CHAPTER VII

BIODYNAMICS BIBLIOGRAPHY
(1966-1969)

Compiled under the direction of

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FOREWORD

This document was prepared for consideration as one section in the manual "Principles of Biodynamics" being compiled by the Biodynamics Committee of the Aerospace Medical Panel of AGARD-NATO. The purpose is to bring together very recent information, not available in earlier literature reviews, concerning biodynamics research findings. Coverage is international and provides a representative view of current research efforts. The abstracts shown were taken directly from the initial source documents.

The materials in this annotated bibliography were collected through literature searches conducted by BioTechnology, Inc., Falls Church, Virginia; the NASA Scientific and Technical Information Facility, and the Biological Sciences Communication Project of the George Washington University. These searches covered published and unpublished documents, primarily for the period 1966 - April 1969. Included were documents originally cited in (1) the Scientific and Technical Aerospace Reports of NASA, (2) the Technical Abstract Bulletin of the Defense Documentation Center, (3) the International Aerospace Abstracts of the American Institute for Aeronautics and Astronautics, (4) the Aerospace Medicine and Biology Bibliography Projects of the Library of Congress, and (5) non-English language documents translated by the Joint Publications Research Service.

Investigators working in the field of biodynamics can obtain comprehensive listings of earlier research through documents such as the following:

Clark, C. C., & Faubert, D. A chronological bibliography on the biological effects of impact. MARER-11953, Martin Company, Baltimore, Md., September 1961.

Ice, J., Snyder, R. G., Hyde, A. S., & Leverett, S., Jr. Biomedical research studies in acceleration, impact, weightlessness, vibration, and emergency escape and restraint systems: A comprehensive bibliography. Supplement one. Civil Aeromedical Research Institute, Federal Aviation Agency; 6570th Aerospace Medical Research Laboratories; and USAF School of Aerospace Medicine. September 1966.

(Contains 18,893 entries including Acceleration, 10,631; Vibration, 1,978; Weightlessness, 2,412; and Escape and Restraint, 3,872. Covers primarily period 1963-1966, but includes earlier material not in 1963 volume.)

National Academy of Sciences, National Research Council, Symposium on impact acceleration stress, with a comprehensive chronological bibliography. Brooks AFB, Texas, November 27-29, 1961. NAS-NRC-977, Washington, D.C., 1962.

Ronco, P. G. Human engineering bibliographies series. Institute for Psychological Research, Tufts University. Prepared for U.S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland.

Schaeffer, V. H., & Ulmer, R. G. A representative bibliography on research in low frequency mechanical vibration. AMRL-405, Army Medical Research Lab., Fort Knox, Ky., November 1959.

Snyder, R. G., Ice, J., Duncan, J. C., Hyde, A. S., & Leverett, S., Jr. Biomedical research studies in acceleration, impact, weightlessness, vibration, and emergency escape and restraint systems. A comprehensive bibliography. CARI Report 63-30. Civil Aeromedical Research Institute, Federal Aviation Agency, 6570th Aerospace Medical Research Laboratories; and USAF School of Aerospace Medicine. December 1963.

(Contains 10,306 entries of which 70% are abstracted: Acceleration, 6,470; Vibration, 1,058; Weightlessness, 873; and Escape and Restraint, 1,905. Covers period 1818-1963.)

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SECTION I

PROLONGED ACCELERATION: LINEAR AND RADIAL

Advisory Group for Aerospace Research and Development. Principles of biodynamics as applied to manned aerospace flight. Section A: Prolonged acceleration: Linear and radial. 1968, 90 p refs. N68-26500 (NASA).

Contents: (1) Acceleration terminology: Table of comparative equivalents. 6 p refs. (See N68-26501 15-05)
(2) An introduction to the physics and physiology of acceleration. 23 p refs. (See N68-26502 15-04)
(3) The dynamics of rotation applied to centrifuges. 14 p refs. (See N68-26503 15-05)
(4) A summary of human tolerance to prolonged acceleration. 35 p refs. (See N68-26504 15-04)

Banchero, N., Rutishauser, W. J., Tsakiris, A. G., & Wood, E. H. Pericardial pressure during transverse acceleration in dogs without thoracotomy. Circulation Research. 1967, 20, 65-77.

Intrapericardial pressures were recorded via a saline-filled Teflon catheter (O.D., 1.3 mm) in eleven anesthetized dog studies without thoracotomy. Seven animals were studied before, during, and after one-minute exposures to transverse acceleration that ranged from 1 G (normal gravitational environment) to 7 G when in the supine ($+G_x$), prone ($-G_x$), left decubitus ($+G_y$), and right decubitus ($-G_y$) positions. Four additional animals were studied at 1 G only, while in the same body positions. Pressures also were recorded for both atria, right ventricle, aorta, esophagus, and the potential plural space. Mean end-exploratory intrapericardial pressure varied directly with the vertical height of the recording site in the thorax during all conditions studied, as would be expected in a hydrostatic system. Transpericardial pressures were not significantly different from zero at all levels of acceleration studied. Transmural left and right atrial pressures were independent of the height of the recording site in the thorax and were unchanged during exposures to transverse acceleration that range from plus to minus 7 G_x.

Barer, A. S., Golov, G. A., Subavin, V. B., Murakchovski, K. I., Rodin, S. A., Sorokina, E. I., & Tikchomirov, E. P. Physiological reactions of the human body to transverse acceleration and some means of increasing the organism's resistance to these effects. Aerospace Medicine, 1966, 37, 127-133, A66-80560 (LC).

Flight in space vehicle is accompanied by the effects of exposure of the subject to different accelerations. Prolonged acceleration appears during the start and at the re-entry of the space vehicle into the earth's atmosphere. It also can occur during maneuvers while in flight. Three general groups of experiments are described. The first group considers the limits of human tolerance to prolonged forward acceleration at an angle of 65° to the longitudinal axis of the body. The second group includes tests of different methods whereby human tolerance to transverse acceleration might be increased. The third group contains investigations in which the tolerance to acceleration was determined in time under selected optimal conditions. Detailed records and data were obtained during each experiment on certain physiological functions of the human body. Complete analyses of these data are discussed. Although estimates were made in this study of methods for increasing resistance of the human being to prolonged acceleration stress, and limits of tolerance to this stress were established, unanswered questions still remain regarding the reaction of the organism to stress. Detailed analyses of the questions raised are considered. Physiological responses of the human being to these stresses are considered in light of the experimental data.

Belai, V. E., Vasillev, P. V., Glod, G. D., & Petrukhin, V. G. Mechanism of cardiac-activity variation during transverse accelerations. In Problems of Space Biology. N. M. Sisakian (Ed.) Moscow: 1967, p 118-124. 16 refs. A68-38217 (IAA).

Study of certain mechanisms disturbing cardiac activity during transverse accelerations. Long-term transverse accelerations are shown to be accompanied by an intense discharge of myocardium and liver glycogen. Disturbed cardiac activity is correlated with the glycogen content in the myocardium. One of the aspects of the pathogenesis of the exhaustion of the cardiac-activity compensating mechanisms is a sharp decrease in the myocardium energy resources. The normalization of the electrocardiogram pattern during the period after accelerations is shown not to be an indication of the total recovery of the myocardium function.

Benson, A. J., & Bodin, M. A. Interaction of linear and angular accelerations on vestibular receptors in man. Aerospace Medicine, 1966, 37, 144-154, A66-80564 (LC).

A 1 g rotating linear acceleration vector, produced by rotation about a horizontal cephalo-caudal axis, was found to produce compensatory nystagmus for as long as rotation continued. The velocity of

the slow phase of nystagmus showed a cyclical modulation, the amplitude of which increased with the speed of rotation. Following rotation about a horizontal axis, the after-sensations were all but abolished and the time constant of decay of post-rotational nystagmus was consistently shorter than when the axis of rotation was vertical. A hypothesis is presented which attempts to explain these findings by the direct action of the linear acceleration on the canal system; however, it is not possible to exclude otolithic mechanisms.

Bjurstedt, H. Gravity and acceleration. In Human Ecology in Space Flight. Vol. I, 1966, p 120-204 refs. N66-36430 (NASA). (New York Academy of Sciences, N. Y.).

The effects of both high and low G forces, which occur in the launch and reentry phases of space flight, on human physiological systems are discussed. The primary effects of acceleration on the systemic and pulmonary circulation, and on gas exchange in the blood are considered. Also discussed are adaptive cardiovascular responses; functional disturbances secondary to insufficient adaption; the need for protection; and the means of protection. Data obtained from monitored human subjects in laboratory environmental stress situations are discussed. Residual effects of atelactasis; and symptomatology studies of normal and deaf students in a counterrotating room are also discussed.

Bjurstedt, H., Rosenhamer, G., & Wigertz, O. High-G environment and responses to graded exercise. Journal of Applied Physiology, 1968, 25, 713-719.

Ventilatory and circulatory responses to graded leg exercise on a bicycle ergometer (300, 600, and 900 kpm/min, i.e., 49, 98, and 147 w, with 6 min. at each work load) were studied in eight healthy untrained subjects in the sitting position at normal gravity (+ 1 G_z) and at + 3 G_z. The effect of increased G on the average work performed by the leg muscles was calculated to be negligible. At the highest work load, mean expired minute volume, oxygen uptake, heart rate, and arterial lactate levels with the sixth minute of exercise were 19.6 liters/min, 241 ml/min, 32 beats/min, and 1.43 mm/liter higher at + 3 G_z than at + 1 G_z; the increases were statistically significant except for arterial lactate. No electrocardiogram (ECG) abnormalities occurred at + 3 G_z even at the highest work load. An increase in the work load from 600 to 900 kpm/min at + 3 G_z caused leveling off of oxygen uptake and rise of arterial lactate in two subjects and, in another, inability to complete the work because of exhaustion. It is concluded that during leg exercise with increasing work loads on the bicycle ergometer while in the sitting position at + 3 G_z, the oxygen transport to working muscles was limited primarily by disturbances in the pulmonary gas exchange; exaggerated hydrostatic pressure differences in this condition present a greater handicap to the pulmonary than to the systemic circulation.

Bricker, L. A., Johnson, W. A., Davies, C. R., & Dottore, R. A. Effect of $-7G_x$ acceleration on renal excretion of solutes in rabbits. Aerospace Medicine, 1967, 38, 35-38.

The effects of one hour of uninterrupted $-7G_x$ acceleration on rate of urine flow and urinary excretion of sodium, potassium, and total solute were studied in rabbits.

Urine flow rate during exposure to acceleration fell to an average of 56 percent of control values; urinary excretion of sodium fell concurrently to 45 percent of control, and potassium to 67 percent. There was no significant change in total solute excretion. The declines observed were abrupt, as were the returns to control levels after acceleration. The data suggest that hemodynamic rather than hormonal influences were primarily responsible for these changes.

Gross or microscopic hematuria observed in the sediments of most acceleration urine specimens disappeared or abated during the recovery phase. Occasional red cell casts indicated that the hematuria was due, at least in part, to an intrarenal lesion.

Bryan, A. C., & Anthonisen, N. R. The effect of acceleration on terminal airway closure. Aerospace Medical Association's Annual Scientific Meeting, Washington, 10-13 April 1967.

Studies with $Xenon^{133}$ during postural change and during increased acceleration have demonstrated the influence of gravity on the distribution of ventilation. Gravity appears to act by altering the gradient of trans-pulmonary pressure, thus altering the relative size and compliance of the regional alveoli. These studies also demonstrated that there is sequential filling at low lung volumes, presumably due to airway closure, but that filling is synchronous at higher lung volume. This observation has been used to further investigate the influence of gravity on ventilation distribution.

Bryan, A. C., Milic-Emili, J., & Pengelly, D. Effect of gravity on the distribution of pulmonary ventilation. Journal of Applied Physiology, 1966, 21, 778-784.

Regional variations in lung volume and in the distribution of ventilation have been measured with Xe 133 during normal gravity and during increased positive ($+G_Z$) acceleration on a human centrifuge. All subjects were studied at $+1G_Z$, 3 and $+2G_Z$, and 1 and $+3G_Z$. At $+1G_Z$ the top of the lung was relatively more expanded than the bottom but the increment in volume (i. e., inhalation) is greater at the bottom than at the top when inspiring above functional residual capacity. During increased acceleration these regional differences were magnified. In addition, static pressure-volume curves were measured on each subject using different balloon depths during normal and increased acceleration. The shape of the static pressure-volume curve did not change significantly during increased acceleration. The probable cause of the regional difference in volume in ventilation which had been demonstrated is a gradient of static transpulmonary pressure down the lung. This gradient appears to be related to the weight of the lung, since this has been shown to be proportional to the magnitude of the acceleration. Extrapolation of the data to the 0 G condition indicates that in weightlessness the regional lung volume and ventilation distribution should be uniform.

Burton, R. R., & Smith, A. H. Hematological criteria of chronic acceleration stress and adaptation. Aerospace Medicine, 1967, 38, 1240-1243, 20 refs. N68-16497 (IAA).

Hematological study (leukocyte counts) on chickens which had been exposed to increased chronic acceleration to determine if they might serve as useful parameters to estimate the physiological status (with respect to stress and adaptation) of these birds. On a group basis, it appeared that the stress pattern continued for approximately five months, after which time the blood picture returned to the control values, and it was assumed that a physiological adaptation had become established in these animals. A relative lymphocyte count was found to be a good method (repeatable) to determine the physiological status of the individual bird.

Cappel, K. L. Determination of physical constants of the semicircular canals from measurement of single neural unit activity under constant angular acceleration. In NASA, Washington The Role of the Vestibular Organs in Space Exploration. 1966, p 229-236 refs. N67-15139 (NASA) (Franklin Inst., Philadelphia, Pa. Research Lab.).

Labyrinthal responses to inertial stimulation are studied in relation to the mechanical properties of the semicircular canals, with the cupula-canal system considered as a damped spring-mass system with a single degree of freedom. It is noted, however, that its representation by a nonhomogeneous second-order differential equation has not always been correct. A decreasing response to continued stimulation is obtained from single nerve units in the anesthesized cat brain stem: and of 29 sets of data, nine have been analyzed. Damping-to-inertia and spring-constant-to-inertia ratios indicate there is underdamping during stimulation and overdamping during return, with the damping almost invariably higher in the return phase. This increase may be related to nonlinearities. Properties of the system are considered consistent with servo design practice in which an increase in gain would be balanced by an increase in damping to prevent instability. Further, a considerable proportion of the nerve units show remarkable symmetry in response under stimulation in opposite directions.

Chambers, R. M., & Ross, B. M. Effects of transverse acceleration on memory task performance. In Aerospace Medical Association. 1966, p 86, 87. 5 refs. A66-32161 (IAA).

Study of abstract higher mental functioning (immediate memory) of a human operator during exposure to transverse acceleration stress. Using the human centrifuge and immediate memory performance tasks, two experiments were performed to test the hypothesis that degradations to memory would occur. In the first experiment, the magnitude of acceleration stress was kept constant while volunteer subjects performed running matching memory tasks which varied in complexity. In the second experiment the running matching memory task was kept constant while the magnitude of transverse acceleration was varied. It was found that degradation did occur as a function of the acceleration stress.

Cook, J. P., & Bancroft, R. W. Centrifuge for chronic acceleration studies of small animals. In Texas Journal of Science, 1966, 18, p 151-156, 15 refs. N66-81768 (LC).

A description is given of the construction and operation of a small animal centrifuge which was devised especially for carrying out long-term, uninterrupted exposures to increased gravity fields. A nomogram is presented for ascertaining the effective gravity forces (g_E) in such a centrifuge in which suspended animal cages are allowed to align with vectorial forces.

Cooper, K. H., & Leverett, S., Jr. Physical conditioning versus +Gz tolerance. Aerospace Medicine, 1966, 37, 462-465, 18 refs. A66-31123 (IAA).

An attempt was made in this study to determine the effect of endurance training on $+G_z$ tolerance in experienced centrifuge subjects. Eleven subjects were divided into six exercisers and five controls. For three months the exercisers engaged in a daily (5 times a week) progressive running program while the controls were asked to avoid vigorous exercise. Frequently during this period, all eleven subjects were subjected to both rapid onset and gradual onset runs on the USAF School of Aerospace Medicine centrifuge. At the conclusion of the three months, significant differences were noticed between the exercise and control groups in endurance capacity as indicated by an increase in maximal oxygen consumption. However, no significant difference was noted between the two groups in their ability to tolerate positive Gs during either gradual or rapid onset centrifuge runs. In this study, neither an increase nor a decrease in $+G_z$ tolerance could be correlated with endurance capacity.

Crampton, G. H. Does linear acceleration modify cupular deflection? In NASA, Washington The Role of the Vestibular Organs in Space Exploration. 1966, p 169-184 refs. N67-15135 (NASA) (Army Edgewood Arsenal, Md.).

Data from two experiments are described. In part I, human nystagmus was recorded with the head at the center of rotation and at a radius under a 1.06-g resultant. The magnitude of nystagmus, especially during constant velocity following angular acceleration, can be manipulated according to the orientation of the head with respect to the centripetal acceleration vector. In part II, single cells responsive to angular acceleration were recorded from anesthetized cat brain stem with the head at the center of rotation and at a radius under 1.03-g resultant. Consistent differences in discharge rates were not found according to various orientations of the head with respect to the centripetal acceleration vector. It is concluded that these nystagmic changes are not due to direct acceleration effects upon the cupula, but are better explained in terms of a centrally converging otolithic influence.

Dagianti, A., Busnengo, E., Rossanigo, F., & Rota, P. Behavior of arterial oxygen saturation and of pulmonary ventilation in dogs subjected to $+G_x$ acceleration. In AGARD Collected Papers Presented at the 22nd Meeting of the AGARD Aerospace Med. Panel, September 1965, p 233-243 refs. N66-33744 (NASA) (Aerospace Medicine Center, Rome (Italy)).

The results of 96 experiments conducted to examine the behavior of arterial saturation in oxygen and pulmonary ventilation in dogs subjected to prolonged acceleration of constant value, in the $+G_x$ axis are presented and assessed. Tables which summarize these results are provided and it was noted that diminution of the saturation in oxygen of the arterial blood in proportion to the acceleration value occurred. The peak was reached during the first minutes of the experiment. Additionally, initial apnea followed by a phase of hyperventilation, which persisted throughout the experiment and increased with the number of G was observed. These indications are compared to those reported by previous investigators, and it is stated that the phenomenon of initial apnea merits additional investigation.

Demange, J., Jacquemin, Ch., Varene, P., & Timbal, J. Utilisation d'un spectrometre de masse sur une centrifugeuse humaine. Med. and biol. Engng., 1966, 4, 153-157.

In aviation and space medicine, rapid gas analysis of mass spectrometer is of great interest in studies of respiration. The object of the work reported here has been to adapt a mass spectrometer for use in experiments with the human centrifuge.

Dowell, A. R., Shropshire, S., Jr., & McCally, M. Ventilation and pulmonary gas exchange during headward ($+G_z$) gradient acceleration. Aerospace Medicine, 1968, 39, 926-934. A68-42596 (IAA).

Measurements of ventilation and pulmonary gas exchange, made in ten subjects exposed to $+3G_z$ gradient acceleration at the feet for one hour. A steady state of pulmonary gas exchange was achieved during acceleration in that minute ventilation, O_2 consumption, CO_2 production, and gas exchange R were not significantly changed from control values. A decrease in end-tidal CO_2 tension accompanied an increase in the a-A CO_2 difference from 0.4 to 5.0 mm Hg. Alveolar dead-space ventilation increased, and the fraction of alveoli which were unperfused but ventilated rose from 2.7 to 18.1%. The rise in the fraction of alveoli which were unperfused but ventilated occurred at the expense of the fraction of alveoli which were evenly perfused and ventilated. Arterial hypoxemia and an increase in A-a O_2 difference were found during acceleration and were related to an increase in venous admixture into the arterial system. The alveolar blood shunt fraction rose from 4.4 to 7.3% during $+G_z$ spin, while the fraction of alveoli which were perfused but unventilated rose from 4.2% to 6.2%. The rise in the A-a O_2 difference during

$+G_z$ gradient spin was due to a marked decrease in the number of perfused alveoli plus a slight increase in the number of perfused but unventilated alveoli.

Duling, B. R. Effects of chronic centrifugation at 3 g's on cardiovascular reflexes of the rat. American Journal of Physiology, 1967, 213, 466-472.

Male Simonsen rats weighing 260-300 g. at the onset of exposure were centrifuged at 3 g's (36.1 rpm) for four weeks. After anesthetization with pentobarbital (ip), peripheral resistance measurements were made on the isolated hindquarters perfused at constant flow. Vascular reflex changes, in response to systemic pressure alterations induced by epinephrine or acetylcholine, were compared in 12 centrifuged and 12 noncentrifuged animals. Centrifuged rats exhibited a significantly greater alteration in peripheral resistance for a given change in systemic pressure. These findings suggest that cardiovascular reflex function is influenced by the characteristics of the inertial environment. The use of nitrous oxide anesthetic and stimulation of the lumbar sympathetic chain failed to demonstrate that this effect was specifically related to the anesthetic or due to an alteration in the peripheral neuroeffector unit.

Evans, J. W., Smith, A. H., & Boda, J. M. Fat metabolism and chronic acceleration. American Journal of Physiology, 1969, 216, 1468-1471.

Mature male single-comb white Leghorn chickens were exposed to 1.75, 2.5, or 3 G for 24 weeks and body mass and percentage body fat were determined. Body mass and percentage body fat were rectilinearly correlated to the accelerative force. Plasma free fatty acid (FFA) metabolism, liver citrate-cleavage, and malic enzyme activities of asymptomatic, acceleration-sick, and recovered birds exposed to chronic acceleration (3 G) were compared with noncentrifuged control birds. The FFA half-lines were the same for all groups, but plasma FFA concentrations, flux, and utilization rates decreased for the asymptomatic, acceleration-sick groups compared with control and recovered birds. Body fat percentages were decreased for all centrifuged birds. Recovered birds were able to return FFA utilization to normal but were unable to return their body fat stores to normal. Liver lymphogenic enzymes followed the same pattern observed with palmitate utilization. Birds surviving chronic acceleration undergo an adaptional process involving changes in FFA metabolism and lymphogenic enzymes.

Farrer, D. M., & Warrell, J. E. Chimpanzee performance during sustained transverse acceleration. 1965, 18 p, AD 461 140 (DDC) (Holloman AFB, N. Mex., Aeromedical Research Lab.).

Continuous avoidance performance during + $1G_x$ and + $4G_x$ was obtained from six chimpanzees in this study of the behavioral effects of sustained acceleration. Performance, heart rate, respiration rate, and temperature were monitored throughout the 126 min test (18 min at + $1G_x$, 90 min at + $4G_x$, 18 min at + $1G_x$). These subjects had prior experience in centrifuge studies and were trained to asymptotic performance on a continuous avoidance task prior to this experiment. Evaluation of the results of the behavioral and physiological data indicated no serious difficulties. It was concluded that chimpanzees can tolerate + $4G_x$ exposure for 90 min without serious decrement to simple performance or impairment to physiological functioning. No indications of maximum time limits were discovered and it was inferred that the + $4G_x$ exposure time could be extended.

Feller, D. D., & Nevile, E. D. Blood glucose and corticosterone changes accompanying altered lipid metabolism induced by exposure to acceleration stress. In Society for Experimental Biology and Medicine, Proceedings, vol. 121, 1966, p 223-227 refs. A66-28868 (IAA).

Experimental investigations of fasted, male, Sprague-Dawley rats exposed to 4.7 g for time periods of up to 24 hr. Plasma glucose, plasma corticosterone, liver lipids, and the incorporation of acetate-1-C^{14} into fatty acids in liver slices were followed in rats exposed for periods of 1 to 24 hr. Plasma glucose and plasma corticosterone curves were bimodal, showing an early maximum during the first 3 hr. of exposure and after rising after 5 hr. through the 24-hour study. It is concluded that changes in fat metabolism induced by acceleration stress were mediated in part by changes in levels of circulating glucose, corticosterone, or the interaction of both.

Fissi, E. Physiopathological effects of accelerations on astronauts during launch into orbit and return to earth of the space capsule. In Space Progress: Space Programs in the Next Decade; International Technical and Scientific Conference on Space, 8th, Rome, Italy, April 1-3, 1968, Proceedings. 1968, 4 p. A68-37243 (IAA).

Discussion of the effects of accelerations on the heart and circulation of astronauts during an orbiting mission and return to earth. The general characteristics of the changes produced by acceleration are discussed, and the effects caused by specific types of acceleration are reviewed. The type of acceleration usually withstood by astronauts during launching and landing is the one that effects the chest and back between 6 and 9 g. This is the type of acceleration that is best withstood by the heart and circulatory system, especially due to the favorable horizontal position in which the astronauts lie.

Glaister, D. H. Acceleration atelectasis - some factors modifying its occurrence and magnitude. FPRC Memo No. 220, 11 pp., 1965.

Acceleration atelectasis has been studied by measuring the reduction in vital capacity, following centrifuge exposure to positive acceleration with subjects wearing anti-g suits and breathing 100% O_2. During acceleration, VC decreases exponentially with time, the final value depending on the subject's individual susceptibility. Significant reduction in VC may follow exposure to 4 'g' lasting only 5 sec, or exposure to only 2.4 'g' lasting for 60 sec. Evidence which is presented suggests that physical collapse of alveoli produces a disappropriate decrease in VC, presumably due to a reflex limitation of inspiration.

Changing from O_2 breathing to air breathing with the onset of plateau acceleration did not influence the degree of VC limitation which resulted. This confirms the theory that the alveoli responsible are very poorly ventilated. Breathing O_2 at a positive pressure of 30 cm H_2O during the plateau acceleration halved the resulting production in VC in three subjects, and prevented it completely in a fourth. It is suggested that this is due to the fact that pressure breathing increases the functional residual capacity (FRC), and this has the effect of increasing the ventilation of the lower lung.

The action of an anti-g suit in promoting lung collapse was shown to be mediated solely through its abdominal compression. It is suggested that this reduces the FRC and so decreases the ventilation of the lower lung.

Glaister, D. H. The effect of gravitational stress upon the distribution of blood flow and ventilation within the human lung measured using Xenon-133 and a scanning technique. Report No. FPRC/1262, 17 pp., 1966.

The uppermost 5 cm of lung were unperfused at $+1G_z$, and 14 cm, or 45% of the ventilated volume, at $+3G_z$. The linear increases in flow below these levels were proportional to acceleration, and were explicable in terms of vascular pressure gradients. Basal lung flow was increased by positive acceleration.

Glaister, D. H. The effect of positive acceleration on the inequality of ventilation and perfusion in the lung. Report No. FPRC/1231, 21 pp., 1964.

The distribution of ventilation and blood flow in the human lung has been studied by means of continuous analysis of expired air for CO_2 and, following a single breath of pure O_2, for N_2. At rest, the concentrations of CO_2 and N_2 both rose slowly and steadily throughout the expiration. During positive acceleration at 1.0 - 3.0 'g', the N_2 concentration rose more steeply, but CO_2 was either unaffected or its concentration fell towards the end of the expiration. These findings are attributed to impaired distribution of ventilation and perfusion and to an increased inequality of their ratio throughout the lung. At 3.0 'g', up to one-third of the total ventilated lung volume was shown to be unperfused. This region is probably the upper lung where the gravitational reduction in blood flow will be most marked.

Ripples in the expired CO_2 and N_2 concentrations, in time with the heart beat, were seen irregularly at rest, but became pronounced and were consistent findings at 3.0 'g'. These cardiogenic oscillations are also explicable on the basis of positive acceleration increasing the ventilation-perfusion ratio inequality. Inflation of the anti-g suit during positive acceleration largely corrected the changes in expired gas composition, but in so doing exacerbated the already low ventilation-perfusion ratio in the basal areas of the lung.

The sudden production of an inequality in the distribution of ventilation and perfusion, as by acceleration, results in a temporary decrease in pulmonary gas exchange and in a lasting reduction in the O_2 saturation of arterial blood. This will not be completely restored by the administration of 100% O_2. The mechanism by which positive acceleration could produce changes in the distribution of ventilation and

perfusion is duscussed, together with the significance of these changes in relation to the lung collapse which may occur when O_2 is breathed during acceleration.

Glaister, D. H. The effect of positive centrifugal acceleration upon the distribution of ventilation and perfusion within the human lung, and its relation to pulmonary arterial and intraoesophageal pressures. Proc. R. Soc. B., 1967, 168, p 311-334 refs.

The influence of gravity on the distributions of ventilation and blood flow, as demonstrated by the effects of posture, is discussed and explained on the theoretical basis of gravitational gradients of pressure within the lung tissue and blood vessels. Positive acceleration steepens these gradients so that measurement of regional ventilation and perfusion in subjects riding on a human centrifuge allows the theory to be extended.

Ventilation and blood flow are measured using radioactive xenon and scanning the lung. In addition, pulmonary arterial pressures were monitored during acceleration, and a hydrostatic indifference plane was demonstrated lying 5 cm below the hilum. At this level, the pulmonary arterial pressure averaged 22.2 cm water (16.3 mm Hg) systolic, 9.3 cm water (6.8 mm Hg) diastolic, and had a mean pressure of 14.5 cm water (10.7 mm Hg). It was unaffected by accelerations of up to three times normal gravity (3 g). A gradient in intraoesophageal pressure was demonstrated by the use of a double balloon lying in the lower oesophagus, and this gradient, believed to be related to the density of the lung, was found to be proportional to the applied acceleration. It averaged 0.37 cm water/cm per g.

At 3 g with the subjects seated erect, the base of the lung was better ventilated than the apex (in terms of ventilation per unit alveolar volume) in the ratio of 2.6 to 1; the corresponding ratio at 1 g was 1.8 to 1. Ventilation increased linearly with distance down the lung at all levels of acceleration investigated. At 3 g, the upper 14 cm of the vertical height of the lung were without perfusion, and perfusion increased linearly with distance down the remaining lung three times as fast as it did at 1 g. At 1 g, only the uppermost 4.5 cm of the lung were without perfusion. The unperfused lung represented 45% of the total ventilated volume of 3 g and 13% of the total at 1 g. At 3 g, the pulmonary blood flow at the lung base was 3.3 times the average value for the whole lung, whereas at 1 g this excess was only 1.8 times.

These results are discussed in terms of an interstitial pressure gradient in the lung of the order of 0.3 cm water/cm per g along the gravitational axis, and an intravascular (hydrostatic) pressure gradient of 1 cm water/cm per g.

Glaister, D. H. The effect of positive acceleration upon cardiac output and regional blood flow in the dog. Aviation and Space Medicine, Oslo: Universitetsforlaget. 1969.

The fractional distribution of cardiac output was determined in 22 greyhound dogs using a modification of the radioisotope uptake technique of Sapirstein (1958). Nine of the dogs served as controls and 13 were studied during exposure to positive ($+G_z$) acceleration, four at 2.6 g and nine at 4.2 g. Cardiac outputs were determined in 20 of the dogs using dye dilution. After 60 sec at peak acceleration, a solution of radioactive rubidium chloride (containing approximately 100 cc of ^{86}Rb) was injected into the right atrium, together with 2.5 mgm of indocyanine green. The animals were killed 1 to 2 min later by an intra-atrial injection of 10 ml saturated potassium chloride and the centrifuge was then stopped. Representative tissues were sampled at autopsy and their up $^{86}RbCl$ determined using a well scintillation counter. The tissues studied included skin, blood, skeletal muscle and diaphragm, heart, lung, kidney and adrenal, liver, spleen, gut and pancreas.

Exposure to acceleration produced gross but often inconsistent changes in the distribution of the cardiac output, though the fraction going to the adrenals rose in all dogs and that to the heart in all but one. The blood flow to the diaphragm rose whilst that to other skeletal muscles fell. A gross reduction in kidney blood flow was seen in three dogs at 4.2 g and in one dog at 2.6 g. These and other results will be discussed in relation to a vasomotor response to acceleration stress.

Glaister, D. H. The effects of positive acceleration on lung mechanics and gas exchange. Ph. D. thesis, University of London, 1966.

Glaister, D. H. A flat beam collimator for radioisotope scanning of the lung. British Journal of Radiology, 1967, 40, 670-675.

Glaister, D. H. A low weight scintillation counter with focusing collimator. British Journal of Radiology, 1965, 38, 625-628.

Glaister, D. H. Lung collapse in aviation medicine. Br. J. Hosp. Med. 1969, 2, p. 635-642.

Glaister, D. H. Physiological problems associated with acceleration in space flight. Journal of the British Interplanetary Society, 1968, 21, 154-165.

Lung Function. Collimators for radioisotope (^{133}Xe) studies of lung function during exposure to positive acceleration. The theoretical requirements for collimators to be used in counting from fixed regions of the lung, or for detecting the vertical distribution of ^{133}Xe within the lung by scanning, are discussed. A 76-channel focusing collimator and a 27-channel focusing flat beam collimator are designed to meet these two sets of requirements, and their construction is described briefly. The performance of the two collimators under representative conditions is discussed in relation to their theoretical design and shows that, for a low energy gamma emitting source such as ^{133}Xe, septal penetration and scattering of radiation are negligible and may be ignored.

Glaister, D. H. Pulmonary gas exchange during positive acceleration. Report No. FPRC/1212, 14 p, 1963.

Pulmonary gas exchange and lung functions have been studied in man subjected to positive (headward, $+G_z$). Acceleration in the sitting position. During runs at 2-3 g lasting 1/2-5 minutes, the oxygen uptake fails to rise, or may even fall, despite the fact that an oxygen debt is being built up which is only repaid on return to 1 g. The oxygen debt is increased by increasing either the duration or the severity of acceleration, and is slightly decreased when an anti-g suit is worn. Breathing 100% oxygen has no effect on the development of the debt, which may reach 500-600 ml without an increase in oxygen uptake during the period of acceleration. Moderately severe exercise has to be performed during acceleration before the oxygen uptake is raised at 2-3 g, and following such a run the oxygen debt may reach 740 ml.

Marked inequalities in ventilation and perfusion are inferred from the pattern of carbon dioxide excretion during tidal and prolonged expirations at 3 g, and the effect of these on the reserves of oxygen and carbon dioxide in blood and tissues is discussed. A falling oxygen reserve secondary to these changes in lung function could explain the decrease in oxygen uptake during acceleration, but could only be responsible for a small fraction of the oxygen debt.

The bulk of the oxygen debt is probably due to the building up of products of anaerobic metabolism, but the reason for anaerobic metabolism at these low levels of acceleration is unclear. A number of other theories to explain the development of an oxygen debt are also discussed, but none provides a satisfactory explanation.

Glaister, D. H. Regional ventilation and perfusion of the lung during gravitational stress measured with radioactive xenon. Report No. FPRC/1236, 33 p, 1965.

The distribution of ventilation and blood flow within the lungs has been measured at rest and during positive acceleration using ^{133}Xe. The normal inequalities are increased so that, at 3 'g', the lower lung has 2.1 times the ventilation per unit lung volume of the upper lung, and the upper third of the lung is unperfused. These findings are explained on the basis of the hydrostatic pressure gradients which occur in the intrapleural space and in the mean pulmonary artery pressure with distance up the lung.

A method for measuring the ventilation of perfused alveoli is described, and with this method nonventilated alveoli have been demonstrated in the lower lung in man exposed to 3 'g' positive acceleration wearing an anti-g suit.

A method for demonstrating pulmonary arterio-venous shunting of ^{133}Xe is also described, and this has been used to demonstrate complete collapse of nonventilated alveoli following exposure to positive acceleration whilst breathing O_2 and wearing an anti-g suit.

Calculation shows that collapse of 7% of the FRC may result in a decrease in VC of 57%. Most of this reduction must be due to reflex limitation of inspiration.

Glaister, D. H. Regional ventilation and perfusion in the lung during positive acceleration measured with ^{133}Xe. Journal of Physiology, 1965, 177, 73-74.

Glaister, D. H. Transient changes in arterial oxygen tension during positive ($+G_z$) acceleration in the dog. Aerospace Medicine, 1968, 39, 54-62. A67-41653 (NASA).

Continuous recordings of arterial oxygen tensions were made in 20 greyhound dogs during 1-2 min exposures to positive accelerations in the range $+2G_z$ to $5G_z$. The recorded changes took place in three phases; a progressive fall during acceleration, a transient recovery following return to 1 G, and a delayed

final recovery. These changes are considered in relation to measurements of ventilation, pulmonary arterial and systemic arterial pressures, mixed venous oxygen tension, expired carbon dioxide concentration, blood carbon dioxide tension and right ventricular output. It is concluded that the observed changes result from, respectively, pulmonary shunting and a reduced cardiac output during acceleration, a redistribution of pulmonary blood flow and possibly also of ventilation on return to 1 G, and a persistence of shunting until closed off alveoli reopen. Right atrial infusions of radioactive xenon were used to monitor right heart output, and the pulmonary extraction of this gas was also investigated during acceleration.

Glaister, D. H., & Howard, P. The effect of positive acceleration upon pulmonary artery pressure in man. Report No. FPRC/1251, 16 p, 1966.

Pulmonary artery pressures have been measured in seated men during exposure to positive accelerations of up to 3 g. At 1 g values obtained from 4 subjects averaged 17.2 cm water systolic and 4.3 cm water diastolic (12.6/3.2 mm Hg) with a mean of 9.5 cm water (7.0 mm Hg), referred to the level of the pulmonary trunk. Exposure to positive acceleration led to a fall in recorded pressures, a 'hydrostatic indifference point' being demonstrated 8 cm below the pulmonary trunk. Results agreed well with predictions based upon previous measurements of pulmonary blood flow distribution, no evidence being found for a significant critical closing pressure in the pulmonary capillaries of the lung apex.

Glaister, D. H., Jones, J. G., & Clarke, S. W. The effect of acceleration on regional lung emptying. Journal of Applied Physiology, 1969, 6, 827-832.

The single breath test of Fowler was modified to produce wide regional differences in lung nitrogen concentration, by inspiring a small volume of nitrogen at residual volume into nitrogen free lungs. The subsequent pattern of sequential lung emptying at varying expiratory flow rates was studied in three normal subjects at increasing levels of acceleration up to $+4G_z$, by continuous analysis of the expired nitrogen. At slow expiratory flow rates there was a marked terminal rise in nitrogen concentration over the last 15-20% of the vital capacity. This rise and the proportion of the vital capacity over which it occurred increased with added acceleration, indicating closure of basal airway units at a progressively higher lung volume. With increasing expiratory flow rate the closure of airway units at higher accelerations was enhanced. It was predicted that there would be virtually no gas trapping at zero G, but a large volume at $+9G_z$ acceleration. Added acceleration changes lung emptying, and leads to increasing inequalities of ventilation and perfusion.

Glazier, J. B., & Hughes, M. B. Effect of acceleration on alveolar size in the lungs of dogs. Aerospace Medicine, 1968, 39, 282-292, 11 refs, A68-23709 (IAA).

Alveolar size has been measured in different regions of the lungs of dogs subjected to 3-g headwards acceleration ($+G_z$) and 5-g supine acceleration ($+5G_x$). The animals were frozen intact on a human centrifuge thereby fixing the lungs while they were exposed to the increased forces. The measurements were made using histological morphometric techniques. The normal gradient of alveolar size of 3.7 to 1 from apex to base in the vertical dog at 1 g increased to 11 to 1 at 3 g if the dog wore an abdominal binder as an antigravity suit. There was no significant change in the gradient of size when the abdominal binder was not worn. When exposed to an acceleration of 5 g, the most superior alveoli in the supine dog more than doubled their volume. Most of the alveoli more than 9 cm below the ventral surface of the dog were collapsed by the g forces.

Grandpierre, R., & Neverre, G. Cardiovascular reactions during space flights. La Recherche Spatiale, Jan. 1968, 7, 1-7, A68-22191 (IAA).

Study of the effect of space flights on the cardiovascular system, with particular attention to the effect of acceleration and deceleration. Acceleration usually provokes a sinus tachycardia, and sometimes leads to an alveolar collapse. After the propulsion stage, when weightlessness sets in, an abrupt decrease in the heart rhythm is observed. This short-phase bradycardia, together with a decrease in blood pressure, occurs at the time of an abrupt reoxygenation following hypoxia. The effects of transverse acceleration and physical exercise in the absence of gravity on the cardiovascular system are also discussed.

Gray, S., III, Shaver, J. A., Kroetz, F. W., & Leonard, J. J. Acute and prolonged effects of G suit inflation on cardiovascular dynamics. Aerospace Medicine, 1969, 40, 40-43.

The acute and prolonged effects of G suit inflation on cardiovascular dynamics were studied in 23 subjects in the recumbent position and in 5 subjects in the 60° passive tilt position. The G suit was inflated to 80 mm Hg in 3 seconds and rapidly sequential dye dilution cardiac outputs were performed simultaneously with the inflation, at 45 seconds, 5 minutes, and with deflation of the suit. Brachial artery and central venous pressures were constantly monitored by means of catheters and central blood volumes were determined. In the recumbent position the inflation of the G suit results in a 12 percent increase in the cardiac output associated with increases in the cardiac index, central venous pressure, and brachial artery pressure and a decrease in the pulse rate. By five minutes all parameters return to control level. In the passively tilted position the hemodynamic trends are identical to the recumbent position but the magnitude of the changes are greater and at five minutes of inflation the values have not quite approached normal. Release of the G suit results in a slight tachycardia with a drop in arterial and central venous pressure and an increased cardiac output and central blood volume suggesting reactive hyperemia. This study shows that acute G suit inflation augments venous return resulting in a transient increase in cardiac output. Prolonged G suit inflation causes reactive hyperemia which may result in an exaggerated loss of peripheral resistance when the garment is deflated.

Gualtierotti, T., & Gerathewohl, S. J. Spontaneous firing and responses to linear acceleration of single otolith units of the frog during short periods of weightlessness during parabolic flight. In Naval School of Aviation Medicine, The Role of the Vestibular Organisms in the Exploration of Space, 1965, p 221-229, N66-16126 (NASA).

Quantitative information on the effect of zero gravity on the vestibular responses is obtained by comparison of records from a single vestibular unit yielding spontaneous and evoked activity on weightlessness and at one G. A tungsten micro-electrode provides recordings from the same nerve fiber over a long period of time and under anticipated flight conditions. To select the desired fiber in the vestibular nerve, a frog is tested on a tilt table and then completely immersed in an aluminum container. During the flight, the frog is placed so that the otolith unit can respond to acceleration in the direction of the stimulus. During parabolic flight, main changes observed in the single otolith unit activity are (1) a sudden increase of spontaneous firing at the beginning of weightlessness preceded by a high G period; (2) an initial larger response to acceleration; (3) a sudden suppression of response, restored to normal by returning to one G; and (4) a large increase in overall spontaneous activity of the nerve after a number of short-interval parabolas. It is doubtful if these changes are due solely to weightlessness. Further, parabolic flight does not give complete information on the effect of weightlessness on the vestibular organ.

Guedry, F. E., Jr. Psychophysiological studies of vestibular function. In Contributions to Sensory Physiology, Vol. 1. New York: Academic Press, Inc., 1965, p 63-135, 163 refs. A65-25648 (IAA).

Investigation of the responses associated with ampular stimulation in human beings with particular attention to the responses elicited by rotation of the subjects and by exposure of them to linear velocities and accelerations. An analogy is worked out between a cupula-endolymph system and a heavily damped torsion pendulum by which it should be possible to predict the system's behavior if the value of the physical coefficients were known and the differential equations applied. Experimental evidence demonstrates that responses to stimuli are predictable and consistent when dealing with stimuli which are approximately the same as those found under normal living conditions. The sensations of rotation and nystagmus induced by vestibular excitation tend to follow similar courses even during unnatural stimulation, but extravestibular arousal may yield marked divergence of these two responses. The otolith system may provide linear velocity information, as experimentally demonstrated by the behavior of subjects on a parallel swing. The Coriolis vestibular reaction is described, and the role of time arousal influence is discussed. Habituation responses are considered in the light of experimental evidence relative to subjects in a rotating room.

Hoppin, F. G., Jr., Kuhl, D. E., & Hyde, R. W. Distribution of pulmonary blood flow as affected by transverse ($+G_X$) acceleration. Journal of Applied Physiology, 1967, 22, 469-474.

The distribution of blood flow in the pulmonary vascular bed under $+G_X$ (forward or transverse acceleration) was studied by intravenous injection of radioactive iodine 131-macroaggregated albumin (131 I-MAA) in three normal subjects while they were under $+1G_X$, $+4G_X$, $+8G_X$ on a human centrifuge. The resulting distribution of radioactivity in the lungs, representing the distribution of pulmonary blood flow at the time of injection, was assessed at 1-3 hours later by lateral isotope scanning. The distribution of pulmonary blood flow was not markedly different at $+1G_X$, $+4G_X$, and $+8G_X$ despite a difference between anterior and posterior pulmonary arterial pressures estimated to be 88 mm Hg under $+8G_X$. These findings indicate that under $+G_X$ (forward or transverse acceleration), unlike $+G_Z$ (headward or positive acceleration), the distribution of pulmonary blood flow is not markedly altered and the regional flow of blood in the lung may not be significantly changed by high intravascular pressures.

Hoppin, F. C., Jr., Sever, R. J., & Hitchcock, L., Jr. Pulmonary function in man under prolonged acceleration. II: Correlation of arterial blood oxygen saturation with ventilation and gas being breathed. December 1965, 23 p refs, N66-37247 (NASA) (Naval Air Development Center, Johnsville, Pa., Aerospace Medical Research Dept.).

Arterial blood oxygen saturation was studied by ear oximetry in 8 subjects undergoing prolonged forward $+G_X$ acceleration. The effects on saturation of voluntary breathing patterns and the composition of the inspired gas were noted. Under $+4G_X$ saturation levels were stable after two minutes. The degree of unsaturation could be modified to a small extent by voluntary breathing efforts. The level of saturation reached correlated significantly with the minute volume breathed. In contrast under $+8G_X$ saturation levels were significantly lower and were still falling after two minutes. Saturation levels were not significantly changed by voluntary breathing efforts and there was no significant correlation between level of saturation reached and minute volume breathed. Breathing of oxygen delayed the onset of arterial blood oxygen unsaturation. After two minutes under $+8G_X$, levels were 20% higher when the subjects breathed oxygen than when they breathed air. When subjects changed from air to oxygen or from oxygen to air on attaining peak acceleration, the effects of the prebreathed gas were apparent for as long as two minutes, suggesting that the prebreathed gas was effectively trapped in some part of the lung.

Huertas, J., Bracchi, F., & Epstein, B. Spinal reflexes during increasing gravity. In The Role of the Vestibular Organs in Space Exploration. 1966, p 151-158 refs, N67-15133 (NASA) (National Aeronautics and Space Administration, Ames Research Center, Moffett Field, Calif.).

An experimental technique is described that permits repeated experiments on the same animal under the same conditions. Monosynaptic responses are obtained in both cats and monkeys by this chronic preparation method when 1 g was applied for periods of 2 to 5 minutes. In animals that are awake, the monosynaptic reflex shows a sponstaneous variation in amplitude from one response to another; and at the onset of 1 g accelerational gravity and for several seconds thereafter, this variation disappears and the amplitude of the reflex increases. In all the animals there was a return to initial values after acceleration. Only after repeated accelerations, and particularly after higher values, was there a fall in reflex amplitude. It is found that the spinal reflexes are generally facilitated during acceleration, and it is postulated that a vestibular mechanism may influence this phenomenon.

Hyde, A. S., & Raab, H. W. A summary of human tolerance to prolonged acceleration. February 1965, 42 p, AD 615 570 (DDC) (Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio).

Human subject tolerance to accelerations of greater than one second duration is summarized for the orthogonal X, Y, and Z axis. Because each investigator at each laboratory utilizes different restraint systems, body positions, ambient temperatures, etc., and most important, utilizes different criteria of 'tolerance', the data are referenced and presented in tables and graphs for each major category (direction) of acceleration. The points presented in the graphs and tables are usually the highest values achieved; in each series there were subjects who could not tolerate the given direction, amplitude, and duration.

Igarashi, M., & Nagaba, M. Vestibular end-organ damage in squirrel monkeys after exposure to intensive linear acceleration. In The Role of the Vestibular Organs in Space Exploration. 1968, p 63-82 refs, N68-29134 (NASA) (Baylor Univ., Houston, Tex.).

Fifty-four squirrel monkeys were exposed to different levels of high intensity linear acceleration stimuli which were directed so as to produce a backward ($-G_X$) reaction force. Otoconia dislocation from

the maculae was observed by light microscopy after an exposure of 1 minute at the 60-g level and above, but was more constant and extensive after 1 minute at the 150-g level and above. No architectural change was detected either in the semicircular canal cristae or organ of Corti. In the monkeys which were exposed to 200 g for 1 minute and to a peak of 450 g, the ultrastructural changes noticed were increased lysosomes and transformation of mitochondria in the nerve chalice. Macroscopic examination immediately after exposure showed the severity of gross ataxia in the monkeys to be relatively parallel to the intensity of g levels. The ataxia rail test of dynamic equilibrium under a behavior-conditioning program carried out 2 to 35 days after exposure demonstrated the same results. No significant change from preexposure values was observed in the caloric threshold tests. Motion-sickness tests in the slow rotation room exhibited almost similar results, although the data were more fluctuating.

Iuganov, E. M., & Gorshkov, A. I. Reactions of the cupular apparatus during G-loading of an organism. Akademiia Nauk SSSR, Izvestiia, Seriia Biologicheskaia. Vol. 31, Nov-Dec 1966, p 816-825, 21 refs, A67-12324 (IAA).

Results of a study of the cupular function of man under acceleration. The latent stage, duration, frequency, and amplitude of the caloric nystagmus are investigated in 28 individuals under loads of 1, 2, 3, and 4 g, with biopotentials being transmitted to an electroencephalograph outside the centrifuge. The postrotational nystagmus is also investigated against a steady 1.2-g background. Acceleration is found to activate basic characteristics of the caloric and postrotational nystagmic reactions. The effect is linked to a functional interaction of the cupular and otolith structures.

Jacquemin, C., Varene, P., Damange, J., & Timbal, J. Recent aspects of respiratory physiology during transverse acceleration. In AGARD Collected Papers Presented at 22nd Meeting of the AGARD Aerospace Medical Panel, September 1965, p 149-177 refs. N66-33739 (NASA) (Centre d'Essais en Vol. Bretigny-sur-Orge France, Laboratoire de Medecine Aerospatiale).

Measurements of respiratory resistance by the interrupter technique confirm that transverse accelerations determine a restrictive respiratory syndrome without the participation of an overall obstructive syndrome. The magnitude of the restrictive syndrome tends to be reduced by a governing mechanism opposing thoracic compression. Similar facts were found both during artificial weighting down of the trunk and during respiration under negative pressure. It is stated however, that a comparison between these two situations is not justified. It is hypothesized that respiration under depression tends to be performed relatively homogeneously as a function of the way in which pressures are transmitted within the mechanical respiratory system while transverse accelerations cause a modification to the distribution of the heterogeneous gas blood system as a function of the centrifuging. Justifications for these hypotheses are given.

Jflek, L., & Trojan, S. Adaptation of the central nervous system to repeated acceleration. In Some Problems of Aviation and Space Medicine. P. Levit (Ed.) Prague: Karlova Universita, 1967, p 101-103, A67-40541 (IAA).

Brief description of experiments testing the survival times of rats exposed to radial acceleration. It is found that when rats are exposed to positive accelerations of 10 g for 42 min twice a day at 6-hr intervals from the first day of life, their resistance to ischemia is significantly higher than that of the controls. On the fifth day of life, their survival times are 15 min longer (60% increase) than in non-adapted animals. It is found that the developmentally immature nervous tissue of newborn animals can adapt to repeated acceleration significantly better than the more developed central nervous system tissue.

Kakurin, L. I., Akhrem-Akhremovich, R. M., Vanyushina, Y. V., Varbaronov, R. A., Georgiyevskiy, V. S. et al. The influence of restricted muscular activity of man's endurance of physical stress, acceleration and orthostatics. In Report presented at Soviet Conf. on Space Biol. and Med. 10 November 1966, p 110-117 refs, N67-13434 (NASA).

Four male subjects maintained strict bed rest for 20 days before undergoing endurance tests to determine the orthostatic factors following restricted muscular activity and the influence of hypokinesia on the motor-cardiac and vasopressure components of the circulatory regulation. Exercycle loads after prolonged rest produced decreased work quantities, oxygen consumption, pulse rate acceleration, arteriovenous differences and oxygenation of the blood. Rotation on a centrifuge was also tolerated with much more difficulty than prior to the enforced inactivity and indicated disorders in the functional regulation centers of the cardiac activity. Also discovered were symptoms of decreased lability of the main neural processes. It was concluded that enforced rest and prolonged maintenance of a horizontal position for man resulted in persistent functional disorders of the locomotor area as well as in the visceral system.

Kirkland, V. A., Leverett, S. D., & Newsom, W. A. A technic for photographing human retinal circulation during blackout on the USAFSAM human centrifuge. March 1968, 11 p refs, N68-35315 (NASA) (School of Aerospace Medicine, Brooks AFB, Tex.).

To study the human retina on a moment-to-moment basis during the rapid sequence of events occuring before, during, and after a blackout episode on the human centrifuge requires a technic which will not harm the subject, yet will allow constant viewing. In a previous study an ophthalmoscope was used to study the retinal changes and then the subjective impressions of the investigator were recounted to a medical illustrator. A method has now been developed using a modified Zeiss fundus camera which allows photographs to be taken on the retinal circulation every 0.6 second during the entire +G maneuver at the subject's blackout level.

Klimovitskii, V. I., Livshits, N. N., & Rodionov, M. I. General and cerebral hemodynamics and the functions of the central nervous system during accelerations - Review of the literature. In Certain Problems of Space Neurophysiology. N. N. Livshits (Ed.) Moscow: Izdatel'stvo Nauka, 1967, p 57-92, A67-40766 (IAA).

Review of papers on the mechanism of hemodynamic disorders related to cirdulatory disorders in the central nervous system during accelerations. General and local hemodynamic effects produced by positive and negative acceleration applied along the three anatomical axes are discussed, noting the cumulative behavior of these effects. Evidence is found for the existence of causes of disorders of vision other than a blood pressure drop in the cerebral arteries. Qualitative indications for a substantial effect of circulatory disorders on the reactions of the central nervous system to acceleration are noted. Insufficient quantitative knowledge of this effect is indicated, and further studies are urged.

Klimovskaya, L. D., & Smirnova, N. P. Some data on the mechanism of the disturbed perceptive function of the cerebellum during accelerations. In Space Biology and Medicine, Vol. 1, No. 6, 1967, p 41-48, N68-18906 (NASA).

Inhibition of induced activity of the cerebellar cortex in white rats exposed for 4 minutes to transverse accelerations of 10 g is described. A similar effect can be brought about by a high-frequency stimulation of the brain stem reticular formation. In this case it can be significantly alleviated by aminazin, whereas in case of accelerations the treatment produces no effect. This indicates a rather complicated genesis of the inhibition of cerebellar activity induced during accelerations. In addition to the influence of the reticular formation, it may involve a direct access of excess afferent signals to the cerebellar cortex, hemodynamic changes and a physical effect of accelerations on nerve cells.

Knepton, J. C., Jr. Centrifugation of the white-fronted capuchin monkey, Cebus albifrons (Humboldt). December 1966, 10 p refs. N67-25677 (NASA).

In preparation for biological experiments aboard orbiting laboratories three Cebus albifrons, white-fronted capuchin monkeys, were exposed to five headward-directed ($+A_z$) resultant linear acceleration stimuli aboard a centrifuge and their ECG's, skin temperatures, and breathing rates recorded. Marked tachycardia was noted at the start of the centrifugation, followed by bradycardia within 6 to 7 minutes at 7.5 g and within 1-1/2 minutes at 10.3 g. Concomitant with the onset of bradycardia, a loud squeal was usually heard. There were no significant temperature changes, and breathing rates did not vary from normal. Normal heart rate was restored upon cessation of centrifugation. It appears that the Cebus can withstand the acceleration of space travel and therefore will be a good experimental animal in that environment.

Konopacka, B. The effects of accelerated centrifugal force upon the development of the frog embryo. Morphological changes in frog embryos centrifuged at various developmental phases. October 1967, 38 p refs. N67-39930 (NASA).

Experiments by the author on the effect of gravitational force on the development of frog eggs are compared with those of Pflüger conducted in 1883-84 and others. The author investigates the differential effects of centrifugal acceleration applied during various well-defined phases of early development of frog eggs and the consequences of these effects upon the further course of the development. Eggs of Rana fusca were artificially fertilized in glass dishes. The eggs were subjected to a wide range of acceleration and temperature.

Korotaev, M. M., & Grigor'ev, A. I. Influence of laterally directed acceleration on certain kidney functions. Kosmicheskaia Biologiia i Meditsina, vol. 1, Nov.-Dec. 1967, p 70-75, 33 p refs. A68-19586 (IAA).

Experimental results of the effect of lateral accelerations on the functional state of human kidneys. Forty subjects aged from 19 to 42 were subjected to three acceleration experiments spaced from two to four days apart. The experiments involved (1) accelerations of 4 and 6 g for a duration of 120 sec at intervals of 5 to 10 sec, (2) an acceleration of 8 g for a duration of 60 sec, and (3) an acceleration of 10 g for 20 sec. The rate of acceleration was 0.2 g/sec. The quantity of the creatinine and nitrogen in the kidneys, before and after the experiments, demonstrated the insignificant dynamics of these indices and did not exceed normal physiological variations. The diuresis increased, due to higher globular filtration after the experiments. The number of erythrocytes in the urine increased by a factor of 1.5 to 2.5 after the experiments for all subjects.

Kotovskaia, A. R. Certain problems concerning the action of g-forces in space flight--cumulative and adaptive effects. International Astronautical Federation, International Astronautical Congress, 17th, Madrid, Spain, October 9-15, 1966, Paper. 19 p. 38 refs. N67-26624 (NASA).

Comparative study of the effects of single and repeated transverse g-forces on animals. It is found that animals trained by being subjected to repeated, gradually increasing g-forces, rather than being subjected all at once to a high g-force lasting from 1 to 3 minutes, may show certain adaptive effects, on the one hand, but may also show pronounced cumulative effects of a harmful nature.

Kotovskaia, A. R., Yeshanov, N. K., Vartbaronov, R. A., & Simpura, S. F. Physiologic reactions of cosmonauts to the action of acceleration during the flight of the spaceship "Voskhod." In Studies in Physiol. Reactions of Humans and Animals to Space Flight, July 1966, p 6-21 refs, N66-34321 (NASA).

The physiologic response to acceleration during the Voskhod manned spacecraft flight was investigated. Results obtained indicate that: (1) Cosmonaut physiological reaction during flight to the effects of g strain differed little from that observed in centrifuge rotation. (2) A 24-hour stay of three cosmonauts under conditions of weightlessness did not lead to an essential change in the level of tolerance to g strain arising from the return of the ship to earth. (3) Compared to centrifuge rotations, cosmonaut physiological reactions to g strain effects during descent to earth showed few individual peculiarities. (4) The preliminary preparation of the cosmonauts in the centrifuge was sufficient for satisfactory endurance of g strain under flight conditions.

Kutateladze, M. G. Reaction of solitary neurons in the visual region of the cat's cerebral cortex to stimulation of the vestibular apparatus. In Space Biology and Medicine, June 1967, p 60-63 refs. N67-29214 (NASA) (International Information, Inc., Philadelphia, Pa.).

Effects of vestibular excitation (exposure to 0.1 to 2 G) on the activity of the neurons of the optic cortex were studied in cats. The microelectric technique was used to monitor the neurons. The results obtained were processed by correlation analysis. Despite the change in the frequency characteristics of the neuron pulse activity, no correlation was found between the changes in neuron activity and the changes in acceleration values. This suggests that excitation of the vestibular apparatus produces a nonspecific effect on the optic cortex.

Lansburg, M. P., Guedry, F. E., Jr., & Graybiel, A. Effect of changing resultant linear acceleration relative to the subject on nystagmus generated by angular acceleration. Aerospace Medicine, 1965, 36, 456-460, 27 refs, A65-24081 (IAA).

Investigation of the effect of centripetal acceleration on nystagmus by placing men at radii of 17 and 20 ft in various orientations relative to the center of rotation. Angular accelerations and decelerations were approximately 10 deg/sec^2. In some of these different positions, the plane of the semicircular canals remained unchanged relative to the plane of rotation, but the orientation of the resultant force relative to the otolith system was changed. In several such situations the magnitude, plane, and direction of nystagmus were changed by centripetal accelerations between 1 and 2 g units. The results are discussed in terms of otolith modulation of sensory input from the semicircular canals.

Leverett, S. D., Jr., Kirkland, V. E., Schermerhorn, T. J., & Newsom, W. A. Retinal circulation in man during $+G_z$ acceleration. In Aerospace Medical Association, 1967 Annual Scientific Meeting, Washington, D.C., April 10-13, 1967, Preprints of Scientific Program. A67-41638 (IAA).

Photographic study of blackout during radial acceleration on a centrifuge. A series of color photographs shows moment-to-moment changes in the retinal circulation. Evidence is presented to confirm central retinal arterial pulsation followed by collapse in the optic disk region. During this arterial collapse, however, the retinal veins appear of normal size with blood gradually darkening. It is assumed that venous collapse may occur even before arterial collapse, provided that the collapse is due to a pure hydrostatic column difference. It may well be that anatomical deformation of the vein at its exit from the globe restricts outward flow, and, since the artery is already collapsed, and, presumably also the capillary bed, blood can only be trapped in the vein. This would also explain the gradually darkened appearance of venous blood while the arteries remain collapsed at the blackout level of the subject. The protection of gradually applied acceleration is demonstrated by showing the retinal circulation remains intact at a level higher under these conditions than when the acceleration is applied at a rapid rate.

Little, V. Z., Leverett, S. D., & Hartman, B. O. Psychomotor and physiologic changes during accelerations of 5, 7, and 9 G_x. Aerospace Medicine, 1968, 39, 1190-1197.

Nine men were studied for physiologic and psychomotor changes during $+5G_x$, $+7G_x$, and $+9G_x$. Each subject participated in three runs at one G level during a single session and underwent 3 such sessions, each at a different G level.

Acceleration stress resulted in a decrement of performance, with the degree of decrement dependent on the level of acceleration.

Heart rate also increased significantly as a function of the level of acceleration.

An increase in systolic blood pressure was dependent only on acceleration stress, without regard for the level of acceleration.

From the psychomotor and physiologic data considered simultaneously, it appears that: (1) performance decrement resulted from specific factors rather than physiologic insult; (2) there was a heightened level of physiologic response to higher levels of acceleration; and (3) the physiologic responses were within tolerable limits, and clearly short of any objective medical or operational end-point.

Matarai, G., Nagasaka, T., & Takagi, S. The effects of positive acceleration on the central nervous system. COSPAR, Plenary Meeting, 11th, Tokyo, Japan, May 9-12, 1968, Paper. 8 p. 8 refs. A68-31950 (IAA).

Study of the effects of positive acceleration on the central nervous system activity by applying negative pressure in the lower body of 82 unanesthetized rabbits. Negative pressures from 50 to 80 mm Hg were used. Measurements were based on cortical and depth EEG, cortical dc potential, cerebral blood flow and temperature, pinna skin temperature, and heart rate. Rather consistent changes in cortical dc potential were obtained by the exposure to negative pressure.

Mayne, R. Spatial orientation in a weightless environment. April 1966, 60 p refs, N66-32618 (NASA) (Goodyear Aerospace Corp., Litchfield Park, Ariz.).

A summary on the various studies on functional aspects of spatial orientation in the control of body movements is presented and a theory of the separation of gravity from acceleration is amplified to explain the reactions of man in space situations. Vertical direction determination and the attempted cancellation of gravity effects by head movements evolved as most likely causes of disturbances when man transfers from an earth to a weightless environment without prior adaptive exercises. Theoretical and experimental results indicate that otoliths and semicircular canals operate synergetically to perform the directional orientations; adaptation to a rotating platform seems to be more difficult than adaptation to a slow rotating room in an earth environment. The computer model simulation of motion sickness production by rotating chair mechanics was analyzed and a physical computer design concept for a simplified situation is outlined.

Meehan, J. P., Henry, J. P., Brunjes, S., & deVries, H. Investigation to determine the effects of long term bed rest on G-tolerance and on psychomotor performance. September 1966, 54 p refs, N68-25095 (NASA) (University of Southern Calif., Los Angeles, Calif., Dept. of Physiology).

Fourteen young men were confined to bed for 28 days. They were randomly divided into three subject groups of 5, 5, and 4 individuals. One group exercised, another did pressure breathing and the third did both. Each subject was exposed to a re-entry acceleration profile in the $-G_x$ position while performing a three dimensional tracking task prior to the bed rest and at the conclusion of the bed rest. Tilt table tolerance and blood volumes were determined in a similar sequence. Cardiovascular deconditioning manifested by plasma volume decrements of 20% and decreased tolerance to passive tilting resulted in all subjects and was not differentially affected by the exercise, pressure breathing or the combination maneuvers. Performance on the tracking task during acceleration was not affected by the cardiovascular deconditioning.

Michie, D. D. Hemodynamic responses of conscious dogs during exposure to various $+G_x$/back angle combinations. Aerospace Medicine, 1967, 38, 883-889, 16 refs. A67-39593 (IAA).

Study to determine the optimum angle for positioning astronauts so that maximum $+G_x$ levels could be tolerated with minimum distortion of cardiovascular functions. Conscious dogs, previously instrumented with ultrasonic flow probes (pulmonary artery, thoracic aorta, common carotid artery) or for pressure measurements (common carotid artery), were subjected to centrifugation of various levels and at different back angles. It is concluded that there is no single optimum back angle. Rather a back angle range between $+10^{\circ}$ through -10° appears to permit minimum distortion of cardiovascular function during a 90 sec exposure to $+G_x$ forces ranging from 1 through 10 with Gz components varying from -0.75 through +2.7.

Motohayasi, F., Ando, S., Yamada, K., Okajima, M., Hori, K., Muraki, H., Mitarai, G., Takagi, S., Suzumura, A., Miwa, T., Takehara, K., Suzuki, H., Murakami, U., Kameyama, Y., & Chiba, T. Effect of high gravity on a living organism. I- Preliminary report. Japanese Journal of Aerospace Medicine and Psychology, vol. 3, June 1966, p 55-68. A66-34408 (IAA).

Study of the effect of head-to-foot accelerations of up to 10 g on rabbits. The changes in the electrocardiogram, electroencephalogram, electroretinogram, fractionation of serum protein, eye ground, and histology of the brain and the internal organs during accelerations lasting from 20 to 30 min are observed. On the basis of an analysis of these data, ischemic conditions, presumably of central origin, in certain organs and congestion of blood in the abdominal organs are demonstrated.

Mulder, W. Quantitative relationship between stimulus and effect in the static organ. March 1968, 111 p refs. N68-19823 (NASA) (National Aeronautics and Space Administration, Washington, D. C.).

A literature survey is presented on the experimental data pertaining to static sensations and to the reflexes stimulated by the labyrinth. To show the quantitative relationship between stimulus and effect in the static organ, experiments were conducted on the otolith organs and on the semicircular canals. Pikes, frogs, turtles, and guinea pigs were used. The acceleration stimulus was kept as uniform as possible, and its effect was determined by recording the reflexes or determining the threshold of the sensations. With respect to reflexes in man, the reflex time of the rotation nystagmus was measured. Data are presented on the minimum perception, differentiation threshold, merging of rotation sensations, and progress of the sensation. A reference bibliography is included.

Murakchovskii, K. I. Biomechanics of the respiratory act during long-term accelerations (an X-ray study). In Space Biology and Medicine, Vol. 2, No. 5, 1968, p 105-114. JPRS-47249 (Joint Publ. Res. Serv., Washington, D. C.).

Using X-ray studies it was found that exposure of man to long-term accelerations of different directions results in peculiar changes of the topographic and anatomic relationships of thoracic organs. These changes play an important role in determining disorders in the biomechanics of the respiratory act. Among them the most important are deformations of the rib cage of the thorax and changes in the configuration and level of the diaphragm. The principal changes in the biomechanics of the respiratory act involve the following events. During exposure to relatively low accelerations (pelvis-to-head accelerations of 4 g and back-to-chest accelerations of 6 g) the respiratory amplitude of the diaphragm and ribs increases in comparison with the initial level (up to 50%). During exposure to accelerations of greater magnitude these indices show a relative and then an absolute decrease. With an increase in acceleration the ribs and muscles assume greater importance in the performance of respiration. Taking into account the more pronounced functional weakness of the diaphragmal component, the rib type of respiration (in the studied range of accelerations) must be considered more effective.

Newsom, W. A., Kirkland, V. E., Leverett, S. D., Jr., & Schermerhorn, T. J. Retinal fluorescence angiography during blackout in the human centrifuge. In Aerospace Medical Association, 1967, Annual Scientific Meeting, Washington, D. C., April 10-13, 1967, Preprints of Scientific Program. 1967, p 269, 270. A67-41639 (IAA).

Application of the fluorescence angiography technique to a study of the effects of centrifugal acceleration on the retinal circulation. Photographic evidence of the stopping of retinal circulation during blackout is obtained. It is shown that the arteries collapse with retrograde flow during blackout.

Nicholson, A. N. Thalamo-cortical activity during increased gravitational stress. Electroencephalography and Clinical Neurophysiology, vol. 21, August 1966, p 168-179, 38 refs. A66-82209 (LC).

Cortical responses of cats evoked by afferent stimulation of the visual pathway were observed during increased gravitational stress simulated by a centrifuge. An enhancement of the responses was observed during positive (long axis) acceleration and was related to the magnitude and duration of the linear acceleration. It was not induced by angular accelerations and did not occur during lateral acceleration. It is concluded that the hypotension induced by positive acceleration is essential to the changes in thalamocortical excitability. The phenomenon arises from reduced cerebral blood flow, but the central effect of carotid receptor activity may be involved. The effects are unlikely to be mediated by the reticular formation but probably arise from changes in cellular excitability induced directly at thalamic and cortical levels. It is suggested that in the conscious animal the increased sensory inflow of gravitational stress

may also modify thalamo-cortical excitability, and under these circumstances the effects of increased gravitational stress may modify both reticular and forebrain mechanisms.

Nyberg, J. W., Grimes, R. H., & White, W. J. Consequence of heart-to-foot acceleration gradient for tolerance to positive acceleration. Aerospace Medicine, 1966, 37, 665-668, 7 refs. A66-36373 (IAA).

Consequences of heart-to-foot acceleration gradients on tolerance to positive acceleration ($+G_z$) were determined in three studies on a variable radius centrifuge. In the first, tolerance was measured at radii ranging from 172 to 30 in., corresponding to gradients of 20 to 116%, respectively. As the radius decreased, the tolerance increased. At the shortest radius, discomfort in the legs resulting from the high acceleration at the feet precluded tolerance determination. In the second and third studies, low-intensity bioassay lights were used as a means of determining tolerance at lower levels of acceleration. In the third study, a slow onset run to blackout was used as a means of reducing the number of runs. Radii of 156 and 16 in. and rates of onset of 0.2 G/sec and 3.0 G/sec were used. At the long radius, tolerance was +3.9 G_z during slow onset, and +3.8 G_z during fast onset. At the 16 in. radius, during fast onset, tolerance was +3.0 G_z and, during the slow onset, tolerance was +3.6 G_z, +3.3 G_z, and +3.4 G_z.

Oyama, J., & Platt, W. T. Metabolic alterations in rats exposed to acute acceleration stress. Endocrinology, 1965, 76, 203-209, 30 refs. A65-23416 (IAA).

Extension of a previous investigation of factors involved in stress-induced liver glycogenesis. Fasted female Sprague-Dawley rats were exposed to a relative centrifugal force of 4.5 g for varying periods ranging from 0.5 to 96 hr, employing an 8.5-ft radius centrifuge. During the first 24 hr, there was a significant and sustained increase in the concentrations of blood glucose, plasma-free fatty acid, and plasma corticosterone. Plasma-free amino acids were decreased. Several of the glucogenic amino acids (alanine, arginine, phenylalanine-tyrosine, and proline) were decreased preferentially. There was a progressive increase in liver glycogen deposition detectable within the first hour of centrifugation which reached a maximum after 5 to 24 hr. The glycogen response was eliminated by adrenalectomy and hypophysectomy Adrenodemedullated rats showed a decreased glycogen response. Alloxan-diabetic rats did not show any increase in liver glycogen above the initially high levels present. The combined stresses of centrifugation and starvation effected a marked depletion of both liver and gastrocnemius muscle glycogen. Starvation alone resulted in an increase in liver glycogen with a concomitant fall in muscle glycogen. It is concluded that the liver glycogen deposited in acceleration-stressed rats is mediated by the secretion of corticosterone following activation of the pituitary-adrenal system.

Paige, L. D., & Kama, W. N. Visual acuity in relation to body orientation and g-vector. Journal of Engineering Psychology, 1965, 4, 45-56, 6 refs. A66-80777 (LC).

Twenty-four subjects were tested for left, right, and binocular acuity of near and far vision under each of four viewing conditions: (a) body upright, head upright, (b) body prone, head upright, (c) body supine, head inverted, and (d) body and head inverted. The first three conditions produced various combinations of acceleration and hydrostatic effects for control measurement, while the last condition effectively produced -1 g acceleration. Acuity was best in condition a, decreased by 5% in condition b, decreased by additional 5% in condition c, and decreased once more by 5% in condition d, when the fully hydrostatic effect was combined with the effect of -1 g at the eye. The total decrement in the visual acuity at -1 g amounted to approximately 15% which was comparable to the decrement in acuity comparable to that reported at 2 g. It appears that equal changes in either direction from the normal acceleration environment produce equal losses in visual acuity, with such losses increasing as a function of the amount of change.

Piemme, T. E., Hyde, A. S., McCally, M., & Potor, G., Jr. Human tolerance to G_z 100 percent gradient spin. Aerospace Medicine, 1966, 37, 16-21.

The concept of short radius on-board centrifugation has been suggested, should simulated gravity be found necessary during prolonged space flight. That this is not equivalent to a distributed gravity field is obvious. As a first step to any further consideration of such a device as a countermeasure to any deconditioning effects of space flight, further understanding of tolerance to, and physiologic effects of, high G gradient systems is necessary.

Seven Air Force volunteers have been studied on a short radius (4 foot, 9 inch) spin table with the subject restrained in the supine position, the Z-axis along the radius. Zero G_z was effectively achieved at eye level; maximum G at the feet. At two arbitrarily selected rates of onset (0.10 G per second and 0.05 per second) the tolerance to levels up to 7G maximum at the feet has been determined.

Electrocardiogram and respiration were monitored. Tolerance end-points were defined as peripheral light loss, cardiac rates in excess of 170 per minute, or the onset of such subjective symptoms as nausea, sweating, or lightheadedness. A logarithmic time duration curve may be constructed from 7 G, tolerable for 2 min. 41 sec., through 1 G, tolerable in excess of two hours (at which experiments were arbitrarily terminated). This clearly exceeds tolerance to standard long arm centrifuge acceleration. At high G levels, grey-out and tachycardia were found to be limiting; in the mid-zone range musculoskeletal discomfort of the back and lower extremities was prominent, but not as limiting as in standard low gradient $+G_z$ profiles. Coriolis phenomena were marked, and demanded fixation of head position. Hematocrits and free fatty acids did not change as a function of G load.

With these background data, one is now in a position to study the high gradient spin system as a countermeasure to adverse effects of "deconditioning" due to bed rest, water immersion, etc.

Piemme, T. E., McCally, M., & Hyde, A. S. Renal response to $+G_z$ gradient acceleration in man. Aerospace Medicine, 1966, 37, 1253-1256, 28 refs. A67-16288 (IAA).

Experimental determination of the effect of high gradient acceleration on the renal clearances of free water and creatinine following a moderate water load. The results imply that acceleration impairs the ability to excrete a water load, and, further, that the response is mediated by antidiuretic hormone.

Pinc, B. W., & Mehelas, J. N. The response of squirrel monkeys to high accelerative forces of brief duration. In Aerospace Medical Association, Annual Scientific Meetings, 37th, Las Vegas, Nev., April 18-21, 1966, Preprints. 1966, p 189, 190, 9 refs. A66-32187 (IAA).

Survey of small simian response to very high g, demonstrating that the squirrel monkey is able to survive unconventionally high (up to 430 g) accelerative stress. Though the samples in each mode are not large enough for statistical proof, indications are that the G_x mode is more lethal than G_y and that there is a lethal "stress threshold" above 1×10^3 kg-g-sec. Three different lethal mechanisms seem to be present, related to the g level.

Putzulu, A., & Rota, P. Experimental investigation of the effects of Müller's maneuver on tolerance of $-G_z$ acceleration. Rivista di Medicina Aeronautics e Spaziale, vol. 29, Oct.-Dec. 1966, p 615-630, 13 refs. A67-25172 (IAA).

Investigation of the effectiveness of Müller's maneuver (forced inhalation with closed glottis) in increasing tolerance to the effects of negative acceleration in 10 healthy subjects exposed to $-0.91\ G_z$. The results obtained showed that Müller's maneuver improves tolerance to negative G, throughout the maneuver, provided it is properly performed. The usefulness of performing the maneuver during 100%-oxygen breathing, and of preparatory training, is pointed out.

Reed, J. H., Vandenberg, R. A., & Wood, E. H. Effect of gravitational and inertial forces on regional distribution of pulmonary blood flow. Physiologist, (Wash.) 1967, 10, 288.

The distribution of pulmonary blood flow (DPBF) in ten mongrel dogs in the right lateral position was determined by an embolization technique utilizing radioactive plastic 35 ±5 microspheres. Injections were made into the right ventricular outflow track while recording femoral and pulmonary arterial, left atrial, and airway pressure. Cardiac output (CO) was determined by dye dilution. The lungs were air dried under 30 cm H_2O pressure for four days, embedded in urethane foam, cut coronally in fifteen to eighteen, one-centimeter slices, the fraction of total lung volume in each slice determined by planemetry and multiple one cubic centimeter sections for each slice capped in a scintillation well counter. DPBF to the dependent lung outgrowth varied from 50 to 73 percent of the total CO. The total of values were associated with higher left atrial pressure and vice-versa. Under increased acceleration, superior regions showed a progressive decrease in the fraction of the cardiac output pulsing through it as compared to 1 G (0.2 to 6.1 at 2 G, 4.5 to 8.0 at 4 G, and 7.5 to 18.4 at 6 G). In the mid-lung region, the fraction of CO increased similarly to the loss in superior region where as the most dependent region of the lung showed little changes inspite of the fact that the greatest change in hydrostatic pressures occurred here. DPBF plus O_2 saturation data from superior and dependent pulmonary veins suggest that redistribution away from the most dependent region occurred towards the end of the 60-second exposure. (Supported in part by NASA research grants.).

Roberts, V. L., Terry, C. T., & Stech, E. L. Review of mathematical models which describe human response to acceleration. American Society of Mechanical Engineers, Winter Annual Meeting and Energy Systems Exposition, New York, N. Y., Nov. 27 - Dec. 1, 1966, Paper 66-WA/BHF-13. 12 p. 58 refs. A67-15402 (IAA).

Review of the models which have been proposed to describe both the reaction of the human body as well as the specific response components of the body when placed in a dynamic environment. The response of bone and soft tissue as predicted by rheological models is first considered. Models have also been constructed for joints, appendages, the head and neck, the spine, and abdominal organs. Whole body models are described which fit experimental data reasonably well and are of use in engineering design calculations.

Rogge, J. D. Relation of signal light intensity of physiologic end points during $+G_z$ acceleration. May 1968, 7 p. SAM-TR-68-38. (Brooks AFB, Tex., USAF School of Aerospace Medicine, Aerospace Med. Div.).

Results of previous studies suggest that lowering the luminance of the signal lights lowers the blackout and grayout level during $+G_z$ acceleration. In this study, variations in luminance of the central and peripheral signal lights in the range that is suitable for routine centrifuge operation failed to produce any detectable change in blackout or grayout levels. The visual phenomena described in the previous studies may have arisen mainly from such local changes in the eye as changes in visual threshold, retinal metabolism, and visual acuity; whereas, blackout obtained with light intensities used in this study resulted from hemodynamic changes caused by $+G_z$ acceleration and possibly some local changes in the eye itself.

Rogge, J. D., Fasola, A. F., & Martz, B. L. Peripheral venous renin levels during $+G_z$ acceleration. Aerospace Medicine, 1967, 38, 1024-1028.

Renin secretion, as measured by changes in peripheral venous renin levels, was used to evaluate the part played by the renin-angiotensin system in the response to $+G_z$ acceleration.

Centrifuge runs were done on the USAF SAM Human Centrifuge and the subjects were members of the USAF SAM Acceleration/Deceleration Panel.

A larger increase in the renin level was found each time the run duration was increased at $+2G_z$. The mean increase in the 20 minute samples was 0.36 ng./ml. ($p < 0.05$) and in the 30 minute samples was 0.76 ng./ml. ($p < 0.01$). A mean rise of 0.63 ng./ml., found after 30 minutes at $+2G_z$ while wearing an anti-G suit, was not significantly different from the rise found in the 30 minute runs without the G-suit.

The renin-angiotensin system may play a part in the response to $+G_z$ acceleration, either alone or in conjunction with the autonomic nervous system.

Rogge, J. D., Meyer, J. F., & Brown, W. K. Comparison of the incidence of cardiac arrhythmias during $+G_x$ acceleration, treadmill exercise and tilt table testing. Aerospace Medicine, 1969, 40, 1-5.

The occurrence and significance of cardiac arrhythmias during acceleration have been discussed by several authors. Recently, a large group of men was referred to the USAF School of Aerospace Medicine for medical evaluation which included exposure to $+G_x$ acceleration, treadmill exercise and tilt table testing. Because of the different hemodynamics during these procedures, a comparison of the incidence of cardiac arrhythmias during these tests was felt to be of interest.

The electrocardiographic records of a total of 61 normal male subjects taken during evaluation on the human centrifuge, treadmill and tilt table were examined for arrhythmias.

There was a significantly increased incidence of arrhythmia during $+G_x$ acceleration compared with that during treadmill and tilt table tests as well as a difference in the predominant type of arrhythmias.

The contributions of cardiac chamber distention, sympathetic nervous system activity, circulating norepinephrine levels and respiratory pattern to the production of the arrhythmias are discussed.

Rosenhamer, G. Influence of increased gravitational stress on the adaptation of cardiovascular and pulmonary function to exercise. Acta. Physiol. Scand., 1967, 68, Suppl. 276.

The bulk of physiological research on the effects of exercise has so far been restricted to the normal gravitational environment to investigate the potential effects of increased gravitation stress upon the adaptation of circulatory, respiratory dynamics to exercise, 12 healthy subjects were exposed to a force three times that of normal gravity in the human centrifuge (3 G) while performing leg exercise on a

bicycle ergometer in a sitting position. The effects of exercise at work loads of 300 and 600 kpm/min., lasting for up to nine minutes were studied and compared with those obtained at normal gravity (1 G).

Rossanigo, F. A simple device for the collection of blood samples from subjects subjected to acceleration by means of a centrifuge. Rivista di Medicina Aeronautica e Spaziale, vol. 28, Jan-Mar 1965, p 77-81. A65-81443 (LC).

A description is presented of the method and apparatus used in obtaining blood samples from subjects during centrifugal acceleration experiments. The apparatus consists of two units with two syringes permitting the obtaining of two blood samples through catheters inserted into the subjects circulatory system during movement of the centrifuge. The blood is easily passed through another catheter aided by an electromagnet which commands the release of the piston of the second syringe. This method is suitable for obtaining arterial and venous blood samples from animals using catheters during centrifugal movements up to 15 g. Included is a diagram and photograph of the apparatus.

Rutishauser, W. J., Banchero, N., Tsakiris, A. G., & Wood, E. H. Effect of gravitational and inertial forces on pleural and esophageal pressures. Journal of Applied Physiology, 1967, 22, 1041-1052.

Seven dogs were exposed to forward, backward, and right and left lateral accelerations for 60 seconds at mean levels of 2.1, 4.3, and 6.7 G. Intrapleural pressures at dorsal (paravertebral), ventral (retrosternal), left and right sides plus esophageal pressure were measured by saline filled catheters and P 23 D Spatham gauges. Increasing acceleration, end-exploratory pleural pressures decreased at sites which, depending on body position, were superior in the thorax and increased at sites which are dependent. Esophageal pressures exceeded pleural pressures interpolated to the same level during all conditions studied. Interpolation of pleural and esophageal pressures to zero G gave -5.5 and -2.7 cm H_2O, respectively, independent of body position and site of measurement. It is concluded that differences in pleural pressure recorded at different sites in the thorax are caused by the weight of the thorax contents and that the resulting pressure imbalances impose a limitation on the levels and durations of accelerations that can be tolerated with safety by animals and man when a given depth of lung is oriented in the direction of the resultant vector of acceleration.

Sadoff, M., & Dolkas, C. B. Acceleration stress effects on pilot performance and dynamic response. IEEE Transactions on Human Factors in Electronics, vol. HFE-8, June 1967, p 103-112, 14 refs. A67-33176 (IAA).

Several brief studies were conducted to assess the effects of a wide range of acceleration environments, varying from zero gravity to high sustained accelerations, on pilot performance and dynamic response. The results indicated that the control performance decrements observed at high sustained accelerations were attributable to decreased pilot gains and corresponding reduction in open-loop system crossover frequency. Limited results for extreme vibratory accelerations suggested that performance deterioration was associated with a reduction in pilot lead equalization (and a corresponding reduction in open-loop crossover). Under short-term weightless conditions, performance in a simulated control task was appreciably poorer than under comparable 1 g conditions for one of two sets of simulated vehicle dynamics investigated. The reason was attributed primarily to increased pilot excitation of the vehicle's lightly damped short-period mode. Soviet data, available from Voskhod flights, indicated that cosmonauts did not perform as well in a simulated control system as during ground training sessions.

Saito, I., Fujihara, H., & Iwane, M. The effects of g force on body temperature. Aerosp. Med. Psychol. vol. 2, p 78-83, 1965, 10 refs. A65-31345 (IAA).

The influence of g force on rectal temperature was studied in rats. The rats, fixed in appropriate cages, were subjected to positive 5, 10, and 15 g; negative 5 g; and transverse 5, 10, and 15 g. The rectal temperature was measured with thermistors at 3-minute intervals after the stress until recovery. In positive g, the rectal temperature decreased 3.2° C., 3.7° C., and 5.4° C. from the control level after 5, 10, and 15 g, respectively, suggesting that the magnitude of decrease of the temperature is a function of the stress. In the case of transverse g, relation is not clear, as the temperature decreases were 2.9° C., 4.1° C., and 3.1° C. at 5, 10, and 15 g, respectively. None of the rats tolerated the negative 10 and 15 g; and at negative 5 g, temperature decreased 3.1° C. The recovery of the temperature took place immediately after the stress; the greater the stress, the less recovery was revealed. The characteristic finding in recovery was the lack of the tremor which had appeared in recovery from low temperature stress. The possible mechanism for the disappearance of tremor is discussed.

Sandler, H. Angiocardiographic and hemodynamic study of transverse (G_x) acceleration. Aerospace Medicine, 1966, 37, 901-910, 27 refs. A66-42450 (IAA).

Cardiopulmonary hemodynamics were studied in dogs during acceleration at $+5G_x$, $+10G_x$, and $+15G_x$ on the dynamic flight simulator at the Aerospace Research Department of the U.S. Naval Air Development Center. Changes in cardiopulmonary parameters were correlated with changes in the heart and lungs recorded by cineradiography and cineangiocardiography using a 9-in. image intensified X-ray system. Decreases in cardiac output and stroke volume were recorded by dye dilution techniques in all animals and confirmed by cineangiocardiographic studies. A marked and consistent fall in arterial oxygen saturation was also recorded. A role of atelectasis as the cause for this fall in oxygen saturation was discussed.

Sandler, H. Cineradiographic observations of human subjects during transverse accelerations of $+5G_x$ and $+10G_x$. Aerospace Medicine, 1966, 37, 445-448.

X-ray motion pictures were recorded for five human subjects during transverse accelerations of $+5G_x$ and $+10G_x$ on the Johnsville centrifuge. Quantitative measurements of change in A-P chest diameter and heart position were made from photographic prints of the films. A slight but significant posterior displacement of heart position could be demonstrated when compared to change in the A-P chest diameter.

Shul'zhenko, E. B. Characteristics of reflex regulation of hemodynamic changes under the action of transversely directed acceleration forces. Biull. Eksper. Bio. Med. vol. 60, p 36-39, October 1965, 8 refs. A66-80496 (LC).

During the action of transversely directed acceleration forces of 9 g continuing for one minute anesthetized dogs were found to have reflex changes in the cardiovascular system. While the hemodynamic changes took place two phases were noted: a phase of functional disorder and a phase of compensation. The latter was observed during the action of overload and was strikingly manifest in the period after completion of rotation. The degree of disturbance in the first phase and the appearance of compensatory hyperfunctions depend upon the integrity of the system of reflex self-regulation of the blood circulation. The carotid sinuses are an important link in the chain of compensatory mechanisms of blood circulation regulation during the action of transversely directed acceleration forces.

Sinha, R. Effect of vestibular coriolis reaction on respiration and blood-flow changes in man. Aerospace Medicine, 1968, 39, 837-844, 86 refs. A68-38087 (IAA).

Simultaneous measurements of forearm blood-flow and respiration have been made in 24 subjects. Each subject was secured in a chair mounted centrally on a horizontal turntable and accelerated to 30 rpm. Rotation at this constant speed was maintained for 5 to 8 min with the head held stationary in relation to the turntable. Then vestibular stimulation was caused by imposing a nodding motion on the head by means of an automatic mechanical device. Blood-flow, respiration rate and volume, and end-expiratory carbon dioxide concentration were measured continuously. Arterial blood samples taken

from five subjects before and after the run were analyzed. Vestibular stimulation caused, almost invariably, an increase in minute ventilation forearm blood-flow and arterial pH, as well as a decrease in end-expiratory and arterial carbon dioxide levels. Although expiration was usually prolonged and jerky, the effects of vestibular stimulation on the respiratory rate and duration of inspiration and expiration were variable. During the 10- to 12-min period after the cessation of vestibular stimulation blood-flow and minute ventilation fell to or below control levels. These findings suggest that the effects of vestibular stimulation may predispose to vasovagal syncope and reduce tolerance to G forces.

Sorokina, Y. I. Certain aspects concerning oxygen metabolism of the body exposed to prolonged accelerations. In Space Biol. and Med., Vol. 1, No. 2, September 1967, p 38-43 refs. N67-39010 (NASA) (Joint Publications Research Service, Washington, D. C.).

Changes in oxygen metabolism of muscular and brain tissues of animals exposed to prolonged transverse accelerations (oxygen tension and redox potential) are described. The paper also discusses the total oxygen consumption and body temperature under the same conditions. A many-faceted approach to the processes studied allows one to establish new regularities in oxygen metabolism of muscular and brain tissues. Their evaluation helps to understand the role of the changes in tolerance of the body for accelerations on the whole.

Spoendlin, H. H., & Graybiel, A. Ultrastructure of the otolith organs in squirrel monkeys after exposure to high levels of gravitoinertial force. Aerospace Medicine, 1965, 36, 497-503, 32 refs. A65-26164 (IAA).

Results of exposing eleven squirrel monkeys to gravitoinertial force of either 5.43 or 10.92 g units for periods up to 10 min in different body (head) positions. Three animals died. The nature of the head support was believed to be responsible in two, and headward (negative) acceleration in the other. Gross examination of the brains revealed no pathological changes. Following centrifugation some of the monkeys manifested disturbances which disappeared in minutes or hours. Human subjects have experienced some of the manifestations following high-g loadings. The ultrastructure of the maculae, revealed by electron microscopy, was not altered in any of the animals exposed to high-g stress. It was concluded that exposure to gravitoinertial forces greater than 10.92 g units is necessary before physical alterations in fine structures of the macula can be demonstrated in squirrel monkeys. The possibility was not ruled out that the clinical manifestations had their genesis in the semicircular canals. If the g loadings in this experiment are not exceeded in orbital space flights, alterations of the macula would be ascribable to other causes, including the prolonged deafferentation associated with weightlessness.

Stone, H. L., & Alexander, W. C. Abdominal blood flow changes during acceleration stress in anesthetized dogs. Aerospace Medicine, 1968, 39, 115-119, 7 refs. A68-20603 (IAA).

Measurement of the changes in abdominal blood flow during acceleration stress by a hydrogen-electrode technique used in nine anesthetized dogs. The electrodes were implanted in the renal cortex, adrenal gland, and the small intestine. Measurements of tissue blood flow, heart rate, and mean arterial pressure were made at levels of acceleration up to $+12G_x$ in the supine position. The position of the animal was changed in 10° increments towards the head-up position, with 30°-head-up tilt being the maximum tilt used. These measurements were repeated at each G level until no discernible tissue flow could be measured. The tissue blood flow was found to remain within normal limits up to 6 or 8 $+G_x$ in the supine and 10°-head-up positions, but was found to be significantly reduced about these G levels. In the 20°- and 30°-head-up positions more rapid decline in tissue flow occurred. The changes in mean arterial pressure and heart rate were recorded.

Sytinskiy, I. A., & Avenirove, Y. L. The gamma-aminobutyric acid system in the brain of animals under the influence of loads. In Probl. in Aerospace Med. 21 October 1966, p 466. N67-11650. (NASA) (Joint Publications Research Services, Washington, D. C.).

The gamma-aminobutyric acid system, which has an inhibiting effect on the bioelectric processes in the cerebral cortex, is studied to determine the effect of accelerations. Under the influence of loads the system of gamma-aminobutyric acid in the brain did not change. The hemato-encephalic barrier effectively blocked the penetration of the acid into the brain when administered. However, the effect of loads was manifested in a disturbance of the integrity of the hemato-encephalic barrier with the occurrence of a depressive action in the central nervous system due to the penetration of the gamma-aminobutyric acid.

Tabusse, L., & Pingannaud, P. M. Physiopathological effects of accelerations in astronautics. Revue Fraincaise d'Astronautique, July 1967, p 11-18 refs. A67-36833 (IAA).

Discussion of some aspects of the problem of accelerations in astronautics. The axis generally followed by different accelerations is determined, and the action of accelerations on the human body is investigated from the standpoint of their duration, intensity, and their effect on the oxygenation of arterial blood. Organic lesions caused by these accelerations are indicated.

Terry, C. T., & Roberts, V. L. A viscoelastic model of the human spine subjected to $+g_z$ accelerations. Journal of Biomechanics, vol. 1, July 1968, p 161-168. 11 refs. A69-19725 (IAA).

Description of a viscoelastic rod model of the human spine, which includes damping and is used to simulate the spinal column mathematically. This one-dimensional rod was subjected to a ramp input acceleration, and the theoretical acceleration at the end of the rod was compared to the experimental head acceleration data from previously conducted cadaver tests. The need for an accurate mathematical model of the spine subject to $+g_z$ acceleration arises from the problems involved in the seat ejection of pilots from aircraft. The mathematical model is used in subtolerance level testing of volunteers and cadavers for extrapolation in the prediction of spinal failure due to acceleration. Results show that the overall response to the viscoelastic rod closely approximates the true acceleration response. They also point to further modifications, such as the use of a viscous element in which the viscosity is a function of the strain rate. It is suggested that model modification continue until a discrete number of mass-spring-dashpot elements (one for each vertebra) is achieved, in order to collect more complex experimental data on the quantitative and qualitative behavior of the individual components of the spinal column.

Torphy, D. E., Leverett, S. D., & Lamb, L. E. Cardiac arrhythmias occurring during acceleration. Aerospace Medicine, 1966, 37, 52-58.

Forty-two pilots were exposed to $+G_x$ and $+G_z$ acceleration in a variety of profiles and the incidence of arrhythmias investigated.

$+G_z$ acceleration did not increase the incidence of arrhythmias. $+G_x$ acceleration increased the incidence of arrhythmias and this increase seemed related to both the degree and duration of acceleration.

Premature contractions, with and without aberrant conduction, from both the atria and ventricles were noted. One subject had paroxysmal atrial tachycardia with $+G_x$ acceleration.

Possible causal mechanisms are discussed.

Urschel, C. W., & Hood, W. B., Jr. Cardiovascular effects of rotation in the Z axis. Aerospace Medicine, 1966, 37, 254-256, 10 refs.

Rotation of the seated subject about the Z axis (Rz) results in a radial acceleration gradient impeding venous return thereby representing a cardiovascular stress. The cardiovascular responses of volunteer subjects instrumented with indwelling arterial and venous catheters were measured during four rotational profiles combining two rates of angular acceleration (0.1 and 0.8 radian per second per second) and two rotational speeds (60 and 120 rpm). There was a three-minute plateau at peak velocity. Centripetal acceleration at hand/foot radius (0.5 meter) was 1.8 and 7.4 g at 60 and 120 rpm, respectively. Rotation at 60 rpm represented no significant stress. Three-minute 120 rpm runs however caused progressive tachycardia, narrowing of pulse pressure, and a drop in mean arterial pressure, thus inferentially a drop in cardiac output. Tolerance would thus be expected to be limited by the ability of the circulation to maintain venous return.

Vacca, C., Vacca, L., & Causa, L. Electroencephalographic changes in albino rats subjected to high tangential (transverse) acceleration before and after splenectomy. Riv. Med. Aeronaut. Spaziale, 28, p 292-301, July-September 1965. A66-19085 (IAA).

Experimental investigation in which three-lead EEG's were recorded from 12 albino rats of both sexes with average weights of 250 g, subject to complete barbituric anesthesia (full resolution of postural tone) in normal animals and in animals 10 days after splenectomy, before, during and after application of high transversal acceleration ranging from 3 to 6 to 8 or 9 g for 90 sec. It is noted that the experimental results show that the changes of frequency, morphology, and voltage observed after splenectomy in basal EEG waves are not clear enough to be considered as significant alterations of the bioelectric activity of nervous cells, at least in the light of the pilot research carried out so far.

Vandenberg, R. A., Nolan, A. C., Reed, J. H., & Wood, E. H. Regional pulmonary arterial and venous shunting caused by gravitational and inertial forces. Journal of Applied Physiology, 1968, 25, 516-527.

Superior (SPV) and dependent pulmonary venous (DPV) aortic, and pulmonary arterial (PA) lung oxygen saturation were measured simultaneously and continuously in anesthetized dogs before, during, and after exposures to acceleration in different body positions. In right and left lateral decubitus positions during respiration with air or 99.6 percent oxygen, blood oxygen saturation in DPV decreased to the same level as PA, remained unchanged in SPV, and decreased in aortic to a level between that in DPV and SPV. These changes, as their time course suggests, indicate that a pulmonary arterial-venous shunting occurs in dependent regions of the lungs and is caused by a combination of compression and absorption atelectasis of dependent alveoli. During respiration with 99.6 percent oxygen aortic saturation increased, and calculated total (mixed) shunt decreased toward the end of 120 second exposures to five to seven g acceleration in lateral position, and more strikingly in the first 30 seconds after termination of the exposures. In fact these decreases in total (mixed) shunt occurred despite persistent 100 percent arterial-venous shunting by a dependent region of the lungs suggests redistribution of pulmonary blood flow away from the atelectactic areas.

Vandenberg, R. A., Nolan, A. C., Williams, J. C. P., Strum, R. E., & Wood, E. H. Regional pulmonary arterial-venous shunting during exposure to transverse acceleration. In Aerospace Medical Association, Annual Scientific Meeting, 37th, Las Vegas, Nev., April 18-21, 1966, p 228, 229. A66-32195 (IAA).

Consideration of the decrease in arterial blood saturation during and after transverse acceleration, attributed to pulmonary arterial-venous shunting in dependent regions of the lungs considered to have become atelectatic as a result of the increased weight of the blood and thoracic contents relative to air. This postulate was examined in anesthetized dogs exposed to 2, 4, and 6 g acceleration in the supine ($+g_x$) and prone ($-g_x$) positions during IPP respiration with air and 99.6% oxygen, and also during spontaneous respiration with 99.6% oxygen. The site of the pulmonary arterial-venous shunt was localized to dependent regions of the lungs by comparing the oxygen saturation of the blood withdrawn continuously from superior and dependent pulmonary veins through cuvette oximeters with similarly determined blood oxygen saturation levels in the aorta.

Vasil'ev, P. V., & Kotovskaia, A. R. Prolonged accelerations-G-forces. In Space Biology and Medicine. V. I. Iazdovskii (Ed.) Moscow: 1966, p 105-137, 124 refs. A66-43136 (IAA).

Study of the physiological disturbances caused by the action of prolonged accelerations on the human organism. A brief description is given of the four main types of accelerations. The results of studies of the effect of g-forces on the central nervous system, the respiration and gaseous metabolism, and the cardiovascular system of the human organism are cited. The problem of the maximum g-forces tolerance level in humans is considered from both the biological and physiological standpoints, and methods of increasing this level are suggested.

Veenhof, V. B. On the influence of linear acceleration on optokinetic nystagmus. Acta Oto-Laryngol., 60, p 339-346, October 1965, 33 refs. A66-80960 (LC).

Rabbits showed a strong enhancement of the number of nystagmus beats if a linear acceleration was combined with optokinetic stimulation. A parallel swing provoked the linear acceleration. On this apparatus the rabbit in prone position was submitted to optokinetic stimulation. Another phenomenon recorded in the experiments was the appearance of nystagmus in a situation where optokinetic stimulation normally fails to provoke nystagmus. Nystagmus was found when one eye was covered and the other was subjected to optokinetic stimulation from nasal to temporal and simultaneously linear acceleration

was given. The nystagmus frequency in those cases was the same as in the cases in which the stripes were running in the opposite direction.

Ward, B. Electroretinogram during 100 percent $+G_z$ gradient acceleration in dogs. Aerospace Medicine, 1968, 39, 468-474, 29 refs. A68-29060 (IAA).

Six anesthetized beagles were exposed to graded $+G_z$ stress on a short radius centrifuge. The ERG (response to a strobe flash) was recorded with an intracorneal electrode. ERG, ECG, and aortic blood pressure (BP) were telemetered to a recorder. The ERG a-wave decreased only at the higher G_z levels. Amplitude of the b-wave fell by 40 to 100% at 1.5 to 3.0 g. Transient increases were noted in b-waves during early stages of acceleration stress and attributed to the effects of anoxia. Mean BP fell as low as 40% of control with later compensatory recovery. Heart rates increased up to 40% above control. ERG recovery was frequently incomplete 10 to 15 min after 3 to 4 min runs at the higher g levels. The amplitude of the b-wave provides a useful physiological index of $+G_z$ acceleration stress, due to retinal ischemia. Application in human studies requires further evaluation of the relationship between retinal and cerebral ischemia in $+G_z$ stress.

Wood, E. G. Cardiopulmonary effects of acceleration in relation to space flight. International Symposium on Basic Environmental Problems of Man in Space, 2nd, Paris, France, June 14-18 1965, Preprint No. 23. 20 p. 12 refs. A65-26531 (IAA).

Investigation of the effects of transverse acceleration on intrathoracic pressure relationships for dogs in the supine, prone, left decubitus, and right decubitus positions. It is felt that, since the average dorsal-ventral thoracic dimension of 20 cm for the dogs studied is similar to that of human subjects, the hydrostatic effects of acceleration on intrathoracic pressures should also be similar when the dogs are in the supine position. Pleural pressures are recorded simultaneously from ventral, dorsal, and lateral regions of the thorax using fluid-filled catheters which are radio-opaque. Pressures are also recorded from the potential pericardial space, the right and left atria, the pulmonary artery, aorta, the oral end of an endotracheal tube, and the esophagus. Runs of 55 sec at accelerations ranging from 2 to 7 g are made with the dogs supported in molded plastic casts. The results indicate that the cardiopulmonary effects of acceleration have a significant probability of causing a mission-limiting or mission-failure threat to the functional integrity or welfare of astronauts.

Wood, E. H. Some effects of gravitational and inertial forces on the cardiopulmonary system. Aerospace Medicine, 1967, 38, 225-233, 15 refs. A67-23810 (IAA).

Discussion of the effects of backward, forward, and transverse acceleration on the cardiopulmonary systems of men and dogs. The effects of forward acceleration on intrathoracic pressures and of "force environment" on mean pressures in pulmonary circulation are shown in diagrams. It is concluded that the lungs are man's most vulnerable organs with respect to his capability to withstand high acceleration levels.

Wunder, C. C., Milojevic, B., & Eberly, L. Growth and food consumption of labyrinthectomized hamsters during chronic centrifugation at 5G and 6G. Nature, 1966, 210, 177.

The results reported support the previously unsubstantiated contention that developmental changes evoked by chronic centrifugation can be explained primarily in terms of an effectively enhanced gravity. Greater nonrotary effects are possible with other organisms or with slightly altered centrifugation procedures. Application of labyrinthectomy to related investigations provides a useful tool in distinguishing the rotary from the gravitational effects of centrifugation.

Yegorov, P. I., Smirnov, K. V., Korotayev, M. M., & Luskasheve, M. V. Effects of acceleration and hypokinesia on the functional state of the stomach. In Kosmich. Bio. Med. (USSR), vol. 1, no. 2, 1967, p 71-74. N67-38019 (NASA) (Scientific Translation Service, La Canada, Calif.).

The experiments were performed on 5 male test subjects who were twice exposed to chest-to-back accelerations of 11.9 - 14.5 g with an interval of 4 to 6 days. After the exposures the test subjects remained in the state of hypokinesia for 2 months after which they were reexposed to accelerations of 11 to 16 g. The exposure to accelerations inhibited the secretory and enzyme forming gastric functions. The acidity of the intestinal juice tended to increase. Hypokinesia conditions produced further inhibition of the stomach glands.

York, E. Post-flight discomfort in aviators: aero atelectasis. Aerospace Medicine, 1967, 38, 192-194.

Three jet pilots recently flew high G bank maneuvers, while breathing 100 percent oxygen and wearing anti-G harnesses, as part of an in-flight project for weapons systems development. As a consequence, on more than one occasion, all three pilots experienced shortness of breath, cough, and aching in the chest--this latter symptom persisted as long as 3 hours following flight. Physical examination was unremarkable. Pulmonary function study revealed a reduction in vital capacity, immediately following flight, of 20-28 percent as compared to preflight levels outside the plane. A partial, reversible collapse of lung tissue ("aero-atelectasis") may be the mechanism for the observed finding, which could conceivably contribute to aircraft accidents, if not modified.

York, E., Colosi, N. J., & Roediger, J. H. Human biochemical parameters of accelerative stress. April 1966, 20 p refs. AD 632 817 (DDC) (Naval Air Development Center, Johnsville, Pa.).

Acceleration stress conditions were imposed on four healthy subjects riding the human centrifuge. Blood biochemical analyses were performed on all subjects, with the demonstration of an increase in blood glucose following centrifugation in three of the four subjects, two of whom developed blackout. All four subjects developed grayout. The changes in blood sugar may suggest a relationship between epinephrine secretion and graduated acceleration stress resulting in physiological changes in the subject. Changes in pooled plasma phospholipid fractions were demonstrated in blood samples obtained before and following acceleration; these changes suggest that acceleration may interfere with intracellular energy transfer mechanisms involving phosphorylated compounds associated with oxidative metabolism. The preliminary results of the pilot project indicate that further biochemical measurements may be desirable in assessing acceleration tolerance in man.

York, E., Oleynik, R. J., & Patton, R. M. Human acceleration experience at the Aerospace Medical Research Department, U.S. Naval Air Development Center, Johnsville, Pa. 1 January 1961 - 30 December 1965. In Aerospace Medical Association, 1967 Annual Scientific Meeting, Washington, D.C., April 10-13 1967, Preprints of Scientific Program. 1967, p 143-144. A67-41590 (IAA).

Study of the effect of acceleration exposure on 380 subjects accelerated on a centrifuge during the period from 1961 through 1965. The symptoms occurring most ofter were: grayout, blackout, and motion sickness; chest pain, dyspnea, and arrythmia. The following miscellaneous complaints were noted: abdominal pain, headaches, syncope, limb myalgia, and parasthesia.

SECTION II

ANGULAR ACCELERATION

Brown, J. H., & Wolfe, J. W. Adaptation to prolonged constant angular acceleration. January 1968, 40 p refs. N68-21397 (NASA) (Army Medical Research Lab., Fort Knox, Ky. Experimental Psychology Div.).

Two independent groups of normal human subjects were exposed to a number of long-duration (up to 96 sec), relatively high-intensity (3 degrees/sec sq - 24 degrees/sec sq) constant, angular acceleration. Nystagmic decrements during stimulation were clearly evident. The decrements were initiated at about the same time after stimulus onset (30-35 sec) for all accelerations used. The decrements in the nystagmic responses were compared to related findings for both subjective and electrophysiological responses.

Clark, B. Thresholds for the perception of angular acceleration in man. Aerospace Medicine, 1967, 38, 443-450, 63 refs. A67-29267 (IAA).

The paper reviews 25 studies which report stimulus thresholds for the perception of angular acceleration in man. These reports constitute a miscellany of definitions of threshold, rotation devices, and psychophysical methods. The thresholds reported varied between 0.035 and 8.2°/sec^2. The results of the effects of several experimental variables on thresholds are reviewed. The data support the notion that man is extremely sensitive to angular acceleration, particularly under optimum conditions. However, two critical limitations of these studies - i.e., the small number of observers studied and the lack of direct measures of angular acceleration - and the variation in methodology between studies limit the generalizations from the data.

Colehour, J. K., & Graybiel, A. Biochemical changes occurring with adaptation to accelerative forces during rotation. Aerospace Medicine, 1966, 37, 1205-1207, 9 refs. A67-16277 (IAA).

The effects of periodically increasing rotational velocity were studied in four young naval officers in the Pensacola Slow Rotation Room. Stress effects originating in the vestibular region as the result of Coriolis forces produced adrenalcortical response, nausea, and mild hyperventilation. Adaptation was virtually complete after two days of rotation at 6.4 rpm, and no further stress effects from rotational forces could be measured although the velocity was increased incrementally each day to 10.0 rpm and then similarly decreased to 3.0 rpm. After adaptation the effects of continued inactivity were measured as decreased excretion of norepinephrine and mild degrees of hypercapnia and hypercalciuria.

Collins, W. E., & Guedry, F. E. Vestibular reactions in cat and man during and after angular acceleration. 1: Responses from the lateral and the vertical canals to two stimulus durations. June 1967, 19 p refs. N67-39777 (NASA) (Naval School of Aviation Medicine, Pensacola, Fla.).

Ocular nystagmus was recorded in darkness from cat and man during 4-deg/sec^2 accelerations about an Earth-vertical axis. Lateral-canal stimulation yielded greater primary and secondary nystagmus than did vertical-canal stimulation. In cat, both lateral- and vertical-canal responses to a 36-second stimuli peaked after 15-21 seconds of angular acceleration, and this was followed by a steady decline. Declines during acceleration were not apparent in nystagmus of man. There was a more consistent secondary nystagmus in cat than in man. In cat, primary after-nystagmus was greater following a 8.4 second stimulus than following a 36-second stimulus. In man, a like difference occurred in the sensation but was not present in nystagmus. In this regard, nystagmus from cat resembled the subjective reactions of man more than they did the nystagmus of man.

Cramer, R. L., Dowd, P. J., Moore, E. W., & Collins, F. G. The changing parameters of the habituating vestibular system, June 1964-January 1967. September 1967, 12 p refs. N68-20060 (NASA) (School of Aerospace Medicine, Brooks AFB, Tex. Aerospace Medical Div.).

Nystagmus responses to a Coriolis stimulation were recorded from a human subject over a period of ten sessions of four stimuli each. The response can be approximated by simple negative exponential growth and decay functions. Repeated exposure results in a reduction of the subject's sensitivity to the stimulus. At the same time the dynamic characteristics of the system mediating the response change so as to provide a more rapid recovery from the stimulus. Both of these changes are beneficial to a pilot, as they improve his resistance to some forms of spatial disorientation.

Dean, F. R., Graybiel, A., & Wood, C. D. Effect of drugs in altering susceptibility to motion sickness in aerobatics and the Slow Rotation Room. Aerospace Medicine, 1967, 38, 842-845, 12 refs. A67-38083 (IAA).

Seven exemplary antimotion sickness drugs and three "individually treated" placebos were investigated in 10 men during 24 aerobatic maneuvers in an A1E "Skyraider" aircraft and in performance of a Slow Rotation Room (SRR) dial test. The rank order of drug effectiveness and of subject susceptibility under each condition was determined and compared. Individual differences in drug effectiveness was significant at the .01 level or better and was similar under the two conditions. Susceptibility to motion sickness in the SRR was generally a good predictor of susceptibility in aerobatics in eight subjects, but

in the remaining two it was grossly in error. A combination of scopolamine and d-amphetamine was by far the most effective of the drugs tested.

Dowd, P. J., & Cramer, R. L. Habituation transference in Coriolis acceleration. Aerospace Medicine, 1967, 38, 1103-1107, 8 refs. A68-12137 (IAA).

Coriolis accelerations in flight adversely affect a pilot's efficiency and physical fitness by two vestibular reactions. One is illusions; the other is vestibulo-autonomic reactions. In this study both these vestibular reactions were modified by the subject's being repeatedly exposed to rotary stimulation while being passively tilted in different planes of rotation or while actively tilting his head into a rotary plane. Three conditions were used during rotation: chair tilts in the lateral plane, active head movements in the lateral plane, and active head movements in the sagittal plane. Results indicate habituation (a decrement in nystagmus, in subjective sensations, and in somatic responses) after repeated exposure to each condition. Transference of this habituation to one head movement or position change appears to have some effect on the duration of nystagmus and sensations to exposure to another head movement or position change. The dynamic characteristics of nystagmic responses and the autonomic reactions, however, do not show any significant transference of habituation. Thus, transfer of habituation cannot be obtained for different conditions. Each condition must be practiced separately despite their similarity in sensations and nystagmic responses.

Dowd, P. J., Wing, M. E., Cramer, R. L., & Collins, F. G. Effects of high acceleration on vestibulo-ocular responses. September 1967, 14 p. AD 665-443 (DDC) (School of Aerospace Medicine, Brooks AFB, Tex.).

Preliminary investigations into the effects of high linear accelerations on the vestibulo-ocular responses to both caloric and Coriolis stimulations were made. Pilots were subjected to short-duration accelerations on the USAF School of Aerospace Medicine centrifuge. A spontaneous slow-phase downward nystagmus was observed in some pilots in post-centrifuge tests. Some peripheral and central-neural modification resulting from centrifugation was observed.

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de Francesco, E., Caporale, R., & Mazza, G. Electronystagmographic investigation in man subjected to complex acceleration. Rivista di Medicina Aeronautica e Spaziale, 1966, 29, 145-149, 9 refs. A68-13809 (IAA).

Investigation of the effects of mild centripetal acceleration on nystagmus caused by variable angular acceleration. A few subjects underwent, on a suitably modified Toennies chair, rotary stimuli, with their heads on the axis of the rotating system, and 15 and 30 cm from the axis, with both labyrinths equidistant from the axis. Latency time, nystagmic-response duration, number of amplitude of oscillations, slow-phase velocity, and vertigo severity were investigated. The results obtained point to a greater excitability of the vestibular apparatus stimulated at 15 cm from the rotation axis, warranting the hypothesis of the probable existence of the highest point of vestibular excitability in eccentric rotary stimulation with a short radius, beyond which, when centripetal acceleration is increased, excitability tends to decrease gradually.

Galle, R. R., & Emel'ianov, M. D. Results of physiological studies in a slowly rotating chamber. In Kosmicheskaia Biologiia i Meditsina, vol. 1, 1967, p 72-79, 11 refs. A68-14847 (IAA).

Results of a series of 16 sessions of observations of the effects of centripetal and Coriolis accelerations on the vestibular function of a group of eight male subjects subjected for seven days to steady rotation at a rate of 10 or 40^{o}/sec in a special chamber. EKG, heart-beat rate, nystagmus, arterial pressure, cutaneous galvanic reaction, equilibrium preservation in the complex Romberg position, and fluctuations of the center of gravity are covered by observations. A certain reduction of adaptation capability during prolonged exposure to slow rotation is established. The 40^{o}/sec rate of rotation is not considered to be the tolerance rate.

Gozulov, S. A., Morozova, N. P., & Eivanov, V. A. Study of the cumulative effect of impact accelerations. Kosmich. Biol. i Med. (USSR), vol. 1, no. 2, 1967, p 22-26. N67-36123 (NASA) (National Aeronautics and Space Administration, Washington, D.C.).

Experiments on rats were performed to study the cumulative effect of impact accelerations of 600 g revealed at postmortem examinations. The accelerations were applied at different intervals and subcritical landing velocities. The cumulative lesions resulting from repeated exposures with an hour interval were detected as the primary lesion on the lungs similarly to the effect of a single exposure at supercritical velocities. Lesions developed after a comparatively small number of repeated exposures (3 to 5) for a wide range of subcritical velocities (7 to 4-5 m/sec). The aftereffect period covers over 24 hours and is related to reactive changes in individual organs.

Graybiel, A., Deane, F. R., & Colehour, J. K. Prevention of overt motion sickness by incremental exposure to otherwise highly stressful Coriolis accelerations. Aerospace Medicine, 1969, 40, 142-148, 18 refs. A69-19425 (IAA).

Discussion of an experiment in which overt symptoms of motion sickness at 10 rpm were prevented solely by means of incremental increases to terminal velocity. This demonstrated that the adaptive processes somehow inhibited the irradiation of vestibular activity to cell assemblies in cerebellar, hypothalamic, and other areas concerned in the genesis of symptoms and that "habituation of symptoms" was not essential in their prevention. By ensuring the subject's stability, these processes may properly be regarded as homeostatic in nature, preserving a homeostatic state. This implies that slow rotation room sickness may be defined as a failure in homeostatic processes caused by too sudden an exposure to strong Coriolis acceleration.

Guedry, F. E., Jr., & Collins, W. E. Vestibular reactions in cat and man during and after angular accelerations. II: Responses to lateral canal stimuli of various accelerations. June 1967, 15 p refs. N67-39776 (NASA).

A direct relationship between duration of acceleration and decline of response during acceleration, rate of decline of response after acceleration, and magnitude of secondary reaction is regarded as an indication of a central process which limits a prolonged vestibular primary reaction. The process is manifested by its influence on relatively basic reflex reactions (nystagmus) in the cat, and is more prominently manifested in man by its influence on sensory perception.

Iwane, M., Ono, M., & Sawada, M. Effects of Coriolis stimulus during mild centrifugal G load upon stick performance. Japan Air Self-Defence Force, Aeromedical Laboratory, Reports, March 1968, 8, 135-141, 12 refs. A69-18023 (IAA).

Investigation of the influence of Coriolis stimulation in a low-g field on spatial orientation and accompanying stick performance. Twenty healthy adults (18 males and 2 females), none of whom were pilots, were subjected to mild centrifugal g loads (up to +1.1G_z), and simultaneous Coriolis stimulation (right and left face turn). EKG, ENG, and stick performance were studied, and the subjective complaints of the subjects were examined. Under clockwise centrifuge at slower than 6 rpm (g level of 1.14 g) it was noted that subjects tended to move the stick in a right-forward direction when their heads were turned to the left. This reaction is considered dangerous if duplicated by pilots during circling or turning in aircraft at low altitudes.

Korneyeva, N. V., & Ushakov, A. S. Some aspects of acetylcholine metabolism in the brain and heart of guinea pigs exposed to angular accelerations. In Space Biology and Medicine, Vol. 1, No. 6, 1967, p 49-54, N68-18906 (NASA).

The acetylcholine content and cholinesterase activity in the brain and heart of guinea pigs exposed to angular acceleration of 1.5 g for 6 hours were investigated. The greatest changes were exhibited by bound acetylcholine. In both organs its content increased sharply in 10 minutes, decreased in 24 hours, and reached normalcy 120 hours after exposure. Tests made at different times revealed a slight decrease of free acetylcholine in both organs with a return to normalcy 120 hours after exposure. The patterns of change of general acetylcholinesterase and pseudocholinesterase activities in the brain and heart tissues were different. The activities of these enzymes increased slightly in the brain tissues and decreased slightly in the heart tissues and returned to normalcy 120 hours after exposure.

Letko, W., & Stone, R. W., Jr. The effects of the plane of vestibular stimulation on task performance and involuntary eye motion. In The Role of the Vestibular Organs in Space Exploration. 1968, p 49-55 refs, N68-29132 (NASA) (National Aeronautics and Space Administration, Langley Research Center, Langley Station, Va.).

The influence of different orientations on vestibular stimulations was studied. To determine the effect of the subject orientation and the resulting differences in cross coupled angular accelerations on task performance, experiments were performed in a rotating space vehicle simulator with the subjects facing axially and tangentially. Results are summarized in relation to rates and amplitude of head-turning motion at various rates of simulator rotation for subjects facing axially and tangentially, and response time while turning head at various rates of simulator rotation for subjects facing axially and tangentially. Results indicate that for a turning head motion, the stimulation experienced by the tangentially oriented subjects is considerably different from that experienced by the axially oriented subjects and that the subjects could tolerate greater cross coupled accelerations when facing tangentially than they could while facing axially.

Lim, S. T., & Fletcher, J. Cardiovascular response of men to stimulation by sinusoidal gravitational field. Aerospace Medicine, 1968, 39, 130-138, 22 refs. A68-20606 (IAA).

Experimental investigation in which seven subjects were each subjected to three-minute roll and pitch rotations at 1.5 to 16 rpm, using a rotation flight simulator. The center of rotation was at the level of the iliac crest. EKG, respiration, prerun and postrun blood pressure, rotational rate, and subject position were continuously telemetered to an eight-channel Beckman strip-chart recorder. The data showed that cardio-acceleration in response to turning toward head-up position was gradual and that cardio-deceleration in response to turning to head-down position was rapid. The peak of cardio-acceleration lagged behind the directly head-up position, while the trough of cardio-deceleration lagged behind the directly head-down position. These phase lags tended to increase with increase of rotational rate. The maximum-to-minimum heart rate range was greatest at the slow rpm and diminished as the rpm was increased. No striking difference was found in the response characteristic between the roll and pitch profiles. The EKG pattern appeared to be related to body position. The blood pressure did not show undue hypertension or hypotension resulting from the rotation. The results were interpreted in terms of the cardiovascular response to stimulation by the sinusoidal component of the earth's gravitational field resulting from the rotation.

Markaryan, S. S. The effect of angular and Coriolis acceleration on certain functions of the human organism. In Effect of Space Flight on Various Physiol. Functions, 30 June 1965, p 34-45 refs. N65-26921 (NASA) (Joint Publications Research Service, Washington, D.C.).

The effects of angular accelerations at rotational speeds of 180, 360, 540, and 720 degrees/second; and the effects of Coriolis accelerations at speeds at 180, 360, and 540 degrees/second; on the physiological responses of seated human subjects, were studied. Augmentation of the speed and duration of angular acceleration caused an increase in the duration of vestibular nystagmus and the illusion of counter-rotation. During angular acceleration and shortly thereafter, there was a deterioration in the ability to discern dial indicators and signs. With augmentation of the speed, there was an increase in pulse and respiration frequency. Repeated angular acceleration lead to general fatigue, disturbances in stasis, and to vestibulo-vegetative disturbances in persons with moderate vestibular sensitivity. Following angular acceleration there was a slowing of the pulse, a reduction in maximal arterial pressure, and an increase in minimal arterial pressure. By altering the position of the head during rotation a displacement of surrounding objects was experienced. With repeated inclinations and increased rotational rates, the displacement effect was amplified and vestibulo-vegetative disturbances occurred more rapidly.

Meiry, J. L., & Young, L. R. Biophysical evaluation of the human vestibular system. January 1968, 14 p refs, N68-25143 (NASA) (Massachusetts Institute of Technology, Cambridge, Mass., Man-Vehicle Control Lab.).

This research was conducted to evaluate the dynamic characteristics of the human semicircular canals by a detailed examination of their physical properties and to correlate them with physiological and behavioral data. Properties of viscosity, thermal coefficient of viscosity, density, and thermal coefficient of expansion were measured for endolymph and perilymph and were used to evaluate the coefficients of the equations of the dynamic response of the semicircular canals. The influences of the inertia and viscous drag of the cupula and of the flexible membranous canalicular duct have resulted in a new dynamic model for the response of the semicircular canals to angular and linear acceleration. Canalicular response to thermal stimulation was found to produce the physiological equivalent of an angular acceleration.

Oosterveld, W. J., & Zelig, S. Effects of a combination of chlorcyclizine hydrochloride and cinnarizine on the linear acceleration test. Acta. Physiol. Pharmacol. Neerl., November 1965, 13, 348-354, 15 refs. A66-80816 (LC).

Three different combinations of chlorcyclizine hydrochloride and cinnarizine were tested as to their effect upon the amplitudes of the eye movements stimulated by linear acceleration on the parallel swing. The test was carried out in 25 human subjects as a double blind test with the three different combinations and a placebo. The authors found a significant (depressive) effect of the combinations of the drugs on the sensitivity of the otolithic part of the vestibular apparatus. The combination of the drugs was advantageous because it combined a faster onset and prolonged action as compared with the effect of each drug used separately.

Parker, D. E., von Gierke, H. E., & Covel, W. P. Preliminary studies of vestibular damage in guinea pigs following high acceleration. In The Role of the Vestibular Organs in the Exploration of Space, 1965, 183-194, 1 ref. N66-16121 (NASA).

Guinea pigs were exposed to high impact deceleration on a sled and short-duration acceleration on a centrifuge. Behavioral examination of swimming ability and the righting reflex revealed evidence of vestibular damage following exposure to peak acceleration in the range of 200-400 g for periods of 14-20 sec. Histological examination of the temporal bones demonstrated extensive structural damage for the same animals which exhibited behavioral deficiency. No evidence of behavioral damage has been observed

following exposure to impact deceleration. Also, histological evidence of damage is considerably less following impact deceleration than short-duration centrifugation.

Polyakov, B. I. Vestibular-vegetative adaptation upon prolonged periodic action of Coriolis accelerations on an organism. In Probl. in Aerospace Med., 21 October 1966, p 405. N67-11616 (NASA) (Joint Publications Research Service, Washington, D.C.).

To investigate the possibility of creating artificial gravity by rotating a space ship about its own axis, studies were made on the vestibular apparatus of rabbits subjected to prolonged rotation. The change in threshold, and the times of the onset and nature of the vestibular-vegetative adaptation, depending on the duration of the effect, were established. The Coriolis accelerations, motion sickness, and nystagmic reactions are mentioned.

Rothe, W. E., Pope, E. E., Lim, S. T., & Fletcher, J. G. Research on human physiologic response to prolonged rotation and angular acceleration. a. Engineering activities; b. Physiologic activities. September 1967, 99 p. N68-20957 (NASA).

Physiologic research has explored the responses of humans to rotation and acceleration. The test vehicle was the Rotational Flight Simulator, an air bearing suspended sphere with unrestricted rotational freedom propelled by internally mounted inertia rings and, later, by a single axis external drive assembly. Engineering efforts established the dynamics and improved the control of the vehicle. Instrumentation was provided for the readout, display, and recording of significant data serving for physiologic evaluation and medical monitoring. The data were telemetered pictorial display of the subject and two-way communication links were provided. A total of 138 experiments yielded valid physiologic and human performance information in a rotational environment from fractional to 16 rpm and for several minutes to a maximum of 30 minutes. The subjects consisted of 7 young, healthy males. Results indicated that the RFS properly used and instrumented represents a valuable and unique test vehicle; that changes in heart rate, and EGG readings depended on body position with respect to gravity; that electro-oculogram, subjective sensations, incipient nausea, and ability of the pilot to right the stationary sphere after tumbling--all depended on the rate, duration, and axis pattern of rotation.

Shul'zhenko, E. B. Nervous reflex mechanisms of hemodynamic shift control during rapidly and slowly increasing acceleration. Kosmicheskaia Biologiia i Meditsina, 1967, 1, 45-49, 6 refs. A67-26757 (IAA).

Study of the function of the cardiovascular system of dogs under morphine-chloralose-nembutal anesthesia during acceleration. Systolic pressure and frequency of systolic contractions in the left ventricle, and systolic, diastolic, pulse and average pressure in the aorta during a systole are determined in two groups of dogs subjected for 1 min to chest-to-back acceleration of 9 g reached either in 30 sec or in 2-1/2 min. The results showed a better adaptivity of the blood circulation system to the slower rate of acceleration buildup.

Solodovnik, F. A., Vorob'ev, L. M., & Khlebnikov, G. F. Mechanism of stimulation of the semicircular canals in humans during rotation in two mutually perpendicular planes. Akademiia Nauk SSSR, Izvestiia, Seriia Biologicheskaia, January - February 1968, p 78-88, 20 refs. A68-21793 (IAA).

Investigation of the effects arising in the human semicircular canals during simultaneous rotation in two mutually perpendicular directions, using a rotating chair and straightening the subject's head from a position initially inclined at 90°. Rotation with a simultaneous inclination or straightening of the head causes a shift of the endolymph in the semicircular canals due to the formation of a pair of inertial Coriolis forces. Rotation with simultaneous displacement of the head relative to the axis of rotation and without inclination causes identical (in magnitude and direction) Coriolis acceleration at all points of the canal. The inertial shift of the endolymph does not arise in this case nor does the pair of rotational forces. To avoid stimulation of the canals during manual labor under space flight conditions it is necessary to move the head in a forward direction--i.e., without rotation relative to the vehicle.

Tardov, V. M. The question of human tolerance of brief gyrations with large magnitudes of angular accelerations and speeds. In Probl. in Aerospace Med. 21 October 1966, p 469-470. N67-11652 (NASA).

Human resistance to the effect of brief angular accelerations (0.2 and 0.25 seconds) was demonstrated in a series of rotation tests. Rotation was accomplished around a transverse axis passing near the center of gravity of the test subject, and also around a longitudinal axis of the body passing vertically between the pyramids of the temporal bones. In both series of experiments there was an absence of vestibular disorders and nystagmus. It was concluded that brief specific action on the semicircular canal of the labyrinth, even in the case of considerable angular accelerations, is a weak stimulus for the vestibular analyzer.

Weaver, R. S. Theoretical aspects of the role of angular acceleration in vestibular stimulation. 1968, 38 p. N68-34656 (NASA) (Defense Research Medical Labs, Toronto, Ontario).

Various types of acceleration are systematically considered, and it is shown that turntable accelerations generally consist of several components, each readily calculable. The equations of motion are applied to the human vestibular apparatus when undergoing acceleration. Turntable experiments and the physical effects of the associated motions are analyzed, with emphasis on the forces experienced by the semicircular canals. The applicable vector algebra is developed, and equations of motion are derived in vector form. Graphs and a nomograph are presented for evaluating the results of centrifugal acceleration.

Wempe, T. E. Effects of gust-induced and maneuvering acceleration stress on pilot-vehicle performance. Aerospace Medicine, 1965, 36, 246-255, 6 refs. A65-80728 (LC).

A simulator study was conducted to assess the effects of gust-induced and maneuvering acceleration stress on pilot-vehicle performance during extended periods of low-level, high-speed flight. NASA test pilots were subjected to this acceleration stress on the Ames Height Control Simulator, a device capable of realistically reproducing the vertical acceleration environment of this flight mode. The primary piloting task consisted of "flying" as close as possible to a 250-foot clearance height above the terrain without ground contact by use of conventional aircraft controls while viewing aircraft instruments and a display depicting the terrain configuration ahead and below. Controlled variables were aircraft velocity, cockpit motion, gust intensity, additional secondary tasks, the presence of a bending mode vibration near the visceral resonance frequency and the requirement for monitoring an automatic terrain-following system.

SECTION III

IMPACT

Advani, S. H., & Lombard, C. F. Pathophysiological responses to $-G_z$ impact as influenced by energy transfer. In Aerospace Medical Association, 1967 Annual Scientific Meeting, Washington, D. C., April 10-13, 1967, Preprints of Scientific Program, p. 201-202. A67-41610 (IAA).

Experimental results for the survival-limit dependence on the energy-transfer rate of guinea pigs during $-G_z$ oriented impact. Tests at velocity changes of 20, 40, and 60 ft/sec indicate that the bradycardia threshold is governed by a definite level of energy transfer and energy-transfer rate. Aortic dynamic considerations are given for Macaca speciosa monkeys for the purpose of studying a mathematical model representation of the aortic subsystem.

Brown, W. K., Rothstein, J. D., & Foster, P. Human response to predicted Apollo landing impacts in selected body orientations. Aerospace Medicine, 1966, 37, 394-398, 14 refs. A66-28663 (IAA).

Two hundred eighty-eight human impact experiments were accomplished on a linear decelerating device (the Daisy Decelerator) for the purpose of studying human response to G forces in certain body orientations likely to occur during impact of the Apollo command module. A proposed Apollo restraint system was used in all human tests. It was observed that impact forces produced effects on the nervous, cardio-respiratory and musculoskeletal systems. Neurological effects of impact were momentary stunning and disorientation. A consistent effect on the cardiovascular system was transitory post-impact slowing of the heart rate in those body orientations in which the decelerative force acts in a footward direction (inertial force acts headward). A theory is presented to explain this effort. Respiratory effects of impact were momentary shortness of breath and chest pain. Effects on the musculoskeletal system were soreness and spasm of muscle groups of the neck and back. Since no effect on the human subject was severe enough to exceed human tolerance, the test program results demonstrate that man can endure certain predicted Apollo landing impact forces in different body orientations without significant incapacitation or undue pain.

Coermann, R. R. Theory of tolerance to impact for humans. July 1968, 55 p refs. N68-35907 (NASA) (Max Planck Institute für Arbeitsphysiologie, Dortmund [West Germany]. Biomechanische Abteilung).

In the frequency range 0-9 Hz the human body may be considered in longitudinal direction as a simple one degree of freedom system with a damping factor of $d = 0.3$. Since the tolerance of impact is determined by the relative displacement of the effective mass, the deformation of such a system with and without damping by impacts with different time history has been calculated. Due to impedance measurement on a centrifuge the non-linear properties of the human body were known. The calculation of the deformation of such a non-linear system has shown that the stress may be much higher than in a corresponding linear system. The optimal elastic properties of protective devices were discussed.

Crocker, J. F., & Higgins, L. S. Impact deformation of vertebrae. In Aerospace Medical Association, 1967 Annual Scientific Meeting, Washington, D. C., April 10-13, 1967, Preprints of Scientific Program, p. 149-150. A67-41592 (IAA).

Measurements of the stiffness of the human spinal column under the rates of deflection produced by impact. It is shown that the spinal column in axial compression behaves as a composite structure in which massive, stiff vertebrae alternate with compliant invertebral disks of low mass. The stiffness of this structure varies with its rate of deflection.

Damon, E. G., Richmond, D. R., & White, C. S. Effects of ambient pressure on the tolerance of mice to air blast. Aerospace Medicine, 1966, 37, 341-347, 15 refs. A66-28655 (IAA).

Mice were exposed to overpressures of "long" duration in the expansion chamber of an air-driven shock tube inside which the initial, preblast pressures were varied over sixfold. When the animals were held at the initial pressure for 1 hr following the blast before being returned to the ambient pressure of the laboratory, tolerance values, expressed as LD_{50}-1-hr gage pressures, increased fourfold; they were 20.3, 31.0, 44.5, 55.4, and 91.8 psi for initial pressures of 7, 12, 18, 24, and 42 psia, respectively. When animals were returned to ambient level soon after blast exposure, the LD_{50} pressures were lower than the above values for initial pressures greater than ambient, and higher for initial pressures lower than ambient. The feasibility of scaling biological blast effects as a function of altitude was discussed and one approach suggested by available empirical data was regarded as a promising, but tentative procedure.

Foster, P., & Sonntag, R. W., Jr. Urinary excretion of catecholamines and 17-hydroxycorticosteroids following $+G_x$ impact in humans. Aerospace Medicine, 1969, 40, 18-23.

Increased heart rate, blood pressure, and muscular tension are frequently present in human subjects before and after impact. Measurement of urinary excretion of vanilmandelic acid (VMA) revealed a possible relationship of impact stress to sympathoadrenal activity. Measurement of norepinephrine, epinephrine, and 17-hydroxycorticosteroid in urine allows more precise analysis of sympatho-adrenal function during and after impact than VMA. Comparison of sham impact and actual impact data reveal that epinephrine is probably the mediator of the increased sympathetic activity associated with impact and that the threatened or actual exposure of a human to impact is more of a psychological than a physical stress.

Haley, J. L., Jr., & Turnbow, J. W. Impact test methods and retention harness criteria for U.S. Army aircrewman protective headgear. AvSER-65-15, March 1966, 55 p. AD 631 493 (DDC) (Aviation Safety Engineering and Research, Phoenix, Arizona).

On the basis of simple analyses and some experimental testing, recommendations are made for the design and testing of helmet retention harnesses. A "collar-type" retention harness is recommended and two tests are suggested as a method of insuring a good design. Impact tests were conducted by an impactor-drop method and a head-form drop method. These test methods employ one movable piece and one fixed piece rather than two movable pieces as are currently used by most test agencies. On the basis of the impact test results, it is recommended that the impactor-drop method be used for the qualification of U.S. Army aircrew helmets. Probable head impact velocities and impact surfaces are discussed, and impact test conditions are specified.

Hanson, P. G. Radiographic studies of cardiac displacement during abrupt deceleration. In Society of Automotive Engineers, Stapp Car Crash Conference, 10th, Holoman AFB, N. Mex., November 8-9, 1966, Proceedings, p. 137-145, 20 refs. A67-20614 (IAA).

Observation that abrupt deceleration associated with vehicle crash environments commonly produces rupture of the heart and great vessels of the thoracic cavity. A study of the mechanism of these lesions has yielded a series of high-speed radiographs obtained at selected time intervals during controlled deceleration. Lightly anesthetized Beagle dogs were rigidly restrained in form-fitted stafoam capsules and subjected to $\pm Gz$ impact on the Bopper and Daisy Decelerator. Flash radiographs were taken with a Flexitron Model 233 (300 kv) X-ray pulser initiated by microswitch on the decelerator track. Preliminary data indicate that the heart undergoes considerable inertial movement during deceleration. These observations suggest that the mechanism of vessel rupture may involve mechanical tearing from violent displacement of the heart and diaphragm.

Hawrylewicz, E. J., & Blair, W. H. Biochemical measure of impact stress in chimpanzees. Aerospace Medicine, 1965, 36, 369-371, 9 refs. A65-22911 (IAA).

Test data for five chimpanzees subjected to various G forces from 54 to 180. Serum lactic dehydrogenase (LDH) and LDH isoenzymes were determined both before and also one hour, 24 hours, and seven to eleven days after the G stress. Total LDH increased two- to threefold one hour after the stress and was still elevated 24 hours later, with a return to normal limits seven to eleven days later. LDH isoenzymes were abnormal one hour after G stress, with a decrease in bands one and two and marked elevation in bands of four and five. This shift in isoenzymes was still apparent 24 hours later. At the preautopsy period (seven to eleven days after stress) the abnormal enzyme pattern shifted to an increase in bands one and two of the three chimpanzees alive at this time. The alteration in serum LDH and LDH isoenzymes appears to be the result of impact stress. The change in isoenzyme pattern seven to eleven days later probably reflects the adaption of the organism to the initial stress and development of postimpact pathology.

Henzel, J. H. The human spinal column and upward ejection acceleration: An appraisal of biodynamic implications, Final Report. AMRL-TR-66-233, September 1967, 57 p refs. N68-18737 (NASA) (Aerospace Medical Division, Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio).

Vertebral compression represents a significant percentage of the morbidity associated with upward ejection. Vertebral and intervertebral structure reacts to and is sometimes irreversibly altered by ejection acceleration. Design and material properties of the normal vertebral column are sufficiently constant that when structural characteristics are defined and acceleration profiles known, prediction of failure may be made. Compressive load analyses of vertebra-disc complexes demontrated that the

vertebral end-plates are the initially failing structures of the spinal column. From experimental data on vertebral breaking-loads, acceptably accurate probability-of-injury curves for static loading were generated. These data together with data describing the dynamic response characteristics of the human body permit calculation of the probability-of-injury for dynamic loading produced by exposure to impact accelerations. As an aid to the designer of ejection systems application of these concepts should refine the estimate of safe acceleration profiles and minimize the risk of irreversible vertebral deformation.

Higgens, L. S., et al. The investigation of the parameters of head injury related to acceleration and deceleration, Final Report. June 1967, 111 p refs. N68-11042 (NASA).

The report describes the results of a three year program in experimental head injury. During this period a highly successful head accelerating device was evolved. Major features of this machine include the application of a reproducible non-deforming stimulus to the head through a controlled path. A series of head acceleration experiments were conducted with this machine. Graded stimuli from no effect through concussion to lethality were found possible without deformation of the skull. Because of the reproducible acceleration waveform produced by this machine, statistical ranking of clinical signs of concussion is possible and is reported. From these experiments, clinical data as well as gross pathological findings are summarized. Detailed design criteria for the head accelerator are included in this report, as well as the associated instrumentation. Conclusions regarding the engineering and physiological findings are followed by recommendations for further work.

Iwataki, N. Emergency ejection escape in Japan air self-defense force. Japanese Journal of Aerospace Medicine and Psychology, 1966, 3, 69-74, 17 refs. A66-34409 (IAA).

Results of emergency escape experiments using ejection seats. Out of 61 pilots participating, the rate of successful escape is found to be 80%. The minimum terrain clearance in successful ejections is found to be 90 m. It is shown that pilots receiving major injuries were ejected at air speeds above 370 km/hr or during dives, spins, or spirals. It is believed that ejectees, after descending on water, are dragged by surface winds above 5 m/sec. Spinal injuries produced by ejection shock are found mostly in the cervical region.

Lalli, G., & Paolucci, G. Behavior of some serum enzymes in rats relative to anatomical and pathological injuries caused by appreciable very short transverse decelerations. Rivista de Medicina Aeronautica e Spaziale, 1966, 29, 412-426. A67-17996 (IAA).

Evaluations of changes in some serum enzymes in correlation with pathological damages due to deceleration, by extending to lateral-axis impacts previous investigations performed on the chest-back and back-chest axes. The conclusions derived from the investigation are: (1) rat tolerance to the investigated deceleration is appreciably greater than previously reported; (2) the lungs underwent the most severe damage, the right one in the right-to-left impact, the left one in the left-to-right impact, with hemorrhagic phenomena predominating in the other organs; and (3) all the serum enzymes investigated in surviving animals increased statistically, showed a significant increase in 15 to 16 hr after impact, especially at the highest decelerations used (900 g).

Lombard, C. F., Advani, S. H., Roy, A., & Estes, M. S. Determination of Apollo emergency impact limits. NASA-CR-92039, 1966, 122 p refs. N68-20480 (Northrop Space Labs., Hawthorne, Calif.).

Pathophysiological responses by guinea pigs and monkeys to tailward acting impact accelerations were studied to develop a theoretical model of the mechanisms of injury to the heart and large vessels exposed to such impact forces. The theoretical analog is described by a modified van der Pol equation, and subsystem study of aorta dynamics furnished data on cardiovascular system responses to the accelerations. Use of bradycardia as a symptom of pending injury with increased acceleration is not considered feasible for the two species tested; this symptom occurred too early in the guinea pig and too late in the monkey. Rupture of the heart and great vessels did not occur as predicted because of compensatory pressure in the thoracic cavity, although lacerations of some pulmonary vessels occurred at very high G levels. At levels of 300 G with velocity change of 60 ft/sec, the subjects were dazed but not unconscious. It is believed that, with a proper support/restraint system, man can survive with recoverable injuries at approximately 100 G with such velocity changes.

Lombard, C. F., Roy, A., Beattie, J. M., & Advani, S. H. The influence of orientation and support-restraint upon survival from impact acceleration. Holoman Air Force Base, ARL-TR-66-20. 1966.

A study was made of 128 guinea pigs to establish survival thresholds for impact in both the sagittal and frontal planes using two different types of support restraint systems. Surviving animals were euthanized two hours following exposure at levels from 100 to 500 G. Fifty-eight of the total of 128 animals were examined microscopically. Curves for survival threshold in all orientations were obtained and an attempt to extrapolate survival threshold for larger animals was made. Ten Macaca speciosa monkeys were exposed to impact at 300 to 600 G. The survival limit was determined for five of the subjects and then using the guinea pig curves, a prediction was made for the survival limits at a position 90 degrees removed. Pathological data on the guinea pigs and monkeys are presented.

McElhaney, J. H., & Byars, E. F. Dynamic response of biological materials. American Society of Mechanical Engineers, 1965, 9 p., 24 refs. A66-15699 (IAA).

This paper represents a study of impacts of varying velocity on the mechanical response of human bone, bovine bone, and bovine muscle tissue. Load-time and displacement-time records for these materials, as well as for nylon and aluminum, were measured over a wide range of strain rates. This research required the development of a special test machine capable of constant-velocity compression tests with strain rates up to 4000/sec, and also high frequency response instrumentation utilizing a piezoelectric load cell and a capacitance displacement transducer. A unique feature of the test machine was the adjustable stops that allowed predetermined strains to be applied. Tabular results are presented which include various mechanical properties at various strain rates. A critical velocity for bone was noted at a strain rate of approximately 1/sec. The relationship between ultimate strength of bone and strain rate can be reasonably well represented by an exponential. A stress, strain, strain-rate surface representation of other data is suggested. The mechanical properties of the biological materials were compared with those of nylon and aluminum.

Miroliubov, G. P. Reaction of a human organism to landing impact overload acting in various directions. In Problems of Space Biology, Vol. 4, 1965, p. 44-53, 27 refs. A66-29445 (IAA).

Study of the effect of landing impact overload on the human organism, conducted in an experimental ground stand with a reinforced mockup cockpit and a mechanical or pneumatic damper. The experimental technique is described and the results are given of observations of the EKG, kinetocardiogram, blood pressure, and respiration of nine individuals.

Payne, P. R. Personnel restraint and support system dynamics. Wright-Patterson AFB, Ohio, AMRL, October 1965, 112 p refs. N66-15859 (NASA).

Like any other complex dynamic system the human body responds in a complex way to acceleration inputs which vary rapidly with time. The need to avoid stresses large enough to cause injury to the body usually imposes limits on the permissible input acceleration. The restraint system interposed between a vehicle and its occupant can modify the physiological effects of a vehicle's acceleration-time history. This modification should be made as favorable as possible by minimizing the stresses generated in the vehicle's occupant. To determine optimum dynamic characteristics for the restraint system, its important characteristics, and those of the human body, need to be represented in terms of a mathematical or "dynamic" model. Through suitable analysis, either mathematical or by means of a computer, those dynamic characteristics of the restraint system can be determined which will minimize the peak stresses developed in its human occupant. A general theory of suitable dynamic models is developed for this type of problem. In addition a method is shown which permits development of simple dynamic models for the human body utilizing existing experimental data.

Rabinovich, B. A. A calculated estimate of the strength of the spine of a man under a longitudinal blow with the load increasing at great speed. In Probl. in Aerospace Med., 21 October 1966, p 411-412. N67-11620 (NASA). (Joint Publications Research Service, Washington, D. C.).

Experimental analyses are briefly reviewed of human physiological capabilities to withstand shock during spacecraft landings. It is reported that the sagging of the human body under a shock action is significantly reduced as the speed of the increase of the load becomes larger. Pain sensations experienced in the spine during landing are mentioned.

Rayne, J. M., & Maslen, K. R. Safety factors in the design of protective helmets. In Aerospace Medical Association Annual Scientific Meeting, 37th, Las Vegas, Nev., April 18-21, 1966, Preprints. Aerospace Medical Association, Washington, D.C., 1966, p. 191-192. A66-32188 (IAA).

Consideration of the fundamentals of the design of aircrew helmets with a view to reconciling the requirements for protection against buffeting in normal flight and possibly some protection against head impact in crash conditions. The amount and type of forces which a helmet must resist are discussed. It is considered that with a liner of the right stiffness and hysteresis, it may be possible to design a helmet giving both crash and buffet protection. A specification for a buffet helmet is suggested. For a crash helmet the main function must be to prevent skull fracture by efficient load spreading. It must resist penetration and abrasion and reduce the transference of angular movement to the head as far as possible.

Snyder, R. G., Young, J. W., Snow, C. C., Price, G. T., & Crosby, W. M. Pathology of trauma attributed to restraint systems in crash impacts. Aerospace Medicine, 1968, 39, 812-829, 84 refs. A68-38085 (IAA).

Considerable attention has been focused on the sophisticated restraint and ejection protection of rigidly selected occupants of military aircraft and manned space vehicles. However, the vast majority of occupants of both military and civil transport and general aviation aircraft, as well as the occupants of more than eight million new automotive vehicles per year, include a much wider range of sex, age, and physical capability. The means of protecting and yet accommodating this wide range of occupant population are restricted to less sophisticated types of restraint systems. The types and severity of injuries attributed to such systems as the lap belt, three-point harness, single diagonal belt, and double-torso harness, as well as an experimental double-torso inverted-Y yoke with inertia reel and an air bag restraint system, have been assessed in this study. Sixty experiments were conducted by the Civil Aeromedical Institute, FAA, with Savannah baboons (Papio cynocephalus), utilizing the 6571st Aerospace Medical Laboratory's Daisy Decelerator at Holloman AFB. Controlled experiments in a related series of study considered a number of factors, including physical impact patterns typical of a commercial jet transport crash, the side-facing seat installation, and forward, rear, and side-facing light-aircraft and automotive impacts. One additional impact series investigated effects of seat belt restraint on pregnant maternal and fetal trauma. Both gross and microscopic examinations were conducted postimpact for acute trauma, and three cases of chronic survival injuries 30 days and 90 days postimpact are described. Trauma patterns distinctive of the various restraint systems are identified and described.

Sonntag, R. W., Jr. Intracranial pressure in Macaca speciosa during controlled abrupt deceleration. In Aerospace Medical Association 1967 Annual Scientific Meeting, Washington, D.C., April 10-13 1967, p. 162-163. A67-41596 (IAA).

Measurement of the intracranial pressure in a Macaca speciosa monkey subjected to linear deceleration at a wide range of g-loads. The greatest increase in intracranial pressure was 1914 mm Hg at -53 G_z. Whereas pressure values recorded at impacts up to -30 G_z appear to be linear, pressure values at comparable $+G_z$ levels are much smaller in magnitude and have a curvilinear relationship. Three different routes by which visceral inertia can influence intracranial pressure are discussed.

Stapp, J. P. Review of Air Force research on biodynamics of collision injury. In Society of Automotive Engineers, Stapp Car Crash Conference, 10th, Holloman AFB, N. Mex., November 8-9, 1966, Proceedings, 1967, p. 204-210, 15 refs. A67-20615 (IAA).

Summary of previously unpublished experiments and results for biological injury encountered in aircraft situations. Acceleration forces exceed primary acceleration of catapult due to oscillations excited between the man-seat system. Theory behind calculation of these effects is reported. Confirming test results on humans and animals are given.

Swearingen, J. J. Evaluation of head and face injury potential of current airline seats during crash deceleration. Federal Aviation Agency, Oklahoma City, Okla. June 1966, 20 p refs. N66-35999 (NASA).

A large percentage of deaths in commercial-airline crashes is produced as the body and lower limbs flail around the seat belt. According to a previous study, a 10-foot-diameter sphere of clear area would be necessary to prevent a person from striking some portion of his body against surrounding structures. This study is concerned primarily with head impacts that may occur against most portions of the seats. Thirty-five impact studies were made with an instrumented dummy head against various

portions of eight different makes of airline seats to determine the "g" time-force parameters of metal deformation and seat break-over. Until recently these data could not be interpreted in terms of head injury or unconsciousness because data on human tolerance to impact against deformable structures were not available; however, a recently published study presents detailed data concerning these tolerances. These data are used here to determine the injury potential of the eight seats studied. Applying the earlier data to the seat-impact studies, 30% of these impacts would have produced fatal head injuries, 80% would have caused facial fractures, 97% would have rendered the passenger unconscious, and only 3% would have caused no injury or unconsciousness.

Wassilev, W. Changes in the neck part of the vertebral column during vertical stress. Anatomischer Anzeiger, vol. 121, no. 5, 1967, p 453-467, 16 refs. A68-81064 (LC).

The variations in cervical vertebrae and disks subjected to various amounts of static and dynamic loads were examined roentgenologically, microscopically and macroscopically. Vertical compression exerted in healthy disk preparations caused a tangential shift of the uncinatum process to the upper vertebral body, thus increasing the diameters. Dengenerate disks reacted insignificantly to applied loads. During greater loads or repeatedly applied impacts, destruction occurred in the lateral disk component, the incinatum process. The concept of secondary characteristics of the unco-vertebral cavity was supported through the determination of ruptures in the lateral disk regions. All compression fractures of the cervical vertebrae were accomplished by disk damage. Front disk hernias in the cervical region were common. They did not directly affect the tissue, but caused irregular distributions of force and abnormal mobility.

Weis, E. G., Jr., & Mohr, G. C. Cineradiographic analysis of human visceral responses to short duration impact. In Aerospace Medical Association, 1967 Annual Scientific Meeting, Washington, D.C., April 10-13, 1967, Preprints of Scientific Program. American Medical Association, Washington, D.C., 1967, p. 43-44. A67-41553 (IAA).

Discussion of the application of a newly developed X-ray unit to the study of visceral responses to impulsive acceleration excitation in humans. Specifically, 16 subjects were exposed to triangular deceleration pulses and successive radiographic images obtained during the impulse. These radiographs were studied, and a preliminary analysis of the results is made. The radiographic findings correspond rather well with the results of experiments on monkeys exposed to short-duration impacts. Some implications of the motion results are discussed in terms of organ sensitivities to velocity change.

White, C. S. The scope of blast and shock biology and problem areas in relating physical and biological parameters, Technical Progress Report. Lovelace Foundation for Medical Education and Research, Albuquerque, N. Mex., November 1966, 32 p refs. N67-32854 (NASA).

A few introductory remarks are followed by a brief discussion of the nature of hazards from air blast noting those due (a) directly to variations in pressure and (b) indirectly to the impact of penetrating and nonpenetrating, blast-energized missiles and the consequences of whole body displacement due to blast-induced winds or ground shock. The need for developing biomedical criteria based upon critical and measurable biological responses following exposure to significant and monitorable physical parameters is discussed in relation to hazards assessment. Also the multifaceted problem of tying up such information with blast-induced variations in the environment that occur free-field and under various conditions of exposure is noted and emphasized.

Whitehouse, A. C., Brown, W. K., Foster, P., & Scherer, H. F. Quantitative effects of abrupt deceleration on pulmonary diffusion in man, Technical Report. Aerospace Medical Div., Aeromedical Research Lab. (6571st), Holloman AFB, N. Mex., May 1966, 20 p refs. AD 633 170 (DDC).

Pulmonary diffusion capacity was measured in nine subjects using the steady state method to determine if this physiological measurement was altered by impact. Each subject rode the Daisy Decelerator twice backward ($+G_x$) at 25 g, twice laterally ($-G_y$) at 15 g, and experienced one sham ride. Carbon monoxide diffusion capacities were measured immediately before and after each ride, and 3 and 24 hours afterward. No significant change in pulmonary diffusion capacity was associated with impact. There was no correlation between observed and predicted CO diffusion capacity based on oxygen consumption, however, observed CO diffusion capacity and oxygen consumption were highly correlated. The validity of the prediction formula as described by Donevan et al., is questioned, but this may be related to the increased altitude (4400 ft) at which the studies were done.

Wittmann, T. J. An analytical model to duplicate human dynamic force response to impact. American Society of Mechanical Engineers, Winter Annual Meeting and Energy Systems Exposition, New York, N. Y., Nov. 27-Dec. 1, 1966, 8 p., 7 refs. A67-15401 (IAA).

Progressive refinement of the parameter values for a spring-mass-damper system representing the human body in the median sagittal plane to develop an analytical model capable of predicting the dynamic force response of human subjects to impact, using data collected in drop tower tests with human subjects. Under several different test conditions, the computed responses obtained by the model compared well with the measured responses of test subjects whose weight ranged from 130 to 230 lb.

Wuensche, O., & Scheele, G. Hematologic and biochemical studies after shock wave injuries of miniature swines. Deutsche Versuchsanstalt für Luft- und Raumfahrt, Bad Godesberg (West Germany). Institut für Flugmedizin. July 1967, 37 p refs. N67-34731 (NASA).

The hematologic and biochemical studies executed on a new species of test animals (miniature swine) serve for the investigation of unknown normal physiological values and their variations after the effects of shock waves in an observation period up to 30 days after the explosion. The numerous pictures and tables show the results of the studies of the hemoglobin content, the osmotic resistance of the blood cells, the hematocrit values, the rate of blood sedimentation and the photometrically conducted analyses of the plasma constituents glucose, total cholesterin, esterified fatty acids, carbamide-nitrogen, chlorides and calcium. The effects of the shock wave on the humoral and corpuscular blood plasma constituents are discussed in detail.

Yost, C. A., & Oates, R. W. Human survival in aircraft emergencies. Asheville, N. C., Stencil Aero Engineering Corporation, January 1969. 55 p. (NASA-CR-1262).

A general study was performed to outline methods for the improvement of human survival in civilian aircraft emergencies. Survival condition criteria, accident statistics and human tolerance limits have been surveyed with respect to those aircraft used in two categories: certificated air carriers and general--private aviation (including official executive aircraft). Methods are presented in this report for aircraft occupant restraint improvement to withstand impact accelerations which are applied to the aircraft.

Zinov'yeva, I. P., Rubashkina, L. A., & Kostin, V. K. Transaminases of the blood as an index of the tolerance by man of the shock loads of landing. In Probl. in Aerospace Med., 21 October 1966, p. 229-230. N67-11522 (NASA).

The feasibility of using transaminases of the blood as a criteria to determine human tolerance characteristics during landing load conditions is considered. It is reported that investigations which were conducted showed that under the action of shock loads the activity of transaminases is a sufficiently sensitive test which makes it possible to a certain degree to judge the reaction of an organism to an applied effect.

SECTION IV

VIBRATION

Barnes, S. Human vibration limits. Machine Design, 1965, 37, 144-149. A65-25991 (IAA).

Study of human subjective reaction to whole-body vibration. The problem is considered important because modern transportation systems (space boosters, spacecraft during reentry, high-performance jet aircraft) impose vibratory loads which are sometimes uncomfortable and occasionally harmful. In experimental investigation men have been placed on shaketables, and experimenters have worked at learning more about the nature of human and animal bodies. Low frequencies have been found to be the most critical. Vibration tolerance is affected by posture, shape and size of the man, and his physical condition. A study by Boeing indicates that a certain amount of heat, noise, and vibration frightens men into better performance.

Blivaiss, B. B., Litta-Modignani, R., Galansino, G., & Foa, P. P. Endocrine and metabolic response of dogs to whole body vibration. Aerospace Medicine, 1965, 36, 1138-1144, 45 refs. A66-16822 (IAA).

To determine the endocrine and metabolic response of restrained dogs to whole body vibration, pentobarbital anesthetized and nonanesthetized dogs were vibrated horizontally. After vibration of anesthetized dogs at either 4 cps, 0.4 G for 30 minutes or 2 hours, or at 10 cps, 2.3 G for 2 hours, there was an average increase of 4.08 mcg 17-hydroxycorticosteroids (17-OH-CS) per 100 ml plasma and a significant increase in blood epinephrine but not serotonin or norepinephrine. Shaking at 4 cps, 1.7 G for 30 minutes produced less of a change in plasma 17-OH-CS than at 0.4 G. However, shaking at 4 cps for 6 hours led to greater increase in plasma 17-OH-CS at 1.7 G than at 0.4 G. Nonanesthetized dogs shaken at 4 cps for 30 minutes had greater increase of plasma 17-OH-CS than similarly shaken anesthetized dogs, thus showing a greater sensitivity of kinesthetic receptors to vibratory stimuli. Possible mechanisms for alterations in endocrine function are discussed.

Boorstin, J. B., Hayes, J. P., & Goldman, D. E. Injury mechanism of internal organs of animals exposed to sinusoidal vibration. Aerospace Medicine, 1966, 37, 22-28, 7 refs. A66-20525 (IAA).

High speed X-ray cinematography has been used to determine organ motion in vibrated cats. Data processing with a motion analyzer and a computer permits rapid analysis of X-ray photographs. Results of experiments at several amplitudes and frequencies are compared to show wave distortions due to heart-lung-chest wall interactions and frequency response characteristics associated with the means of restraint of the animal and the way in which the vibratory motion is impressed. Gross and microscopic pathological studies as well as some chemical determinations provide correlation of mechanical response and tissue damage.

Brady, J. F., & Newsom, B. D. Effect of positive pressure breathing on the vibration tolerance of the mouse. Aerospace Medicine, 1966, 37, 40-45, 30 refs. A66-20529 (IAA).

Experimental investigation of PPB (positive pressure breathing) as a method for increasing the inherent tolerance of crews of boosters for manned spacecraft to intense, low-frequency mechanical vibrations. A total of 153 mice were vibrated along their Z-axis at 20 cps, with an intensity of 7.07 rms g, for 10 min. The 63 controls breathed ambient air and the 90 experimental animals breathed one of three levels of PPB air: 1.5, 3.75, and 6.00 in. of H_2O. It is noted that those receiving the two highest levels of PPB air sustained significantly less tissue damage and mortality, validating PPB as a feasible means of low-frequency vibration protection for mammals.

Carmichael, J. B., Jr., Henzel, J. H., Mohr, G. C., & von Gierke, H. E. On the measurement of the transmission of external force through fluid systems in primates. Aerospace Medicine, 1967, 38, 282-285. A67-23821 (IAA).

Discussion of the characterization of pressure changes in the cerebrospinal fluid in the cranial cavity of rhesus monkeys to an external force directed at the abdominal wall, and the relationship of these changes to other observable parameters. Alternation forces are applied to the abdominal wall; this allows the body to be kept at rest and facilitates the accuracy of the measurement techniques. One monkey is vibrated in the supine position, and oscillatory volume through the trachea is measured as a function of frequency; the resonance curve obtained is given. When the animal's abdominal wall is mechanically displaced in a sinusoidal manner, the measured amplitude ratio of intracranial pressure to airway volume velocity is found to be relatively constant for 2-to-30-cps driving frequencies.

Chaney, R. E. Whole-body vibration of standing subjects. Technical Report. August 1965, 69 p. AD 472 912 (DDC) (Boeing Co., Wichita, Kansas, Airplane Div.).

Five male volunteers were utilized in a study of subjective response to vibration while in the standing position. Four reaction levels (perceptible, mildly annoying, extremely annoying and alarming) were established in the range of 1 through 27 cycles per second utilizing the Boeing Human Vibration Facility as the test instrument. Experimental procedures and controls were identical; preannoying levels established were at higher acceleration input values than their counterparts of the seated studies, with only minor variations in the perceptible and alarming curves under the two conditions. Possible explanations of the noted differences, physiological effects of vibration on the standing subject, and body absorption characteristics and their relationship to the subjects' reactions are discussed.

Clark, J. G., Williams, J. D., Hood, W. B., & Murray, R. H. Initial cardiovascular response to low frequency whole body vibration in humans and animals. Aerospace Medicine, 1967, 38, 464-467.

Measurements of cardiovascular function were made during the onset of the whole body, X-axis sinusoidal vibration in anesthetized mongrel dogs and awake unsedated human volunteers. The anesthetized animals showed a drop in mean arterial pressure averaging 27 mm Hg. An increase in heart rate occurred during the blood pressure drop. Awake humans revealed no drop in mean arterial pressure during this time interval. In addition, four dogs had electromagnetic flow probes placed around the ascending aorta and subjected to whole body, X-axis, sinusoidal vibration but flow was maintained by the increased heart rate suggesting a fall in peripheral vascular resistance. Mechanisms are postulated to explain these findings.

Dennis, J. P. The effect of whole-body vibration on a visual performance task. Ergonomics, 1965, 8, 193-205, 17 refs. A65-81226 (LC).

The effect of whole-body vibration upon a task requiring the reading of printed numbers has been investigated at two levels of peak-to-peak acceleration of 1/2g and 1g over a frequency range of 5 to 37 cps. Head movement in the vertical plane was measured during performance of the visual task. Movement of the head showed progressive attenuation as frequency of vibration was increased, the transmission factor being approximately 100 percent at 5 cps and 10 percent at 37 cps. Changes in frequency of vibration had considerable effects on visual performance, e.g., similar amounts of deterioration in visual performance being produced at head movements of 0.200 in. and 0.0006 in. at 5 and 37 cps respectively. These results support previous theories of resonance of eyeball and/or facial tissue to account for the impairment of vision found with very small head movements in the upper frequencies. Changes in amplitude of head movement appeared to have more effect at the lower and middle frequencies (7 to 19 cps) than at 27 cps. This also was in accordance with previous theory.

Dines, J. H., Sutphen, J. H., Roberts, L. B., & Ashe, W. F. Intravascular pressure measurements during vibration. In Archives of Environmental Health, Vol. 11, 1965, p. 323-326. A66-30622 (IAA).

Cardiovascular measurements were made on anesthetized dogs while they were being subjected to various vibration intensities. The modifications made to an existing blood pressure catheter transducer so that it could be used to make measurements during vibration are described. The measurements reported here were made primarily to test the instrument sensitivity, types of anesthesia, recording techniques, and methods of restraining the subjects.

Enin, E. P. Morphological changes in the organ of hearing of laboratory animals under the effect of high-parameter vibration and of noise. Vestnik Otorino-Laringologii, Vol. 27, Jan-Feb 1965, p. 25-29, 8 refs. A66-81367 (LC).

Vibration with frequency of 50/sec and an amplitude of 0.9 mm in conjunction with medium-frequency noise of up to 100 db intensity provokes in albino mice and rats degenerative-atrophic alterations, first in ganglionic cells of the upper helix and then in the organ of Corti and in the spiral ganglion of the underlying helices. All this is paralleled by changes in the tympanic cavity muscles and exudative manifestations in the middle ear. Such a noise alone results in less marked changes, commencing in the organ of Corti of the lower helix and gradually extending to upper helices.

Grognot, P., Loubiere, R., & Pfister, A. Note on mitosis changes encountered in connection with mechanical vibrations. Revue de Médecine Aeronautique, Vol. 4, May-June 1965, p. 21. A66-80104 (IAA).

Ehrlich ascites tumor cells were inoculated into mice and the mice were mechanically vibrated for 7, 15, or 30 minutes six days after inoculation and killed 24 hours later. Abnormal anaphases were observed in 13.6% of the neoplastic cells from the control animals, but were present in 43.7% of the cells from the animals vibrated for 7, 15, or 30 minutes.

Guignard, J. C. Effects of vibration on man. In Society of Environmental Engineers Symposium on Environmental Engineering and Its Role in Society, Volume 1--Environmental Effects on Man, April 1966, 11 p, 15 refs. A66-34202 (IAA).

Examination of the effects of vibration on man where vibration is defined as any fluctuating mechanical force which man perceives by the senses other than hearing. The quality and spectrum of vibration affecting man are outlined under five headings, including complex periodic and nonperiodic vibrations. The extent of the vibration frequency spectrum that is of physiological significance is divided into five distinct bands: (1) 0.1 to 1 cps - which provokes motion sickness if severe, (2) 1 to 30 cps, especially up to 15 cps - is especially important because it is this band in which major resonances occur in the human body, (3) 30 to 100 cps, (4) 100 to 20,000 cps, and (5) above 20,000 cps. The experimental testing and measurement of the effects of vibration on man are described. Principal effects - mechanical, physiological, psychological, and pathological are discussed. Principles of vibration control are considered.

Harris, C. S., & Shoenberger, R. W. Effects of frequency of vibration on human performance. Journal of Engineering Psychology, 1966, 5, 1-15, 39 refs. A67-12632 (IAA).

Investigation of the effect on human performance of whole-body vibration at frequencies of 5, 7, and 11 cps. The minimum G level necessary to produce a significant decrement in tracking performance was determined at each frequency. The results showed that performance decrements tend to follow the general shape of physiological tolerance curves.

Henzel, J. H., Clarke, N. P., & Mohr, G. C. Effect of anterior intercostal nerve block on the threshold of thoracic pain associated with G_Z and G_X vibration. Aerospace Medicine, 1966, 37, 682-687, 18 refs. A66-36375 (IAA).

In investigating the origin of chest pain associated with $G_Z \pm ng_Z$ and $G_X \pm ng_X$ sinusoidal vibration, the effect of anterior chest wall anesthetization was studied. Subjects were exposed to vibration of increasing amplitude, and the acceleration required to induce perceptible chest pain was taken as the threshold. Two randomly ordered threshold determinations were made in each test. In one, vibration was preceded by bilateral anesthetization of the second through sixth intercostal nerves. In the other, intradermal infiltration of anesthetic created a sensation somewhat similar to this without actually blocking the nerves; this provided a control condition with minimal subjective bias for comparison. Subsequent to intercostal nerve block, there was a statistically significant ($p < 0.01$) increase in threshold of chest pain for both orientations of vibration. These results strongly suggest that vibration induced chest pain originates in the chest wall and not in the more critical cardiac-great vessel complex.

Holland, C. L., Jr. Performance effects of long term random vertical vibration. Human Factors, 1967, 9, 93-104, 10 refs. A67-34336 (IAA).

Compensatory tracking performance was assessed during six hours of continuous exposure to random vertical vibration conditions. The results indicate that performance is significantly affected by the location of peak vibration acceleration power. Longitudinal assessment of tracking performance revealed that subjects can track and perform other tasks without serious decrement for as long as six hours while experiencing vibration acceleration intensities of 0.16 g rms.

Hood, W. B., Jr., Murray, R. H., Urschel, C. W., Bowers, J. A., & Clark, J. G. Cardiopulmonary effects of whole-body vibration in man. Journal of Applied Physiology, 1966, 21, 1725-1731, 31 refs. A66-82310 (LC).

Supine whole-body x-axis sinusoidal vibration in four human volunteers produced increases in mean arterial blood pressure, heart rate, cardiac output, oxygen consumption, and minute volume of

ventilation. These physiologic effects were more marked at 1.2 g peak acceleration than at 0.6 g and at 8 and 10 cps than at frequencies to either side of this range. The changes observed were similar to those produced either by passive movement of the relaxed extremities or by mild muscular exertion. It is postulated that whole body vibration elicits these changes by reflex stimulation of muscular contraction, and that such a mechanism may play a role in producing the physiologic effects of active muscular exercise.

Hornick, R. J., & Lefritz, N. L. Aircrew response to the environment of low-altitude high-speed flight. Institute of Electrical and Electronics Engineers, 1966, 81-85, 5 refs. A66-35507 (IAA).

Study for determining the effects of long-duration vibration of low-altitude high-speed (LAHS) aircraft on pilot performance. An experiment was conducted in which pilots were exposed to 4 hr of continuous vibration; the subjects were ten experienced pilots each of which was exposed to three different intensity levels of LAHS vibration while performing LAHS piloting tasks. The recorded parameters for flight path error, reaction time, vigilance, physiological responses, and biodynamic responses are discussed. Performance measures indicate no major decrements for a 1- to 12-cps band at intensities of 0.20 rms g, no decrement as a function of duration to 4 hr, and definite human tolerance to intensities that were once considered "intolerable."

Kakhana, A. M. To the vibration-sickness clinic. In Medical Practice, 1965, 1-7 p refs. N65-22643 (NASA).

Clinical data on 65 males, subjected to vibration frequencies within the 30- to 250-cps limits, indicated definite changes in the peripheral nervous system and vessels. The character of the pain, the trophic breakdown on the skin of the wrists and of the nails, the secretion disturbances of the Raynaud syndrome type were among the symptoms noted. In the more advanced stages of the vibration sickness phenomena, diencephalous distrubances were observed in the breakdown of neurovascular regulation and metabolic endocrine functions; neurological damage was found in separate craniocerebral nerves in the form of anisocoria, insufficient convergence, and flattening of the nasolabial fold; and neuritis of the hearing nerves, constriction of the arteries, and reduced muscular force were also noted. Individual case histories are given, and brief reference is made to other research findings.

Knepton, J. C., Jr. Influence of vibrations on chromosomes. Aerospace Medicine, 1966, 37, 608-612, 10 refs. A66-33781 (IAA).

Russian workers have discovered chromosome rearrangements in microspores of Tradescantia paludosa which were subjected to the flight factors of their Vostok series of earth-satellite experiments. They stress the importance of vibration as a contributory factor to disturbances of chromatin material during microsporogenesis in Tradescantia. This reports gives the results of an initial series of experiments in which cells from various organisms were vibrated at frequencies of 40 and 70 cps with 10 and 20 G. Microspores of Tradescantia paludosa (Clone 3 of Sax), conidia of Neurospora crassa (L-prolineless clock-mutant, FGSC No. 491a), Neurospora crassa (N. C. R. No. 865A), and ova, larvae, and pupae of Drosophial melanogaster (wild type) were studied for chromosomal rearrangements. No influence was found of these vibration frequencies and accelerations on N. crassa, T. paludosa, and the P_1 generation of D. melanogaster, but there was observed the presence of body color and wing shape mutants among the F_1 generation of D. melanogaster. In future work these organisms will be subjected to other frequencies and displacements of vibration.

Lamb, T. W., & Tenney, S. M. Nature of vibration hyperventilation. Journal of Applied Physiology, 1966, 21, 404-410, 19 refs. A66-80590 (LC).

Total-body vibration in supine, unanesthetized humans was studied at different frequencies up to 6.6 cycles/sec. In roughly one-third of 24 subjects, ventilation increased more than did metabolism, resulting in a lowering of alveolar P_{CO_2}. The fall in PA_{CO_2} was highly reproducible, persistent, and quantitatively related to the intensity of the vibratory stimulus. No isolated anatomical site for reception of the stimulus to ventilation was found. The response seemed rather to depend on the whole experience of vibration. While it could not be inhibited by direct voluntary control, vibration-induced hyperventilation disappeared with light general anesthesia. Hyperventilation tended to occur only in those subjects who characteristically had low resting respiratory frequencies and a low ventilatory responsiveness to CO_2. Large individual differences in ventilatory response to CO_2 which were observed at rest were found to disappear during vibration. The ventilatory response to vibration had many of the characteristics of a classical Pavlovian conditional response.

Larue, M. A., Jr. The effects of vibration on accuracy of a positioning task. Journal of Environmental Sciences, 1965, 8, 33-35, 5 refs. A65-32984 (IAA).

Experimental program to determine what degradation in accuracy would occur if man were required to perform a positioning task in a vibration environment. Of particular concern were the frequency levels in the 5- to 22.5-cps range. It was concluded that, for the positioning task utilized, man in a vibration environment can achieve accuracy levels equal to those which he can achieve in a static environment as long as the frequencies are kept above approximately 5 cps.

Loubiere, R., Grognot, P., & Violette, F. Concerning the modifications in anaphase mitosis caused by mechanical vibrations. COSPAR, 6th International Space Science Symposium, Paper, 13-19 May 1965, 4 p. A65-25550 (IAA).

Discussion of the effects of mechanical vibrations on mitosis, as observed in neoplastic ascitis cells injected into mice. The frequency of vibration was 70 cps, the vibration amplitude 4/10 mm, and the time during which the mice were exposed to vibration ranged from 7 to 30 minutes. The test mice were thoroughbred, of Swiss origin, and weighed more than 25 g on innoculation. The mice were vibrated six days after innoculation, which corresponds to the phase of exponential tumor growth. They were then sacrificed and the ascitis liquid was stained and fixed with Carnoy's liquid. Mitosis count was effected by a fluorescence method, using acridine orange as the fluorochrome. Abnormal anaphase mitosis was observed in 42.3% of the animals that had been vibrated for 15 minutes, as compared with 13.6% for the control animals. The abnormal anaphase rate is fairly constant within the 7- to 30-minute vibration range.

Martin, P. J., Wooding, H. C., Clarke, N. P., Mohr, G. C., & Brinkley, J. W. Evaluation of peak vs RMS acceleration in periodic low frequency vibration exposures. Aerospace Medicine, 1965, 36, 1083-1089. AD 630 785 (DDC).

Subjects were exposed to vibrations with varying peak and RMS accelerations and frequencies to explore the relative importance of these parameters in determining the effect of the vibration produced by turbulence in low altitude high speed flight. For various RMS acceleration levels and frequency contents, pairs of periodic vibration exposures having the same RMS but different peak accelerations were evaluated using both a subjective severity rating and a measure of vibration induced hand motion. The higher peak acceleration of the various pairs having the same RMS values was subjectively rated more severe in 32 of 40 observations. However, when attempting to hold the hand in a fixed position during vibration, the induced deviations from the null point, expressed either as average or peak-to-peak errors, appeared to depend more on RMS acceleration and frequency than on the small differences in peak acceleration studied here.

Nicholson, A. N., & Guignard, J. C. Electrocorticogram during whole body vibration. Electroencephalography and Clinical Neurophysiology, 1966, 20, 494-505, 11 refs. A66-82130 (LC).

The influence of widespread excitation of mechanoreceptors (by whole body vibration) was measured on spontaneous electrocortical and deep brain activity of monkeys, dogs, and cats. In conscious monkeys, rhythms at the vibration frequency appeared intermittently in the electrocorticogram (ECoG) during low frequency vibration (4.5 - 19.5 cps). The rhythms were commonly dissociated between recordings from different but adjacent areas of the cortex and augmented with changes in the orientation of the head. The appearance of the rhythms was force dependent and independent of the frequency of vibration. The rhythms were observed during anesthesia provided that a sufficient intensity of vibration was applied to the animal. The disappearance of the rhythms often induced by anesthesia during steady state vibration is considered to result from the loss of postural activity and the associated changes in the pattern of vibration reaching the head. On cessation of vibration, normal ECoG activity and behavior were observed. During vibration restricted to the trunk the rhythms were not present. Bilateral section of the fifth or seventh and eighth cranial nerves in dogs and cats did not abolish the rhythms.

Pfister, A. M., Bregliano, J. P., Deltour, G., & Kaiser, R. Contribution to the study of the genetic effects of mechanical vibrations on drosophila melanogaster. Revue de Médecine Aéronautique et Spatiale, Vol. 6, 2nd Quarter, 1967, p. 21-23. A68-11713 (IAA).

Description of the results of four investigations of the effects of mechanical vibrations on the total number of descendants and number of recombined descendants in drosophila melanogaster. It is pointed out that, in a control group, Abeleva et al. (1961) had found 0.11% of recombined individuals out of 3662 flies. This figure is too high to represent simply spontaneous crossing over, therefore it is not to

be ruled out that a factor other than vibrations may have caused the results obtained by them. Although they may play a definite role in the determination of mitotic anomalies, mechanical vibrations of 70 Hz and 0.4 mm of amplitude do not seem to have any genetic consequences.

Pols, L. C. W. Effects of high-intensity noise levels on the human body. March 1967, 25 p refs. N67-37413 (NASA) (Institute for Perception RVO-TNO, Soesterberg, Netherlands).

A discussion is given, based on a number of publications, on the nonauditory influence of high-intensity noise levels on humans. The influence of low frequency mechanical vibrations is included in this study. Suggestions are made for maximum tolerable levels so far as the present data permit.

Pradko, F., Lee, R., & Kaluza, V. Theory of human vibration response. American Society of Mechical Engineers, Paper 66-WA/BHF-15, 1966, 13 p., 7 refs. A67-15937 (IAA).

Analytical and experimental studies of whole-body human dynamics under random vibration. The criteria of "absorbed power" is developed through the application of transfer functions; this method is applicable to assessment of the effects of stationary and nonstationary vibration records. The linearity of human response to vibration is established on a qualitative basis. The findings indicate that "absorbed power" and transfer function techniques may provide the basis for a universally usable human vibration measurement method which is applicable to air, sea, and land transportation media.

Roberts, L. B. Cardiovascular effects of vibration, Part 1, Final Report. August 1968, 65 p refs. N68-34931 (NASA) (Ohio State University Research Foundation, Columbus, Ohio).

The ECG was studied first to determine how clinically useful ECG tracings could be obtained from human subjects undergoing severe vibration. In order to evaluate equipment, procedures, and techniques, ECGs were obtained and averaged from six male volunteers while they were being vibrated G_Z at vibration intensities from moderate to severe. The vibrations did not exceed one minute for moderate intensities or one-half minute for severe intensities. The study included the selection and modification of existing equipment, selection of adequate electrodes, development of optimum skin preparation techniques, and adaptation of signal-averaging techniques to the ECG signal.

Roberts, V. L., & Ashton, R. Pharmacological alterations of vibration tolerance. American Medical Association, 1967, 207-208, 6 refs. A67-41613 (IAA).

Continuation of a previous study which indicated that pharmacological alteration of mortality due to low-frequency vibration is possible in the mouse. Additional pharmacological agents are evaluated for possible protective effects. Extensive studies were made of two automatic drugs, three centrally acting drugs, and one local anesthetic. It suggested that a pharmacologically sensitive component of vibration lethality exists, apart from physical trauma, which is related to central nervous system stimulation.

Sackler, A. M., & Weltman, A. S. Effects of vibration on the endocrine system of male and female rats. Aerospace Medicine, 1966, 37, 158-166, 40 refs. A66-80566 (LC).

This investigation reports the acute and prolonged effects of low-gravity vibration stress on body weights, growth, food metabolism, white blood cells and the endocrine system of albino, Wistar rats. Male and female test groups were subjected to peak acceleration forces of 2.1 g for 15- or 30-minute intervals administered daily during a 3-week period. The reciprocating shaker produced a horizontal movement having an amplitude of 4.6 cm and a frequency of 203 cycles/min. Depending upon the degree and duration of the vibratory stress as well as sex-related resistance factors, significant and/or pronounced decreases were noted in the body weights, body weight gains, food comsumption, leukocyte counts, absolute liver, kidney, spleen, thymus and seminal vesicle weights of the male rats. Corresponding significant increases were noted in the adrenal weights. In the females, vibration stress produced less pronounced effects. However, somewhat similar changes were also observed in the leukocyte counts and absolute, splenic, thymic and adrenal weights. In both sexes, the degree of change tended to diminish during the 2nd and 3rd weeks of stress indicating adaptation and acclimatization to vibration. In males, the data indicate that vibration produces changes typical of nonspecific stress in that it stimulates adrenal function even as it may inhibit body growth and gonadal function. The greater resistance of female rats to vibration stress modified and reduced the extent of body growth, food utilization and endocrinal alterations.

Sass, D. J., Hayes, J. R., & Goldman, D. E. Mechanisms of injury from vibration. In AGARD Behavioral Problems in Aerospace Medicine, October 1967, 12 p refs. N68-24888 (NASA).

Studies were carried out on anesthetized cats immersed in a transparent water-filled tank and vibrated erect along the longitudinal body axis. Gross examinations were performed on all animals immediately after vibration. Autopsy findings showed similarities to blast injury. Mediastinal emphysema and air embolism were found in cats vibrated erect at relatively low levels of acceleration. At higher levels, mediastinal air dissected downward to inflate the peritoneal cavity and retroperitoneal spaces. The presence of intra-abdominal air was associated with rupture of the liver and tearing of both the portal vein and the inferior vena cava. Previous investigations in the laboratory on cats vibrated in the supine position in a water immersion tank had shown lung contusion to be the predominant injury. This was attributed to the heart pounding the lungs against the chest wall. Results of the present study when compared with this earlier work, indicate that body position is a critical factor in the mechanism of vibration injury.

Seeman, J. S., & Williams, R. B. Deck motion simulator program--horizontal sinusoidal oscillation effects upon performance of standing workers. NASA-TN-D-3594, October 1966, 48 p refs. N66-37268 (National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, Alabama).

Simulation experiments were conducted to determine the effects on maintenance personnel of exposure to wind-induced oscillations of the Saturn V vehicle servicing platforms. It was determined that horizontal, linear, sinusoidal oscillation frequencies of 0.33 cps and 0.80 were satisfactory samples of expected wind conditions; corresponding amplitudes were ± 6.3 inches and ± 7 inches. A floor-mounted, electrohydraulically controlled deck motion simulator was used to reproduce some of the known motions; however, it did not reproduce the elipsoidal motion pattern. Six mechanics, designers, and engineers participated in three tasks at each frequency and amplitude: hand assembly accuracy test, hand probe steadiness test, and visual acuity test. The instructions read by the subjects, and to the subjects, are included. Tentative conclusions based on test results indicate no significant differences at 0.33 cps; however, significant performance decrements appeared at 0.80 cps. It was found that at 0.80 cps workers cannot perform tasks requiring two-hand operations, and increase of time does not result in increased performance accuracy of precision tasks.

Shoenberger, R. W. Effects of vibration on complex psychomotor performance. Aerospace Medicine, 1967, 38, 1264-1269, 9 refs. A68-16502 (IAA).

Measurement of human performance on a complex of three psychomotor tasks, during vertical sinusoidal vibration lasting 30 minutes. The tasks of target identification, probability monitoring, and warning-lights monitoring had relatively small motor components and were largely mental or intellectual in nature. The results provided very little evidence of decrement on these tasks as a result of vibration. The results suggest that direct mechanical interference with the motor aspects of the task may be the most significant factor contributing to performance decrements during short-duration vibration of relatively low intensity.

Sinitsin, S. N., et al. Soviet research on the effects of vibration. Gigiena Truda i Prof. Zabolevaniya, No. 3, March 1964, 13 p refs. N65-27030 (NASA).

Two studies dealing with the biochemical effects of vibration are presented. The first deals with the influence of generalized vibrations of varying amplitude on carbohydrate metabolism and adrenaline activity in rabbits. Four series of experiments were performed, each with a frequency of 50 cps. With an amplitude of 15μ, there were no changes in the animals. Exposures between 50μ and 100μ were associated with changes in the nature of the glycemic curves, whereas 200μ exposure was characterized by a drop in blood sugar and glycogen level as well as abnormal glycemic curves. When amplitude was raised to 800μ, there was marked decrease in blood sugar and an imbalance and drop in adrenaline activity. A study with shipyard workers suffering from vibration sickness showed their blood was low in 17-oxycorticosteroid. Administration of ACTH usually did not bring about a change in 17-OCS content. It was concluded that decreased sensitivity of the adrenal cortex to ACTH is part of a general pattern of decreased sensitivity to external stimuli in persons suffering from vibration sickness.

Snyder, F. W. Vibration and vision. In Visual Capabilities in the Space Environment. C. A. Baker (Ed.) Oxford: 1965, p. 183-201, 36 refs. A65-35496 (IAA).

Analysis of the vibration environment in space flight and how it affects human visual capabilities. Data and estimates are presented to indicate the probable nature of the vibration environment in a space capsule. A review is made of studies which indicate that visual decrements of varying kinds and degrees occur under vibration bearing resemblance to the vibration that may be present in the astronaut's physical environment. The present knowledge of visual capability under low-frequency vibration is discussed in relation to both basic and applied uses of this information; some of the research problems incurred are also considered. Research that is required for a fuller understanding of visual capability under low-frequency vibration is suggested.

Taub, H. A. Dial-reading performance as a function of frequency of vibration and head restraint system, Final Report. January 1965, 28 p refs. N66-38200 (NASA) (Cornell Aeronautical Lab, Inc., Buffalo, New York).

Dial-reading performance under vibration was investigated at 6.11 and 15 cps +1 G_x (acceleration vector of gravity) ± 1.1 G_x (vibration) with three X-axis head restraint configurations (a rigid restraint system, a piston-spring damper system and a spring (only) isolator system) and two Z-axis head restraint configurations (head locked in Z-axis and head allowed to move freely in the Z-axis). Ten subjects were tested. The results indicated that less decrements in performance occurred at 6 cps than at 11 and 15 cps. Further, the use of the X-axis piston-spring damper isolation system resulted in significantly less errors as compared to the X-axis rigid restraint system. At 15 cps, where all three X-axis head configurations could be compared, there was no difference in performance with the piston-spring and spring (only) systems, while both resulted in less errors than the rigid system. Finally, the Z-axis restraint system had an effect upon performance only at 15 cps. The data suggested that allowing the head to move freely in the Z-axis at 15 cps resulted in less errors than when the head was locked in the Z-axis.

Walter, D. O., & Adey, W. R. Linear and nonlinear mechanisms of brain-wave generation. New York Academy of Sciences, Annals, 1966, 128, 772-780, 9 refs. A66-24228 (IAA).

Quantitative analysis of EEGs of monkeys stimulated cyclically by whole-body vibration. Coherence functions relating brain records to the acceleration records and coherent and incoherent peaks at the shaker frequency are plotted. Some specimen findings about the brain's physiological responses to vibration, made through multivariate spectral analysis, are exhibited. It is thought that these findings depend heavily on having available a comprehensive machine system for spectral analysis by digital filtering. Records can be processed, the intensities of which differ by factors of more than 1000, and calculations can be carried as far as inverting matrices without concern for excessive leakage or error buildup.

Weisz, A. Z., Allen, R. W., & Goddard, C. J. An evaluation of three types of hand controllers under random vertical vibration. In NASA, Washington Manual Control, 1966, p 269-277 refs. N67-15870 (NASA).

Investigated was the effect of hand control design on continuous manual control performance in a vibration environment. Degradations in manual tracking due to whole-body vertical vibration were experimentally determined. The three controllers compared in the study consisted of: (1) a standard free-moving hand control without spring centering and with negligible friction or viscous damping; (2) a viscously damped low-inertia pencil stick without spring centering; and (3) a torque stick with negligible motion response to applied torques about the center of the hand grip. Results of the study indicate that the speed of response possible with a rigid controller leads to improved tracking performance in both static and vibration environments.

Wisner, A., Donnadieu, A., & Berthoz, A. Biomechanical study of man exposed to low frequency vibrations. Travail Humain, Vol. 28, Jan-Jun 1965, p 17-56, 55 refs. A65-81364 (LC).

A description is given of the results obtained by recording the sensations of subjects undergoing vibrations of a moderate intensity on a vibrating table. Known clinical syndromes (vertebral, gastrointestinal, urinary) were related to the disorders shown by human and animal subjects undergoing violent experimental vibration. These observations may be explained by mechanical considerations. Biomechanical studies revealed that the movements of large body segments, pelvis, thorax, and table, are similar

to those of a model. The latter may be used to show the constancy of answers obtained during experimentation and that the subjects' individual characteristics have a negligible influence upon the results. Accelerations observed at different body levels varied if the sitting subject had a more or less stiff attitude. This led to a description of the body as a system of suspended masses. A clear relationship was found between the subject's excitation intensity and the type of seat comfort. It is proposed that a technique be established for the dynamic evaluation of seats, along with a method to calculate vehicle suspensions.

Woods, A. G. Human response to low frequency sinusoidal and random vibration. Aircraft Engineering, 1967, 39, 6-14. A67-35557 (IAA).

Description of a series of tests made with a vibration simulator to evaluate the effect of vibration on task performance. The design and operation of a vibration simulator is described, and the measurements of the body resonances of a number of human subjects over the frequency range of 1 to 10 cps for vertical and lateral vibrations are presented. Comfort ratings were obtained for these vibrations at various levels of acceleration. The response of an aircraft to atmospheric turbulence has been simulated assuming that the aircraft fuselage will vibrate predominantly in one flexible mode. Comfort ratings were obtained for lateral turbulence, and a comparison is made between these results and those for sinusoidal vibrations. The effect of random, vertical, and lateral vibrations separately on task performance was measured, as well as the effect of length of exposure to vibration on task performance for random vertical vibrations at various magnitudes.

Zechman, F. W., Jr., & Peck, D. Error in measurement of pulmonary ventilation during sinusoidal vibration and a method of correction. Aerospace Medicine, 1966, 37, 32-34, 5 refs. A66-20527 (IAA).

Determination of the origin of the error in measurements of ventilation by the open-circuit technique caused by amplitudes of oscillation greater than the amplitude of airflow produced by a subject during whole-body vibration, when respiratory airflow is forced into oscillation. A device is proposed for eliminating the forced-oscillation component from the airflow signal. The device consists of a time delay and summing circuits.

SECTION V

COMBINED STRESSES

Alexander, W. C., Sever, R. J., & Hoppin, F. G., Jr. Hypoxemia induced in man by sustained forward acceleration while breathing pure oxygen in a five pounds per square inch absolute environment. Aerospace Medicine, 1966, 37, 372-378, 17 refs. A66-81120 (LC).

Presently planned atmospheric entry missions were simulated with respect to predicted acceleration profiles and gaseous environment. Arterial oxygen saturation was measured by earpiece oximetry calibrated with Van Slyke analyses of arterial blood samples collected simultaneously under acceleration. The patterns and severity of hypoxemia were studied by varying the magnitude and duration of the acceleration exposure and the environment of the pilot. The patterns and severity of hypoxemia induced by forward acceleration varied as a function of the magnitude and duration of the exposure and the gaseous environment of the experimental subject. Saturation levels below 80% were uncommon under the conditions of this simulation; however, marked deviations from this value were encountered. Although the present investigation was designed to evaluate the tolerability of the space crew to the dynamic and environmental conditions of manned earth entry characteristics of the Apollo mission, some relevant findings concerning the probable mechanisms of acceleration-induced hypoxemia are discussed.

Andrianova, L. A. The change of the neurosecretory activity of the hypothalamic region under the action of some extreme factors of space flight. In Problems of Aerospace Medicine, 21 October 1966, p 34-35. N67-11417 (NASA) (Joint Publications Research Service, Washington, D. C.).

Histochemical analyses of neurosecretory materials in the cells of the supraoptic and paraventricular hypothalamus nuclei of male rabbits, exposed to an acceleration of 10 g for four minutes or to a total gamma radiation dose of 400 roentgens, indicated a change of neurosecretory processes in the nuclei of the hypothalamic region. After acceleration for 10 to 15 minutes, and animals displayed antidiuretic activity of the blood plasma. Irradiated animals showed an accumulation of neurosecretion in the neurons of the supraoptical and paraventricular nuclei and intensified antidiuretic and oxytotic activity in hypothalumus extracts 3 hours after radiation exposure.

Apanasenko, Z. I. Effect of space-flight factors on the functional state of the vestibular analyzer, Review of the Literature. In Certain Problems of Space Neurophysiology. N. N. Livshits (Ed.) Moscow: 1967, p. 9-44. A67-40764 (IAA).

Review of bibliography dealing with the effects of vibration, acceleration, and ionizing radiation on the functions of the vestibular analyzer, covering papers published through 1965. The review shows that the vestibular analyzer is responsible for various disorders in motor coordination and spatial orientation during parabolic and orbital flights and points out a general lack of information on many aspects of the subject.

Arsen'yeva, M. A., Belyayeva, L. A., Demin, Yu. S., Pokroyskaya, G. L., Golovkina, A. V., et al. In Cosmic Research, Vol. 3, No. 5, 20 January 1966, p 216-234 refs. N66-21583 (NASA) (Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. Foreign Technology Div.).

The effects of vibration and acceleration (of varying duration and intensity), and the combined action of these factors with radiation on the hereditary structures of mammals were studied. It was shown that such dynamic factors as vibration and acceleration cause certain disturbances in the nuclei of bone marrow and spleen cells, and modify the effect of radiation when it is combined with other factors.

Bokhov, B. B. The mechanism of the seasickness syndrome. In Rept. Presented at Soviet Conf. on Space Biol. and Med. 10 November 1966, p 143-144 refs. N67-13438 (NASA) (Joint Publications Research Service, Washington, D. C.).

The appearance of various combinations of excitation and inhibition signals in the receptive field of the vestibular analyzer impairs the normal course of vestibular reactions and leads to sensory disturbances associated with marked vegetative shifts. Training of subjects exposed to Coriolis accelerations diminishes or extinguishes these reactions. The same principle can be applied to disturbances observed during weightlessness: appearance of unfamiliar configurations of excitation due to the disappearance of gravitational forces acting upon the otolithic plate.

Casey, H. W., Cordy, D., Goldman, M., & Smith, A. H. The influence of chronic acceleration on the effects of whole body irradiation in rats at 760 MM of mercury. Aerospace Medicine, 1967, 38, 451. AD 663 053 (DDC).

Studies of the combined effects of chronic acceleration and acute Co 60 whole body irradiation were performed on rats. Rats exposed to accelerative forces (2.0 to 3.0 G), produced by continuous centrifugation, were observed for periods up to four months. Deleterious effects were not produced by acceleration per se, as physiologic adaptation was evident by the seventh to fourteenth day. On gross and histologic examinations a depletion of body fat deposits and a reduction in body mass were the only detectable differences in accelerated rats when compared with control rats. Continuous acceleration, immediately following irradiation, increased radiation mortality and the mortality increased progressively with increases in the accelerative force. Prior adaptation of rats to acceleration had no influence on the increased mortality. Deceleration to normal gravity followed by irradiation had no effect on mortality. In accelerated-irradiated rats that died, the lesions found by gross and histologic examinations were typical of those produced by radiation. Accelerated rats, sacrificed 30 days following irradiation, had lesions comparable to non-accelerated irradiated rats indicating that the pathologic changes produced by irradiation were not altered by acceleration. The results show that the biologic response to whole body irradiation is altered by changing the weight to mass ratio with accelerative forces above normal gravity. The exact cause of the increased mortality was not determined. These findings suggest additional radiation studies should be conducted in environments both below and above that of normal gravity.

Davydov, B. I. Tolerance to high acceleration stress after exposure to ionizing radiation. Doklady Akademii Nauk SSSR, vol. 168, no. 3, 1966, p. 691-693, 9 refs. A66-82110 (LC).

White mice exposed to 200 - 4,000 r' showed, 1-6 days after exposure, a greater tolerance to high acceleration stress than controls. The mechanism of this effect has not been fully studied. The greater tolerance to acceleration stress after radiation exposure may be due to changes in the system of blood clotting and cell membrane permeability. The degree of tolerance depends on the amount of radiation received.

Dean, R. Human stress in space. Science Journal, 1966, 2, 70-75. A67-14389 (IAA) (Boeing Co., Multiple Stress Research Group, Seattle, Wash.).

Discussion of recent research which indicates that environmental stresses in space are not necessarily harmful, but in fact may have a beneficial effect by making astronauts more alert and by counteracting those stresses which are detrimental. Tests simulating boost and reentry stresses are investigated, and the effects of combining such stresses as heat, noise, vibration, and acceleration are studied. Finally, the pain-relieving effects of white noise are considered.

Demin, Yu. S. The effect of whole-body vertical vibration and X-rays on the nucleus of cells of bone marrow cells of mammals. In Effect of Ionizing Radiation and Dyn. Factors of the Function of the Central Nervous System; Probl. in Space Physiol., 15 September 1967, p. 13-27. N68-33288 (NASA) (Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. Foreign Technology Div.).

Mice were subjected to 20 min. of vertical vibration and irradiated with X-ray doses of 50 to 100 r. Four groups of mice were used. The first group was subjected to vibration alone and the second group was exposed to radiation alone. The third group was exposed to vibration followed 3 to 5 min. later by irradiation, and the fourth group was exposed to irradiation followed 3 to 5 min. later by vibration. It was found that vibration increases the number of mitoses in bone marrow cells. Most of the affected cells showed chromosome adhesions. The number of disturbed mitoses caused by the combined effects of vibration and irradiation did not exceed the number produced by the effects of radiation alone. However, some differences were noted in the types of changes encountered: exposure to combined factors increased the proportion of chromosome adhesions to chromosome aberrations. The mitotic activity picture in bone marrow exposed to a 50-r X-ray dose alone was similar to that produced by the combined effect of vibration and irradiation. Increasing the vibration frequency from 60 cps to 70 cps produced no statistically significant difference in the number of changes in mitotic activity.

Frank, G. M., Livshits, N. N., Arsen'yeva, M. A., Apanasenko, Z. I., Belyayeva, L. A., et al. The effects of combined space flight factors on some bodily functions. Izvestiia Akademii Nauk SSSR, Serija Biologicheskaia, no. 5, September 1966, p. 625-642. N67-13807 (NASA) (Joint Publications Research Service, Washington, D. C.).

Examined were the effects of acceleration, vibration, ionizing radiation, and the combined action of dynamic and radiation factors on some functions and the oxidative metabolism of the central nervous system and on mitosis in hematopoietic tissues. (1) Acceleration changed cerebral circulation markedly as a result of the interaction of mechanical and physiological factors; however, the resistance of cerebral circulation was increased by training. (2) Vibration intensified the oxidative metabolism and inhibited various divisions of the nervous system. (3) Combined acceleration and vibration effects reduced mitotic activity in bone marrow cells for 30 days. (4) Ionizing radiation and the investigated dynamic factors combined had an unidirectional effect on the oxidative metabolism in brain tissues and on mitosis in the hematopoietic system. Changes in CNS functions were complex and varied for sometime after exposure to a combination of factors.

Gaydamakin, N. A., Petrukhin, V. G., Antipov, V. V., Saksanov, P. P., & Shashkov, V. C. Pathomorphologic changes in hemopoietic organs of mice exposed to the combined effect of several kinds of ionizing radiation and dynamic space flight factors. In Studies in Physiol. Reactions of Humans and Animals to Space Flight. 29 July 1966, p. 22-33 refs. N66-34322 (NASA) (Joint Publications Research Service, Washington, D. C.).

The effects of ionizing radiation combined with vibration and acceleration factors are studied from the pathomorphologic changes seen in the spleen and bone marrow of 245 male mice. Experimental conclusions indicate that: (1) The combined action on mice of ionizing radiation-protons or gamma-rays, with vibration or acceleration, usually changed the degree of expression and character of pathomorphologic changes in the blood-forming organs. (2) The preliminary action of vibration three days and especially one day before radiation increased in destruction of the blood-forming organs. (3) The subsequent action of vibration three or especially five days after radiation markedly increased destructive changes in the blood-forming organs.

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von Gierke, H. E. Response of the body to mechanical forces--an overview. In Lectures in Aerospace Med., 6th Ser., 1967, p. 325-344 refs. N68-20564 (NASA) (School of Aerospace Medicine, Brooks Air Force Base, Texas).

Starting with present-day knowledge of the dynamic and strength properties of various types of tissue, the dynamic response of the complex body structure to the various types of force application is reviewed. The different methods for the collection of experimental data on man and animals are described and the combined information is used to give an integrated overview of the body's dynamic response to environmental pressure (acoustic loading, blast overpressure or decompression) as well as force changes (whole body vibration, whole body impact and small area impact). Examples of theoretical models describing the response of the whole body as well as models describing specific subsystems such as the respiratory system, the skull or the ear are presented. The discussion covers the status, value, and limitations of such theoretical models for explaining physiological and pathologic findings, for predicting the body's response to force environments not yet experienced, for extrapolating biodynamic data among the mammalian species including man, and for aiding in formulating biomedical criteria for not only estimating various human hazards but for guiding those interested in safety and protection engineering.

Gyurdzhian, A. A. The effect of prolonged acceleration on gas exchange and resistance of rats to hypoxia. November 1966, 5 p refs. N67-26573 (NASA) (National Aeronautics and Space Administration, Washington, D. C.).

An investigation is made of the effect of prolonged acceleration on gas exchange and resistance of rats to hypoxia. An automatic gas-exchange investigating stand is described. It is found that in rats subjected to an increased force of gravity the gas exchange was lower than in control rats. The resistance of rats to "fatal hypoxia" proved to be higher than that of control rats. The resistance of test rats to "fatal acceleration," however, was lower than that of the control rats.

Khazen, I. M. Some of the physiological positions on development of theoretical and practical bases of astronaut training for prolonged flights. In Rept. presented at Soviet Conf. on Space Biol. and Med., 10 November 1966, p. 82-109 refs. N67-13433 (NASA) (Joint Publications Research Service, Washington, D.C.).

The physiological significance of altered gravitation and acceleration as specific stimuli of the neuro-glandular apparatus of the gastrointestinal tract in man was studied. An overall literature review on various acceleration experiments on man and animals as performed elsewhere is included. The author exposed animals to various types of acceleration and found disturbances in the periodic motor activity of their stomachs, a reduced secretion of gastric juice and enzymes from intestinal loops and glands, as well as changes in the permeability of the vascular wall. Observed decreases in lysozyme activity were related to a weakening of antibacterial properties of the digestive juices and to immuno-chemical changes in the body's internal environment. In man, many of the disturbances attributable to acceleration, hypoxia, or certain other extreme factors could be leveled off to a significant degree by intervals between repeated exposure to the same stimulus, through adaptation acquired in high mountain regions, and through general training.

Klein, K. E., Brüner, H., Voigt, E. D., & Wegmann, H. M. Comparative studies on physiological indices of fitness in man under exercise, low pressure and acceleration. In Human Adaptability and Its Methodology. H. Yoshimura & J. S. Weiner (Eds.) Tokyo: 1966, p. 234-247, 50 refs. A68-19934 (IAA).

Study of the effects of low pressure and acceleration on the physical performance and adaptability of a group of 20 young men unused to these conditions. Various methods of measuring physical fitness and stress tolerance are applied, and the results are compared. The meaning and the definition of these two concepts are discussed.

Kotovskaia, A. R., Eshanov, N. Kh., Vartbaronov, R. A., & Simpura, S. F. Physiological reactions of cosmonauts exposed to accelerations during the "Voskhod" space flight. In Izvestiia Akademii Nauk SSSR, Serii Biologicheskaia, no. 3, May-June 1966, p. 337-345, 18 refs. A66-82111 (IAA).

Physiological reactions of cosmonauts exposed to accelerations during the Voskhod space flight are reported. Electrocardiograms, seismocardiograms, pneumograms, television observations, and personal reports of the crew are discussed. The crewmembers showed a higher emotional stress than during simulated flights in the centrifuge. In the course of re-entry K. P. Feoktistov and B. B. Egorov showed peculiar physiological responses to increased g due to a change in their reactivity that followed vestibulo-vegetative disturbances which occurred in the weightless state. Nevertheless, the authors do not attribute these peculiarities to a significant change in the cosmonauts' tolerance to accelerations during the space flight.

Kotovskaia, A. R., Vartbaronov, R. A., & Simpura, S. F. Human physiological reactions under the action of transverse accelerations after preceding hypodynamia. In Problems of Space Biology. Volume 6. Moscow: 1967, p. 106-117, 22 refs. A68-38216 (IAA).

Comparative analysis of the physiological reactions of Vostok and Voskhod astronauts to transverse accelerations in space and during centrifuge experiments. The ability to sustain accelerations after long-term hypodynamia (imitating certain effects of weightlessness) is examined, along with certain methods of increasing the resistance of the organism by physical exercise, pharmacological techniques, and adaptation to hypoxia in pressure chambers and mountainous environments.

Livshits, N. N. The effect of spaceflight factors on central nervous system functions: Summary of data. 4 August 1966, 42 p. AD 642 186 (DDC) (Library of Congress, Washington, D.C., Aerospace Technology Div.).

The report summarizes 16 articles which concentrate heavily on the isolated and combined effects of acceleration and radiation on mammals. Titles are as follows: Effect of radial accelerations on brain temperature; Effect of centrifugation on otolith function; Effect of vibration on cerebrospinal reflexes; Changes in cerebral bioelectricity and oxygen metabolism; Effect of vibration and analyzer exclusion on brain metabolism; Cerebral oxygen metabolism, bioelectricity, and conditioned reflex activity during vibration; Respiratory changes during vibration; X-ray effect on cerebral venous flow; Comparative effect on neutron, proton, and gamma irradiation (300 rad); Comparative effect of neutron and gamma irradiation (25 rad); Comparative effect of neutron, proton, and gamma irradiation (150 rad); Comparative effect of chronic and acute gamma irradiation on nervous activity; Effect of prolonged gamma

irradiation on vestibular function; Combined effects of vibration and chronic irradiation on vestibular function; Combined effects of vibration and ionizing radiation on conditioned reflexes.

McClernan, L. M., & Thayer, W. S. Development of a pilot universal couch for acceleration, vibration, and shock. In Institute of Environmental Sciences Annual Technical Meeting Proceedings, 1965, p. 225-240, 21 refs. A65-30013 (IAA) (Aircraft Armaments, Inc., Cockeysville, Md.).

Analysis of a cushioned contour couch designed to transmit a minimum of discomfort to its occupant due to acceleration, vibration, and/or shock environments that could reduce efficiency or cause permanent injury. The couch was demonstrated as a highly damped system in shock deceleration, completing its response in one and a half cycles. In acceleration, g-forces were evenly distributed over the subject's dorsal surface, and at high g-levels the couch tended to envelop the subject's sides, providing lateral support. Universality was shown by a wide range of subjects who individually evaluated the couch under dynamic load as the most comfortable one they had ever ridden. The system of straps used to maintain body position was unnecessary during vibration and G_x acceleration tests.

Mazy, R. S., Mattingly, T. E., Felder, J. W., Jr., & Lombard, C. F. Development of an internal restraint system for an integrated restraint-pressure suit. NASA CR-718, February 1967, 49 p refs. N67-18398 (NASA) (Northrop Space Labs., Hawthorne, Calif.).

The fabrication of a working laboratory model of an internal restraint system for use in an integrated pressure suit system is presented. The system provides acceleration protection and thermal control by means of fluid-filled bladders. The thermal transport system is designed to remove at least 2,500 Btu/hr metabolic heat from the occupant. Results of studies conducted to determine the physical loads imposed on the restraint system under acceleration fields of $\pm 30\ G_x$, $+20\ G_z$, $-10\ G_z$, and $\pm 15\ G_y$ are included.

Newberry, P. D., Johnson, W. H., & Smiley, J. R. Effect of hypoxia on nystagmus induced by angular acceleration. Aerospace Medicine, 1965, 36, p. 1090-1093, 13 refs. A66-13356 (IAA).

Four subjects were exposed to a horizontal angular acceleration of approximately $156^{o}/sec^{2}$ for 1 sec, while breathing air at ground level, and then while breathing air at 20,000 ft. On a different day the angular acceleration was repeated while breathing 10% oxygen at ground level, and then while breathing air at ground level. Total slow phase angular deviation of the eye, maximum slow phase angular velocity and total duration of nystagmus were used as criteria of the magnitude of the nystagmic response. There was a mean increase of 61% in the slow phase angular velocity of the nystagmus occurring while breathing 10% oxygen compared with breathing air at ground level. At 20,000 ft, however, there was a mean increase of almost 100% in total angular deviation, maximum angular velocity and total duration of nystagmus compared to breathing either 10% O_2 or air at ground level. This is attributed to the obvious anxiety displayed by the subjects at 20,000 ft. It is suggested that hypoxic hypoxia and the associated hyperventilation cause a trivial increase in the nystagmus resulting from a horizontal angular acceleration without hypoxia but that apprehension may cause a profound increase in nystagmus.

Pyle, D. M., & Smith J. Soviet high-altitude equipment for aircrew protection. 9 June 1966, 86 p refs. N67-12494 (NASA) (Library of Congress, Washington, D.C., Aerospace Technology Div.).

Contents:
(1) G-suits, pressure suits and protective helmets. Accelerations during parachute jumps. refs. (See N67-12495 03-05)
(2) Protective equipment for high-altitude flights. S. P. Umanskiy, p 45-51. (See N67-12496 03-05)
(3) Pressurized cabins. M. F. Rebrov, p 52-62 (See N67-12497 03-05)
(4) High altitude instrumentation and equipment failure. I. G. Rabkin, p 63-65. (See N67-12498 03-05)
(5) Hermetically sealed hull compartments and methods of calculating their strength. B. L. Bel'skiy, I. P. Vlasov, V. N. Zaytsev, S. N. Kan, V. P. Karnozhitskiy et al., p 66-72. (See N67-12499 03-02)
(6) High altitude equipment. Ye. V. Sofronov, p 73-75. (See N67-12500 03-02).

Raymond, S. A., Greenleaf, J. E., & Matter, M., Jr. Effects of acute and chronic hypohydration on tolerance to $+G_z$ acceleration in man. II: Impressions of subjects. NASA-TM-X-1255, September 1966, 47 p refs. N66-37042 (NASA) (National Aeronautics and Space Administration, Ames Research Center, Moffett Field, Calif.).

The postcentrifugation comments of young male, water depleted subjects following $+G_z$ acceleration was assessed and summarized. Two methods of water depletion were utilized: a sauna bath (acute group) and 48-hour water restriction (chronic group). The acute group lost 3.4 percent of their total body weight and the chronic group, 3.8 percent. Blackout tolerances were measured following the two hypohydration (dehydration) periods and also during normohydration (ad libitum control) at an acceleration buildup of 3.7 G/min. The main conclusions were: (1) Moderate hypohydration, both chronic and acute, is associated with tolerance decrements; (2) the decreased tolerance is traceable to increased fatigue brought about by the water deficit; (3) leg pain and cardiovascular embarrassment during acceleration is increased with hypohydration; (4) the progressive lessening of the leg pain with each succeeding run is partially attributable to muscular effort. Muscular effort increases subjective tolerance to acceleration, often restoring peripheral or central vision; and (5) subjective impressions of changes in tolerance only infrequently correspond to actual performance records.

Schoenbrun, R. L., & Adey, W. R. Space-flight-related stresses on the central nervous system. Radiation Research Supplement, 1967, 7, 423-438, 18 refs. A68-22130 (IAA).

Description of computerized methods for the precise specification of different states of the central-nervous-system function. The effects of centrifuging acceleration, whole-body vibration, and focal-brain irradiation on cerebral electrical activity are discussed, with emphasis on temporal-lobe structures.

Short, L. L., Newson, B. D., & Brady, J. F. X-radiation effects on vibration tolerance of rats. Aerospace Medicine, 1967, 38, 140-144, 45 refs. A67-21719 (IAA).

One hundred and forty-one Sprague-Dawley white rats were allotted into seven experimental groups to test the working hypothesis that a prior X-radiation exposure might weaken the rats and make them more susceptible to death from an acute vibration test. An X-ray dose of 632 roentgens, administered at a low dose rate and in an intermittent and prolonged manner, produced a low 30-day borderline mortality of 5 to 10%. An acute vibration test produced a mortality of 34% in the controls. The vibration test was applied at 7, 14, and 21 days postirradiation to initially irradiated groups and their non-irradiated controls. The mortality from the vibration test did not differ significantly in the comparison of the irradiated vs non-irradiated groups. Although the results are not fully conclusive, no synergism in mortality from radiation and vibration in sequence was observed under the conditions of the experiment.

Sisakian, N. M. Some problems of ecophysiology. Paper presented at 2nd International Symposium on Basic Problems of Man in Space, Paris, 14-18 June 1965, Preprint no. 27, 31 p. A65-29945 (IAA).

Symposium sponsored by the International Astronautical Federation, International Academy of Astronautics, UNESCO, International Atomic Energy Agency, International Telecommunication Union, World Health Organization, and World Meteorological Organization. General outline of ecophysiology as a branch of biological science concerned with the behavior and reactions of live organisms exposed to space conditions. Biological studies on the cell and molecular levels, cryolysis, radiolysis, and photolysis of nucleoprotein molecules, the determination of the maximum endurable vibration limits, and attempts at simulating the martian climate are among the topics given special attention. Works of numerous Soviet scientists in the field are quoted.

Sorokina, Ye. I. The interaction of a series of indices of the oxygen regime of an organism under the influence of reduced barometric pressure and long-acting accelerations. In Probl. in Aerospace Med. 21 October 1966, p 452-453. N67-11643 (NASA) (Joint Publications Research Service, Washington, D.C.).

The dynamics of the regulation of oxygen in an organism are reviewed for the following cases: hypoxic hypoxia for varying barometric pressures, and a mixed form of hypoxia with the presence of a hemodynamic factor under the influence of transverse accelerations. Experiments on white rats, and determinations of oxygen pressure and the oxidizing-reducing potential in muscular and brain tissues are also mentioned.

Stapp, J. P. The hostile kinetic environment on sea, on land, and in the air and in space. In Southwest Res. Inst. Bioastronautics and the Exploration of Space, December 1965, p. 129-140 refs. N66-23055 (NASA) (Air Force Systems Command, Brooks Air Force Base, Texas. Aerospace Medical Div.).

A discussion is presented of the hostile kinetic environment, with emphasis on bioastronautics and the exploration of space. Consideration is given to the earth's chemical equilibrium, a brief theory of the origin of the earth, and the evolution of life. Various acceleration and deceleration experiments are cited, and results of human and chimpanzee exposures to rocket sled impact decelerations and wind blasts are tabulated.

Taliaferro, E. H., Wempen, R. R., & White, W. J. The effects of minimal dehydration upon human tolerance to positive acceleration. Aerospace Medicine, 1965, 36, 922-926, 7 refs. A66-12353 (IAA).

The responses of three groups of human subjects to positive acceleration after undergoing minimal dehydration and heat stress are presented. A decrease in acceleration tolerance of 15 to 18% is noted. It was determined that the effects of heat stress alone did not produce the observed decrease. The possible underlying mechanisms producing these effects are discussed and recommendations are made for future studies.

Troy, P., & Williamson, I. M. Environmental simulation. Space/Aeronautics, R & D Issue 48(2): 122-125. July 31, 1967.

The general trend in aerospace simulation clearly points to the development of ever larger facilities and to combined-environments testing whose ultimate goal seems to be the simultaneous simulation of the entire range of natural and man-made environmental effects to which an aerospace vehicle is exposed--from pressure, temperature, and solar and micrometeoroid radiation through shock and vibration, electromagnetic radiation, and acoustic energy. Just what combinations of environments will be applied in the near future, however, is much less clear. So far, there has been a lot of thermal-vacuum-solar testing, and there is reason to believe that this combination will continue to predominate. Additions to it conceivably might emerge from current studies of the combined simulation of electron and proton radiation and micrometeorite showers. In a few tests, thermal, vacuum and vibration environments have been applied together, and very occasionally acceleration effects have been added to this combination. It appears, though, that these latter groupings of environments will be useful only in exceptional cases. The same seems to hold for the combination of vibrational, acoustic and thermal effects, which has been the subject of some study recently. In view of the tremendous cost of combined-environments simulation, it is rather surprising that no systematic attempt appears to have been made so far to evaluate the benefits of this form of testing. There are lots of reports on the methodology of combined-environments simulation and on the specific data that such simulation has provided for specific vehicles and projects, but there has been little analysis of the value of the data obtained by testing in combined environments--even though it is this sort of information that is primarily needed for the further development of the philosophy of environmental testing. Regardless of the extent to which combined-environments testing is felt to be justified, sophisticated aerospace simulation on a major scale is expensive enough to warrant consideration of less costly (and perhaps more revealing) approaches involving the use of scale and mathematical models. It is of the first importance, therefore, that we improve our knowledge of scaling and modeling techniques, which can appreciably reduce the volume of test operations. Similarly, more work should be done on augmenting and modernizing information-sharing and data bank systems to insure more efficient exchange of both theoretical and empirical data.

Voskresenskii, A. D., Kas'ian, I. I., & Maksimov, D. G. Changes in the cardiac activity and respiration of the cosmonauts during the orbital flight of Voskhod-1 spacecraft. Izv. Akad. Nauk SSSR, no. 31, January-February 1966, p. 21-28, 11 refs. A66-81194 (LC).

When performing light work with a dynamometer, the cosmonauts--V. M. Komarov, K. P. Feoktistov, and B. B. Egorov--showed a slight increase of the pulse and respiration rate. The phenomenon can be regarded as a result of the trigger effects of the nervous system during the onset of accelerations and subsequent adaptation of circulation and respiration to higher oxygen requirements. When working, V. M. Komarov and K. P. Feoktistov exhibited less variability of the R-R interval and shorter duration of respiratory cycles. This is an evidence of the normalizing effect of a light physical load upon the regulation of the cardiac activity and respiration during weightlessness. While doing exercises, B. B. Egorov showed greater variability of the R-R interval. An analysis of the pneumogram revealed periods of tachypnea with a decrease of the duration of the respiratory cycle down to 2 sec. An analysis of the dynamogram showed symptoms of rapid fatigue. Peculiarities of the response of

B. B. Egorov can be associated with the feeling of discomfort due to illusionary perception of the body position, though conceptually a direct effect of weightlessness upon the function of external respiration cannot be excluded.

Vykukal, H. C. Dynamic response of the human body to vibration when combined with various magnitudes of linear acceleration. Aerospace Medicine, 1968, 39, 1163-1166.

In order to determine the effects of vibration combined with higher linear accelerations on human body dynamics, a study was conducted whereby four subjects, in a semisupine position, were exposed to vibration (± 0.4 g at 2-1/2 to 20 cps in 1/2 cps increments) combined with linear accelerations of 1, 2-1/2, and 4 g. The mechanical impedance of each subject was measured. A vibration device developed at the Ames Research Center for use with various motion generators was utilized in this investigation. Results of this study show significant changes in both impedance magnitude and body resonance. The effects of higher linear accelerations on the human body dynamics are increased stiffness, reduced damping of the whole body, and higher energy transmission to internal organs. Resonances at higher frequencies became more predominant in magnitude because of increased coupling of the body system when immersed in a high g environment.

Wolfe, J. W., & Brown, J. H. Effects of sleep deprivation on the vestibulo-ocular reflex. Aerospace Medicine, 1968, 39, 947-949, 18 refs. A68-42600 (IAA).

Sixteen young adult men were deprived of sleep for a period of 24 hr in order to assess possible interactions between sleep mechanisms and the vestibular system. The subjects were given pre- and post-tests consisting of angular accelerations of $8^{o}/sec^{2}$ and $24^{o}/sec^{2}$. Following sleep deprivation, the subjects showed a significant increase in fast-phase frequency at $24^{o}/sec^{2}$, and a nonsignificant increment at $8^{o}/sec^{2}$. Slow-phase output showed no significant change at either $8^{o}/sec^{2}$ or $24^{o}/sec^{2}$. Neither thresholds for stimulus onset nor durations of primary nystagmus showed significant changes for either intensity. Discussion centers around possible physiological mechanisms related to the interaction of sleep and vestibular responses.

Young, W. A., Shaw, D. B., Navach, J., Shizgal, H., & Kowalsky, N. Effect of CO_2 and whole-body vibration on ventilation. Journal of Applied Physiology, 1965, 20, 844-848. AD 630 579 (DDC).

The ventilatory response of six subjects to increasing levels of alveolar CO_2 was measured at rest and during the hyperventilation induced by passive vibratory movements of the whole body. During vibration, addition of CO_2 to the inspired air produced no increase in ventilation until the $PACO_2$ reached a critical level which coincided closely with the intersection of the vibration with the resting CO_2 response curve. Above this level the vibration curve was almost superimposed on the resting one. There was no evidence of an additive effect of the two stimuli, and no increase in sensitivity to CO_2 during vibration. In these respects the situation differs from that in which CO_2 is combined with hypoxia or hyperthermia. The findings indicate that when respiration is stimulated by vibration and CO_2 simultaneously, the resultant ventilation at any point is solely that produced by the stronger of the two stimuli.

SECTION VI

GENERAL DOCUMENTS

Advisory Group for Aerospace Research and Development (AGARD). Collected papers presented at the twenty-second meeting of the AGARD Aerospace Medical Panel. September 1965, 543 p refs. N66-33726 (NASA).

Papers on thermal and vestibular problems, psycho-physiology, cardiovascular and respiratory problems, environment, acceleration and vibration, and aeromedical research equipment are presented.

Altman, P. L., & Dittmer, D. S. Environmental biology. AMRL-TR-66-194, November 1966, 718 p. AD 646 890 (DDC) (Federation of American Societies of Experimental Biology, Bethesda, Md.).

Contents: Temperature; Radiant Energy; Sound, Vibration, and Impact; Acceleration and Gravity; Atmosphere and Pollutants; Atmospheric Pressures; Gases; Water; Solutes; Biological Rhythms.

Bjurstedt, H. (Ed.) Proceedings of the 2nd International Symposium on Basic Environmental Problems of Man in Space. Paris, France. June 1965, 540 p. A68-10434 (IAA).

Pertinent Contents:

Functional Disturbances of Vestibular Origin of Significance in Space Flight. Ashton Graybiel (U.S. Naval School of Aviation Medicine, Pensacola, Florida), p. 8-32, 46 refs. (A68-10435 01-04).

Cardiopulmonary Effects of Acceleration in Relation to Space Flight. Earl H. Wood, W. J. Rutishauser, N. Banchero, A. Clark Nolan, A. G. Tsakiris, & D. E. Donald (Mayo Clinic and Mayo Graduate School of Medicine, Rochester, Minn.), p. 198-211, 12 refs. (A68-10433 01-04).

Typical Problem of Aerospace Biology--Effects of Mechanical Vibrations at the Mitosis Level. P. Grognot, R. Loubiere, & A. Pfister (Centre d'Enseignement et de Recherches de Médecine Aéronautique, Paris, France), p. 229-233, 5 refs. (A68-10446 01-04).

Dodge, C. H. Soviet biotechnology and bioastronautics. Surveys of Foreign Scientific and Technical Literature, 1965, 169 p refs. N66-38129 (NASA).

This compilation of abstracts is based on Soviet-Satellite Western open sources published in 1965. The third in a series, this report reflects Soviet research in the fields of bioastronautics, space biology, and space-oriented biotechnology published during the last three quarters of 1965. There are 93 entries in the form of indicative abstracts, expanded abstracts, and analytical reviews designed to present as much quantitative data as is permissible within the limitation of the abstracting format. These entries have been arranged in nine parts according to subject area: Part I. Biomedical effects of altered gravity (10 entries); Part II. Biological effects of vibration and ultrasound (5 entries); Part III. Radiation effects, dosimetry, and technology (23 entries); Part IV. Biological effects of radio frequency and magnetic fields (10 entries); Part V. Effects of altered gas environments (10 entries); Part VI. Effects of combined spaceflight factors (12 entries); Part VII. Life support systems (7 entries); Part IX. Biomedical monitoring, biotelemetry, and biotechnology (9 entries). The first page of each part contains a list of the entries by number, title, and page title, page number. Not included in this report is material from PKB-4 ("Problems of Space Biology," Vol. 4, 1965). However, Appendix No. 1 gives the table of contents of this volume. Also included in the report are an alphabetical author index and an alphabetical subject index. There is no bibliography.

Dodge, C. H., & Smith, J. L. The effect of spaceflight factors on central nervous system functions. Surveys of Foreign Scientific and Technical Literature, 1966, 42 p refs. N67-12030 (NASA).

Reported is an annotated bibliography of Soviet scientific and technical literature on the isolated and combined effects of spaceflight acceleration and ionizing space radiation on the central nervous system. Cited are studies on respiratory changes during vibration; the comparative effects of neutron, proton, and gamma irradiation; the effect of radial accelerations on brain temperature; the effect of prolonged gamma irradiation on vestibular functions; and cerebral oxygen metabolism; bioelectricity, and conditioned reflex activity during vibration.

Gillies, J. A. (Ed.) A Textbook of Aviation Physiology. Oxford: Pergamon Press, 1965. A66-22104 (IAA).

Pertinent Contents:

Accelerations:
Introduction. P. Howard, p. 517-550.
The Physiology of Positive Acceleration. P. Howard, p. 551-687, 296 refs.
The Physiology of Negative Acceleration. P. Howard, p. 668-716, 53 refs.
The Physiology of Transverse Acceleration. P. Howard, p. 717-745, 53 refs.
The Effects of Acceleration of Short Duration. D. H. Glaister, p. 746-795, 42 refs.
Motion Sickness. T. C. D. Whiteside, 803, 24 refs.

Noise and Vibration:
Introduction. J. C. Guignard, p. 807-812.
Vibration. J. C. Guignard, p. 813-894, 189 refs.
Noise. J. C. Guignard, p. 895-967, 171 refs.
Auditory Perception in Aircrew. P. F. King, p. 968-986, 12 refs.

Henry, J. P. Biomedical Aspects of Space Flight. New York: Holt, Rinehart, and Winston, 1966. 184 p., 33 refs. A66-81934 (LC).

A semi-technical survey of studies on the physiology of man in space is presented. The effects of reduced atmospheric pressure and oxygen partial pressure (oxygen tension, protection by oxygen equipment, pressure suits, problems of gas expansion, and oxygen poisoning) are followed by discussions of terrestrial gravity and acceleration; biomedical problems of weightlessness, self-sustaining systems of space vehicles; hazards of, and protection against, solar and cosmic radiation, radio and heat waves, visible light, and short wave radiation; man-machine systems; the designing of space vehicles and controls; and the selection and training of astronauts.

Iazdovskii, V. I. (Ed.) Space Biology and Medicine. Moscow: 1966, 462 p. A66-43130 (IAA).

Pertinent Contents:

Prolonged Accelerations--G Forces. P. V. Vasil'ev and A. R. Kotovskaia, p. 105-137, 124 refs. (A66-43136 24-04).
Impact Accelerations--G Forces. S. A. Gozulov, p. 138-157, 33 refs. (A66-43137 24-04).
Main Problems of Space Biology and Medicine. V. I. Iazdovskii, p. 61-67. (A66-43134 24-04).

Library of Congress. Soviet bioastronautics and biotechnology, 1964: Compilation of Abstracts. Surveys of Foreign Scientific and Technical Literature, 1965, 122 p. N65-16653 (NASA).

Pertinent Contents:

Effects of Altered Gravity, p. 27-33.
Effects of Vibration and Acceleration, p. 34-40.

Library of Congress. Soviet biotechnology and bioastronautics, January 1966-June 1966. Surveys of Foreign Scientific and Technical Literature, 1967, 167 p refs. N67-27772 (NASA).

Abstracts covering the following general subject areas are presented: (1) Altered gravity, accelerations, vestibular reactions, extravehicular movement, and training for altered gravity conditions, (2) Noise, vibration, and ultrasound, (3) Radiation effects and dosimetry, (4) Biomedical effects of radio frequency and magnetic fields, (5) Hypothermia, clinical death, and reanimatology, (6) Altered gas environments, (7) Astrobotany, exobiology, closed ecological systems, hydroponics, and algae, (8) Modeling of biological processes, human engineering, and man-machine factors, (9) Biomedical monitoring and biotelemetry, (10) Kosmos-110 biosatellite experiments, (11) Manned flight results from Voskhod-1 and Voskhod-2, and (12) Soviet plans and prospects for manned flight. An alphabetical author index appears at the end of the text.

Library of Congress. Soviet bioastronautics. Surveys of Foreign Scientific and Technical Literature, 1968, 199 p refs. N68-26845 (NASA).

Abstracts are presented of Soviet research studies in bioastronautics, and a general commentary reviews some of the major accomplishments. Headings for this bibliography include weightlessness and acceleration, noise and vibration, closed cabins and altered gas environment, and hypodynamia and hypokinesia. Effects of combined factors, excluding radiation, are considered; as are hypothermia, biorhythms, and exobiology and spacecraft sterilization.

Livshits, N. N. (Ed.) Effect of Space Flight Factors on the Functions of the Central Nervous System. Moscow: 1966, 272 p. A66-41334 (IAA).

Pertinent Contents:

Effect of Radial Accelerations on the Brain Temperature of Animals. V. Ia. Klimavitskii, p. 11-24. (A66-41336 23-04).

Effect of Repeated Vibration on the Functional State of the Spinal Reflex Arch. M. A. Kuznetsova, p. 45-67. (A66-41338 23-04).

Effect of Vertical Vibration and Noise on the Conditioned Reflexes of Rats. N. N. Livshits and E. S. Meizerov, p. 68-80. (A66-41339 23-04).

Effect of Vibrational Stimulus on the Oxidation Metabolism of the Brain in Animals with Partial Destruction of the Auditory and Vestibular Apparatus. L. D. Luk'ianova and S. M. Ambrosova, p. 95-104. (A66-41341 23-04).

Livshits, N. N. Certain Problems of Space Neurophysiology. Moscow: 1967, 232 p., 562 refs. A67-40763 (IAA).

Pertinent Contents:

Effect of Space Flight Factors on the Functional State of the Vestibular Analyzer--Review of the Literature. Z. I. Apanasenko, p. 9-44. (A67-40764 23-04).

Definition, Terminology, and Classification of Experimental Accelerations. V. Ia. Klimovitskii, p. 45-56. (A67-40765 23-05).

General and Cerebral Hemodynamics and the Functions of the Central Nervous System During Accelerations--Review of the Literature. V. Ia. Klimovitskii, N. N. Livshits, and M. I. Rodionov, p. 57-92. (A67-40766 23-04).

Remote Aftereffect of Transverse Accelerations on Conditioned Alimentary Reflexes of Rats. N. N. Livshits and E. S. Meizerov, p. 159-168. (A67-40771 23-04).

Lune, M. (Ed.) Life in spacecraft. Proceedings of the International Astronautical Federation, International Astronautical Congress, Vol. 5, 1966, 322 p. A68-42774 (IAA).

Pertinent Contents:

The effect of Prolonged Accelerations on Gas Exchange and Resistance to Hypoxia in Rats. A. A. Giurdzhian, p. 81-84. (A68-42783 22-04).

Effects of Combined Linear and Vibratory Accelerations on Human Body Dynamics and Pilot Performance Capabilities. H. C. Vykukal and C. B. Dolkas, p. 107-116, 7 refs. (A68-42786 22-05).

Certain Problems Concerning the Action of G Forces in Space Flight. A. R. Kotovskaia, p. 287-292. (A68-42804 22-05).

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