Nuclear Medicine

Nuclear Medicine Helps Patients
Everywhere in Healthcare
And so does BER

Converting ENERGY to MEDICAL PROGRESS

April 2001

An introduction to the unique research funded by the **Medical Sciences Division**

Biological and Environmental Research (BER)
Office of Science, U.S. Department of Energy

*"For over 50 years the Office of Biological and Environmental Research (BER) of the United States Department of Energy (DOE) has been investing to advance environmental and biomedical knowledge connected to energy. The **BER Medical Sciences** program fosters research to develop beneficial applications of nuclear technologies for medical diagnosis and treatment of many diseases. Today, nuclear medicine helps millions of patients annually in the United States. Nearly every nuclear medicine scan or test used today was made possible by past **BER**-funded research on radiotracers, radiation detection devices, gamma cameras, PET and SPECT scanners, and computer science.*

*The heart of biological research within **BER** has always been the pursuit of improved human health. The nuclear medicine of tomorrow will depend greatly on today's **BER**-supported research, particularly in the discovery of radiopharmaceuticals that seek specific molecular and genetic targets, the design of advanced scanners needed to create meaningful images with these future radiotracers, and the promise of new radiopharmaceutical treatments for cancers and genetic diseases."*

Michael V. Viola, M.D., *Director Medical Sciences Division, BER*

Note: Before the U.S. Department of Energy was created in 1977, BER existed under different names within other federal agencies.

Nuclear Medicine Helps Patients Everywhere in Healthcare

And so does BER Medical Sciences

(DOE Office of **B**iological and **E**nvironmental **R**esearch)

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Doctors Rely on Nuclear Medicine To Help Many Types of Patients

Nuclear medicine is an exciting field in healthcare that provides important information for diagnosing, evaluating, and managing disease. Virtually all hospitals, as well as many clinics and private doctors' offices, perform nuclear medicine tests and scans. About 13 million nuclear medicine procedures are performed on patients each year (35,000 a day) in the United States. Previous research, carried out from the 1940s through the 1990s—funded by the **U.S. Department of Energy's (DOE) Office of Biological and Environmental Research (BER)**—made it possible for today's doctors to rely on nuclear medicine to help patients. These photographs represent several types of patients who benefit every day from clinical nuclear medicine procedures. Nuclear medicine truly helps patients "everywhere in healthcare"—and so does **BER Medical Sciences** through its 50-year legacy of nuclear medicine research.

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Cardiology

Patients with Heart Disease

Nuclear medicine provides several ways to evaluate heart disease. Heart scans can show whether certain regions of the heart muscle lack an adequate supply of blood, which can help cardiologists decide whether a patient needs angioplasty, bypass surgery, or changes in lifestyle. Images that show metabolic activity can help predict the success of these revascularization procedures. Other nuclear medicine tests can evaluate the strength of heart muscle contraction.

Oncology

Patients with Cancer

Nuclear medicine scans can detect and stage many types of cancer. These scans can also show how well a patient responds to treatment, such as surgery, chemotherapy, or radiation therapy. In some cases, nuclear medicine can be used to treat selected cancers.

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Neurology

Patients at Risk for, or Recovering from, **Stroke**

Nuclear medicine brain imaging can show regions of the brain with inadequate blood flow or metabolism, which can help doctors choose therapy for preventing a stroke. Brain scans obtained after a stroke can help doctors monitor the patient's recovery.

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Sports Medicine

Athletes at Risk for **Stress Fractures**

Nuclear medicine bone scans play a major role in sports medicine since they can detect stress fractures before they show up on x-rays.

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Digestive Diseases

Patients with **Abdominal Pain**

Nuclear medicine tests can show whether the gallbladder functions normally or whether a patient has gallbladder disease. These scans are also used after surgery to detect abnormal bile drainage from the liver.

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Thyroid Disorders

Patients with **Graves' Disease**

Nuclear medicine tests help evaluate many thyroid disorders. Moreover, therapy with radioactive iodine has become the treatment of choice for overactive thyroids (Graves' disease) and for most thyroid cancers following surgery.

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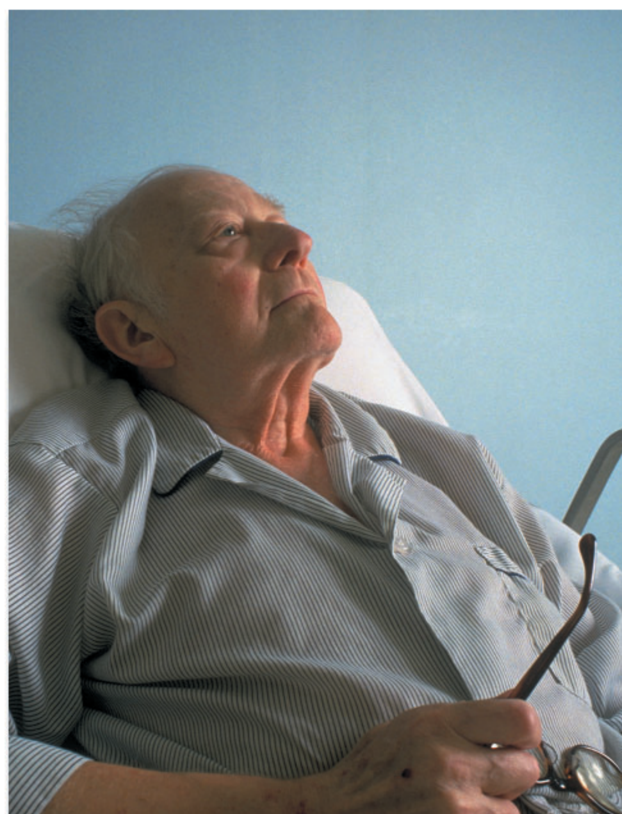
Surgery

For Children with **Epilepsy**

Nuclear medicine brain scans can guide surgeons to operate on the region of the brain that causes a child's epilepsy when the seizures cannot be controlled with drugs.



Gastrointestinal Disease

Patients with **GI Bleeding**

Nuclear medicine tests can determine whether a patient is actively bleeding into the bowel. Such gastrointestinal (GI) bleeds can be caused by polyps, ulcers, tumors, inflammation, diverticulitis, and other GI disorders. Frequently, the nuclear medicine scan also discloses the location of the bleeding site so the problem can be treated more efficiently.

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Pulmonology

Patients with **Lung Disease**

Nuclear medicine lung tests are used to evaluate respiratory disorders. These tests provide information about the extent and severity of such disorders as emphysema, cystic fibrosis, chronic obstructive pulmonary disease (COPD), and life-threatening blood clots in the lung.

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Infection

Patients with **Hidden Abscess**

Nuclear medicine scans can identify a hidden abscess in a patient with an internal infection. Typically, these patients have fever of unknown origin, a sign of infection.

© Yoav Levy / Phototake

Dementia

Patients with **Alzheimer's Disease**

Nuclear medicine brain scans can help doctors diagnose Alzheimer's disease, and differentiate it from other types of dementia early in the course of disease when treatments are more effective.

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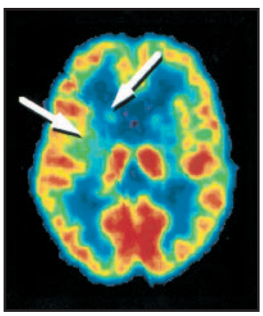
How Does Nuclear Medicine Work?

Radiopharmaceutical Energy Reveals World of Human Biology

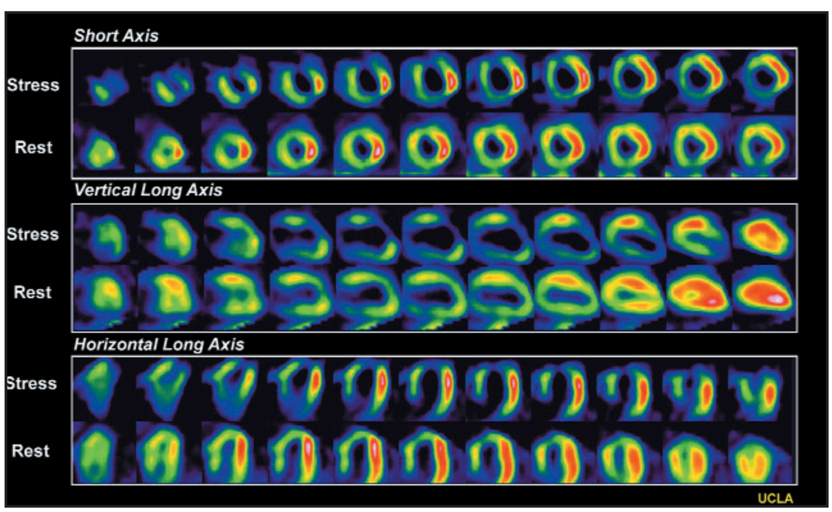
Nuclear medicine images are produced by the energy emitted from radiopharmaceuticals inside a patient's body with imaging systems ("scanners") that detect and process the energy signals. The special ability of radiopharmaceuticals to visualize human biology, both healthy and diseased, arises from their distribution through the body as "radiotracers." Nearly all radiopharmaceuticals (i.e., medically useful radiotracers) and imaging systems described here were discovered, designed, or developed by scientists supported by the **BER Medical Sciences** program during the past 50 years.

Biological Imaging

Of a **Physiologic Process**, Not Anatomy

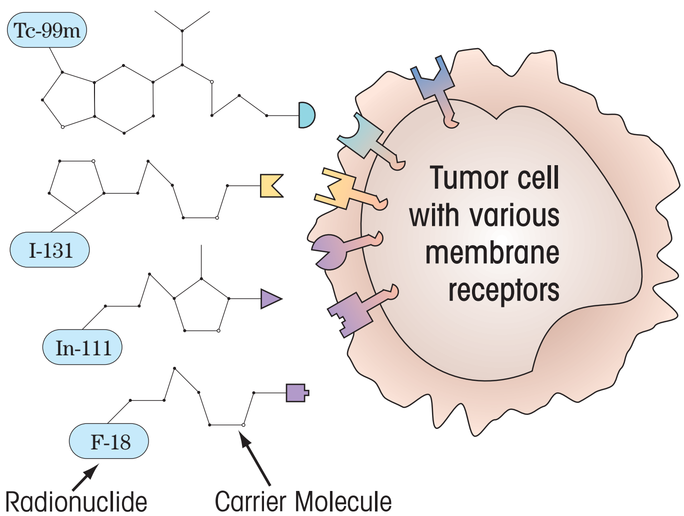


Disease is a biological process, and nuclear medicine provides images of these biological processes. Most radiotracers interact with a biological process—such as bone mineral turnover, potassium transport in heart muscle, or glucose (sugar) metabolism in various organs or tumors—and emit low levels of radiation. Highly sensitive detector systems collect these energy signals, and computer programs reconstruct them into diagnostic images. Because it provides images of a biological process (physiology), nuclear medicine differs from other imaging techniques—such as x-rays, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound—which primarily visualize structure and shape (anatomy).



A single image from a brain scan (top left), a bone scan (bottom left), and a series of images from a heart scan (right) during exercise ("stress") and "rest." The brain scan shows reduced glucose metabolism in a pattern characteristic of **Huntington's disease**, evident years before the patient exhibited abnormal movements or other symptoms of this hereditary disease. The bone scan is from a patient with **prostate cancer** that has spread to the spine and other bones. The radiopharmaceutical, similar to the mineral in bone, accumulates at bone tumors (dark spots) because the diseased bone has faster mineral turnover. The heart scan, from a patient with **coronary artery disease**, shows where the heart muscle lacks adequate blood flow. The radiopharmaceutical, thallium-201, mimics potassium and accumulates more in regions of normal blood flow.

Targeting individual receptors with specific radiopharmaceuticals



Radiopharmaceuticals

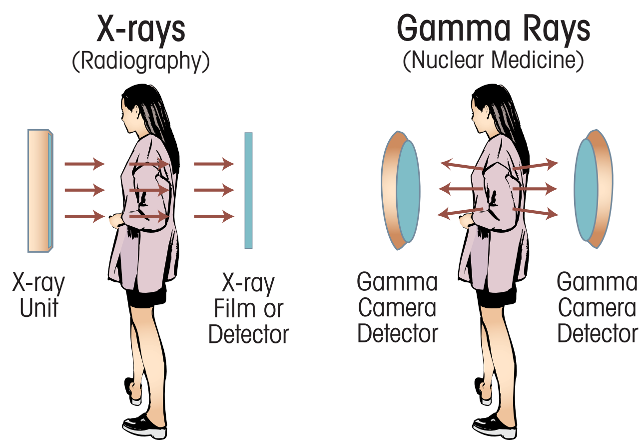
Equal **Radionuclides** Plus **Carrier Molecules**

Most radiopharmaceuticals have two components: a radionuclide and a carrier molecule. The radionuclide is an "excited" atom that emits energy so that the atom can convert to a more stable form. Common radionuclides used in nuclear medicine include technetium-99m, thallium-201, fluorine-18, indium-111, gallium-67, iodine-123, iodine-131, and xenon-133. Once a radiopharmaceutical is injected into a patient, the carrier molecule travels through the body until it interacts with its target cell, tissue, or organ system. Almost all the radionuclides, and many of the carrier molecules, used in nuclear medicine today were discovered or developed by **BER** scientists over the past 50 years.

Energy Signals

From the **Inside Out**

Like an x-ray image, a nuclear medicine scan depends on energy passing through the body toward a detection device. In nuclear medicine, radiopharmaceuticals placed in the body emit radiation from the inside out. Diagnostic nuclear medicine scans expose patients to levels of radiation comparable to what patients receive in routine x-ray procedures.



Imaging Systems

Gamma Cameras Use Large Wafer-Like **Detectors**

Specialized imaging systems (e.g., gamma cameras or other scanners) stop gamma rays emitted from the patient. Fast, sophisticated computers map the energy signals into medically useful pictures that represent a biological process. The gamma camera was invented by a **BER** scientist in 1952.

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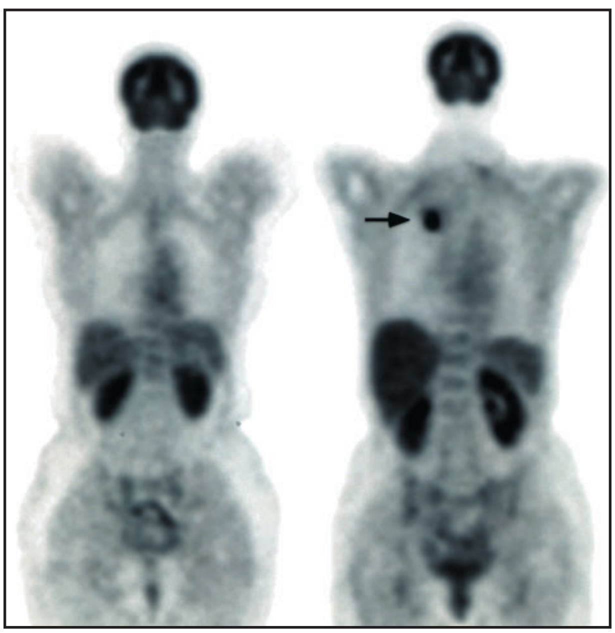
PET and SPECT

Advanced **Imaging Systems**

Special imaging systems called "positron emission tomography" (or PET) and "single-photon emission computed tomography" (or SPECT) scanners produce 3-dimensional (tomographic) images. The scans look like multiple slices through the body. In SPECT (scanner at left), a gantry rotates one or more detectors around the body to acquire many image projections. PET scanners usually surround the body with a stationary ring of detectors. PET and SPECT were first conceived by **BER** scientists and developed over the 1950s, 1960s, and 1970s.



Whole-body PET scans from two patients. The left scan is normal; the right scan is from a patient with a lung tumor that spread from **primary breast cancer**. This scan shows increased F-18 FDG uptake in the tumor (arrow) because a growing tumor has a higher rate of sugar metabolism than the surrounding normal tissue.

PET and SPECT

Advanced **Radiopharmaceuticals**

SPECT radiopharmaceuticals emit gamma rays, whereas PET radiopharmaceuticals emit another form of energy, positrons, which converts to gamma rays. These radiopharmaceuticals "interrogate" cells and molecules. They are "molecular probes" designed to provide answers about healthy, normal biology, the biological process of disease, and even the molecular errors that cause disease.

These PET scans (on the left) were obtained with fluorine-18 fluorodeoxyglucose (FDG, a form of sugar). F-18 FDG, the most common PET radiopharmaceutical used in medicine today, was developed by **BER** scientists in the 1970s.

Glucose (a sugar, the primary fuel for cells) is just one example of the thousands of molecules related to human biology that can serve as carrier molecules for radiopharmaceuticals. In the future, PET and SPECT radiopharmaceuticals may target gene function and expression to answer questions about the genetic causes of disease.

BER Medical Sciences

The Office of **Biological and Environmental Research (BER)** is part of the Office of Science in the U.S. Department of Energy (DOE). The Medical Sciences Division of BER manages the nuclear medicine research program, which pursues two main areas of scientific investigation—Imaging Systems and Radiopharmaceuticals.

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Imaging Systems

Future Scanners and Detectors

To provide accurate and clear images of very specific biochemical activities targeted by radiopharmaceuticals, **BER** scientists are designing more sensitive detectors and scanning equipment. In addition, advanced data acquisition, image processing, mathematical, computer, and engineering techniques are in development to measure extremely small amounts of a radiotracer more accurately anywhere in a patient's body.

Radiopharmaceuticals

Future Molecular Probes

There are hundreds of possible radionuclides and thousands of potential carrier molecules to explore living body functions or to provide radionuclide therapy. The key requirement for an effective carrier molecule (e.g., a protein, hormone, antibody, fatty acid, neurotransmitter, DNA, RNA, etc.) is its ability to probe a specific biochemical process. **BER** researchers are developing radiopharmaceuticals that have increased "functional specificity."

Bringing the Human Genome to Life

Nuclear medicine can visualize biochemistry of Genetic Diseases

Defects in genes may cause about 5,000 hereditary diseases, such as Parkinson's disease, cystic fibrosis, Huntington's disease, sickle-cell anemia, diabetes, and cancer. It's possible that most diseases have a genetic factor since genetic instructions control how all cells, normal and abnormal, function.

BER nuclear medicine is developing methods to study beneficial or harmful genetic changes with molecular probes for three targets:

- Altered DNA (deoxyribonucleic acid)
- Altered messenger RNA (ribonucleic acid)
- Abnormal cell or organ function induced by altered DNA.

BER scientists have successfully created images of genetically altered organ function in animals *(see page 15)*. Now, **BER Medical Sciences** has initiated exploratory research to develop new messenger RNA-based radiotracers for dynamic imaging of gene expression in animals in real time. In the future, drugs may be custom-made for individual patients based on genetic "fingerprinting." Nuclear medicine will play a crucial role in this pursuit.

Today's BER Research Leads to the

In the year 2001, **BER Medical Sciences** funds cutting-edge nuclear medicine research at three DOE National Laboratories and more than 20 universities and private institutions. The next eight pages briefly highlight just a few **BER** research projects.

Brookhaven National Laboratory, New York

Located in Upton (Long Island) New York, Brookhaven scientists have conducted **BER** research since 1950, when Brookhaven opened the first nuclear medicine hospital. Today, Brookhaven is one of the world's leading laboratories for the design, synthesis, and application of radiopharmaceuticals. As scientists discover more information about the relationship between genes and disease and behavior, they can identify new molecular targets for imaging the biologic activity of disease.

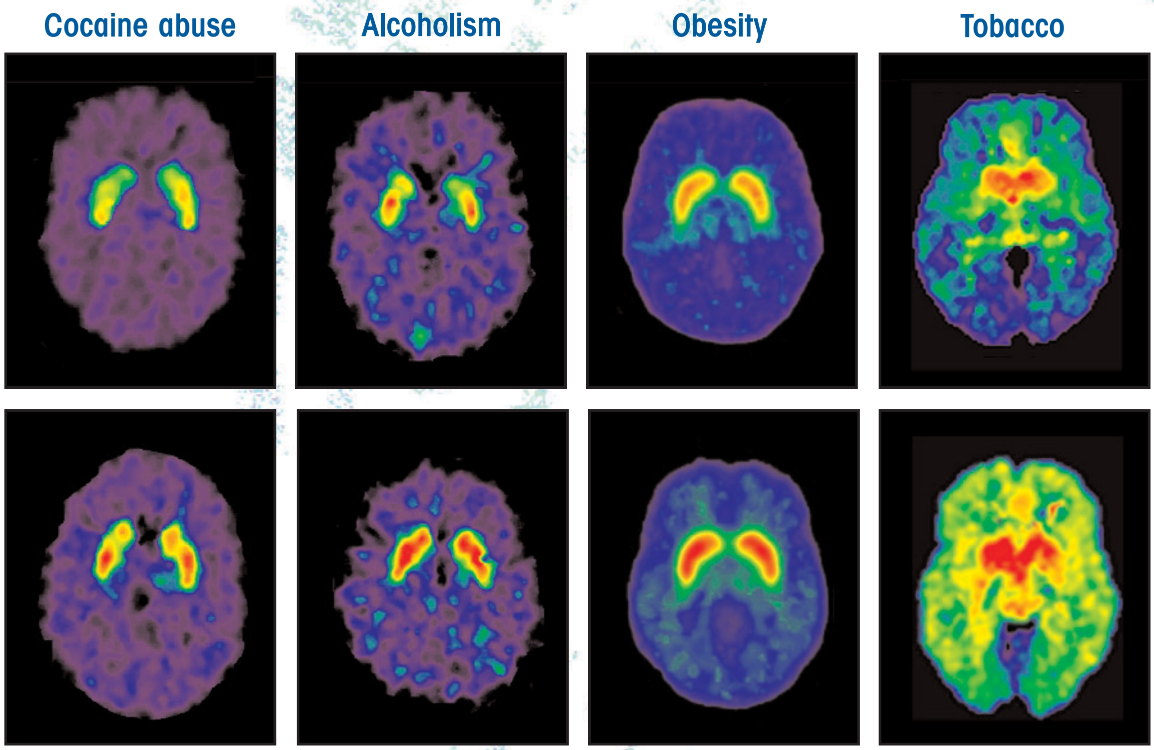
Nuclear medicine scientists at Brookhaven actively pursue new ideas for the two essential building blocks of novel radiopharmaceuticals:

- Improved methods of using atomic particle accelerators to create a variety of radionuclides, including positron emitters for PET.
- innovative synthetic chemistry for linking radionuclides to biologically important carrier molecules.

Like several other **BER** research sites, Brookhaven has the facilities and expertise to translate the fruits of this basic research into medical imaging tools.

BER Scientists from Brookhaven National Laboratory enjoying a weekend get-together.

Nuclear Medicine of Tomorrow



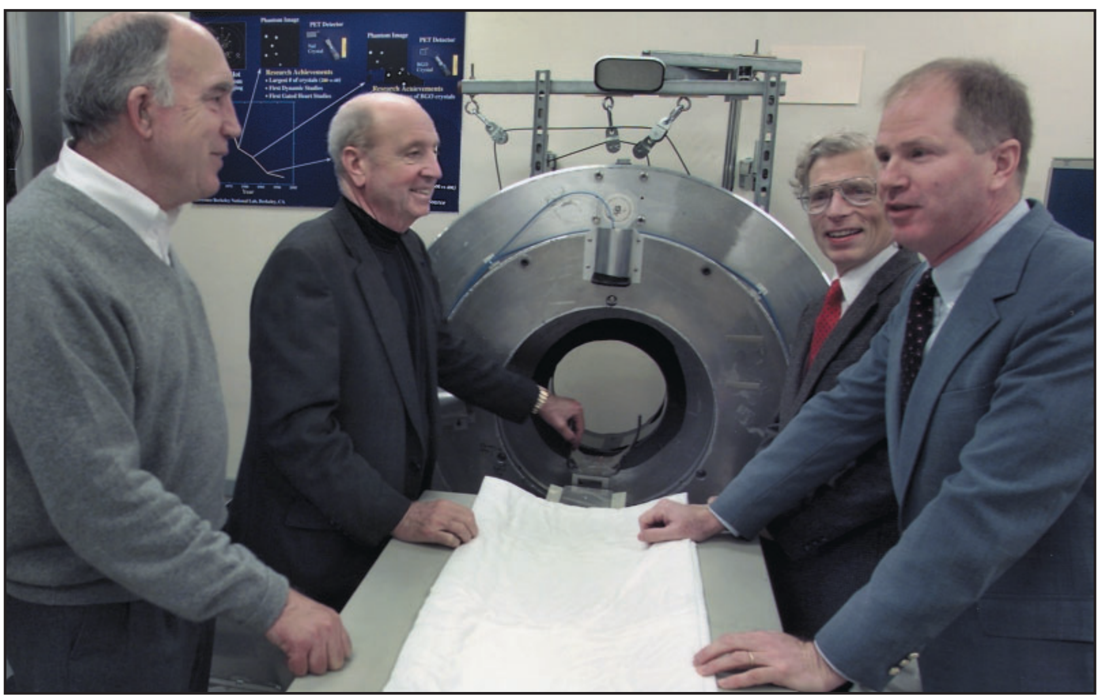
With PET and SPECT imaging, scientists here make vital contributions to medical science's understanding of the molecular mechanisms of disease and the search for new treatments. Their current priorities for medical research focus on **drug addiction** and substance abuse, **aging** and **degenerative diseases**, and the biology of tumors that may lead to more effective cancer therapies.

PET brain scans reveal chemical differences in the brain between addicts and non-addicts. The normal images in the bottom row come from non-addicts; the abnormal images in the top row come from patients with addiction disorders. The PET scans from the cocaine abuser, the alcoholic, and the obese patient with food addiction show reduced levels of dopamine receptors (molecules that transmit pleasure signals in the brain). Low levels of dopamine receptors suggest an under-stimulated biochemical "reward system" in the brain. The PET scan from the cigarette smoker with nicotine addiction shows lower levels of monoamine oxidase (MAO), a brain enzyme that regulates dopamine levels. BER researchers are investigating pharmaceutical therapies for curbing or curing addictive behaviors.

Lawrence Berkeley National Laboratory, California

Since the 1920s and 1930s, scientists at this California site pursued the frontiers of radiation research—inventing the cyclotron, discovering iodine-131 and technetium-99m, and using the first artificially produced radionuclide to treat a patient with leukemia. Today, BER researchers continue to keep Lawrence Berkeley at the forefront of engineering, mathematics, and computer science focused on the advancement of nuclear medicine imaging systems.

As radiotracers become more refined and sophisticated, visualizing specific molecular reactions in the living human body, physicians will need more advanced nuclear medicine scanners—with capabilities far beyond those envisioned by commercial manufacturers—to capture those images.



Members of the Lawrence Berkeley **BER Research team** that built this PET scanner, known as the highest resolution brain and animal PET system in the world.

Current BER research here includes development of:

- Specialized instruments to improve the detection of **prostate cancer, breast cancer**, and other cancers.
- Advancements in sophisticated, quantitative PET and SPECT imaging for brain studies of **mental illness**, including **schizophrenia**, **Alzheimer's disease**, and other dementias.
- New radiopharmaceuticals to study **aging**, **heart disease**, and **cancer**.

Oak Ridge National Laboratory, Tennessee

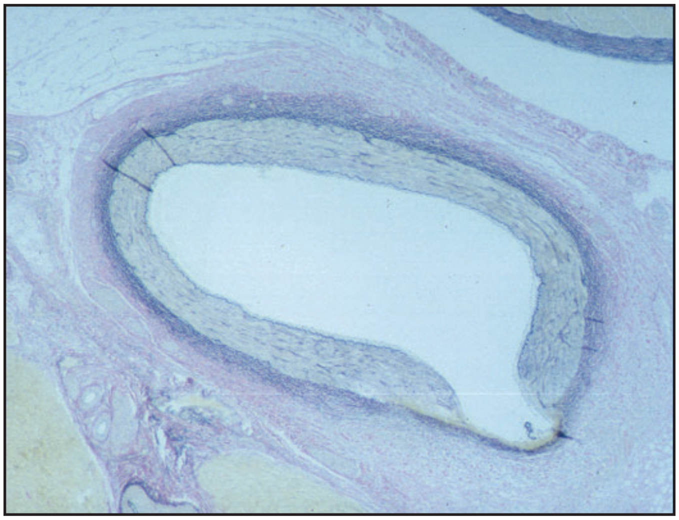
In 1946, BER originated in Oak Ridge when the research site made a vast selection of radionuclides available for nuclear medicine research. The laboratory also formed a network of universities to study the clinical potential of radiotracers. Today, scientists here continue to study the future potential of new radiopharmaceuticals.

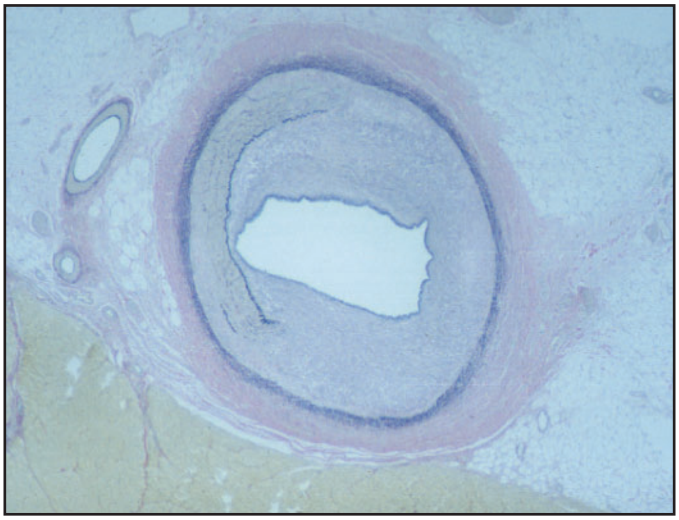
This group has developed a variety of radiopharmaceuticals for both diagnostic and therapeutic applications. One example is a generator to produce rhenium-188, a therapeutic radionuclide used to provide economical **cancer** treatment in developing countries. Another potential use of rhenium-188 is to prolong the beneficial effects of balloon angioplasty, a procedure that opens up narrowed arteries of the heart in patients with **coronary artery disease**. Patients often need repeated angioplasties because the coronary arteries gradually become reclogged.

These images show cross sections of swine arteries after angioplasty. One artery (top), treated with a rhenium-188, liquid-filled balloon, remained wide open 30 days after the angioplasty. The untreated artery (bottom) became reclogged within that same time period.

Using a fatty acid as the carrier molecule, Oak Ridge scientists have also developed a radiopharmaceutical (iodine-123 BMIPP) that shows how much heart muscle remains alive after a heart attack. These scans help doctors decide whether those portions of the heart muscle can recover after bypass surgery or angioplasty.

Coronary Artery Disease





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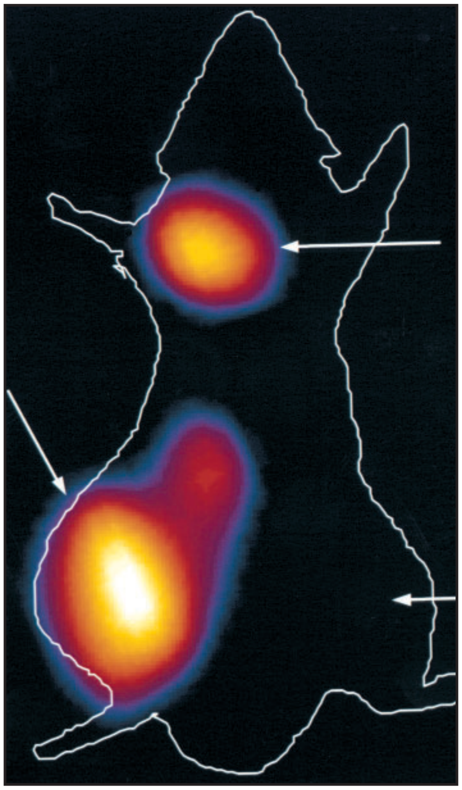
Memorial Sloan-Kettering Cancer Center, New York

Since the 1940s, the quest for better cancer treatment at Memorial Sloan-Kettering Cancer Center has included BER radiopharmaceutical research. The nuclear medicine group here has developed more than 30 radiopharmaceuticals—with important research in both the radionuclide and carrier molecule components.

BER scientists at Sloan-Kettering carry out pioneering work in the use of "monoclonal antibodies" as carrier molecules that target specific molecules (called "antigens") on the surface of **cancer** cells. These antibodies can carry either a diagnostic radionuclide (for imaging small tumors) or a more powerful therapeutic radionuclide (for selectively killing cancer cells).

The BER research group here has also discovered novel ways to produce a variety of radionuclides, including a bismuth-213 generator system. Bismuth-213, which emits alpha particles with greater potential to kill cancer cells, was first used here experimentally to treat patients with **lymphoma**, **leukemia**, and **prostate cancer**.

Tumor Targeting



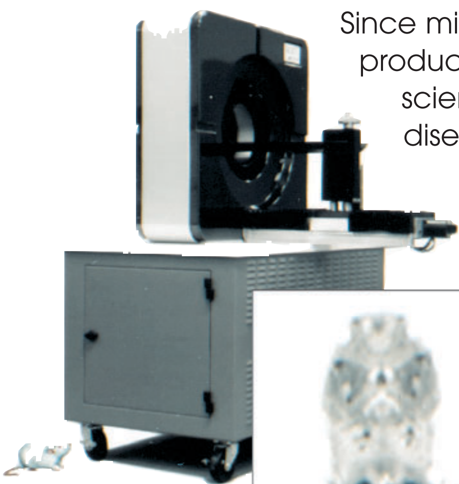
According to Nobel Laureate Harold Varmus, president and CEO of Sloan-Kettering, medicine is moving beyond the era of chance discoveries of partially effective treatments for **chronic diseases**, such as cancer. We're entering an exciting new era with "systematic discoveries of more powerful therapies, based on detailed pictures of the molecular events by which such disorders arise," said Dr. Varmus. Nuclear medicine, led by BER research, will provide many of these detailed pictures.

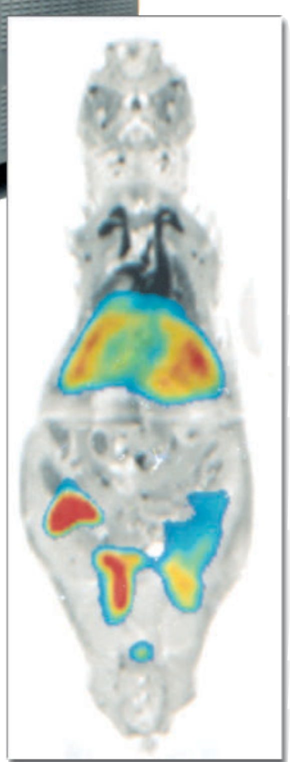
BER researchers at Sloan-Kettering created iodine-124 FAIU, a highly specific radiopharmaceutical that provided the first nuclear medicine images that showed the expression of certain genes in tumors in a live animal. This rat (left) had two types of tumors, with different genes, transplanted within the left and right sides of its body. The PET scan shows that iodine-124 FAIU designed to target specific genes in the left-side tumors, worked successfully since the right-side tumors do not appear on the image.

University of California, Los Angeles (UCLA)

UCLA has been an important **BER** research center since its School of Medicine was founded in the mid-1940s. The first PET clinic for patient care was established here in 1976. Today, **BER** research at UCLA focuses on new ways to image the biology and genetics of several diseases, including **cancer**, **diabetes**, **heart disease**, **Alzheimer's disease**, and **Parkinson's disease**.

BER scientists at UCLA recently invented a miniature PET scanner, the "microPET," for imaging mice. This device enables scientists to develop new ways to provide real-time images of the molecules that transform normal cells to diseased cells in a living mouse. The same experimental radiopharmaceuticals can be used in human patients imaged with a PET scanner. With microPET and PET, therefore, **BER** scientists at UCLA now have a safe and noninvasive way to study the same biological processes in both mice and humans.





Since mice can be biologically engineered to carry genes that produce disease, molecular probes are being developed to allow scientists to "watch" (image) the initiation and progression of a disease in a living mouse. In concert with this research, scientists are investigating highly sophisticated drugs designed to correct the molecular errors of disease. With microPET, scientists can watch and measure the capability of these new therapies to correct the abnormal biology of disease. Combined with the explosive growth of knowledge from genome research, PET and microPET play a major role in the promising new era of molecular diagnostics and therapeutics.

The microPET mouse image (at left) shows an example of how **BER** scientists at UCLA watch the genome of cells at work in the living mouse. In this mouse, insulin genes in liver cells have initiated instructions to produce insulin, a hormone that regulates the body's use of sugar. This type of research helps scientists better understand diabetes—at the molecular and genetic levels—and guides the development of future therapies for human patients with **diabetes**.

Many research programs worldwide—in nuclear medicine, biology, genetics, and drug discovery—have adopted UCLA's microPET technology. These microPET studies are constantly moving new knowledge from research labs to PET clinics, working to improve the future healthcare of patients.

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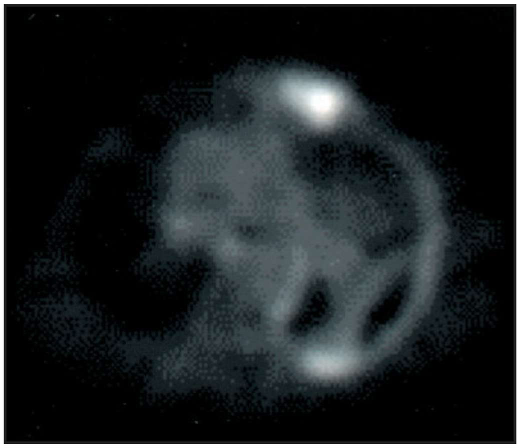
Washington University, St. Louis, Missouri

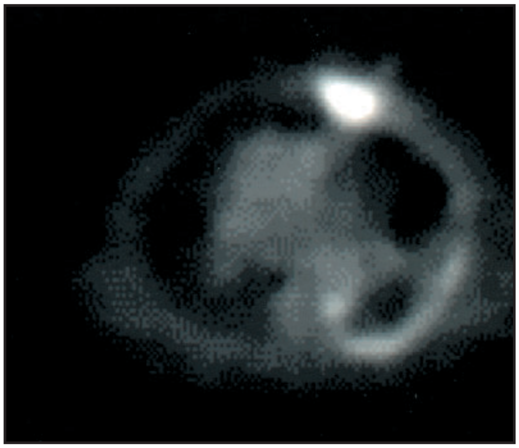
Washington University has explored innovative ways to use radionuclides in medicine since the early 1930s. Supported by BER for many decades, the nuclear medicine research group here has made important contributions to the development of PET imaging. Today, it's at the forefront of developing new organic carrier molecules and a new class of PET radiopharmaceuticals based on metal radionuclides (e.g., copper-64, gallium-68, titanium-45).

PET imaging techniques developed here can help identify which patients with **breast cancer** will respond to tamoxifen hormone therapy. In some patients, tamoxifen treats breast cancer as effectively as standard chemotherapy with ewer side effects. However, doctors need better methods to determine which patients will respond to tamoxifen.

Breast Cancer



Pre-tamoxifen Therapy



Post-tamoxifen Therapy

These PET images were obtained from a breast cancer patient before tamoxifen therapy and about a week after starting tamoxifen therapy. In the post-tamoxifen scan, the bright spot (called a "tamoxifen metabolic flare") indicates that this patient will likely respond well to tamoxifen.

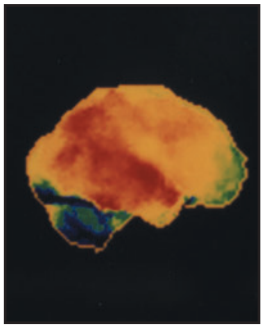
BER scientists at Washington University have also developed a radiopharmaceutical, fluorine-18 fluoroestradiol (FES), that targets estrogen receptors on breast tumors. The presence or absence of abundant estrogen receptors in breast cancer cells can help doctors select the most appropriate chemotherapy for these patients.

For some cancer patients who need chemotherapy, multi-drug resistance poses a serious problem. BER researchers here have developed radiopharmaceuticals that contribute to our current understanding of the molecular and genetic mechanisms that govern the ability of cancerous tissues to resist drug effects. This work may lead to future techniques to overcome multi-drug resistance.

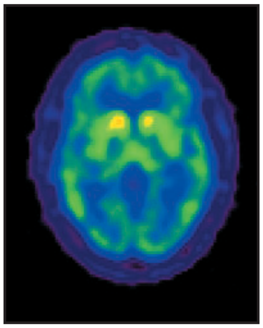
University of Michigan, Ann Arbor

The BER research program at the University of Michigan covers a spectrum of research in radiopharmaceuticals, from their chemical design and synthesis to their implementation in PET and SPECT brain chemistry studies. Scientists here also have renowned expertise in the development of computer science for nuclear medicine imaging systems. This coordinated effort has contributed valuable insight to several **neurologic disorders** that affect movement, memory, **aging**, and **dementia**.

Alzheimer's Disease



Parkinson's Disease



Radiochemists here have developed several techniques that now make it practical and economical for drug companies to commercially manufacture certain radiopharmaceuticals. In the area of imaging systems, scientists here were among the first to develop a pixel-by-pixel method for analyzing PET data to study pharmacokinetics (i.e., the activity and fate of drugs in the body, such as absorption, distribution, and excretion).

These brain scans illustrate the functional specificity of two radiopharmaceuticals for different biochemical processes. The patient with **Alzheimer's disease** shows a diffuse pattern of decreased activity of acetylcholine esterase, an enzyme involved in memory. In the patient with **Parkinson's disease**, the image shows reduced activity of a specific monoamine transporter, a brain function crucial to the dopamine system that controls body movements.

BER scientists in Ann Arbor anticipate that their nuclear medicine research will lead to improved medical management of neurologic diseases, a better match of patients to effective drug therapies, a more rational pathway to the development of new drug treatments, and new insights about biochemical mechanisms that naturally protect the brain from neurologic diseases.

Future Promise of Nuclear Medicine Depends on BER

The human body operates on millions of chemical reactions. All the characteristics of a living human being—our hair color, the activity of the heart, how we think and remember, the way we laugh—depend on a galaxy of biochemical reactions that occur many millions of times per minute within the cells and tissues of our body. A deranged chemical process can cause disease. And a disease results in other abnormal biochemical changes. Nuclear medicine, with its unique ability to reveal biochemical processes, provides crucial information about numerous diseases. More than any other federal agency, the Department of Energy (DOE), through the **BER Medical Sciences** program, has fostered the development of nuclear medicine. The future promise of nuclear medicine, the radiopharmaceuticals and imaging systems of tomorrow, depends on the progress and creativity of today's BER researchers *(see page 21)*.

Vital Legacy of BER Medical Sciences

50-Year Commitment to Improved

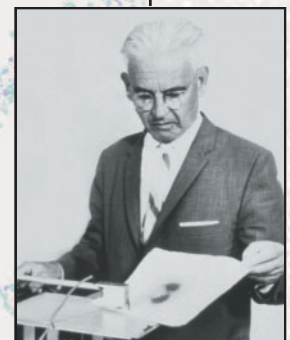
1929 1930 1940 1946 1950 1951 1952 1953 1958

Ernest O. Lawrence invents cyclotron

At the University of California's Radiation Laboratory in Berkeley (later to become Lawrence Berkeley National Laboratory), the cyclotron will soon produce the first medically useful radionuclides (iodine-131, thallium-201, technetium-99m, carbon-14, and gallium-67). For this invention, Lawrence will receive the Nobel Prize in Physics in 1939.

First delivery of a medical radionuclide to a hospital

Reactor-produced radionuclides from Oak Ridge now become available for medical research. Eugene P. Wigner (in dark suit), director of BER research and development at Oak Ridge, delivers lead-lined container of carbon-14 to Barnard Free Skin and Cancer Hospital in St. Louis. Wigner will receive the Nobel Prize in 1963 for his research on the structure of the atom and its nucleus.



Benedict Cassen invents rectilinear scanner

Cassen and other BER scientists at UCLA build a scanner that provides images of a thyroid gland based on distribution of an iodine radiotracer, the start of imaging in nuclear medicine.

Hal Anger invents gamma camera

In Berkeley, California, Anger and his BER colleagues introduce a revolutionary new technique for radionuclide imaging. The gamma camera will become the "workhorse" of nuclear medicine for the next 50 years.

Birth of positron imaging

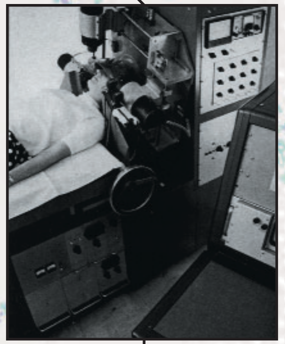
Gordon Brownell at MIT constructs the first detector device to exploit positron-electron annihilation as an imaging tool, creating a precursor of future PET scanners.

Technetium-99m generator invented

BER scientists at Brookhaven (Walter Tucker, Powell Richards, and colleagues) invent a generator system that will make Tc-99m the most widely used radionuclide in hospitals worldwide for millions of nuclear medicine patients each year.

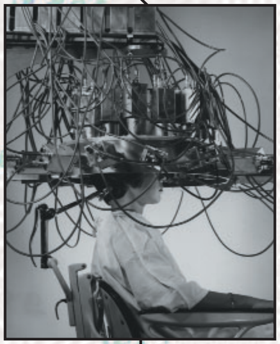
Healthcare through Nuclear Medicine

1959 1960 1961 1970 1973 1974 1976



Beginning of emission computed tomography

David E. Kuhl and other BER scientists at the University of Pennsylvania build the Mark II scanner, ancestor to today's CT and SPECT scanners.



"Headshrinker" direct forerunner of PET

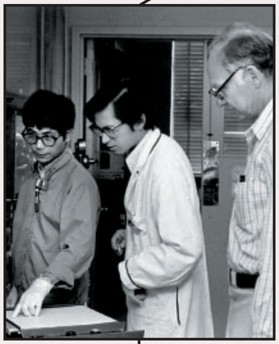
James S. Robertson, a BER scientist at Brookhaven, develops the "headshrinker," a direct forerunner of PET.

Thallium-201 for medical use

BER scientists at Brookhaven (Elliot Lebowitz, Harold Atkins, and colleagues) develop a faster, more efficient method for producing thallium-201, leading to nuclear stress testing as a routine scan for heart imaging. By the 1990s, doctors will use thallium-201 about a million times a year, accounting for 13% of all nuclear medicine scans.

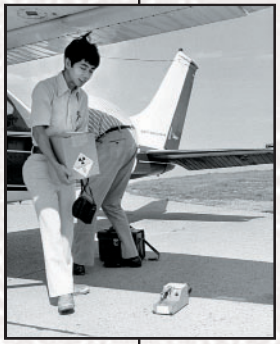
First PET camera built for human studies

Following several prototypes, Michael E. Phelps, Edward Hoffman, and Michel M. Ter-Pogossian at Washington University, with DOE and NIH support, build the PETT III to use advanced algorithms for computing three-dimensional images.



Development of fluorine-18 FDG for PET

Alfred P. Wolf (right), Joanna S. Fowler (not shown), Tatsuo Ido (middle), and other BER colleagues at Brookhaven developed and synthesized fluorine-18 fluorodeoxyglucose (FDG), a form of radiolabeled sugar, for PET imaging of glucose metabolism.



First shipment of fluorine-18 FDG to a hospital

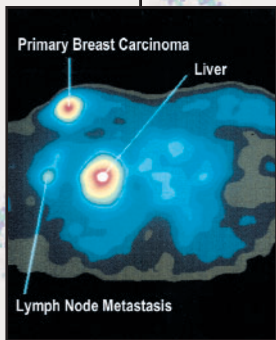
Brookhaven sends F-18 FDG, a PET radiotracer, to the University of Pennsylvania, also a BER research site.

1980

Iodine-131 MIBG for diagnosing and treating rare childhood cancers

New radiopharmaceutical developed by Donald Wieland and other BER scientists at the University of Michigan.

1984



PET image of estrogen receptors in breast tumor

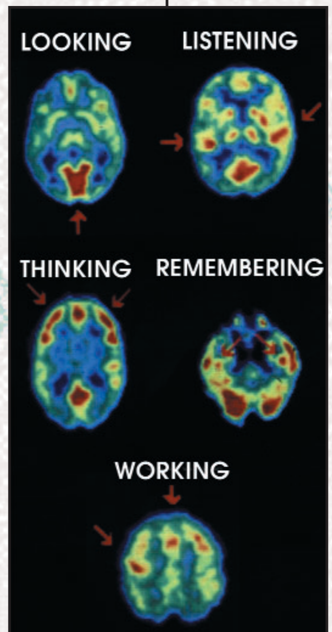
The first PET radiotracer to image a tumor based on a fluorine-18-labeled carrier molecule (fluoroestradiol) that targets a specific hormone receptor of the cell, developed by BER scientists Michael J. Welch (Washington University, St. Louis) and John A. Katzenellenbogen (University of Illinois, Urbana-Champaign).

1986

Highest resolution PET scanner in the world

BER scientists led by Thomas F. Budinger (left) design more advanced PET imaging systems.

1987



PET scans show different patterns of glucose (sugar) metabolism related to performing various mental tasks

At UCLA, fluorine-18 FDG PET studies, supported by BER, show different patterns of glucose (sugar) metabolism in the brain during five tasks: (1) looking at scenery, (2) listening to a mystery story with music, (3) thinking by counting backwards from 100 by 7s, (4) remembering objects previously memorized, and (5) working by touching the thumb consecutively to the four fingers.

1990

Enrico Fermi Award from DOE

Presidential award presented to Michael E. Phelps, a BER scientist now at UCLA, for his 1970's work as one of the developers of the first PET camera built for human studies at Washington University, St. Louis.

1998

E.O. Lawrence Award from DOE

Joanna S. Fowler, a BER scientist at Brookhaven, receives this award for her innovations in radiopharmaceutical development and their application for imaging brain chemistry and the biological action of various drugs.

2001

Current BER Scientists: Principal Investigators

Jorge Barrio, University of California, Los Angeles, School of Medicine, California / Surinder K. Batra, University of Nebraska Medical Center, Nebraska / Steven R. Bergmann, Columbia University College of Physicians & Surgeons, New York / Donald J. Buchsbaum, University of Alabama at Birmingham, Alabama / Thomas F. Budinger, Lawrence Berkeley National Laboratory, California / Simon Cherry, University of California, Los Angeles, School of Medicine, California / Nai-Kong V. Cheung, Memorial Sloan-Kettering Cancer Center, New York / Stephen E. Derenzo, Lawrence Berkeley National Laboratory, California / Eugene R. DeSombre, University of Chicago, Illinois / Stephen Dewey, Brookhaven National Laboratory, New York / Yu-Shin Ding, Brookhaven National Laboratory, New York / Richard Ferrieri, Brookhaven National Laboratory, New York /Ronald D. Finn, Memorial Sloan-Kettering Cancer Center, New York / Alan J. Fischman, Massachusetts General Hospital, Massachusetts / Joanna S. Fowler, Brookhaven National Laboratory, New York / Sam Gambhir, University of California, Los Angeles, School of Medicine, California / Samuel John Gatley, Brookhaven National Laboratory, New York / Mark M. Goodman, Emory University Center for PET, Georgia / Harvey R. Herschman, University of California, Los Angeles, School of Medicine, California / Donald Hnatowich, University of Massachusetts Medical Center, Massachusetts / Edward J. Hoffman, University of California, Los Angeles, School of Medicine, California / Henry Huang, University of California, Los Angeles, School of Medicine, California / Ronald H. Huesman, Lawrence Berkeley National Laboratory, California / Ronald J. Jaszczak, Duke University Medical Center, North Carolina / George W. Kabalka, University of Tennessee Medical Center, Tennessee / Joel S. Karp, University of Pennsylvania, Pennsylvania / Amin I. Kassis, Harvard Medical School, Massachusetts / John A. Katzenellenbogen, University of Illinois, Illinois / Stephen J. Kennel, Oak Ridge National Laboratory, Tennessee / Michael R. Kilbourn, University of Michigan Medical Center, Michigan / F.F. (Russ) Knapp, Jr., Oak Ridge National Laboratory, Tennessee / Robert A. Koeppe, University of Michigan Medical Center, Michigan / Harley I. Kornblum, University of California, Los Angeles, School of Medicine, California / David E. Kuhl, University of Michigan Medical Center, Michigan / Hank F. Kung, University of Pennsylvania, Pennsylvania / Steven M. Larson, Memorial Sloan-Kettering Cancer Center, New York / Alexander Lempicki, Boston University School of Medicine, Massachusetts / Jean Logan, Brookhaven National Laboratory, New York / Daniel W. McPherson, Oak Ridge National Laboratory, Tennessee / William P. Melega, University of California, Los Angeles, School of Medicine, California / Saed Mirzadeh, Oak Ridge National Laboratory, Tennessee / William W. Moses, Lawrence Berkeley National Laboratory, California / Jogeshwar Mukherjee, Wright State University, Kettering Medical Center, Ohio / Marit Nilsen-Hamilton, Iowa State University, Iowa / William M. Pardridge, University of California, Los Angeles, School of Medicine, California / Michael E. Phelps, University of California, Los Angeles, Medical Center, California / David R. Piwnica-Worms, Washington University School of Medicine, Missouri / Thomas P. Quinn, University of Missouri–Columbia, Missouri / N. Satyamurthy, University of California, Los Angeles, School of Medicine, California / Heinrich R. Schelbert, University of California, Los Angeles, Medical Center, California / David J. Schlyer, Brookhaven National Laboratory, New York / Robert M. Sharkey, Garden State Cancer Center, New Jersey / Robert H. Singer, Albert Einstein College of Medicine, New York / Suresh C. Srivastava, Brookhaven National Laboratory, New York / Scott E. Taylor, Lawrence Berkeley National Laboratory, California / Henry F. Van Brocklin, Lawrence Berkeley National Laboratory, California / Wynn A. Volkert, University of Missouri–Columbia, Missouri / Nora D. Volkow, Brookhaven National Laboratory, New York / David C. Ward, Yale University School of Medicine, Connecticut / Gene-Jack Wang, Brookhaven National Laboratory, New York / Michael J. Welch, Washington University School of Medicine, Missouri / Eric Wickstrom, Thomas Jefferson University, Pennsylvania / D. Scott Wilbur, University of Washington Medical Center, Washington / Michael R. Zalutsky, Duke University Medical Center, North Carolina / Jon Zubieta, Syracuse University, New York

BER supports many other senior investigators, post-doctoral fellows, and graduate students that cannot be listed.

Nuclear Medicine Helps Patients Everywhere in Healthcare

And so does BER Medical Sciences

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