,000.

Under the plan, which is described in the *Harvard Alumni Bulletin*, the present Harvard Dental School