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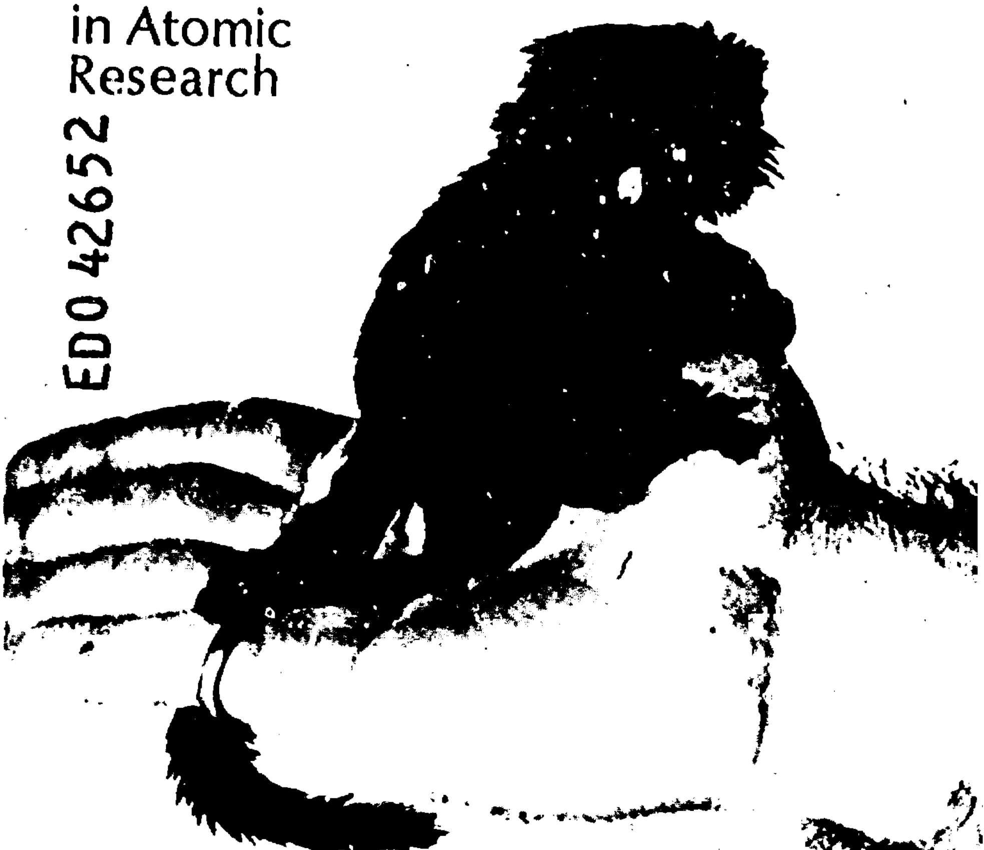
ABSTRACT

A brief historical account of the use of animals in research is followed by descriptions of the use of animals in modern bio-medical experiments. Emphasis is given to studies investigating the effects of radiation on animals including both somatic and genetic effects. The effects of radiation in the environment are studied by analyzing animals for traces of radioactive isotopes, determining the effects of reactor operations on birds and studying wasps nesting near a radioactive waste disposal pond. Studies with animals enabled establishment of safety standards for humans exposed to radiation. Applied uses of radiation in medicine, veterinary medicine, and insect control are described. Details of the care, use, and production of laboratory animals are given. The first appendix gives a census of laboratory animals used by the Atomic Energy Commission and the second lists guiding principles for the use of animals by secondary school students. Suggested references and a film list are included. (AL)

Animals in Atomic Research



U. S. ATOMIC ENERGY COMMISSION / Division of Technical Information

The Understanding the Atom Series

Nuclear energy is playing a vital role in the life of every man, woman, and child in the United States today. In the years ahead it will affect increasingly all the peoples of the earth. It is essential that all Americans gain an understanding of this vital force if they are to discharge thoughtfully their responsibilities as citizens and if they are to realize fully the myriad benefits that nuclear energy offers them.

The United States Atomic Energy Commission provides this booklet to help you achieve such understanding.

Edward J. Brunenkant

Edward J. Brunenkant, Director
Division of Technical Information

Animals in Atomic Research

by Edward R. Ricciuti

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Animals in Atomic Research

By EDWARD R. RICCIUTI

INTRODUCTION

Millions of animals are playing a part in the progress of nuclear science. They are to be found in almost every laboratory where nuclear research goes on. Animals also are studied in their natural habitats—in rivers, the air, grasslands, and forests—from the Arctic to the tropics.

What use are these animals to science?

Why are they important to the development of nuclear energy for peaceful uses?

This booklet attempts to answer these questions. It contains examples of the roles animals of many kinds play in the development of nuclear science for the well-being of mankind.

These beagles at the Los Alamos Scientific Laboratory explore their new quarters in the Health Research Laboratory building. The laboratory was awarded a citation for excellence in animal quarters and stress-free humane handling of its animals.

ANIMALS, MEN, AND SCIENCE

Living Books of Life

More than 2500 years ago, the doctors of ancient India used black Bengali ants to close intestinal wounds. An Indian surgeon would arrange several of these large insects along the opening of the patient's wound. The ants would immediately bite, clamping the edges of the wound together in the bulldog grip of their fierce jaws. Then the doctor would remove the bodies of the ants. The heads were left clinging to the closed wound like a row of black buttons.

Harsh treatment? Not 25 centuries ago, when the only fibers available for stitching wounds quickly decomposed within the body.

Like the doctors of India, men through the centuries have depended on animals for treating the sick and injured. At the same time, these creatures have been—and still are—living books from which man reads the story of life.

Research with animals has furnished scientists with a vast storehouse of knowledge. In fact studies of animals led the way to most great achievements in medicine and biology.

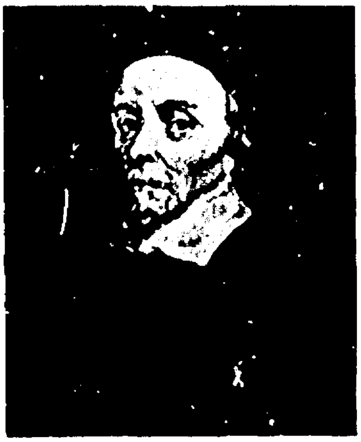
Observation of animals, for instance, enabled Aristotle, the Greek philosopher, to found the sciences of physiology, zoology, and comparative anatomy.

Harvey and the Circulatory System

A little over 2000 years later, animal experiments led William Harvey to one of the most important biomedical discoveries of all time. Harvey, an Englishman, unraveled the true nature of the circulatory system—the twisting network of vessels and organs that channels blood through the body.

Harvey's discovery in 1628 followed 14 years of research with animals. He studied at least 15 different species, from insects to dogs, and found that the blood pulses away from the heart through one set of vessels (arteries) and back to the heart through another set (veins).

These experiments revealed that the circulatory system is the route over which food, oxygen, and water travel to



William Harvey 1578–1657.

every cell in the body. It is also the network through which waste is removed, and a route by which disease can penetrate the body's innermost strongholds.

Smallpox Conquered by Cowpox

One of the most feared diseases of Harvey's day was smallpox. Eventually an English country doctor, Edward Jenner, conquered smallpox in 1796 with the help of a cow. Jenner noticed that cowpox, a cattle disease that sometimes made farmers and dairy workers mildly ill, was a cousin of smallpox. He obtained some infected matter from an inflammation on a milkmaid stricken with cowpox and injected it into other persons. Thereafter the patients Jenner had so inoculated were immune to smallpox. Jenner named his technique vaccination after *vaccinia*, the Latin word for cowpox.*

What occurred in the bodies of Jenner's patients that enabled them to ward off smallpox? The answer came a century later after two European scientists, working independently, conducted extensive studies on anthrax, a disease that animals sometimes transmit to man, usually with fatal results.

One of these men was Robert Koch, a German physician. It is still less than 100 years since Koch, working with anthrax bacteria, first proved that microorganisms — germs — cause disease in higher animals.

*Based, in turn, on *vacca*, Latin word for cow.

Germs and Disease

Searching for the cause of anthrax, then a serious problem for Europe's farmers, Koch placed bits of tissue from animals sick with anthrax into serum from healthy rabbits. Koch transferred the bacterial culture through several successive samples of rabbit serum. Then he inoculated a healthy mouse with part of the last sample. The mouse contracted anthrax, just as had mice infected directly with blood of animals killed by the disease.

Robert Koch 1843–1910.

This experiment seemed to prove that the bacteria carry anthrax, yet skeptics still doubted. Maybe something else in the serum produced the disease, they said. Doubts were silenced, however, when the great French scientist Louis Pasteur confirmed Koch's findings. From infected serum, he prepared a culture of almost pure anthrax bacteria. Even a tiny drop of the culture killed experimental guinea pigs and rabbits.

Armed with his "germ theory of disease", Pasteur went on to show that vaccination could prevent many other diseases. The germ theory of disease explains how vaccination works: When a disease agent enters the body, the body calls up proteins called "antibodies". These are the body's defense against foreign substances such as invading germs. Particular antibodies are produced by the body to match specific diseases. If you vaccinate someone with a mild form of a disease, his body produces antibodies effective against that disease. These proteins stave off possible future attacks of the full-strength illness, and the vaccinated person is then "immune" to the disease.

Pasteur soon developed a successful vaccine for anthrax, by "cooking" anthrax bacteria at a high temperature, until the germs were weakened. Vaccinated cows, sheep, and goats stayed healthy, but unprotected animals that were exposed to anthrax quickly died.

Anthrax conquered, Pasteur turned to rabies, another disease transmitted from animals to man. Rabies is caused by an incredibly small virus—so small that it takes a very high-powered electron microscope to see it. Pasteur did not have a modern microscope, therefore he could not see the rabies virus. But he suspected that whatever caused rabies was so tiny he could not isolate it in a test tube. The only way to obtain a sample for a rabies vaccine, he conjectured, was to grow the tiny agent in the tissue of a living animal. Pasteur did this by infecting rabbits with rabies. Then he made a vaccine of weakened samples of the infected rabbit tissue and injected it into dogs. It worked. The dogs were able to ward off rabies. The first human test of the new rabies vaccine came on July 6, 1885, when Pasteur saved the life of a young boy who had been severely bitten by a rabid dog.

Other Discoveries in Medicine

A half century after Pasteur's work, experiments with dogs led to the discovery of a treatment for diabetes, a disease that afflicts millions of people. Today, doctors know that a diabetic's body lacks insulin. Insulin is a hormone, a chemical messenger that helps cells take glucose from the blood and convert it to needed energy. Without glucose, the body looks elsewhere for fuel to burn. It turns cannibal and feeds on its own fats and proteins. The diabetic patient slowly wastes away.

Insulin, produced by the pancreas gland, was discovered in the early 1920s by two Canadian researchers, Dr. Frederick G. Banting and medical student Charles H. Best. This important advance resulted from experiments with 20 dogs,

Drs. Frederick G. Banting (right) and Charles H. Best stand with one of the first diabetic dogs to have its life prolonged by insulin. This photograph was taken in August 1921, just after they were convinced that their preparation was effective.

conducted in a stuffy Toronto laboratory. Millions of diabetics who otherwise would have died are alive today because of insulin injections.

Best, now a doctor, described his experiments in an interview not long ago. "We never would have achieved any measure of success in our work without the use of dogs," he said.

Many other discoveries in modern biology and medicine stem directly from animal studies. Here are some of these from a list prepared by the American Medical Association:

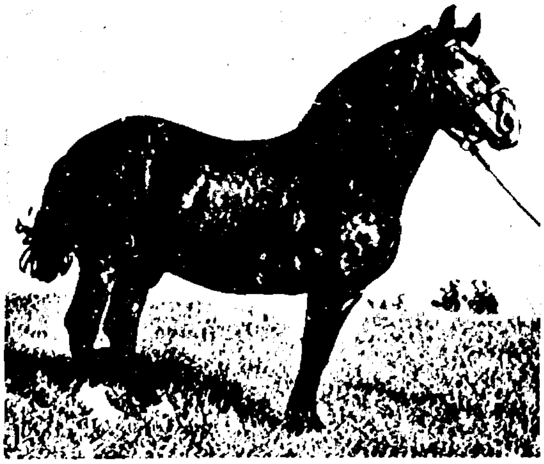
Discovery of the endocrine glands.

Techniques of modern heart surgery.

Proof that injuries and burns can be treated with blood transfusions.

There are many more. In addition, every medicine that doctors use to treat human illness has been tested on animals for safety. Horses provide serum for treatment of tetanus and gangrene. Polio vaccine is prepared in cultures from the kidneys of African green monkeys, and tested on Rhesus monkeys.

Jumbo, a bay gelding, provided enough blood over an 11-year period to produce tetanus antitoxin and pneumonia antiserum inoculations for 210,000 people. He was retired in 1940, and when he died 4 years later a granite plaque was erected in memory of his service to mankind.



Research Animal Population

All told, research animals in this country include about 30 million mice, 12 million rats, a million guinea pigs, a half million hamsters, 150,000 cats, and hundreds of thousands of rabbits and dogs.

At the same time, millions of more unusual animals — from amoebas to alligators, from beetles to salmon — also aid scientific research. Much of this research includes studies of the effects of nuclear radiation on life.

ATOMIC AGE ANIMALS

Granny

An old range cow named Granny died in 1964 at the Atomic Energy Commission–University of Tennessee Agricultural Research Laboratory, Oak Ridge, Tennessee. Newspapers around the world carried her obituary notice. They told how Granny had been painlessly put to sleep to relieve her of the sufferings of old age. What made the passing of an ordinary cow so noteworthy? During most of her 21 years—a long life for a cow—Granny had been one of the most famous research animals in nuclear science.

Granny's fame stemmed from a historic event. On July 16, 1945, she had been one of a herd of cattle grazing on a patch of New Mexico rangeland. Nearby, on the same day, the world's first atomic bomb exploded. The herd was dusted with radioactive fallout from the test explosion, a blast that marked the beginning of the atomic age. Scientists brought all the cattle to Oak Ridge for study. After almost 20 years, Granny was the last survivor of the herd.

Granny and her 15th calf.

During those years, scientists studied the herd carefully. They sought answers to such questions as: Would exposure to fallout* interfere with the ability of the cattle to produce young?

Granny gave them an answer to that question when she produced a healthy, frisky calf every year for 16 years.

Animal Studies and Radiation

Granny received worldwide attention because of her brush with history. There are millions of other research animals, much like Granny, from which scientists are learning about radiation and life. Unlike Granny, however, most laboratory animals never are mentioned in newspaper headlines. Yet knowledge gained from these studies is important to all of us in this nuclear age.

For by prying into atoms, man has opened new frontiers in biology and medicine. Atomic radiation has a vast range of effects on living organisms. And many of these effects are still not understood.

The action of radiation on the living organism can be for better or worse. If nuclear energy is to be used for the good of mankind then scientists must more fully understand this two-edged relationship, especially as it applies to human life.

Basically all the unknowns are tied up in three main questions:

What changes—especially damage—does radiation make on man and his environment?

What can be done to control radiation and safeguard man against possible harm from exposure to it?

Can scientists find new beneficial uses for radiation in biology and medicine?

The answers will come only after long years of research. And, as in all past biomedical research, the investigations will require experiments with animals.

Here is an example. A sample of tissue or a smear of cells may indicate how radiation acts on bits and fragments of a living organism. Only through studies of whole ani-

*For more details about this subject, see *Fallout from Nuclear Tests*, a companion booklet in this series.

mals, however, can scientists judge the effects of radiation on all these bits and fragments working together. And, from lesser creatures, scientists can predict what will happen to the most advanced animal — man. For, after all, man is not very different physiologically from other animals, especially other mammals.

How Many Animals?

According to a recent inventory, some 5 million animals were used in a single year for laboratory research sponsored by the Atomic Energy Commission Division of Biology and Medicine.* Besides these are whole flocks of wild birds and herds of larger wild animals and uncounted myriads of lower animals such as protozoans and fruit flies.

This animal farm in Richland, Washington, houses African pygmy goats among its experimental animals. These goats make excellent experimental animals because of their small size and adaptability.

The AEC Division of Biology and Medicine supports the nation's principal program of research into the effects of radiation on life. One goal of this program is to understand the consequences of radiation originating from peaceful uses of atomic energy. At the same time, scientists whose work is sponsored by the division are developing new uses for radiation in the diagnosis and treatment of disease, and in the investigation of life itself.

*See the Appendix for the full list.

RADIATION AND LIFE

Radiation Past and Present

Our world has always been subjected to radiation. When the earth was a young ball of steaming rock, it was bathed in high-energy radiation from the sun. Gradually however, the globe was wrapped in an atmosphere. This envelope of air around the earth screens out the forms of solar radiation that could endanger life.

Yet, today, as in the past, a certain amount of radiation is part of the environment that supports all living creatures. Some of it comes from space, such as cosmic rays that rip through the atmosphere. Some is "background radiation" from the small amounts of naturally radioactive elements present in rocks of the earth's crust. And some comes from the traces of naturally radioactive materials, such as carbon-14 and potassium-40, present in all living matter.

Since long before man chipped his first stone tools, this background radiation remained at a constant level. It remained so until man began to tinker with the atom. Within the past few decades the nuclear age has dawned, and the globe has received a new outpouring of radiation.

These are some of the sources of present-day radiation:

High-energy accelerators,

X-ray machines,

Nuclear reactors,

Radioactive wastes, and

Radioactive fallout, lingering in the atmosphere like the ghost of past nuclear bomb tests.

Radiation is therefore a part of our lives. More than that, however, it can affect the very biological fabric of life itself—the chemical constituents of the cells within our bodies.

Types of Radiation

Radiation travels in the form of particles or rays. Nuclear radiation—with which we are here concerned—is released by unstable atoms as they change their form to become stable. There are four principal kinds:

Gamma rays: High-energy radiation, like X rays, similar to visible light but with far more energy. Gamma rays are invisible to the eye and deeply penetrate matter.

Alpha particles: Heavy particles with a positive electrical charge. They penetrate matter only slightly.

Beta particles: Fast-moving, negatively charged electrons that are more penetrating than alpha particles.

Neutrons: Heavy particles without electrical charge. Fast ones are extremely penetrating.

These forms of radiation possess enough energy to disrupt the delicate electrical balance of atoms and molecules. The result is "ionization". When an atom is ionized, it becomes electrically charged, and therefore enters more readily into chemical reactions with other atoms.

Vital Molecules

Unfortunately, the molecules (and atoms) most vulnerable to ionizing radiation are those involved in the function of living cells. These molecules are large, complicated, and loosely held together. They therefore make good "targets" for radiation. When they are ionized, the chemical bonds that hold them together are shattered. The symphony of delicate biological processes within each cell may lose its harmony; the chemical makeup and organization of the cell may be disrupted.

Any organism, such as a man or a rat, is a biological machine of billions of cells, each dependent on others. Radiation damage to a small group of cells, therefore, can affect the entire body. This is particularly true if the injured cells are vital ones.

Selective Effects

Experiments with animals have shown that the effects of exposure to ionizing radiation depend largely on the part of the body that receives the dose. A dog, for example, might survive a strong dose of radiation to a leg, but become ill or die if its stomach were exposed to the same dose. (Similarly, a cutting wound in a man's arm is usually less serious than an equally severe wound into his abdomen.)

Early studies with animals also demonstrated that the tissues most easily damaged by radiation include the bone marrow and spleen, which manufacture ingredients of the blood.

Interestingly, effects of radiation also vary with the kind of animal. Usually, simple organisms withstand larger amounts of radiation than complex organisms. This is because the complicated cellular organization of a complex organism is more easily disturbed than the fundamental cellular network of simple animals. Scientists find, for example, that a snail can live through a dose of up to 20,000 rads.* Ants have withstood doses of radiation up to 200,000 rads. But anything more than 450 rads is usually fatal to a man.

Effects of radiation on living organisms are classified in either of two categories—"acute" or "chronic". Acute effects are usually noticeable almost at once. Chronic effects are the result of small but continuing doses of radiation. These may not be detected for many years.

Radiation and Aging

One of the most interesting relationships between normal life processes and radiation is that between radiation and aging. This relationship is a puzzler. Does a small, non-fatal amount of radiation shorten or lengthen an animal's normal life-span? Experiments have indicated that either effect may result.

Certainly, exposure to radiation may cut short an animal's life by leaving it vulnerable to infection. Moreover, experiments indicate that radiation does seem to cause genuine signs of aging in some animals. Female beagles exposed to doses of 100 rads (chronic dosage) or 300 rads (acute dosage) were found to be aging rapidly only a few years later. The signs of old age were wrinkled skin, worn teeth, greying coats, and heart disease.

Investigations into the effects of gamma rays and X rays on both rats and dogs show that, while the animals may

*The rad is the basic unit of absorbed dose of ionizing radiation. A dose of 1 rad means the absorption of 100 ergs of energy per gram of absorbing material.

Two groups of 14-month-old mice that were originally identical. The group on the left was untreated; the group on the right received a large, but not fatal, dose of radiation as young adults. There are only three surviving members of the treated group, and they are gray and senile, while mice in the untreated group are all normal, healthy, and active. Radiation accelerates the aging process and so has been used as an important tool in studies of aging.

survive a single acute dose, their life-span is shortened in proportion to the strength of the dose received.

Other studies, however, provide seemingly contradictory results. Normally the tails of rats and mice stiffen with increasing age. Scientists subjected the tails of rats and mice to high-level radiation, wondering if a dose of this size would result in such a proven sign of aging. It did not.

Some other examples:

Rats exposed for a lifetime to 0.8 rad per day lived for 600 days. "Control" rats, not irradiated, lived only 460 days.

Mice, rats, and guinea pigs exposed to 1 rad a week for life lived longer than their expected life-span.

Flour beetles exposed to small doses of radiation also lived an exceptionally long time.

Not surprisingly, it appears that young animals are more sensitive to radiation than adults in their prime. Adult rats, in one study, withstood up to 700 rads. A dose of 400 rads is fatal to young rats.

One possible explanation is that younger cells, so abundant in young animals, are rapidly dividing, and cells are very sensitive to radiation when undergoing cell division. Therefore more cells are affected in younger animals than in adults.

Much more research must be carried out before scientists can explain fully the relationship between radiation and aging, however. They are still far from having all the answers, for the aging process itself is not completely understood. Radiation studies with animals are providing clues about why and how men and other living creatures grow old.

Body Repair

Early experiments with guinea pigs demonstrated that the body can repair itself even after receiving a sizeable dose of radiation. The experimental animals were irradiated, but their legs were shielded from exposure. The blood-forming tissues were put out of commission all through the animals' bodies except in their legs. Tissue in the legs took over the job of producing vital blood ingredients until damaged tissue elsewhere recovered.

Studies of the one-celled amoeba, one of the simplest animals, have provided a hint of the way irradiated cells repair themselves. Amoebas reproduce by cell division. Irradiated amoebas are slow to divide, but if cytoplasm from a non-irradiated amoeba is injected into an irradiated amoeba, the latter divides at normal speed. Thus cytoplasm may hold the secret of cellular repair.

Somatic and Genetic Effects

The biological effects of radiation are considered "somatic" or "genetic". Somatic effects are changes in the whole body or its functioning parts. They are limited to the life-span of an organism. Genetic effects occur when radiation disturbs the genes in reproductive cells. They alter the biological instructions by which genes pass on inherited characteristics from generation to generation. Therefore genetic effects of radiation may turn up in the descendants of the irradiated animal.*

*See *Your Body and Radiation* and *The Genetic Effects of Radiation*, other booklets in this series, for more information on somatic and genetic effects of radiation.

RADIATION IN THE ENVIRONMENT

Part of Our World

From the time when life first stirred on earth, all living organisms have been irradiated. Recently, however, with the arrival of the atomic age, the level of radiation in the environment has increased. What does this mean to human and animal communities? This is one of the most important questions of our day. For instance, radiation-emitting strontium-90 originating in nuclear tests may occasionally be picked up with forage by dairy cows. It finds its way into their milk. Eventually, the milk—containing a trace of strontium-90—is consumed by man. Thus it is important to know the amount of strontium-90 taken in by cattle.*

Tracking Radioisotopes

For many years, scientists have been tracing the paths by which strontium-90 and other radioisotopes—radioactive forms of atoms—travel from the environment into the bodies of animals. Studies of grazing animals show that the amount of one important radioisotope, iodine-131, usually increases in the bodies of these animals after nuclear tests. (Like ordinary iodine, radioiodine collects in the thyroid gland.) Shortly after a series of nuclear explosions in the early 1950s, for instance, scientists discovered a measurable buildup of radioiodine in thyroids of sheep and cattle.

Not long before scheduled nuclear tests in March and April 1962, scientists measured radioiodine in the thyroids of California and Colorado deer. When the tests were completed, they found a marked radioiodine increase in the thyroids of the animals in both states. Radioiodine finds its way into the bodies of grazing animals with the plants these animals consume. Many plants take up radioiodine through their roots and leaves almost as efficiently as

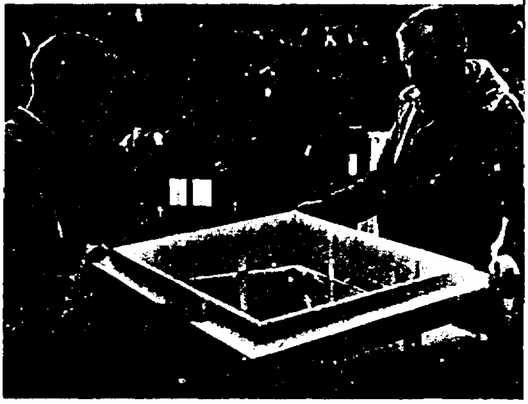
*The United States, Great Britain, and Russia in 1962 agreed not to eject new fallout from nuclear tests into the atmosphere. For more information on this topic, see *Fallout from Nuclear Tests*.

blotters absorb water. One experiment revealed that cattle and sheep grazing on open range accumulated 10,000 times as much radioiodine as penned cattle and sheep fed on stored fodder.

Measurement of the radioiodine content of the thyroid of a cow, which had eaten forage containing radioiodine.

Although radioiodine has been detected in wild animals and livestock throughout the world, and is usually the first fallout product to be found in animals, it is still found only in amounts much too small to endanger animals or men. Of all animals tested, the Alaskan caribou seems to accumulate the least iodine-131 in the thyroid. Still another

The liner of a fallout collector is changed in an AEC-supported study of the food chain pattern of strontium-90, cesium-137, and iodine-131 in a wild deer population in the Rocky Mountains.



fallout product that finds its way through plants into animals is cesium-137. It has been detected in the bodies of Alaskan caribou and in Alaskan Eskimos and Indians who dine on caribou meat. Caribou browse on lichens (simple plants) during the winter. Lichens easily absorb cesium-137. Caribou hunted by the Eskimos in early spring contain cesium-137 from lichens. And, researchers found, cesium-137 from caribou meat accumulates in the Eskimos' bodies in considerable amounts in late spring and summer.*

Radioactive Waste

Wild animals may come into contact with traces of radioactive waste from nuclear industry and research. A tiny trickle of radioactivity from the big nuclear reactors near Richland, Washington, for instance, is released into the Columbia River. What happens to the many species of fish teeming in the river when they are exposed to these low levels of radioactivity? Seeking answers, scientists reared the young of a common Columbia River fish, the Chinook salmon, in waters to which radioactive wastes had been added. They discovered that the fish amass radionuclides directly from the water, as it washes through their gills.

A sturgeon is removed from the Columbia River for examination to determine how much radiation it has absorbed.

*For more about these studies see *Whole Body Counters* and *Atoms, Nature and Man*, companion booklets in this series.

The researchers were also able to determine how to release radioactivity gradually into the river to avoid killing large numbers of fish.

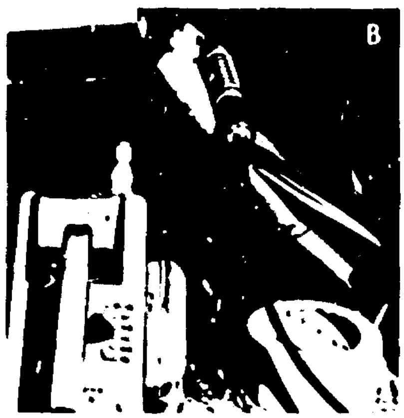
WATERFOWL Waterfowl are among the most common wild creatures in the vicinity of the Columbia River reactors. Ducks and Canada geese flock over the laboratory grounds, which stretch for 57 miles along the river. Scientists wanted to know if the reactor operations disturbed these birds, especially while they are nesting.

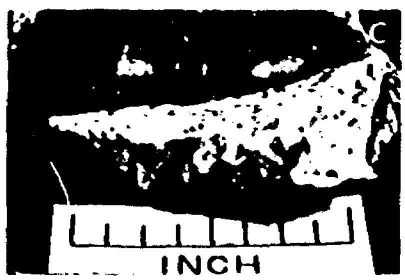
Most of the geese nest on 18 small gravel islands. Other nests occupy nooks at the base of clay and sand bluffs that wall some parts of the river bank.

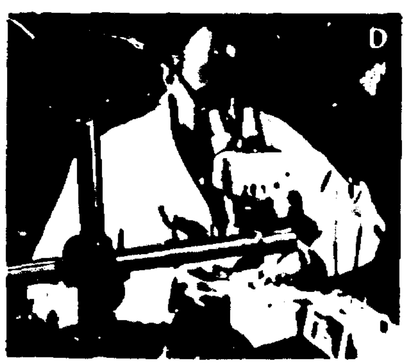
Banding wild geese to study environmental effects of radionuclides on wildlife and possible entry of radionuclides into the human food chain.

From boats on the river, scientists trained field glasses on the cliffside nests. They trekked across the larger islands and examined nests on the ground. All told, they checked 1032 nests. They noted the number of eggs in each, the type of nesting sites chosen by the geese, and the nesting periods. Ninety-two percent of the eggs hatched. What happened to the others? Most were destroyed by coyotes, raccoons, and magpies, which haunt some of the islands. The scientists concluded that the reactor operations had no ill effects on the geese, their eggs, or young.

MYSTERY WASPS Radioactivity in a waste disposal pool near another AEC laboratory has revealed a fascinating science mystery. The pool is in a sunny meadow near the Oak Ridge National Laboratory in Tennessee. Yellow-legged mud-dauber wasps use radioactive mud from the slick sides of the pool to build their clump-like nests. The wasps can not carry their "hot" cargo more than a few hundred feet, so their nests are all close to the pool. The level of radiation right at poolside is high enough to endanger any human who stayed there very long, but does not seem to harm the wasps.







Mud-dauber wasps, building nests of radioactive mud in a waste disposal area near an Oak Ridge, Tennessee, atomic plant, are the object of intensive environmental radiation study. In A an ecologist inspects new nests built in a laboratory flight cage from radioactive mud provided in pans at the bottom. B shows radioactive reading from a nest. C is an enlarged view of the nest with two tiny dosimeters in place to measure radiation. In D wasps are anesthetized, marked with tiny plastic disks for future identification, and released.

Strangely, however, a close relative of the yellow-legged mud dauber—the pipe-organ mud-dauber wasp—will not touch mud that is radioactive. Nevertheless, nests of both types are found side by side on the outside of buildings near the lake. The nests of the yellow-legged wasps give off beta and gamma radiation at a relatively high rate, without apparent effects on the wasps. The pipe organ nests are almost never radioactive.

Both species have now been bred in the laboratory at Oak Ridge. The reactions of each to radiation are being tested. Yellow-legged mud daubers will use either radioactive or normal mud to build nests, scientists find. The pipe-organ mud daubers use only normal mud. Moreover, hungry pipe-organ wasps will not even eat honey that has been placed in the path of radiation from a cobalt source, but yellow-legged wasps will.

Why do the pipe-organ wasps shy away from radiation? Do they have some sort of "built-in" radiation detector? Why doesn't radiation bother the yellow-legged mud daubers? The mystery is still unsolved.

RADIATION SAFETY

Circle in the Sage

A great circle of metal shimmers amidst the sagebrush of the Nevada desert northwest of Las Vegas. It is a low wire fence surrounding 20 acres of land. Within it live about 400 kangaroo rats and pocket mice, in their natural environment. Each animal has an identity mark—the rats have ear tags and the mice have toe markings.

Every minute, around the clock, the bright-eyed rodents are subjected to low-level radiation from a lump of cesium-137 fixed atop a 50-foot-high tower in the center of the ring.

The animals are subjects of an important study. Its purpose is to determine possible biological hazards of long-term exposure to low-level, but steady, radiation.

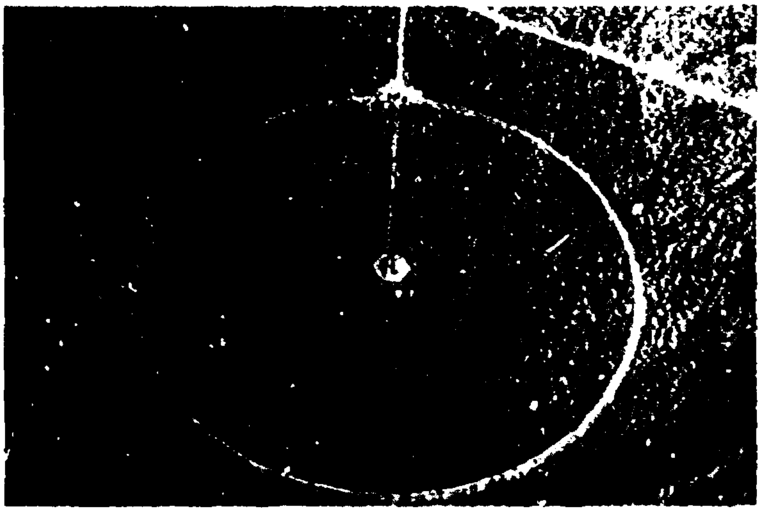
Each month, the animals are caught in harmless traps, examined by scientists, and then released. The reports of these examinations are fed into the "memory" of a computer that stores the findings. The project will continue for several years until the results can be analyzed for significant trends in the findings on hundreds of animals.

Why has the AEC undertaken such a long study of low-level radiation effects? Because continuous low-level radiation may be encountered in the future by people working with nuclear devices—crewmen of a nuclear-powered spacecraft for example.

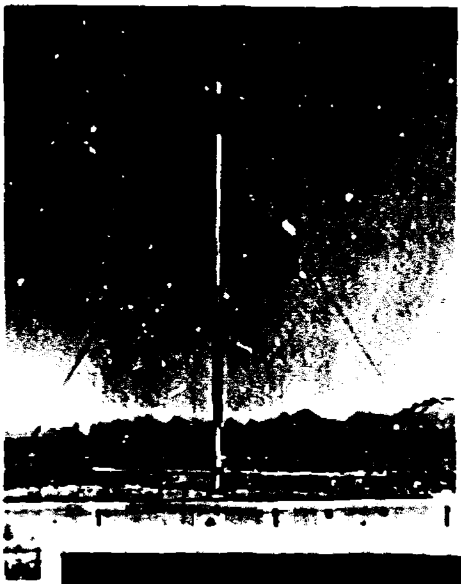
As radioactive materials find more and more uses, steps must be taken to ensure the safety of people who work with them, and to be sure that the existence of more radiation sources does not create new problems. Scientists may be able to predict possible dangers through experiments with animals.

Since different animals may react in various ways to radiation, studies must be conducted on several species in order to make accurate predictions.

Now, let's look at several areas of "radiation safety" research based on animal studies.



The 20-acre area in Nevada used to study the effects of radiation on desert plants and animals. Below left is the tower containing the radiation source. Below right a technician sets a harmless trap. The number on the stake designates the location within the study area. In bottom photo, a dosimeter, which will register the exposure dose of this lizard, is being placed below the white patch.



Whole Body Irradiation

Space-walking outside his spacecraft, an astronaut is suddenly caught in a burst of high-energy radiation, spawned by a "storm" on the sun. Is the astronaut in danger? How long can he remain safely out of his craft?

Because human lives may depend on correct answers to questions such as these, scientists are evaluating the effects of whole body irradiation on animals. (Whole body irradiation comes from a source outside of the animal and encompasses the entire body.)

One of 6 astromonks, brought to the Los Alamos Scientific Laboratory in New Mexico for space radiation environment experiments, is unloaded from an Air Force transport by James Warrel, an animal psychologist.

Because of their small size, mice are often used for whole body experiments. They can be easily placed in special individual containers that can be inserted in a research reactor, or kept in rooms irradiated by radioisotopes.

Mice are the principal research animals in the JANUS research reactor program at the Argonne National Laboratory* near Chicago, where scientists are measuring the extent of neutron radiation damage to white blood cells. (White blood cells are vital to health because they are part of the body's defense against disease.)

A litter of mice at the Argonne National Laboratory.

Dogs also are used. Mongrel and beagle dogs exposed to single strong doses of X rays or gamma rays were studied for more than 8 years at one laboratory. The animals were examined regularly after exposure. Within 6 months after irradiation, many of the dogs developed heart defects. Often the passage of blood through the heart was hindered, heart walls became inflamed, and obstructions developed in the lungs. Since something similar might happen to an unprotected astronaut, this research may lead to measures that will provide protection.

*The JANUS reactor gets its name from the two-faced Roman god "Janus" because it has a pair of radiation faces — one opposite the other — where scientists can conduct experiments.

Skin Exposure

If a worker in the nuclear industry should be accidentally exposed to radiation, chances are good that one part of his body affected would be his skin. The skin can absorb radiation, or radioactive particles may enter the skin through a cut or scratch. When studying the possible hazards of skin exposure, scientists need an animal with a skin similar to man's. Their choice, in many cases, is a kind of miniature swine developed at the Pacific Northwest Laboratory in the State of Washington. The skin of these small pigs has about the same amount of hair as human skin, and it is just about as thick.

The 100-pound Hanford miniature swine, compared here with a 600-pound Palouse swine, was developed for its similarities in size and physiology to man.

An experiment with miniature swine has shown that the normal defensive mechanism employed by the skin against all foreign bodies also helps to protect against radioactive material when it enters a wound. Plutonium, an important nuclear fuel, was injected by scientists into the experimental animals. The injection was accomplished much as a doctor vaccinates humans against disease—by making a slight scratch on the skin. Plutonium was absorbed by body tissues through the scratch.

A day after the injection, scientists found that traces of radioactive plutonium had spread to the liver. After 8 days, 30% of the dose had left the site of the injection and moved on to the lymph glands, bones, liver, and other organs.

When the researchers injected plutonium with a very high level of radioactivity, however, a sore soon formed around the injection site. A day or two after the infection appeared, fluids began to drain from the sore. These fluids carried away 90% of the remaining activity.

Inhalation

Nuclear industry workers, such as those engaged in mining and milling uranium, radium, and thorium ores, may sometimes inhale radioactive gas or dust particles. Researchers at the University of Rochester have determined what happens in the bodies of rats when the animals inhale uranium and thorium dust, as a miner might.

Studies of inhalation of radioactive materials are conducted in this specially constructed aerosol chamber. Soft drink bottles have been adapted to serve as animal holders.

They find these two radioactive materials separate in the lungs after being inhaled. At first, the scientists detect large amounts of uranium in the kidneys. After several weeks, they find that thorium follows the uranium into these organs. Eventually, more thorium than uranium can be found in the kidneys. Such studies demonstrate that separate safety standards should be set for each element that is present in radioactive dust, since each behaves differently in the body.

Internal Emitters

Once a radioisotope enters the body (with air, in food, or through a cut) it may irradiate the body from within. Such an "internal emitter" gives off radiation and continues to irradiate nearby tissues until its radioactivity decays or it is eliminated by the body. Since 1950, scientists at the University of Utah have been studying beagles to determine the internal effects of several radioisotopes—radium-226, radium-228, plutonium-239, thorium-228, and strontium-90. Their study provides clues to what happens when these same radioisotopes get into the human body.

Here are just a few of these clues: All five radioelements accumulate in the skeleton and any of these may produce bone tumors. Of the five, however, strontium-90 is least likely to cause tumors, and then only after extremely high levels of strontium have accumulated in the bone. Plutonium-239 contributes to a large number of fractures in leg bones, and radium-228 weakens bones throughout the body, the scientists report.

Other experiments show that radionuclides entering the body with food do not always follow the same paths as those that invade through a cut or in inhaled air. Like the food, they pass through the digestive system. Unlike the food, however, radionuclides are neither digested nor absorbed in the bloodstream. Instead, they move through the stomach and intestine, emitting radiation all the while until they are eliminated as waste.

Insoluble plutonium-239, for instance, emits alpha particles and gamma rays as it travels through the body. Yttrium-91 emits beta particles, and when included in food given to rats causes fatal intestinal damage.

Cerium-144 and promethium-147 may someday fuel isotopic power generators. Both of these have been fed to adult miniature swine. Ten days after feeding, scientists found neither radioisotope had been absorbed in the animals' stomachs or intestines. Instead, both had been quickly disposed of with bodily waste, indicating that both radioisotopes pass rapidly through the body. Therefore, if a human working with either one were to swallow a small amount, it is likely the radioisotope would leave his body before it could cause serious damage.

Radiation and the Nervous System

Recent experiments indicate that radiation may interfere with the functioning of an animal's nervous system. Air Force scientists working at Oak Ridge National Laboratory trained 13 monkeys to pull an overhead handle at a signal—either a flashing light or a tone. The scientists measured the time it took the monkeys to respond after the signal was given. Then, they exposed the animals to high doses of mixed gamma and neutron radiation. When the signal was given again, the animals did not respond correctly, and appeared confused. Why? The scientists believe that high-level radiation interferes with the way the brain receives information from the sense organs.

It also appears that low levels of radiation may affect functioning of the nervous system. Sleeping animals, such as rats and cats, are immediately aroused when subjected to low radiation. Scientists have also measured brain waves of animals exposed to low-level radiation and found electrical changes similar to those produced by certain drugs.

Genetic Effects

So far, we have considered somatic, or immediate effects of radiation on an individual animal's body. Unlike somatic effects, genetic effects outlive the animal and may affect its offspring and their offspring for several generations after the ancestor animal is exposed to radiation. To study these effects, scientists must conduct tests with animals that breed quickly, and produce several generations in a short time. Two excellent choices are mice and rats, but fruit flies are e' better because they produce swarms of offspring in a f days.

Experiments on fruit flies indicate that the number of "mutations" (hereditary changes) in the offspring of an irradiated insect relates to the *total* dose of radiation the parent receives—not to the *rate* at which it is given.

Mouse studies, however, have produced findings that seem to be at odds with the results of the fruit fly experiments. They show that a low dose rate triggers fewer mutations in mice than the same amount of radiation delivered in fewer, stronger doses. Chronic radiation seems to affect male mice more seriously than it does females. These are good examples of why scientists must conduct experiments on different kinds of animals to get an accurate and complete picture of radiation effects.

Miss Hap, the unplanned (hence her name) descendant of 36 rhesus monkeys imported by Argonne National Laboratory for research, is being watched with scientific interest because her mother had received large doses of gamma rays before and during pregnancy. Affection for Miss Hap is sometimes sorely tried. Behind her inscrutable expression is a genius for mischief. She is not only expert at breaking out of her own quarters, but believes in letting nearby dogs out of their cages, too.

The blood pressure and heart rate of a male chicken are checked in an AEC-supported study of the effects of embryonic irradiation on life-span.

Could radiation—by producing changes in offspring—head a species toward extinction? Probably not, according to experiments at Los Alamos Scientific Laboratory in New Mexico. Twenty-five successive generations of mice were exposed to radiation 6000 times greater than normal background radiation. At the end of the tests, each new litter had fewer newborn mice, and fewer mice survived birth. Succeeding generations were more sensitive than their ancestors to ionizing radiation. However, as if nature had provided a safeguard against extinction, the mice parents produced more litters, and therefore the total mouse population did not decrease.

BENEFICIAL APPLICATIONS

Radiation is one of the newest "tools" in biology and medicine. It helps scientists and physicians understand and treat disease and study the biological processes that add up to life. All new medical tools and procedures must first be tested on animals to make certain they are safe for man. New uses of radiation are no exception. And, of course, almost any study of biology means experiments with biological materials, including animals.

Radiation, Insects, and Disease

Radiation has been especially effective against diseases carried by insects. Among the most serious of these is malaria, which is caused by a tiny protozoan, transmitted from person to person by the bite of the female *Anopheles* mosquito.

The *Anopheles* lays its eggs in stagnant water. When the eggs hatch, young "wigglers" skitter across the surface of the water. Later, they mature, change to adult mosquitoes, and fly off.

Scientists need to understand the movement of the *Anopheles* to control malaria in tropical countries. They need to know, for example, how far insects can fly from their breeding waters.

Radioisotopes help the scientists keep tab on them. The young can be "tagged" for life with a bit of radioisotope placed in waters where the insects breed. Once they leave the breeding area, the mosquitoes may be detected wherever they go by instruments that record the amount of radiation given off by the radioactive "tracer".

Probing Pesticides

Pesticides—poisons such as DDT—are still our main weapon for insect control. Many health officials worry that man has spread too much insect poison into the environment. They fear, for example, that the poisons may contaminate human food. It is important, therefore, to know how much and how fast insecticides accumulate in various animals' bodies.

Ohio State University scientists in 1964 "tagged" DDT with a radioisotope and studied the pesticide absorbed by marsh animals near Sandusky, Ohio. A helicopter first spread the tagged DDT granules over the marsh. Each acre of land was dusted with the amount of DDT usually used in mosquito control. Afterwards, 20 species of animals were collected from the marsh and the DDT in their tissues was measured.

The researchers found that:

Tadpoles, carp, and crayfish picked up DDT residue only 4 hours after it was spread.

Several other species of fish contained DDT within a day.

After 3 days, the largest quantity of DDT in a whole animal—36 parts per million—was found in a pond snail.

Two months later, the fat of a watersnake had accumulated 38 parts per million of the radioactive insecticide.

Spare Parts for Man

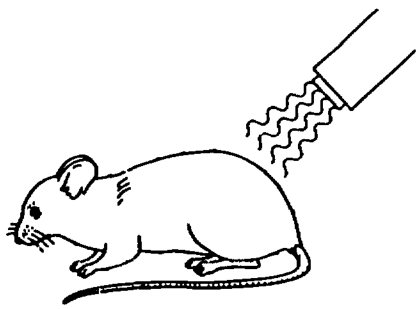
Researchers have long sought a successful method of transplanting tissues and organs from healthy persons to sick or injured people. The main obstacle has been the antibody reaction in the body of the person who is to receive the transplant, or "graft". Antibodies attack grafts from other individuals just as they combat invading disease germs.

Strong doses of radiation, however, temporarily destroy antibody reaction. Using X rays, doctors have successfully grafted tissue and organs from one experimental animal to another. The first successful case of skin grafting following a strong dose of X rays was performed in 1955, on a mouse, at the National Cancer Institute in Bethesda, Maryland. (See figure on next page.)

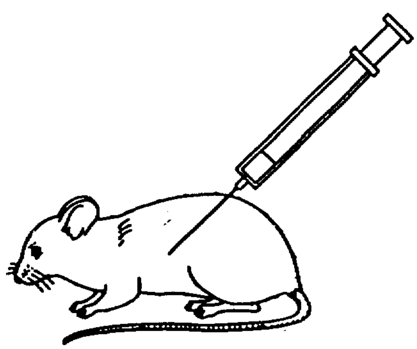
Experiments with rodents show that the animals' bodies are most receptive to grafts one or two days after exposure to radiation. Why then isn't this technique used on man?

The reason is that the dose required to stop the antibody reaction in animals is greater than the fatal dose. Moreover, suppressing the antibodies leaves the animal vul-

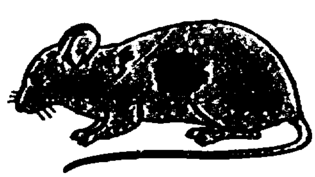
1 *Because of its immune response, a mouse of one breed will reject a skin graft from another mouse.*



2 *A heavy radiation dose destroys the mouse's blood-forming tissue as well as its immune response to alien grafts.*



3 *Blood-forming tissue from the liver of a fetal mouse is injected, and the mouse's own blood-building system is restored.*



4 *Now the mouse will accept an alien skin graft.*

nerable to infection. The method, therefore, is not yet safe for use on humans. Radiation may still hold the key to successful transplantation, but before anyone can be certain much additional research will be needed.

Cancer

Radiation is already widely used in treating human cancer —a disease that usually is fatal if not treated. Yet, new forms of radiation treatment for cancer are still being tested on animals. For instance, radiation released from a substance inside the brain of a mouse has been used to destroy tumors in that organ.

How does radiation find the target in a tumor deep inside an animal's brain? Certain chemical compounds can be injected in the animal. These tend to gather in or near the brain tumors. When atoms in some of these are struck by a beam of neutrons, they capture the neutrons and become radioactive. Then they give off radiation close to the site of the tumor and nowhere else.*

Scientists are also experimenting with radioisotopes that can be sent through blood vessels to deliver internal radiation against cancers lurking in organs such as the lungs. Some cancers have been successfully treated this way in rabbits, using radioactive yttrium-90.

Other Diseases

Radiation is also employed to study other diseases — narrowing of the arteries, for example. Sugars are an important ingredient of the fats that sometimes clog arteries and narrow the channels through which the blood flows. By labeling sugars in the blood of mice with radioisotopes scientists are able to study the process of fat production and discover where it is deposited.

Development of Detection Devices

New devices for detecting radioisotopes in the body are first tested on animals. One of the earliest was a detector

*For more about such methods, see *Radioisotopes in Medicine*, a companion booklet in this series.

used to trace the accumulation of radioiodine in the thyroid gland. Scientists found that the device could "map" the thyroid of a rabbit by indicating the exact location of the radioiodine. It made possible the development of improved instruments now used to scan the thyroids of hospital patients who have glandular problems.

Through the Circulatory System

Several species of animals are employed in studies of blood circulation, sponsored by the U. S. Public Health Service, at Temple University in Philadelphia. Its aim is to develop new methods of studying blood flow by "cine-radiography" —motion pictures of an X-ray image. At the same time, the Temple researchers are testing the use of "radiopaque" materials in the body, which block out some forms of radiation, particularly X rays. These materials provide an X-ray image of tissue and organs that are ordinarily not visible on an X-ray screen. X rays usually pass easily through the stomach, for example, so it cannot be seen by the doctor who wishes to examine it. If filled with a radiopaque material such as barium, however, the stomach shows clearly on the viewing screen.

The researchers tested devices and materials with dogs, cats, calves, pigs, fish, monkeys, guinea pigs, bats, and gerbils (small desert rodents) to increase our understanding of blood-flow patterns in large veins and arteries. They found, for example, that the flow of blood increases during forced breathing in anesthetized rhesus monkeys.

Another study was prompted by fear that a catheter (a small sampling tube) used in heart surgery might interfere with the functioning of the heart's mitral valve. Surgery was performed on dogs and the tube inserted across the mitral valve, exactly as in operations on human patients. X-ray films indicated that the tube does not obstruct the normal flow of blood through the valve.

One unusual animal, the brown bat, has a part in the Temple research. This bat's wing contains a fine network of small blood vessels that are ideal for the study of the way radiopaque materials act in the bloodstream.

VETERINARY MEDICINE IN THE NUCLEAR AGE

Not only does man benefit from radiation research on animals, but animals do also. The AEC sponsors research to develop new applications of radiation and radioisotopes in veterinary medicine.

Some of the aims of this program are:

To reduce losses of farm animals through insect control by irradiation.

To improve the quality of farm animals by determining, with the help of radioisotopes, the most efficient methods of feeding, breeding, and maintaining good nutrition.

And, of course, to treat, diagnose, and understand animal diseases through radiation studies so as to prevent animal suffering and save their lives whenever possible.

Radiation Effects on Farm Animals

As we have learned, both wild and domestic animals come in contact with radiation. One question posed by this fact is: What effect will this non-fatal, whole body radiation have on the growth of young farm animals?

A veterinarian at the University of Tennessee–Atomic Energy Commission Agricultural Research Laboratory, examines the teeth of a baby burro.

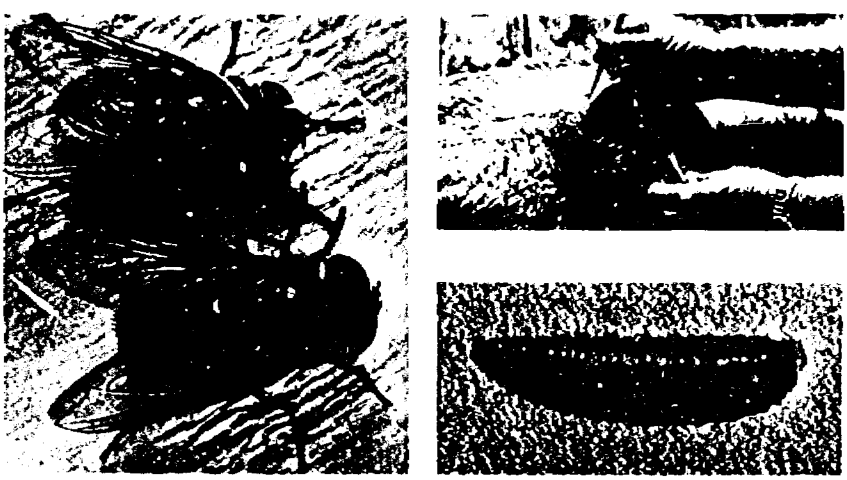
To answer this, Oak Ridge National Laboratory scientists exposed 18 young burros to a single moderately high dose of gamma radiation. The burros were then divided into three groups. Each group was fed a diet differing from the others in the amount of protein it contained. The scientists also fed the same rations to three groups of burros that had not been irradiated. The weight of each animal was recorded monthly for more than 3 years. The radiation appeared to have no effect on growth, the researchers found, if the animals received a diet balanced with adequate protein.

Atoms Used to Combat Insects

One of the most important agricultural uses of radiation is to eliminate insect pests that injure and kill farm animals. The success of radiation was demonstrated dramatically against the screwworm fly.

The female of this insect—twice the size of a housefly—lays eggs in open wounds of many warm-blooded animals, including man. Even a tiny scratch in the hide of a cow, for instance, serves as a hatchery for this insect's eggs. And, each female deposits about 250 eggs at a time.

The eggs develop quickly into larvae that look like tiny screws, hence the fly's name. About the size of a paper clip, these larvae burrow deep into the flesh. They can kill a full-grown steer or a sheep in a little more than a week.



On the left are female (top) and male screwworm flies. Right above, a livestock owner collects insect eggs from an animal's wound for laboratory identification as part of the U. S. Department of Agriculture's eradication program. Below is a screwworm larva.

Screwworm fly larvae once caused an estimated $20 million a year livestock damage in the Southeast. The southwestern states suffered an annual loss in livestock of up to $100 million. So during the 1950s, the U. S. Department of Agriculture began a program that set fly against fly.

Scientists knew that radiation impairs the ability of the male fly to reproduce. Male screwworm flies were subjected to heavy radiation from a cobalt-60 isotope source. Then, in a dramatic test, hordes of the irradiated flies were released on the island of Curaçao in the Caribbean, where screwworm flies infested most of the livestock. Five months later, there were no screwworm flies left on Curaçao. How were they exterminated?

The irradiated males had mated with native female flies. Because of the irradiation, the eggs produced by the mating were not fertile. No young flies appeared. The native flies died off, and, isolated by the ocean, Curaçao was saved from the insect menace.

In a follow-up, 7 billion irradiated males were released in the southern part of the United States by the mid-1960s. The screwworm fly now has been all but eliminated from this country.

On the left 18,000 pupae in a canister are about to be exposed to cobalt-60 irradiation. After exposure, the canister is conveyed to the packaging room where 50 cartons of irradiated pupae are packed per minute and sent to distribution centers.

Radiation has also proven deadly to other agricultural pests. Lambs have been immunized against a form of parasitic worm by inoculations with larvae of the worm, previously weakened by radiation.

Radiation and Animal Diseases

Radiation techniques employed against human ills are also useful in animal diseases. Beta rays from the radioisotope strontium-90, for example, are effective against cancer of the eye in Hereford cattle.

Use of radioisotopes in veterinary medicine is similar to use for diagnosis and treatment of human disease. Above is an eye cancer in a cow. This type of cancer grows relatively slowly, but if left untreated will extend beyond the point of possible treatment; the animal then must be destroyed. Treatment includes surgical removal of the outer portion, then irradiation with strontium-90, as shown right above. Because strontium-90 emits beta rays of low penetrating power, the radiation will not damage the lens and deeper structures of the eye. Photo opposite shows an eye after successful treatment.

Researchers also have learned much about animal diseases through the use of radioactive tracers. One group of scientists used tracers to measure the life-span of blood cells in cattle with anemia. They "tagged" red blood cells with radioactive carbon and iron. Then they timed the life of the radioactive cells. Cells in sick cattle, they found, survived only a fifth as long as in healthy cattle.

Animal Nutrition

Radioactive tracers are invaluable in determining the proper food for good animal nutrition. In one instance researchers found that certain hormones mixed in feed would speed the fattening of cattle and sheep. The mix could not be used, of course, if the hormones were unsafe for humans who would later eat the meat of the animals.

The hormones were "labeled" with tritium, a radioactive isotope of hydrogen, and fed to animals. Ninety days later, measurements of radiation from the tracer showed that the hormone content in meat from the animals was only 1 part per million—not enough to affect humans.

Other radioactive tracers useful in livestock improvement are carbon-14, sulfur-35, and iron-59.

GERM-FREE ANIMALS

No Animal Lives Alone

No creature in nature lives alone. Mice, monkeys, man—just about every animal that flies, crawls, or walks—lives in association with microorganisms, or "germs". We live our entire lives with colonies of bacteria in our bodies, particularly in the intestinal tract. We usually think of germs as harmful but many microorganisms are helpful to basic life processes. Of course, many microorganisms are responsible for disease. These are called pathogens.

Life Without Germs

In recent years, scientists have been able to breed research animals that are absolutely free of germs. These laboratory animals spend their entire lives in isolation—separated from all other forms of life.

By careful breeding, animals free from only particular, specified germs also have been bred. A large number of these animals are used in radiation research.

Why develop germ-free animals? For one thing, to test the pure effect of radiation. Low-level radiation may have such a subtle effect on an animal that it could be concealed by the action of germs. (Remember that radiation also weakens the natural defenses, leaving the body open to infection—disease that may cover up or confuse the results of irradiation.)

History

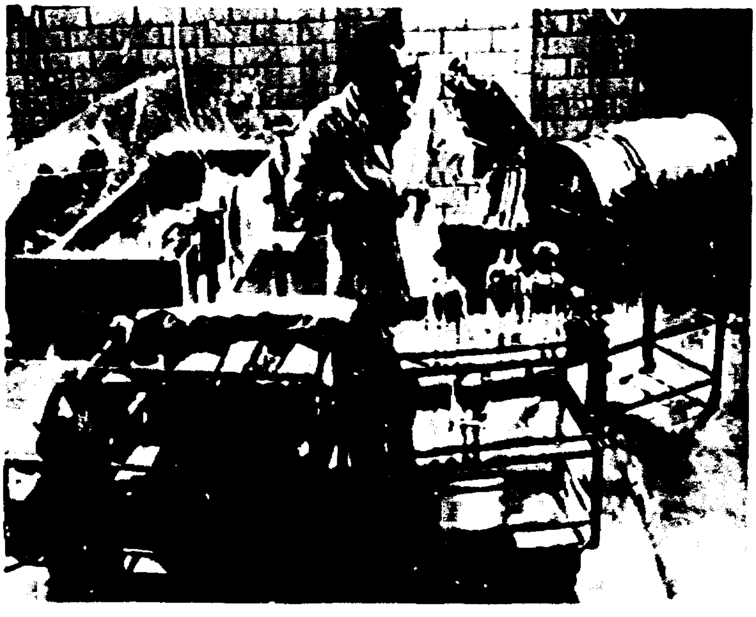
For many, many years, scientists thought the microorganisms living in the digestive tract were essential to the life of an animal. Then, in 1885, Louis Pasteur suggested that an attempt be made to breed germ-free chickens. Pasteur, however, was then too old to attempt the project himself.

Eventually, in 1895, two German scientists successfully raised germ-free guinea pigs. Their method is still the basis for breeding "gnotobiotes"—germ-free animals.

Working in aseptic surroundings—as clean as a hospital operating room—the Germans removed young animals from their mothers just before birth. They nursed and weaned the animals in sterile cages and fed them a sterilized diet. The guinea pigs lived under germ-free conditions through adulthood and produced germ-free young.

These procedures were so demanding and equipment so poor that the German scientists put their project aside. Twenty years later, however, germ-free chickens—Pasteur's goal—were hatched from germ-free eggs and lived for 40 days.

Gradually new techniques and equipment were perfected. During the past 20 years, research institutions such as the University of Notre Dame's Lobund Institute have produced large numbers of germ-free mice, rats, rabbits, chickens, guinea pigs, dogs, pigs, and lambs



A technician sprays water bottles in one of the many steps necessary in preparing a germ-free environment for mice. On the right is a cylinder containing food and bedding and on the left is an isolator with rubber gloves for manipulating the environment from the outside. Food and water are transferred into the isolator in a careful procedure designed to keep pathogenic organisms at a minimum.

Gnotobiotes must be kept germ-free or they lose their usefulness. Everything with which they come in contact is sterilized. Often the sterilization is accomplished by irradiation. Scientists use a combination of beta and gamma radiation, for instance, to clean equipment and safely sterilize feed.

Radiation Research

One of the largest projects with germ-free animals is under way at Colorado State University, Fort Collins, Colorado. Scientists there are developing a colony of 2500 beagle dogs, free of specific pathogens. The dogs are used for studies of chronic radiation effects; scientists observing the dogs will ' certain that any changes they may find in the beagles' bodies after irradiation will be due to radiation, not germs. The project is supported by the U. S. Public Health Service.

Scientists hope to observe the results of low-level radiation through the lifetime of the dogs, from birth to old age, and watch for such developments as tumors or shortening of life. Through this study, they hope to determine if traces of radiation from sources such as X-ray machines have any measurable effect on human health.

Experiments have shown that microorganisms present in the body increase the dangerous effects of radiation. Germ-free chickens, for instance, survive X-radiation at higher rates than normal chickens—up to a point. The death rate is the same when the birds are exposed to larger doses, although germ-free chickens live longer even then.

CARE OF LABORATORY ANIMALS

Sense and Humanity

Would you try to test the purity of a chemical in a dirty test tube? Certainly not. Neither would an experienced scientist conduct an experiment with an animal that was sick or run-down. Laboratory animals must be in tip-top condition, for the results of an experiment are only as good as the animal—the living test tube.

Additionally, laboratory animals are expensive. The original cost in dollars is important, for scientists usually have limited budgets, and prices mount up rapidly when many animals are used. Moreover, once an animal is involved in an experiment, and has been observed for some time, it may be almost priceless, since the scientist's professional goals may depend on continuing observation of the same animal. It therefore makes good sense to provide the best of care for laboratory animals.

Of course, humane reasons also dictate that animals used for man's good be well cared for. Reputable laboratories take precautions to ensure that animals experience as little discomfort as possible. During experiments that may cause pain, for instance, animals are anesthetized. Animal surgery is as painless as human surgery, and if an experiment ends with death, the animal is put to sleep with an anesthetic.

Results of animal experiments may eventually save human lives and prevent human suffering. Only through animal experiments can scientists predict the effects of disease, drugs, and radiation on humans. There is no substitute.

A famed researcher and expert in the care of laboratory animals, Dr. A. J. Carlson, many years ago said: "When man uses or destroys the animal for man's own protection, aid or interests, such use or destruction must be done without cruelty. However," he added, "as between man and animal, man comes first."

The Life of a Laboratory Animal

Dr. Carlson's advice is put into practice at research institutions throughout the country. Recently built animal quarters, for instance, have heated loading docks, secure from the weather, on which animals are delivered from breeders. They contain sparkling kitchens where the diets of laboratory animals are prepared. Floors at some are heated to prevent pneumonia in susceptible animals.

Surgical experiments—and treatment of sick animals—are performed in operating rooms equipped exactly like those in the best hospitals. Animal quarters themselves are temperature-controlled or air-conditioned. In one institution, for example, air conditioning was installed in animal rooms before it was in the rooms where the scientists worked. Attendants clean animal quarters regularly, for a dirty animal soon becomes sick and unfit for research use.

A beagle at the Argonne National Laboratory receives one of his periodic physical examinations.

A Close Look at Animal Laboratories

Let's look specifically at animal quarters of institutions where radiation research is carried on.

At Colorado State University, for instanc , dog pens are covered with a 6-inch bed of clean gravel. The pens are connected to kennels that shelter the dogs in bad weather. Only one or two dogs are kept in each 15-by-15-foot pen.

Beagles at the University of Utah are housed in three buildings. Kennels are connected to 164 outdoor pens and the dogs travel freely between the shelter and the pens. Each animal has more than 3 square feet of indoor resting space, and 14 square feet of outside exercise space.

The dogs are fed dry dog food, supplemented by meat, fat, and vitamins—a diet determined by careful testing of several feeds. Water is always available. Each animal gets a physical examination twice yearly, when even their teeth are cleaned and repaired.

Purebred beagles at the Pacific Northwest Laboratory are cared for in similar fashion. The routine care consists of feeding, sanitizing, grooming, examination for parasites, physical examinations, immunization against dog diseases, and treatment of ailments. Each dog is observed daily.

The Men Who Care

Animal care at most laboratories is supervised by a trained scientist—often a veterinarian, biologist, or medical doctor. However, the real quality of laboratory animal care rests with those who handle the animals each day—the animal care technicians. A genuine liking for animals is the most important attribute for these persons to have. Few men would take a job caring for animals unless they liked animals.

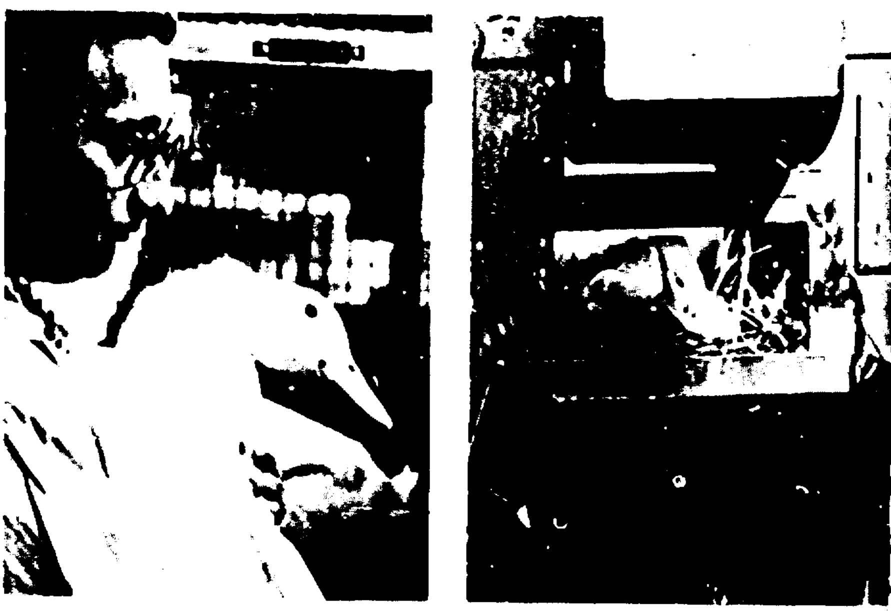
Many animal caretakers have studied the scientific principles of proper animal care. Several scientific organizations sponsor courses held in many places around the nation to teach dozens of subjects.

Like the technicians, the scientists who direct the work with animals usually are fond of their charges. Many of these men spend most of their lives probing what they regard as the magnificent mysteries of life. It is usual for men like this to have respect for all living creatures.

Researchers have, in fact, established organizations that promote better animal care, including the Animal Care Panel (ACP) and the Institute of Laboratory Animal Resources (ILAR).

The Animal Care Panel helps develop and publicize improved methods of caring for laboratory animals — including treatment of animal diseases and injuries.

The ILAR provides researchers with up-to-date advice on maintaining particular kinds of laboratory animals. These instructions, based on long study, are followed in laboratories throughout the country.



Pekin ducks, Anas domesticus, *in the Animal Quarters of the Biology Department at Brookhaven National Laboratory in New York. On the right a duck looks through the opening that gives access to the water pan below. The container above holds food. These ducks are used in research on the effects of irradiation on blood components. The Brookhaven unit is a member of the American Association for Accreditation of Laboratory Care and is headed by Mr. Richard Emanovsky, who is a Senior Animal Technician of the Animal Care Panel.*

The ACP and ILAR cooperate in promoting better laboratory animal care. An example of this cooperation is the *Guide for Laboratory Animal Facilities and Care*, published by the U. S. Department of Health, Education, and Welfare. The guide was prepared by the ACP and adopted for use by the ILAR.

All in all, laboratory animals are as well cared for as most pets. Science does its best to make its animals comfortable, for the list of benefits to mankind from animal research is long and still growing.

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Motion Pictures

Available for loan without charge from the AEC Headquarters Film Library, Division of Public Information, U. S. Atomic Energy Commission, Washington, D. C. 20545 and from other AEC film libraries.

Roundup, 18¼ minutes, color, 1960. Produced by the U. S. Department of Agriculture. Describes the use of radiation to eradicate the screwworm fly in the southeastern United States.

Time — The Surest Poison, 29 minutes, black and white, 1962. Produced by Ross-McElroy Productions for the National Educational Television and Radio Center under a grant from the Argonne National Laboratory. This film explores the natural process of aging through research on animals using low-level gamma radiation.

The following films in the Magic of the Atom Series were produced by the Handel Film Corporation. They are each 12½ minutes long and are in black and white.

Atomic Biology for Medicine (1955) explains experiments performed to discover effects of radiation on mammals.

The Atomic Zoo (1954) shows experiments with sheep, fowl, and fish to determine how radioactivity affects basic food products.

APPENDIX I

Census of Laboratory Animals Used in Programs of the Division of Biology and Medicine, U. S. Atomic Energy Commission in 1968

Species	Average daily inventory	Number on experimentation during year
Mice	432,294	639,160
Rats	20,069	75,826
Hamsters	3,454	11,057
Guinea pigs	609	2,175
Other rodents	2,278	7,070
Rabbits	1,369	4,861
Dogs	4,105	4,403
Cats	62	62
Primates	471	471
Swine	1,187	1,192
Cattle, burros, ponies, and horses	1,057	418
Sheep and goats	789	521
Marmosa	162	162
Rat-kangaroos	8	8
Wallabies	6	6
Birds	1,889	4,827
TOTAL RODENTS	458,704	735,288
TOTAL NON-RODENTS	11,105	17,986
TOTAL ANIMAL USE	469,809	753,274

APPENDIX II

Guiding Principles for Secondary School Students and Science Club Members in the Use of Animals*

1. The basic aims of scientific studies involving animals are to achieve an understanding of life and to advance our knowledge of life processes. Such studies lead to respect for life.

2. Insects, other invertebrates and protozoa are materials of choice for many experiments. They offer opportunities for exploration of biological principles and extension of established ones. Their wide variety and the feasibility of using larger numbers than is usually possible with vertebrates makes them especially suitable for illustrating principles.

3. A qualified adult supervisor must assume primary responsibility for the purposes and conditions of any experiment that involves living animals.

4. No experiment should be undertaken that involves anesthetic drugs, surgical procedures, pathogenic organisms, toxicological products, carcinogens, or ionizing radiation unless a trained life scientist, physician, dentist or veterinarian directly supervises the experiment.

5. Any experiment must be performed with the animal under appropriate anesthesia if pain is involved.

6. The comfort of the animal used in any study shall be a prime concern of the student investigator. Gentle handling, proper feeding, and provision of appropriate sanitary quarters shall be strictly observed. Any experiment in nutritional deficiency may proceed only to the point where symptoms of the deficiency appear. Appropriate measures shall then be taken to correct the deficiency, if such action is feasible, the animal(s) shall be killed by a humane method.

*Prepared and approved by the National Society for Medical Research, the Institute of Laboratory Animal Resources (National Research Council), and the American Association for Laboratory Animal Science (1968).

THE COVER

On the cover is a 4-week-old New World monkey of the marmoset family, *Saguinus fuscicollis*. This baby weighs 2 ounces and when full growr will weigh 13 ounces. Several years ago Dr. Nazareth Gengozian established a colony of these tamarins at the Oak Ridge Institute of Nuclear Studies in Tennessee. They are es pecially suitable for immunological studies for several reasons. These primates usually give birth to fraternal twins, and there is a prenatal connection between the twins that leads to an interchange of blood-forming tissue. As a result a female with a brother twin possesses male cells in addition to her own genetically derived ones, and vice versa. Another useful feature is their sensitivity to radiation. The exposure necessary to cause progressive patterns of radiation effects is considerably less than the dose to be expected from measurements on other mammals.

THE AUTHOR

EDWARD R. RICCIUTI is an Associate Curator and head of the Department of Publications for the New York Zoological Society at the Bronx Zoo. Previously he was an Associate Editor on the staff of *Science World* and *Senior Science*, magazines published for junior and senior high school students by Scholastic Magazines, Inc. In addition, he has written on scientific topics for magazines and newspapers. A newspaper series on animals in research, "Monkeys, Mice, and Medicine", published by *The* (Hackensack, N. J.) *Record*, won for Mr. Ricciuti · Public Education Citation by the Animal Care Panel. He received an A.B. degree from the University of Notre Dame in 1959, and was awarded a fellowship for 1 year of graduate study under the Advanced Science Writing Program at Columbia University.

PHOTO CREDITS

Cover courtesy Dr. Nazareth Gengozian, Oak Ridge Associated Universities (ORAU)
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