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animals. Two of the animals died, one in October 1956 and the other in January 1958. Postmortem examinations revealed bone marrow changes.

Radiation Induced Hypertension and Renal Failure. SAM financed research at the University of California where irradiated rats were being followed to determine the incidence of hypertension and renal failure. Studies involving the irradiation of kidneys with shielding of the adrenal glands (and vice versa) were in progress in an attempt to identify the sensitive area in hypertension and renal failure.

Operation Plumbob. On several occasions, accidental exposure of individuals to ionizing radiation demonstrated certain unfavorable effects and gave rise to a requirement for determining long-term prognosis following exposure to ionizing radiation. It had been demonstrated that certain biologic endpoints of concern among survivors of the accidental exposures could be observed in the monkey under conditions of similar exposure. Laboratory experiments involving pure neutron, pure gamma, and mixed neutron/gamma radiation produced in the monkey early lens abnormalities, mature cataracts, bone-marrow changes, and later a suggestion that brain tumors may have been radiation induced. It was obvious that a better understanding of radiation effects was imperative if people were to continue to be exposed in working with radiation sources.

To collect data, experimental animals were taken to the bomb test sites where they were exposed to atomic radiation during bomb detonations. Animals were arranged in an exposure pattern so that (1) the dose required

to produce 50 percent lethality in 30 days was determined; (2) the range of doses permitted studies on acute clinical symptoms, such as vomiting, diarrhea, anorexia, eye damage, epilation and fatigue; and (3) a sufficient number of low-dose exposure were obtained so that many animals could be followed for several years to determine the incidence of long-term acute effects, such as cataract production, life shortening, bone marrow changes, and malignancy.

Later the data from these animal experiments would be extrapolated and correlated with data being collected at the Atom Bomb Casualty Commission from survivors of Hiroshima and Nagasaki.

Effects of Weightlessness and G-Forces on Monkeys. Monkeys were exposed to weightlessness by placing them (one at a time) in a specifically designed box and putting the box in an F-94 jet aircraft. The plane then followed a flight pattern which resulted in approximately 40 seconds at zero-gravity. During the time of weightlessness the animal could perform a specific psychomotor test that was included in the design of the box. Motion pictures taken during this time interval indicated that the animal did perform effectively.

To test the monkey's ability to withstand the rigors of high G-forces such as may be encountered in space travel, the animal and psychomotor box were placed on the Navy's centrifuge at Johnsville, Pennsylvania, where it was then subjected to five to six G's for approximately six minutes. Motion pictures of the test indicated that the animal could perform limited tasks under these conditions.¹⁵

15. Progress Report No. 2, "Primate in Space," 1 May 1958, No. 21 in Supporting Documents.

Physical Fitness and Radiation Exposure. An in-house task was under way to establish procedures for assessing fitness for duty in persons exposed to nuclear radiation. Three areas were under investigation, as follows: (1) value of the white blood cell count for determining radiation injury; (2) relationship between radiation damage and urinary constituents; and (3) comparative analysis of human and animal data.

A pilot experiment on 12 rabbits was nearing completion. The findings suggested that repeated radiation exposure to relatively high doses did not lead to enhanced damage when the interval between exposures was long enough to allow complete recovery of the bone marrow. Later, larger groups of animals were to be used to verify the findings.

Apparatus was assembled, procedures were worked out and pilot experiments were undertaken to record enzyme urinary excretion after irradiation.

Antiemetic for Radiation Exposed Aircrews. Preliminary studies were begun to produce an antiemetic to counteract nausea in aircrews. This program, however, was temporarily halted for a higher priority project.

Relative Biological Effectiveness of Different Ionizing Radiations. For some time it had been realized that different types of radiation produced a different degree of biological responses over the same identical time period with the same amount of radiation. Because all types of radiation could be expected in most Air Force operations, it was felt imperative that the relative biological effects of each of

these radiations be well defined. This was important in nuclear propulsion for manned systems since shielding characteristics would be different for different radiation environments, and also for ground handling construction and for any nuclear program.

Monkeys were exposed to various types of radiation. The biological responses of concern were cataractogenic threshold, increased incidence of leukemia or other forms of cancer, and the incidence of life shortening performance decrement. Continued evaluation and refinement of the data and conclusions were underway.

More Accurate Radiation Measurements. An in-house task was devoted to a search for new and more accurate dosimeters for measuring radiation total dose, dose rate, type, and energy. Dosimeters then used included fission foils, Victoreen chambers, germanium fast neutron detectors, Hurst proportional counters, and film and chemical methods.

Radiation Hazards to Aircrews in Nuclear Propelled Systems. The application of nuclear energy in aircraft, rocket, or satellite propulsion subjected Air Force personnel to cumulative doses of radiation through normal operation and maintenance, crashes, meltdowns, etc. The existing levels of permissible exposure recommended by the National Committee of Radiation Protection was believed to be extremely low. Consequently, biologic endpoints of performance had to be established and then threshold doses determined. Data from accidental exposures had clearly defined areas of concern. Fast and thermal neutron, Co⁶⁰ gamma, bomb and reactor mixtures of neutron/gamma radiation, fallout

radiation, and selected fission products--Ce, Cs, Sr, A, and I were all being investigated.

A basic Radiobiology Guide of mission dose schedules, ground handling doses, as well as inhalation concentrations under various conditions of release had been published. This was a continuing study with constant re-evaluation of environmental hazards as new weapons were made known.

Biological Effects of Cosmic Rays. Although a primary cosmic ray source was not available as a laboratory device, it was possible to simulate similar tissue effects using other high energy sources. Preliminary discussions were under way between the Departments of Radiobiology and Microbiology and the Texas Nuclear Corporation. Some neutron work was completed by Dr. Pomerat (of the University of Texas) and the SAM physics group. A neutron generator had been acquired. Efforts were being made to collimate the neutrons from this source and also x-rays so that beams with very small cross sections and high ionization densities could be produced. It was intended to use micro-beams to simulate in the laboratory the effects of energetic heavy particles in cosmic radiation.

Radiation Protective Agents. The Albert Einstein Medical Center, New York, carried out studies supported by SAM to investigate the mode by which thiouronium salts protected animals against the damaging action of radiation. Information concerning the mode of action of prophylactic radiation protective agents of the thiouronium class would constitute the foundation for the development of therapeutic drugs.

Effects of Total Body Irradiation. Whole body x-irradiation was therapeutically used in certain cases of leukemia, generalized lymphoma, polycythemia, and disseminated cancer at the M. D. Anderson Hospital, University of Texas Medical Branch, Houston. The patients so treated offered an opportunity for studying in humans the clinical reaction to a well-measured dose of ionizing radiation. Fourteen patients were treated with 175r whole-body irradiation. A report on the hematologic response, and the initial reaction of these patients was in preparation.

Transfer of Funds to AEC. It had been showed that it was not feasible to provide in an aircraft the quantity of shielding necessary to bring radiation levels down to the limits customarily enforced around the conventional reactor. Consequently, crews of nuclear powered aircraft would be exposed to radiation intensities above the normally regarded maximum permissible levels, and it was appropriate to find out to what extent this added to the risk of biological damage. Consequently, the SAM transferred funds to the AEC to support such work at the Oak Ridge National Laboratories.

The SAM-AEC program was directed toward evaluating the effects of chronic exposure to comparatively low levels of radiation intensity, both gamma and neutron, with special emphasis on life-shortening, leukemia, tumors, cataracts, and other delayed effects. Various strains of mice were exposed to chronic and acute doses of irradiation. The protective qualities of drugs or compounds and bone marrow transplantation were being examined.

Preliminary results revealed that life span is shortened by exposure to ionizing radiation, the decrease in life expectancy being proportional to the amount of radiation absorbed. There was evidence, however, that chronic irradiation produced reversible as well as irreversible injury.

Effects of Gamma Radiation. The SAM financed studies at Southwest Research Institute, San Antonio, on the survival of monkeys subjected to gamma radiation. This work was designed to compile gamma ray data which could be used as a basis for comparison with animals exposed during weapons tests. Also the mode of death following gamma irradiation over a wide range of doses was examined. Evaluation of experimental results was in progress.

New Research Task. A contract was being negotiated with Southwest Research Institute for "The Study of Free Radical Formation Using the Techniques of Electroparamagnetic."

Meetings and Conferences. Col. John E. Pickering, chief of the Department, attended the Hazards Research Meeting for Nuclear Propelled Aircraft, Convair Aircraft Corporation, Fort Worth, Texas, 6-7 January to gain information in guiding the Department's participation in the aircraft nuclear (ANP) radiobiology program.

He also briefed the Air Force Surgeon General's Research Council on the SAM Radiobiology Program at a meeting held 22-23 January in Washington.

Maj. R. G. Allen of the Department's staff, participated in a Cosmic Ray Conference at the Aero Medical Field Laboratory, Air Force Missile Development Center, Donner Laboratory, Berkeley, California, 21-22 January.

Colonel Pickering was present at the Armed Forces Special Weapons Project Briefing, Washington, D. C., 14 March, where he discussed objectives of the SAM program for future atomic tests.

Major Allen represented the School at the Fifth ANP Shielding Information Meeting sponsored by the Aircraft Nuclear Propulsion Office, USAF-AEC, Lockheed Aircraft Corporation, Marietta, Georgia, 14-15 May. The purpose of the meeting was to correlate the engineering and biological requirements of shielding problems.

Capt. L. C. Logie, of the Radiobiological Laboratory, Austin, visited the Los Alamos Scientific Laboratory to talk over the joint SAM-Los Alamos Plumbob Project.

Col. G. L. Hekhuis and Capt. Robert Zellmer attended the Federal Civil Defense Authority Advisory Council Meeting on "Biomedical Series-1960", where continued biomedical testing in the field was endorsed by all members present.

DEPARTMENT OF SPACE MEDICINE

Four in-house and two contractual tasks under investigation by this Department.

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| 7756-1 | The Effect of Drugs Upon Psychological Processes |
| 7758-17 | Studies on the Bioclimatology of Space Flight:
Studies in the Space Cabin Simulator |
| 7758-20 | Studies on the Biological Effect of Sub-Gravity
and Zero-Gravity |
| 7758-52 | Study of Physical Requirements for Manned Rockets
and Artificial Satellites Relating to Specific
Vehicles and Weapons Systems |