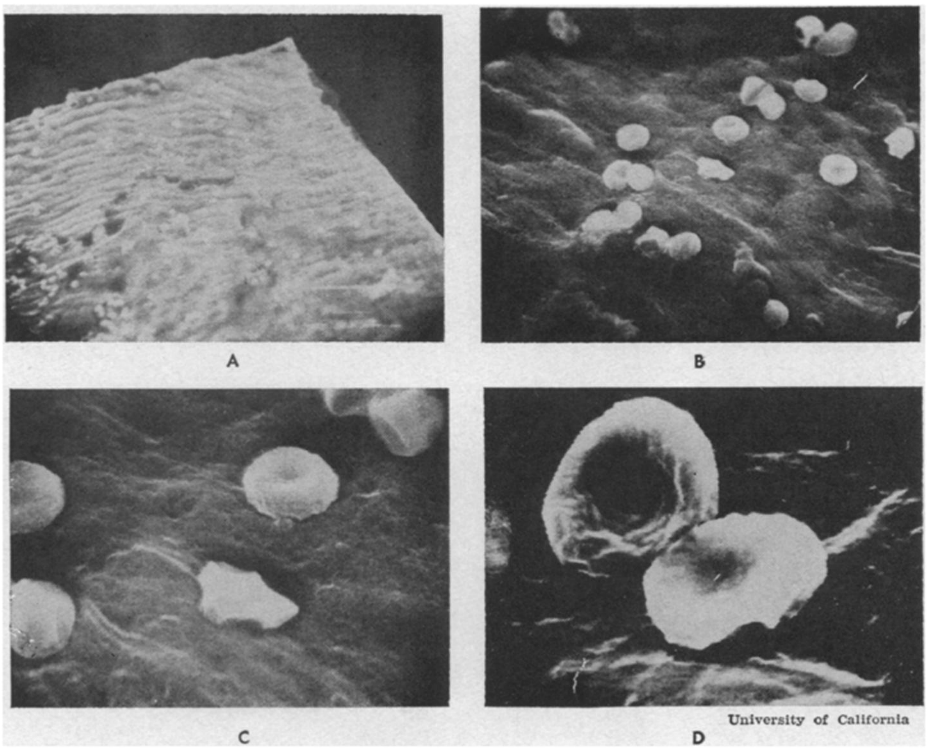

University of California

Arterial blood cells. Magnified: A, 300; B, 1,500; C, 4,000; D, 6,000.

Scanning Microscope

Engineers and scientists at the University of California, Berkeley, are revealing a submicroscopic wonderland of biology in a way that has never before been visualized.

The researchers have been applying the relatively new scanning electron microscope, a variation of the conventional electron microscope, to the systematic photographic study of tissues.

One achievement is a series of highly magnified photographs of living beetles (see opposite page). This appears to be the first time living organisms exposed to the vacuum and radiation of an electron microscope have survived.

The research has been conducted by joint "bio-engineering" collaboration between the College of Engineering and the Lawrence Radiation Laboratory, Berkeley, and supported by the U.S. Joint Services Electronics program and the Atomic Energy Commission.

The photographs show the surfaces of tissues in three dimensions at magnifications 100 times greater than has been possible by other methods. The result is a startling direct visualization of the submicroscopic convolutions, ridges, and other surface features of tissue at magnifications of up to 5,000 times. Magnifications of 20,000 are feasible.

The scanning electron microscope provides the scientist information he cannot obtain from the light microscope or from the conventional electron microscope. This information offers broad new avenues of biological research with possible future applications in the diagnosis of disease.

Examples of photographs taken with the scanning electron microscope at Berkeley are a cell from the lining of the mouth, showing the cell nucleus standing out in the center of the cell like a raised plateau. One series of photos shows, at different magnifications, bacteria lying in different patterns on skin cells. Still another series (above) reveals the corrugated surface of the lining of the human coronary artery, with red blood cells dotting the surface. Photos at higher magnifications show the red cells to have the biconcave shape (like tires, but without holes all the way through the center) previously articulated only through drawings made from painstaking observations with the light microscope.

The work has been done by an engineer, Dr. R. F. W. Pease, assistant professor of engineering, who comes from the University of Cambridge (England) group that pioneered the new instrument and who has been in charge of the development and use of the scanning electron microscope at Berkeley; and by a team of biologists headed by Dr. Thomas L. Hayes, biophysicist in the Donner Laboratory of the Lawrence Radiation Laboratory, and including L. W. McDonald, pathologist, and N. M. Amer, biophysicist, and Mrs. A. S. Camp, a graduate student in bioradiology. The Berkeley scanning electron microscope was constructed under the direction of Dr. T. E. Everhart and supported by the U.S. Air Force Avionics Laboratory.

In the past, scientists have been severely limited in their ability to visualize the surfaces of tissue at a submicroscopic level. The ordinary light microscope can allow the scientist to see a tissue surface directly in three dimensions up to a useful magnification of only about 100, barely reaching down to the cell level and leaving fine detail beyond reach. At this magnification, bacteria, for example, are not visible. At higher magnifications—up to 1,000—the light microscope is useful only in looking at thin sections or slices.

Pathologists, focusing the light microscope on different levels of cross sections of tissue, at magnification up to 1,000, have been able with considerable effort to build up drawings of many submicroscopic structures of tissue. But highly magnified instant visualization of surfaces and their relationships to germs and other biological agents has awaited the present application of the scanning electron microscope. The routine visualization of submicroscopic biological tissues in a way that corresponds to experienced human vision gives the researcher a significant dimension with which to work.

The conventional electron microscope is capable of high magnifications—100,000 being common. But this widely used instrument cannot "see" the surfaces of tissues satisfactorily. It normally pours a heavy stream of electrons through a thin slice of chemically treated tissue, and focuses the electrons on the other side, forming a shadow image of the specimen. The image is somewhat like looking at one's hand, held up against a bright light.

The scanning electron microscope, on the other hand, scans a low power beam of electrons over the surface of a specimen that can remain unmodified by slicing or chemical preparation. The electrons make secondary radiations emerge from the surface, and these are collected by a sensitive detector and translated into an image in a system similar to a television tube.

ELECTRON MICROSCOPY

Survival in a Vacuum

A beetle that wears its own pressure suit and can survive in a vacuum has been found by the Berkeley scientists. Taking advantage of the insect's unique adaptations, researchers were able to take the first electron microscope photographs of a living organism.

The difficulity has been that a vacuum must be created in the electron microscope to generate a satisfactory electron beam. The specimen must be placed in this vacuum, in which living organisms normally cannot survive. It must also survive the intense radiation of the electron beam. The Berkeley researchers had heard of a beetle, of an unspecified species, surviving a vacuum.

In the Donner Laboratory of the Lawrence Radiation Laboratory, Berkeley, scientists for years have cultivated flour beetles for studies in radiation biology, both with accelerators and in space. The insect, Tribolium confusum, has the capacity to survive in the dry, confined environment of flour. It has developed a shell-like covering with which it is able to seal off vital organs, protecting them from the loss of water that normally occurs when living organisms are placed in vacuum.

The Berkeley scientists kept specimens of the insect at all stages of development—eggs, larvae, pupae, and adults—in the vacuum of the scanning electron microscope for periods of from two minutes to an hour. They exposed the specimens to an electron beam that had about half the energy and

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Head of the space-suited beetle.

1/10,000th the intensity of that used in the conventional electron microscope—giving a radiation exposure only about one percent as high.

In most cases the specimens resumed their normal activity after being examined in the instrument, and underwent normal change into the next stage of development. This was important in demonstrating "survival" of the vacuum and electron beam. The scientists said that while in these initial experiments the highest magnification was 7,000 times, useful magnifications as high as 20,000 can be obtained.