

Nutrition and Related Studies in the Office of Advanced Research and Technology, NASA

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One of the missions of the Biotechnology and Human Research Division of NASA's Office of Advanced Research and Technology (OART) is the development of psychophysiological facts relative to man's response to environments, particularly to the stressful environment of space. A number of research tasks are being undertaken by NASA to study the effects on metabolic and physiologic functions resulting from various stresses which will be encountered in manned space flights. These studies are concerned with the atmospheric, nutritional, and metabolic requirements of the astronauts. In order to be aware of metabolic changes in the body, it is important to establish normal terrestrial baselines.

One important area of concern is that of water metabolism. At present, we have a study underway at Stanford Research Institute entitled "Gastrointestinal Tract and Water Metabolism," whose chief investigator is Dr. Callo-way. The objective of this task is to develop and understand certain characteristics and functions of the intestinal tract with regard to water metabolism and overall body metabolism. The effect of diet and physical activity on water metabolism is being investigated. Information will be developed concerning intestinal epithelial desquamation, motility, and secretory function relative to diet, isolation and confinement, altered atmospheres, and body irradiation. Earlier studies have shown that exercise or diet can cause body dehydration despite a copious intake of water. Relatively slight dehydration

can lead to rapid fatigue, loss of performance, and eventually death. It is therefore most important to understand the mechanisms by which water is absorbed and maintained in the body.

A task complementing this study is being conducted at Ames Research Center. The objective of this task, entitled "Human Water Metabolism in the Space Environment," is to investigate the effects of space environmental stresses such as heat, physical exercise, and atmospheric content on the water metabolism of the human with emphasis on the mechanisms of voluntary dehydration. This task will answer two questions: (1) Is some degree of dehydration beneficial to men performing under stress? (2) How long does it take a man to recover lost water and what physiological changes are involved?

Proceeding logically from our efforts in water metabolism, we must study the metabolism of the basic materials for maintaining life, namely carbohydrates, proteins, and fats. We have underway at Ames a task entitled "Metabolism, Temperature Regulation, Diet, and Performance of Man in Relationship to His Environment." This study will develop information pertinent to the understanding of carbohydrate, protein, and fat metabolism relative to stress tolerance in man and also information concerning dietary factors necessary to maintain optimum performance. One primary objective will be to determine if man can convert body fat into easily utilizable carbohydrate and therefore obtain optimum utilization of the

body energy reserves. Procedures such as the feeding of special diets, food deprivation, and the use of certain drugs will be studied for their influence on metabolism and human tolerance under unusual stress conditions.

Many foods are being recommended for space diets on the basis of the principles of nutrition relative to life on earth. However, we do not know whether these recommendations are valid for the conditions of space environments. Factual data probably will not be obtained until actual experiments in space have been conducted. However, on the basis of carefully controlled metabolic experiments under selected simulated space flight conditions, it should be possible to make recommendations concerning space-flight diets with a high degree of confidence. In order to obtain this information, OART originally contracted and then transferred to the Manned Spacecraft Center a task with the Aerospace Medical Research Laboratories (AMRL), Wright-Patterson Air Force Base, for the "study of caloric, protein, and water requirements of young men subjected to simulated space stresses and the evaluation of foods planned for long term space flight." The objective of this task is initially to establish individual baselines and then utilize newly developed full pressure suits to (1) study the nutrient requirements of man subjected to simulated space stresses, (2) to make a nutritional evaluation of foods to be used in space missions, (3) to study the interrelationships of the intestinal microflora and diet.

The experiments to determine the optimum requirement for energy, protein, and water for young healthy males exposed to various stresses are being carried out on 16 subjects per year. Four to eight subjects are utilized at a time in the AMRL Space Vehicle Environment Simulator with and without space suits. Various types of diets are being utilized. Blood, feces, and urine are collected and analyzed. By this study, new and revolutionary space suit systems will be evaluated.

The subjects undergo a stabilization period of 1 week during which baseline data are recorded. This is followed immediately by a 3-week balance study. Careful control of activity is main-

tained on each subject. Following the balance studies, various stresses are imposed. Each subject is exposed to the various and combined stresses while wearing a pressure suit at various atmospheric states at pressures from sea level to 5 pounds per square inch. Other factors such as 200° F for several minutes are imposed to promote psychophysiological stresses at various intervals.

Individual balance studies are accomplished on each subject to determine optimum energy requirements. Studies are conducted on water, calcium, and sodium balance to determine optimum maintenance levels for the subjects. Ideal protein requirements are calculated on an individual basis. Baseline information is obtained concerning metabolic utilization of diets composed of common foods that have been prepared from predetermined levels of protein and caloric density needs of the individual subject. Urine catecholamine levels are used as an index of stress at suitable intervals. Blood lipid levels are measured twice weekly during each experimental period. The usual physiological measurements are recorded.

Although this project has been underway for some time, evaluation of the data has not yet been made.

As these studies indicate, we are conducting a reasonably intense research program in the various facets of metabolism related to water, protein, fats, and carbohydrates. In addition to these substances, we must know to what extent mineral and vitamin metabolism is affected by various types of stress. Jointly with the U.S. Air Force we support a study into the "effects of environment on absorption and metabolism of minerals" at the Johns Hopkins University under the direction of Dr. Bacon Chow.

The object of this study is to determine the effects of isolation, illumination, confinement, temperature, altered atmospheric pressures and gaseous percentages, noise, and other stresses on the cellular metabolic processes relative to Fe⁵⁹, Zn⁶⁵, and Mg²⁸ absorption and metabolism. Preliminary studies will utilize rats as the experimental animals with primates being used later.

Iron was chosen because of its role in hemopoiesis, and magnesium and zinc for their roles in certain phosphorylation enzymes. Metabolic zinc deficiency has been reported to be responsible for certain types of dwarfism. This study apparently confirms this fact by showing that zinc deficiency also results in retardation of growth in rats.

Balance of the intestinal flora population influences the nutrition, health, and well being of humans. Many dietary and environmental conditions encountered by the host upset this balance in the microbiological flora of the intestines and have an effect on the health, nutrition, and performance capabilities of man. This fact is of vital concern in space flight.

In order to evaluate the effect of space conditions on the intestinal flora, it is necessary to know the character of the balance of intestinal flora of man in a normal environment. To date this information has been meager, especially in respect to the predominating anaerobic flora. We have underway a "study of the normal fecal bacterial flora in man." This study is being conducted by Republic Aviation Corporation under the direction of Dr. Lorraine Gall. For the first time a rather complete assay of intestinal microbiology will be available. Microbiological studies will be extended to space vehicle

environments and to cross-contamination of crew members.

In addition to the studies previously mentioned having direct relation to metabolism and nutrition, we have "studies to determine the optimum space cabin environments" being conducted by the U.S. Air Force at the School of Aerospace Medicine, Brooks Air Force Base, Texas. This task will look into the effect of metabolism of 100 percent oxygen and of varying percentages of oxygen mixed with the so-called inert gases.

Other studies of a similar nature entitled "Atmospheric Conditions" and "The Toxicity Criteria for Gas Environments in Closed Ecological Systems" are being conducted at Ames Research Center. Details of these and the other studies noted in this presentation will be discussed in detail in subsequent papers.

From the foregoing, it can be seen that NASA is concerned about the fundamental metabolism and nutrition of man under the stress conditions of space flight. We have made a start, but we need aid and guidance in this tremendously important field. In order to fashion and execute a well-balanced research program, we look to those engaged in research in nutrition and related fields for additional information and professional advice.

Nutritional Trends in Future Manned Space Flights

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Nutritional trends in manned space flights might best be discussed in terms of the recommendations relevant to food, water, and waste of the Space Medicine Advisory Group (SPAMAG) in their conceptual study of an orbiting research laboratory (ORL).

The SPAMAG is a working group of 19 consultants in medical and paramedical fields, each of whom is an outstanding contributor in his own speciality area. The Group was organized by the NASA Space Medicine Division, Office of Manned Space Flight, for the purpose of studying requirements for the ORL in order to lend support to other in-house and contractual ORL studies.

By way of providing a proper framework for this report, it would probably be worthwhile to spend a few minutes discussing the general method of approach employed by SPAMAG in this study.

Members of the Group are listed as follows:

John A. Buessler
Loren D. Carlson
Robert E. Forster
Edgar S. Gordon
Douglas Grahn
Ashton Graybiel
Milford D. Harris, Jr.
Andres I. Karstens
Edward C. Knoblock
Joseph F. Kubis
Edward A. Liske
Ross A. McFarland
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Herbert Pollack

Ralph Reitan

Scott H. Swisher

John C. Townsend

Sherman P. Vinograd

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G. Donald Whedon

Earl A. Wood

DOD/NASA coordination is effected by the attendance of Lt. Col. Milford D. Harris, Jr., and Dr. Edward A. Liske as DOD observers, and Col. Andres I. Karstens who is serving in the capacity of cochairman. Two-day meetings have been held at monthly intervals since the first meeting of the group in January 1964. Present estimates are that six or eight such meetings will be required to complete the study, after which the Group will meet three or four times a year in order to update its findings in the light of newer knowledge and further contemplation of the total problem.

The first morning of each 2-day session is devoted to briefings, chiefly by NASA personnel. These are designed to familiarize the Group with the unique constraints, problems, and developments of manned space flight. This is considered to be a highly important step toward significantly enhancing the value and applicability of recommendations made by the Group.

Prior to the first meeting, a 12-page format or working procedure was devised. This was adopted by the Group at the time of the first meeting. In general, the study falls into three