PHYSICS

Exploring A New World

New Super-Microscope Peers Deeper Than Ever Into Details of Living and Non-Living Things

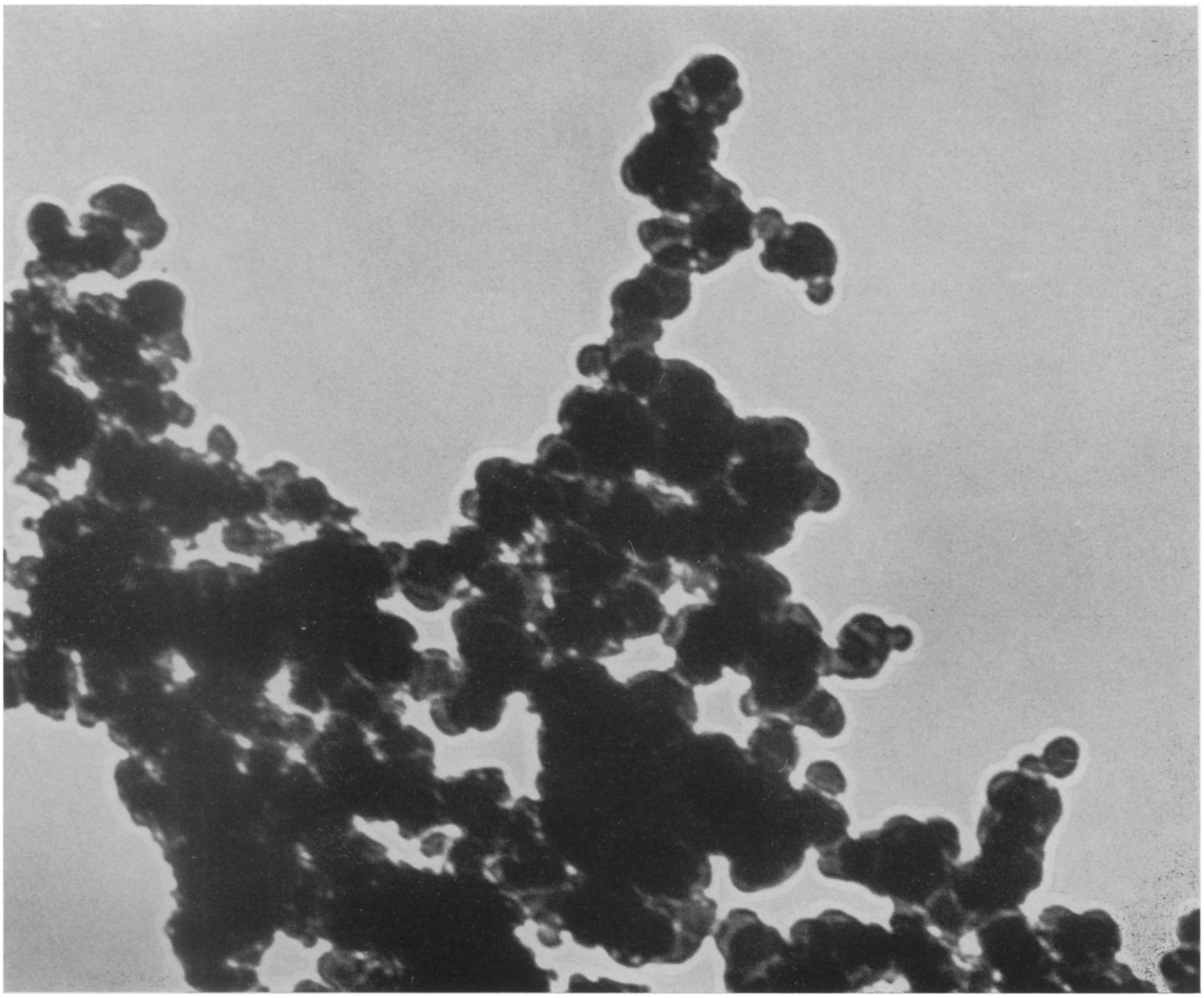
By WATSON DAVIS

MAN'S eyes are being resharpened by a new kind of super-microscope that peers deeper than lenses ever reached before into the way living and non-living things are put together. It uses particles of electricity—electrons—instead of rays of light, and magnetic fields instead of glass lenses, to reveal a world hitherto invisible. Scientists using the new instrument get the thrill that Leeuwenhoek, the Dutch pioneer, felt when he looked through his crude little microscope 250 years ago and was the first man to see the microorganisms that we now commonly call germs.

The familiar microscope of school and laboratory takes us into a world where things are at most 2,000 times larger than life. The microscope which uses ultraviolet light, its rays too short for the eye to perceive, photographs things which are about half as large as the smallest that can be distinguished by the best optical lens microscope; it shows images 5,000 times larger than life. The new apparatus that "sees" by means of electrons attains direct magnifications of 10,000 to 30,000 with such fine detail that photographic enlargements to 100,000 and even 200,000 times life-size are possible. Objects are being seen that are but a fiftieth the size of anything heretofore visible. This means that science is crossing the frontier of a new world.

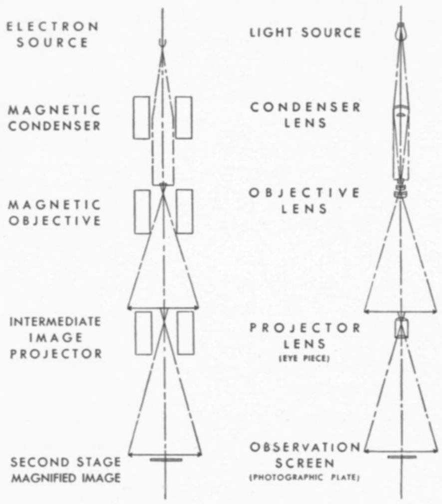
ENLARGED!

Carbon black particles, magnified 113,000 times. They are self-supporting by their own cohesive force and were deposited upon a wire mesh from a sooty flame.



Hesitatingly, hints of what is being seen in this new world are filtering out of the laboratories. Familiar bacteria are sitting for new and more intimate portraits. Disease-causing organisms which up to now have completely avoided the camera are being photographed. The typhoid germ, it is now plainly seen, has wavy flagella sticking out from it. No one knows what they do. The streptococcus germs have rigid and continuous outer membranes that bind them in chains. The germs of whooping cough show a curious internal structure. These bits of knowledge are too new for anyone as yet to put them to practical use. Getting photographs of known murderers for the rogue's gallery, however, is frequently a long step toward sending them to the chair. Just so, the electron microscope holds out hope for further conquest of disease. We need, now, new Pasteurs and Kochs to use the new instrument as those geniuses used the old microscopes.

And, of course, industry is intensely interested. There is a continuous procession of men from industrial laboratories

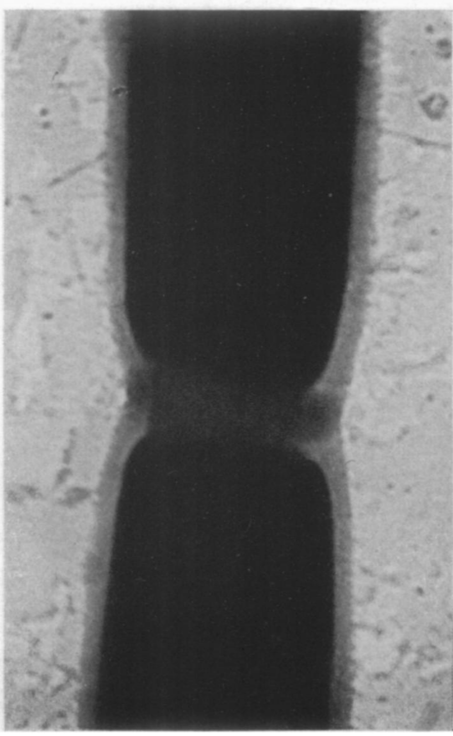


to Camden, N. J. where the Radio Corporation of America is developing the most advanced American electron microscope. The visitors slide specimens of their products into the instrument and depart excitedly whispering among themselves about their new vision of the real structure of, let us say, a synthetic textile fiber. Naturally, they give no hint as yet of where new knowledge may lead them. But a suggestion of the way business may use the new tool seeps out of Germany. There, the manufacture of cement already has been improved, and there is hope that the study of mine dusts under way may give a clue toward solving the problem of mine sanitation.

Under the electron microscope, the iron oxide powder called rouge, which is the finest polishing material used industrially, is shown when magnified 15,000 diameters to consist of jagged masses. The carbon particles in a gas flame and the crystals in the smoke of a cigar are shown to have distinctive shapes, easily identified. Particles of colloidal gold and silver are seen plainly. Physicists, chemists and bacteriologists have built all of their past achievements on the foundation of the exact knowledge yielded by instruments, and every new instrument has brought new advances. The electron microscope will have the same effect.

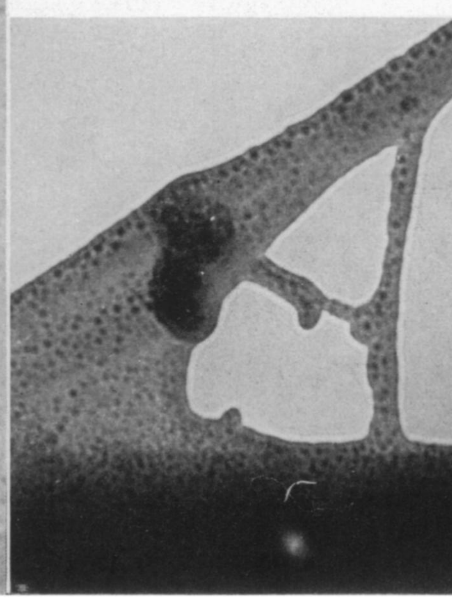
KILLER

Anthrax bacilli, magnified 45,000 times. This view is interesting to scientists because of the structure between the ends of the portions of the two bacilli shown. They also want to know the meaning of the plate-like structures in the background.



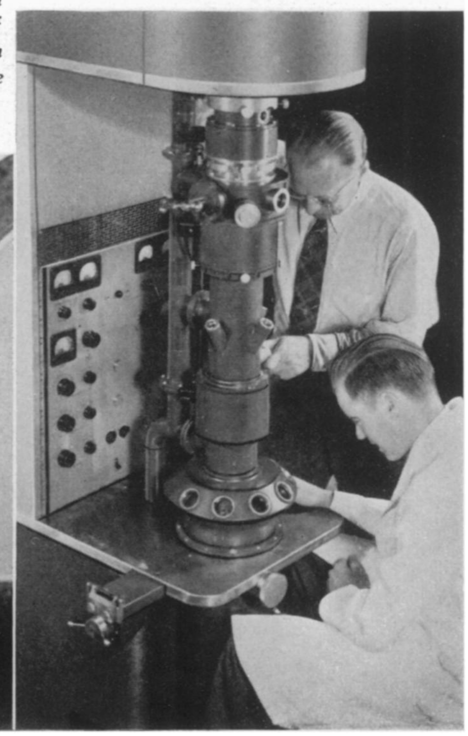
SMALLEST VISIBLE

Molecules themselves may be seen in this electron micrograph, magnification 105,000 times. Scientists guess that the smallest particles visible are really molecules. This is a thin filament of a plasticized polymer of vinylchloride containing about 2% carbon black, a synthetic rubber-like substance manufactured by Goodrich.



NEW INSTRUMENT

Dr. V. K. Zworykin, standing, head of the RCA Electronic Research Laboratory, under whose supervision James Hillier (at the controls) and a group of associates developed the new RCA electron microscope. The microscope magnifies bacteria and other minute objects from 20 to 50 times as much as is possible with the finest optical microscope. The new instrument shown here incorporates radical improvements in design over an earlier one announced in April (see SNL, May 4). Its size and cost have been reduced by almost half to place it within reach of more laboratories, schools and research workers.



It is not an impressive looking thing—not nearly as impressive as the great 200-inch telescope, though it may well prove to be more important in extending man's knowledge of his universe. The first super-microscope built in Camden was enormous. The newest, stream-lined model is a pillar about six and a half feet tall. It sits on a desk. There are knobs and dials; that's all you see. But inside, there is a hairpin filament of tungsten at the top of the column. When current flows through this filament, it emits streams of electrons. A fundamental principle of electronic radiation is that the beams are affected by magnetic force. Just below the filament is a difference of voltage which accelerates the downward speed of the electron streams. Further along are magnetic fields which deflect the rays—change their direction of travel. The object is to bring the electrons to a focus. In other words, the magnetic fields act on the electron radiation precisely as glass lenses act on light rays.

The interior of the column has to be airless so that the electron streams may flow freely, and one of the tricks in making the apparatus has been to devise an air lock so that specimens can be placed in the microscope without destroying this high vacuum. Specimens to be viewed are put on very thin but tough films, often cellulose nitrate. One disadvantage is that electron beams are deadly to living things; the electron microscope gives a still, killed image contrasted with the moving, living picture of an ordinary microscope.

Seen on Fluorescent Screen

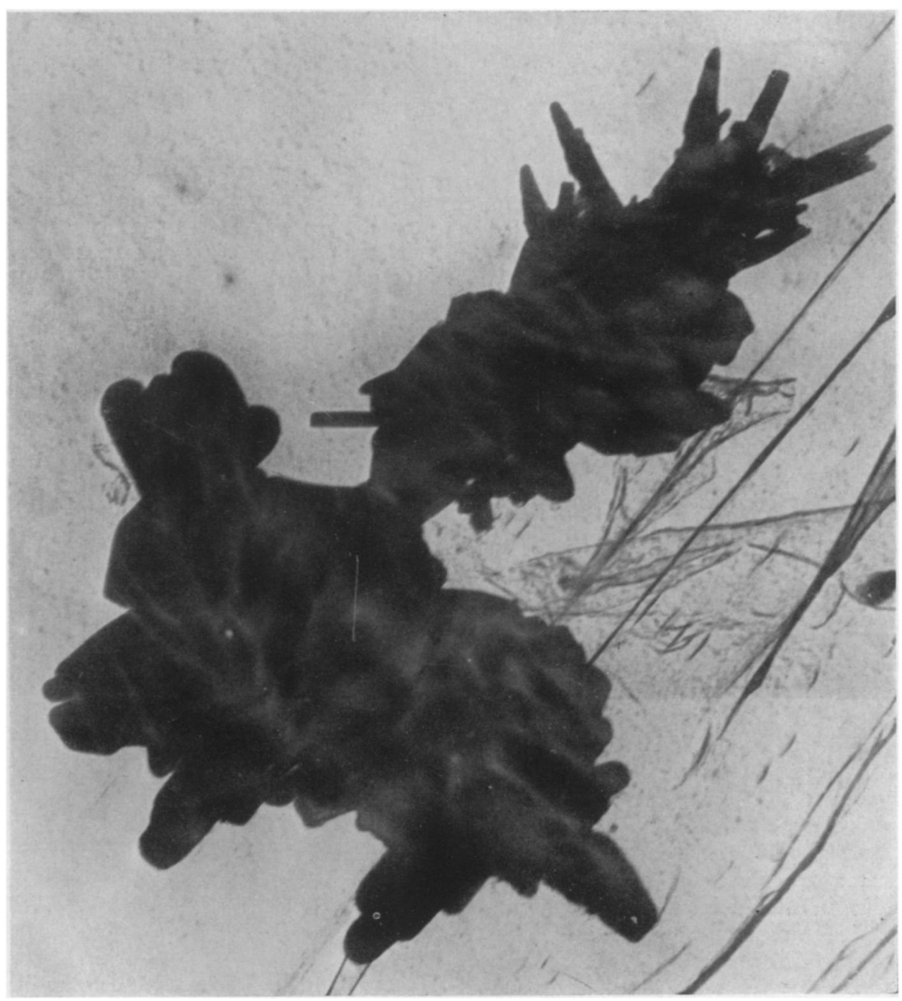
When electrons beat upon layers of certain chemicals, the chemicals fluoresce, that is, they give off light. A fluorescent screen placed at the point of focus allows the human eye to see in great detail the shadow cast by the specimen in the path of the electronic beam. Replace the screen with a photographic plate and you get a permanent image, to be examined at leisure. This is not "photography", by the way, for no "photons", no light "particles", are used. So meticulous scientists have coined the phrase "electron micrographs".

Two great electrical companies are leading in the development of the new instrument, Siemens & Halske A.G. in Germany and RCA. The Germans, especially Dr. E. Ruska, got started first on the "übermikroskop." Anything in the domain of the electron is in the province of RCA—radio, television, the "electric eye", the new phonograph—and the corporation promptly started its own research to catch up with the Germans. A group of specialists joined RCA's Dr. V. K. Zworykin in developing the microscope. Dr. Ladislaus Marton came from the University of Brussels, young James Hillier from the University of Toronto, while Arthur W. Vance developed the intricate electrical circuits necessary.

The first instrument they turned out was as big as the side of a house. The latest model can be carried through any laboratory door, and it retails for a modest $9,500. Obvious customers are the medical, physical and chemical laboratories of the great research foundations, the universities and industries.

The scientific genealogy of the electron microscope starts with the discovery of the electron itself by J. J. Thomson before the turn of the century—the Thomson who was to become famous and knighted and remain active until his death this year. In the course of the revolution in physics that arose out of the work of Einstein and Heisenberg, de Broglie, the Frenchman, predicted from theory that electrons were waves. Davisson and Germer, of Bell Telephone Laboratories, and G. P. Thomson, in England, son of J. J., independently demonstrated that de Broglie was right and that electrons act like light. In 1926, H. Busch and others introduced the idea of electron lenses. This established the field of electron optics which is the basis of the present-day electron microscope. What is believed to be the first electron picture ever made was a crude thing—the shadow of a dollar bill laid upon a photographic plate under an intense beam of cathode rays from a tube, which could be done even if electrons did not act like light. That was fifteen years ago.

It is a deep dive from the picture of a dollar bill to photographs of the viruses, those living organisms or mere chemical



IT CLINGS

Face powder, one minute grain enlarged 25,000 times. It is a kind that clings to the face, probably because it is so rough.

molecules, according to which scientist is talking at the moment. Whatever they are, they cause influenza, the common cold, smallpox, infantile paralysis and, who knows, perhaps cancer. We are about to have our first look at them—new pictures to enlarge the rogue's gallery of medicine.

We also are about to photograph the vitamins and the enzymes, which like the viruses are too small in structure for any previous instrument to catch. There will be hundreds of surprises in the common substances around us and within us when there are a sufficient number of electron microscopes put to work.

Even Molecules of Matter

But the possibility which gets the scientists most excited is that they may even see the molecules of matter. Though micrographs of the molecule are just now a little beyond the horizon of the instrument, there is no theoretical reason why they may not be achieved; the super-microscope will only have to reach particles one hundredth the size of those it now easily photographs. Lifetimes of labor and millions of dollars are being spent on chemical methods of getting circumstantial evidence of molecular design. Direct molecular micrography would be a great fundamental achievement. It might even surpass in its consequences the roles that electrons play in telephone and radio. Chemists have been like clever blind men, using their brains instead of eyes to puzzle out the structure of the molecule. If they could really see how molecules of various substances are put together, it might—almost certainly would—speed up enormously the advance of organic chemistry, the science which already has given us nylon, rayon, synthetic rubber, the plastics—whole new industries.

To understand how it may be possible to reach down into the infinitesimal and actually study the arrangement of the atoms in the molecule, we shall have to know the dimensions involved in the problem. The convenient scale is the Angstrom, used in measuring light waves. (The name honors a Swedish physicist.) An ordinary pencil lead is about a millimeter in diameter. A millimeter is 10,000,000 Angstroms. Like Alice in Wonderland, nibble your imaginative mushroom on the side labeled "Going Down" and note the various stops as we descend. Starting at a millimeter—10,000,000 Angstroms—we come to the reddest light we can distinguish with the eye, in other words, the longest wave-length of visible light, at 7600 Angstroms, and we pass the shortest visible light, deep violet, at 3900 Angstroms. How small a thing we can see depends upon the wave-length of the light we use to do the seeing, much as the size of human fingers sets a limit to how tiny an object we can pick up. With visible light, that is, in the ordinary microscope, we can pick up objects about 2000 Angstroms in diameter, about half the wave-length of the shortest visible light ray. The ultraviolet ray microscope, using wave-lengths about half as long as the shortest we can see, can pick up objects about 800 Angstroms in diameter.

The wave-length of electronic radiation varies according to how fast the electrons are traveling. An electron pushed along by a potential of only one volt travels nearly 370 miles per second, which is slow going in the electronic world, but gives a wave-length of 12 Angstroms. A million-volt potential pushes electrons whizzing at more than 175,000 miles per second, giving a wave-length of about one-hundredth of an Angstrom. Atoms are about 2 Angstroms apart in a molecule consisting of carbon and hydrogen atoms, to choose one example. That is why scientists believe it probable molecules may be photographed.

The electron microscopes in use up to now have a range of 10,000 to 90,000 volts. The smallest sizes of particles now being seen with the instrument are about 100 down to 50 Angstroms. The one thing in the universe the electron microscope never will be able to "see" is the electron itself, smallest particle or least gob of electricity, or most minute atomic fragment, whichever you may wish to call it.

This suggests the horizon toward which scientists in London, Berlin, Camden, Toronto and Pasadena are pushing. The hard exciting trail toward the infinitely small beckons. A new era of exploration has begun.

Science News Letter, October 12, 1940

PHYSICS

"Whiskers" Made Visible On Micro-organisms

See Front Cover

THE micro-organism on the cover is 45,000 times life-size. It was photographed with the new electron microscope in the RCA laboratories at Camden. It is Aerobacter cloacae found in the intestines. Note that the electron microscope shows flagella extending from the organism. There is what appears to be a capsule about the organism. Preparation by Dr. K. Polevitsky of the University of Pennsylvania Dental School.

Science News Letter, October 12, 1940

PUBLIC HEALTH

Warns U. S. Is in Danger Of Invasion by Epidemics

AMERICA is in greater immediate danger of an invasion of her shores by epidemics almost sure to sweep Europe this winter, than by any armed forces. This was the gist of a statement by the chairman of the Medical Preparedness Committee for the State of Michigan, Dr. Burton R. Corbus. He said that American medicine is rallying to meet this threat.

Dr. Corbus pointed out that typhus in the Balkans and France is very prevalent, and "it is expected that influenza will hit these regions and others this year. Almost surely the epidemics will leak to these shores."

He said that another problem to be met by American medicine, in the unfortunate eventuality of war, was the impossibility of avoiding dealing with tropical diseases unfamiliar to many doctors taken from civil practice. If our troops had to move southward, "some additional instruction in these subjects would have to be given physicians attached to troop units," he said.

"Remember what havoc yellow fever caused among the men working on the Panama Canal," Dr. Corbus emphasized, "and yellow fever, together with malaria, is one of the more familiar tropical diseases."

He stressed the well-known fact that this country's supply of quinine is not adequate to meet the demands which such conditions would place upon it, pointing out that the substitute for this drug has not been thoroughly proven.

Dr. Corbus served during the first world war as a major in the medical department, attached to an evacuation hospital.

Science News Letter, October 12, 1940