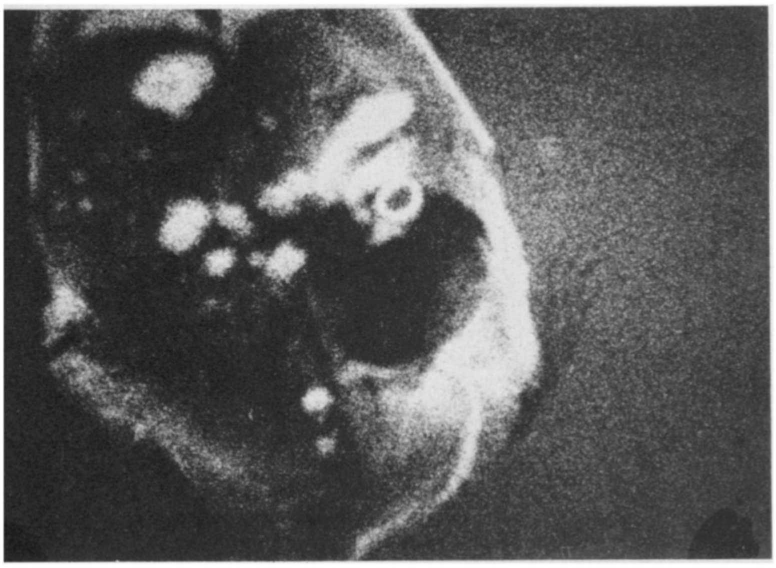
New window on the body

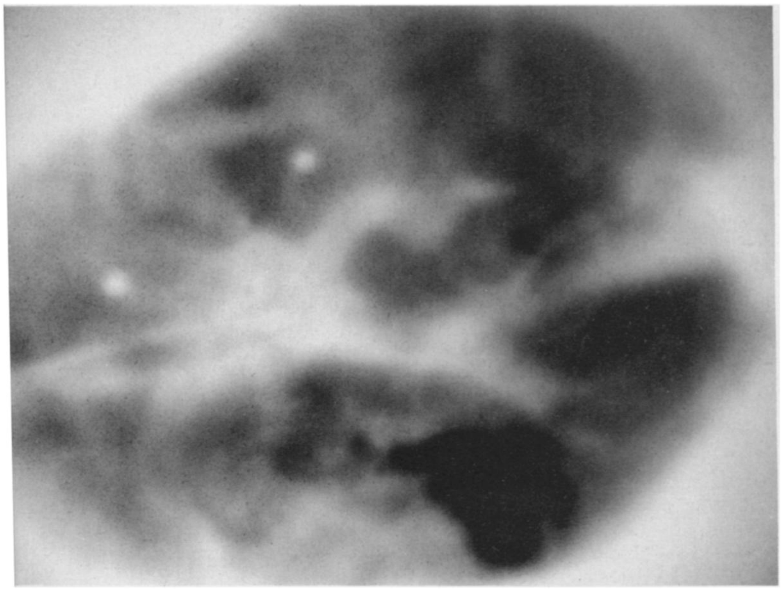
Charged particles challenge X-rays in medical diagnosis and treatment

by Joan Arehart-Treichel



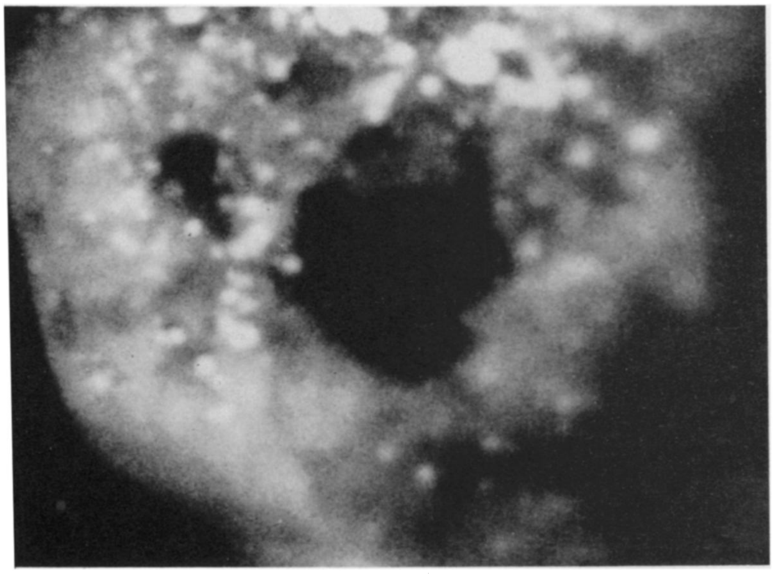
Benton

Heavy-particle radiograph showing internal organs of mouse.



Steward and Koehler

Proton radiograph of a brain shows tumor (dark area).



Steward and Koehler

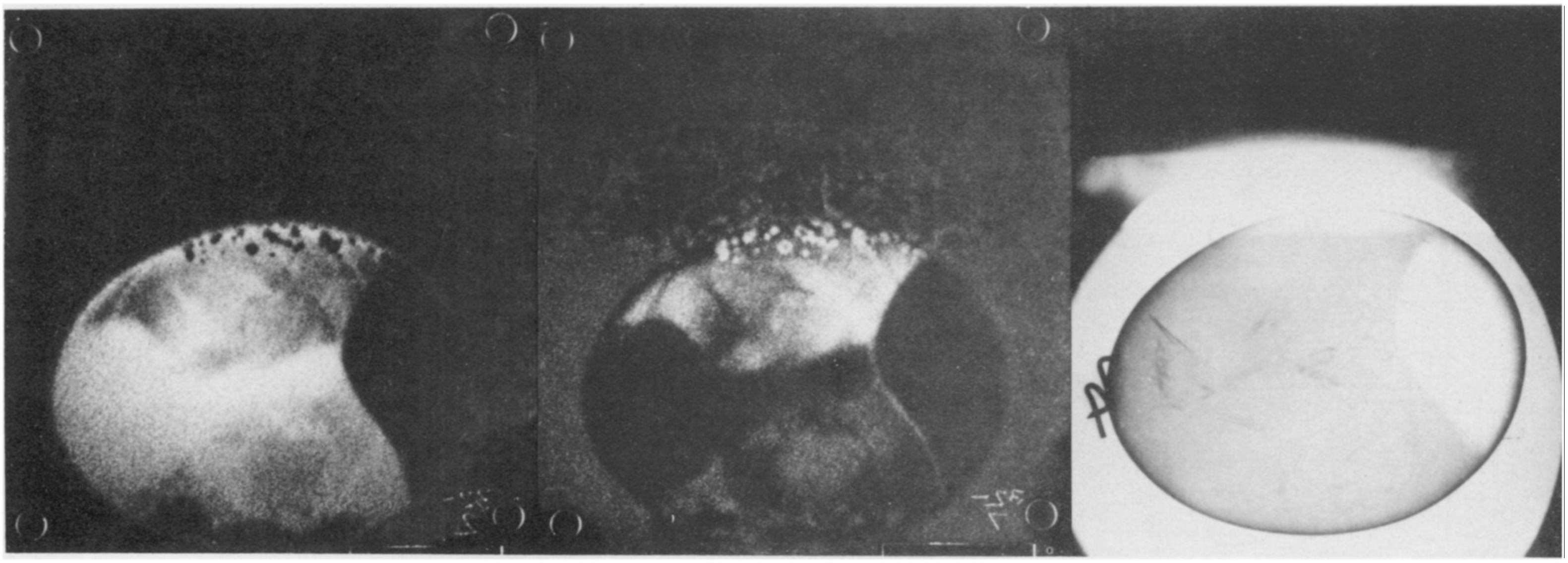
Proton radiograph of a breast (dark patches are tumors).

In 1895, a Bavarian physicist came upon a mysterious light ray. It produced a visible image after passing through flesh, cloth, wood or metal. The scientist was Wilhelm Konrad Roentgen. His discovery—the X-ray.

During the first half of the 20th century, X-rays revolutionized medical diagnosis and treatment. Since then, X-ray machines have been improved so that X-rays penetrate the body better. Cobalt 60 has become available through nuclear reactors. It emits gamma rays, a more energetic form of X-ray. These rays are now used for medical treatment. Recently electron radiography was developed. It offers a clearer image of deep-body tissues than do conventional X-rays (SN: 2/3/73, p. 72). X-ray scanners that picture cross sections of the brain are also now available (SN: 9/1/73, p. 134). Some physicians regard the scanners as the most revolutionary radiological advance since Roentgen discovered X-rays.

Now another technique promises to supplement if not challenge X-rays in medical diagnosis and treatment. It is called charged-particle radiography. It consists of passing charged atomic particles (matter) through tissue, as opposed to passing X-rays (light) through tissue. The particles may be protons, the nuclei of hydrogen atoms. Or they may be the nuclei of heavier elements, such as carbon or oxygen.

Charged-particle treatment is not totally new. It has been used experimentally for a few years now to treat several kinds of pituitary gland tumors. But only during the past year or two has charged-particle radiography been extensively explored for other medical uses, especially for the diagnosis of a blood clot or obstruction in the brain and for the diagnosis and treatment of cancer. The new interest is largely due to improvements in acceleration.



Benton

Two heavy-particle radiographs of a chicken egg containing an embryo, compared with a conventional X-ray of an egg.

Charged-particle diagnosis and treatment is being developed at two American accelerator centers—Harvard's Cyclotron Laboratory and the University of California's Lawrence Berkeley Laboratory. The Harvard Cyclotron accelerates protons. The Berkeley Bevatron accelerates heavy particles (SN: 10/16/71, p. 266). Charged-particle diagnosis and treatment is also being explored in England and Sweden.

X-ray diagnosis and charged-particle diagnosis are the same in that energy is passed through tissue, and whatever energy emerges on the other side of the tissue is photographed or recorded in some manner. X-ray diagnosis and charged-particle diagnosis differ, however, in the way they affect tissues.

X-rays are preferentially absorbed by elements that are heavy in the human body. (Most of the body is comprised of very light elements.) One of the body's heavier elements is calcium. Since bone is mostly calcium, X-rays are absorbed well by bone. X-rays not absorbed by bone pass through the body to be recorded. The resulting X-ray picture consists of a sharply defined outline of the bones in the body. If tissues in the body are injected with dyes containing heavier elements, they too show up well on X-ray film. Otherwise they usually do not.

Charged particles, on the other hand, act in a somewhat different manner. The particles don't get through dense tissue. Only where tissue is less dense do particles emerge to be recorded. The resulting picture shows up density differences in the tissue. And differences in density can reflect certain abnormalities or obstructions in the tissue.

A blood clot in the brain, for example, is two or three percent denser than healthy brain tissue. A brain infarct (obstruction of a blood vessel in the brain) is about five percent less dense than healthy brain tissue. Proton radiography of autopsy tissues, taken by physicist Andreas B. Koehler at the Harvard Cyclotron Laboratory and by pathologist V. W. Steward at the University of Chicago, reveals variations in density between a clot and an infarct. So they hope that proton radiography might be used to diagnose brain clots and infarcts in patients. Because treatment for the two conditions is different, diagnostic distinction between them could mean life or death to a patient.

Asked whether charged particles might eventually match the new X-ray scanners in diagnosing a brain clot or infarct, Steward replied: "I think we can do a damn sight better. With the scanner you can see only a slice of brain at a time. We hope to do a whole head at a time."

Steward and Koehler have used protons to examine the breast of a patient with breast cancer. They have also used protons to examine autopsy tissues with cancer. They can see striking contrasts between malignant tissues and normal tissues. So they are confident that protons can be used for the early diagnosis of breast cancer. In fact they will be undertaking clinical trials soon to explore the possibility. If a breast cancer is diagnosed early enough, there is a good chance of a cure. Early diagnosis is difficult with conventional X-rays.

Protons might also be used to diagnose brain diseases such as multiple sclerosis, Steward and Koehler believe. Multiple sclerosis constitutes a destruction of the fatty sheaths surrounding nerve fibers. Certain cells in the brain react to the damage by forming plaque (scar tissue). "I'm pretty convinced we can see the plaque in multiple sclerosis," says Steward, "but I want to substantiate it."

Detecting the buildup of calcium in animal and human aortas with heavy particles, and using heavy particles to treat deep-tissue cancers, are being exploited by C. A. Tobias of the Lawrence Berkeley Laboratory and by E. V. Benton and R. P. Henke of the University of San Francisco. Because heavy particles are absorbed by deep-body tissues, they hold value for killing tumors deep within the body. X-rays tend to be absorbed at the surface of tissues and therefore do not always kill deep-body cancer. "People have been thinking for some time about using heavy particles to treat cancer," says Benton. "The problem is that heavy particles have not been available."

The California physicists, with coworker David Cavisco, are also planning to take heavy-particle pictures of moving animal hearts. X-rays have trouble capturing the moving heart.

Some problems will have to be overcome, of course, before charged-particle diagnosis and treatment become widespread clinical tools. One is making sure that density readouts represent this or that medical complication. Another is making sure that charged particles will be no more hazardous to healthy cells than X-rays are. "The impact of charged particles on healthy cells must be better understood," Benton insists. Actually charged particles may be safer since they can be used in smaller doses than X-rays to achieve comparable effects.

Most crucially, charged-particle accelerators, now available only in nuclear physics laboratories, must become part of the hospital setting. The Argonne National Laboratory in Illinois is prepared to build an accelerator that many hospitals can afford—in the $150,000 range. The laboratory needs money, however, to undertake construction. Steward is courting the National Cancer Institute this month in hopes of getting funds for this purpose. □