

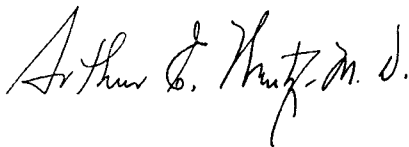
STUDIES ON AGING IN AVIATION PERSONNEL

By ARTHUR E. WENTZ, M.D.

DIRECTOR

Georgetown Clinical Research Institute

Approved by



Arthur E. Wentz, M.D.
Director, GCRI

Released by



M. S. White, M.D.
Federal Air Surgeon

AUGUST 1964

FEDERAL AVIATION AGENCY
Office of Aviation Medicine
Georgetown Clinical Research Institute
Washington, D.C.

CAT. FOR *clearing*
LOAN STACK *(1/11/68)*
(DOC. COLL.) *EW*

RC 1054
U5A4
1964

FOREWORD

This publication represents the first report of a new series issued by the Office of Aviation Medicine, Federal Aviation Agency.

The Office of Aviation Medicine reports will include technical and research reports emanating from the medical divisions in the regions, the divisions in the Office of Aviation Medicine and the research institutes. The publishing of reports from the Civil Aeromedical Research Institute, Oklahoma City, and the Georgetown Clinical Research Institute, Washington, D.C., under separate institute covers, has been discontinued since they will be included in this series.

The number of copies available for distribution will be limited. It is requested that optimum circulation be given to these publications by the personnel to whom they are sent.

Inquiries regarding the contents and availability of these reports should be addressed to the Office of Aviation Medicine, Federal Aviation Agency Headquarters, Washington, D.C., 20553.

M. S. White

M. S. WHITE, M.D.,
Federal Air Surgeon.

PREFACE

This report was originally presented at the dedication of the Civil Aero-medical Research Institute of the Federal Aviation Agency in Oklahoma City, Okla., on October 20, 1962. It has been brought up to date and revised to include a more detailed description of work being done in the individual laboratories of the Georgetown Clinical Research Institute.

Many passages of this paper are contributions from the various members of the Georgetown Clinical Research Institute staff, in their respective specialties.

STUDIES ON AGING IN AVIATION PERSONNEL

Civil aviation represents an area of activity which, in its various facets, is obliged to deal with the entire age range of the general population, both in its user and in its operational personnel. Thus it presents to the Federal Aviation Agency, its regulatory agency, problems which are unique in many respects, and which have not been encountered in the development of military aviation activities, since the latter does not engage in extensive air carrier activities and its operational personnel are subject to mandatory limitations. Therefore, the Federal Aviation Agency, in the organization of its medical service and in acknowledging the importance of identifying in the individual airman decrements in performance resulting from physiological changes (some of which are noted to occur more rapidly in certain individuals than in others), created an Aeromedical Research and Education Division.

The AR&E Division is charged with the responsibility of accurately detecting such changes, as well as with investigating the human factors problems affecting safety in flying. This research is necessary because at the present time no medical methods exist for evaluating an adult human being in terms that will provide a useful estimate of his overall status as an aging individual. To make fullest use of the extensive experience and skills developed by older air crewmembers, it is necessary to develop medical guidelines to determine when decreasing capabilities cancel the benefits of experience. This becomes an increasingly important consideration as additional technical demands of high-speed aircraft evolve.

Chronological age fails to serve as an accurate index of the rate at which these capabilities change in every individual. Men who are in their fifth and sixth decades may demonstrate a physiological performance commensurate with

second- and third-decade function, whereas young men may be "old for their age." This particular study in FAA's research effort is oriented toward improving methods for more accurate measurements of these changes and for their detection at the earliest possible chronological age.

To insure the validity of the results of such research, which will proffer, ultimately, guidelines to a Federal regulatory agency and to acquire the professional talents and capabilities needed to undertake studies of this proportion, the Federal Aviation Agency has sought to integrate its research facilities with those of universities which are outstanding in their research efforts. Such a group of medical scientists has undertaken the clinical aspects of the problems of aging in aviation personnel, organized as the Georgetown Clinical Research Institute, located in the Georgetown University Medical Center in Washington, D.C.

Significant aging changes may be identified in all physiological systems. The changes in some systems can be evaluated with greater facility and offer a closer age correlation than others, so that in selecting a battery of studies which could reasonably be expected to reflect significant aging changes, and where existing techniques afford promise of refinement, these several factors were taken into consideration. Investigative work has therefore been undertaken in the cardiovascular, neurological, pulmonary, visual and auditory, and biochemical systems, and to appropriately relate the functional status of these systems to performance, behavioral tasks have been incorporated in the individual survey.

The format of an aging study, if an individual evaluation of the physiological competence of each airman is to be identified with the passage of time, must be one of a longi-

tudinal or long-range observation of his performance capability. Coincident with such an evaluation, there must be an evaluation of the pathological changes which have presented themselves with the passage of time, in relation to the individual's physiological capability. Depending upon the basic requirements of the man to perform a specific task, we know that certain physiological alterations and pathological changes per se do not interfere with performance. However, the significance of such changes in relation to the total performance of the man must be determined to give him a fair consideration.

The subjects for these studies have been selected from aviation personnel. A relatively gross screening was accomplished by limiting the subjects examined to those who require airman's certification. Inasmuch as there are several groups of aviation personnel whose basic tasks are significantly different but all of whom are required by law to carry airman's certification, data are analyzed in relation to a specific work category. Thus, factors ultimately identified as contributing to an accelerated aging process will be considered in the light of the part they may play in the man's specific work category. To satisfy the statistical requirements of a randomly selected group of subjects, personnel submit themselves for the experimental test battery. This includes all of the examinations required for the issuance of an airman's certificate in addition to the many studies performed in conjunction with the research of their physiological appraisal. Only information required by current physical standards is forwarded to the Certification Division and serves as the basis for the airman's certification. The remainder of the information is analyzed and stored for use in research projects. Statistically significant numbers have been selected for each 10-year age group; these subjects are examined annually and decrements noted with the passage of time, so that ultimately a profile for each individual will be determined. Subsequently, changes in this profile will be correlated with the man's performance capability.

The study of the effect of the aging process in aviation personnel and the assessment of

pathology as it may affect the performance of aviation personnel, are currently being undertaken in the various laboratories of the Institute. A brief description of the work being pursued in the individual laboratories follows.

CARDIOVASCULAR LABORATORY

It is important to reemphasize the dearth of knowledge concerning the circulatory adaptations to age. Circulatory diseases are foremost causes of death at the present time and represent a major cause of morbidity. Recent evidence also indicates that younger segments of the population are victims of these diseases, and in fact, atherosclerosis has been shown to be a universal finding in the adult American male. The clinical manifestations of this change are most common after 40 years of age with almost exponential frequency each decade thereafter. The years after 40 are the fruitful years—the time when learning has been tempered with experience, the time of an individual's greatest productivity.

The loss of these trained individuals represents to the community a major economic drain and causes social consequences that can be as catastrophic as the initial clinical manifestations of the disease process. For those of us in aviation medicine the implications of such losses are all too visible. Also apparent is the need for definitive, scientifically sound knowledge of the alterations in circulatory capacity with time which can serve as a basis for detecting early significant changes which represent a hazard to personal and public safety, in the citizen's role as aviator.

A major consideration in the design of the studies has been methodology. The subjects to be participants in the projects are healthy aviation personnel; and the studies, while requiring a high degree of precision, must therefore be adaptable to outpatients. In addition, the usual type of hemodynamic studies which require intravascular techniques are not acceptable for this subject population.

For these reasons the following generally accepted and widely employed techniques have been incorporated in the series of studies on each subject. The general protocol includes a complete history and medical examination.

These are considered diagnostic consultations in internal medicine and are extensive in scope. A comprehensive cardiovascular review and examination are therefore an integral part of the examination.

Laboratory studies supplementing this examination are blood sugar and serum cholesterol. Serum triglycerids and phospholipids will be incorporated as well. Because there is now experimental evidence to indicate that subjects with abnormalities in lipid metabolism and atherosclerosis also have difficulties in handling carbohydrate, it is planned to do insulin levels with glucose tolerance tests. The appearance of a delayed insulin response to a CHO load as seen in diabetes may be an early clue to the presence of an accelerated atherosclerosis process, especially when related to our other aging parameters.

Special studies are then carried out; these include electrocardiograms at rest, radiocardiograms during exercise, and the conventional Double Masters test. Vectorcardiograms are being recorded to supplement this data and to assess its own merit in regard to early myocardial changes. Studies already completed suggest that VCG supplies only supplementary and complementary data and the accumulated results are being readied for publication. Other recently reported results indicate that, using Mattingly's criteria, subjects who have abnormal RKG's during exercise manifest positive conventional Masters tests. Unsuspected conduction disturbances and alterations in rhythm, however, are often seen on RKG and not on the conventional resting tracing or Masters tracings. Because the RKG does appear to provide valuable additional data it forms an integral part of our evaluation.

Phonocardiography with EKG and with records of precordial movements (apex cardiogram) is used to provide an objective baseline in all subjects of auscultatory and palpatory events. This method also allows sequential comparison of these events and documents murmurs and extra heart sounds. For example, Gallop Rhythm has been interpreted in older individuals as abnormal. We are currently assessing this statistically in normals and correlating its appearance and frequency with our other evi-

dence, to determine its significance and its value as an indicator of aging.

Because of our requirements for indirect methods of assessing myocardial function we are also attempting to devise, standardize, and quantitate conventional and new methods for indirect assessment of the heart. This latter program utilizes patients with known heart disease who undergo conventional cardiac catheterization and in whom an opportunity is therefore present to simultaneously record and relate internal and external circulatory events.

Ballistocardiographic changes with age have been known to occur. A much-improved system for recording the ballistocardiogram has gradually evolved and the superiority of this new "ultra-low frequency" (ULF) BCG method is conceded by the leaders in this field, both in this country and elsewhere. Its physical requirements are not critical and it readily lends itself to standardization and calibration. Justifiable dissatisfaction and confusing multiplicity of older, technically inferior BCG techniques have made capable investigators and research groups reluctant to attempt a reappraisal of this whole area with the newer method until convincing proof of its value was demonstrated. This attitude and the lack of a suitable, commercially available instrument have greatly hindered progress in this field at a time when physiologic and biophysical studies are providing strong evidence of the ultimate potential value of this technique in clinical medicine. The method clearly deserves a careful, clinical reappraisal. It is a well-documented fact that in most patients with overt cardiovascular disease the ballistocardiogram is abnormal in waveform. Furthermore, studies have shown it to be abnormal in about 80 percent of subjects with definite coronary artery disease; and in a considerable number of these, the ballistocardiogram provided the only evidence of abnormality.

One of the most promising areas for research in ballistocardiography has been that dealing with the association of the ballistocardiogram and age. Past experience has revealed that in normal persons the amplitude of the ballistocardiogram progressively declines with increasing age from 20 to 40 years, but waveform or "pattern" remains relatively normal over this

age span. However, above the age of 40 there is a rather striking increase in waveform abnormality in clinically normal subjects such that above the age of 50 approximately 50 percent of these individuals have ballistocardiograms that are clearly abnormal. These results were based on cross-sectional studies and these age trends are generally similar to those for the incidence of development of clinical coronary disease, severity of coronary atherosclerosis at autopsy, and frequency of death due to atherosclerosis and coronary heart disease. However, it has not been proven that the abnormal ballistocardiograms observed in these "normal" individuals are a direct consequence of "subclinical" coronary artery disease, although this remains a good possibility; other age-related changes, such as decrease in arterial elasticity, are probably implicated. The single most important question involved here is the clinical significance—both diagnostic and prognostic—of the age-associated ballistocardiographic abnormalities observed in individuals considered normal on the basis of studies with currently available methods, known to be insensitive. This matter assumes even greater importance since such changes are found in individuals whose ages make the presence of *anatomical* coronary atherosclerosis in some degree a virtual certainty.

One of the best methods for answering this basic question is to carry out long-range, longitudinal studies on normal airmen in different age groups with careful clinical followup. If it could be shown that those individuals whose ballistocardiograms were abnormal at the outset developed cardiovascular disease (and specifically coronary disease) earlier or more frequently than did those with normal ballistocardiograms, then it would become evident that ballistocardiography is a remarkably sensitive method for demonstrating progressive deterioration of circulatory function with increasing age. Although final proof of this relation has not been obtained, there is a substantial and increasing body of evidence which supports it. Starr's recently published results representing a 20-year followup revealed that cardiovascular disease (and especially coronary heart disease) had developed with far greater frequency

in those individuals whose original ballistocardiograms were either very small or abnormal in waveform than in those whose records were normal. Preliminary results from a similar study by Scarborough, Baker and others, though with shorter followup, appear to be rather similar. Moss, Graybiel, and their associates, in studies on Naval aviators, have found that the ballistocardiogram provides a means of detecting "accelerated cardiovascular aging" in these airmen. Inasmuch as the insidious development of advanced circulatory disease (especially coronary heart disease) in aging aviation personnel is one of the most difficult problems that confronts the FAA's Office of Aviation Medicine, longitudinal and cross-sectional ballistocardiographic studies on airmen would seem to be a most promising kind of research in a critical area.

The Cardiovascular Laboratory is well equipped to conduct investigations of this kind; ballistocardiographic instruments of the ultra-low-frequency type, as well as the older, conventional Starr type, are in routine use for studies on normal individuals and subjects with various cardiovascular disease states. To provide intercorrelations, a variety of other physiologic events (EKG, respiration, heart sounds, apex cardiograms, arterial pulses, etc.) are recorded simultaneously. Acquisition of these data on magnetic tape, as well as on conventional media, is now in progress and this will not only permit easy recall of the data in electrical analog form at a later date, but also permit analyses and correlation by computer methods.

Routine radiographic methods have also been used thus far; and as indicated by the requirement of our subject population and known abnormalities in the hospitalized population to which we have access, coronary arteriography and other special methods are employed.

Exercise and pharmacologic stress and the circulatory adaptations to such stress, are being used to assess overall circulatory capacity. Astrand, Reeves, Bishop, and others have compiled an extensive body of data on isolated aspects of these adaptations. The value of this approach is without question, and while our own information is not yet subject to analysis,

reproducible or sensitive, are not likely to prove completely satisfactory. The functional reserve of the respiratory apparatus is so large that resting abnormalities are, in reality, indicative of rather far-advanced disorders. Studies of this reserve capacity would appear to be essential if we are to detect age-related decrements, since such decrements are likely to be expressed primarily as a loss of functional reserve.

Therefore, studies of pulmonary function which will achieve the objectives of this project must include observations made upon the subject during various forms of stress, as well as the usual basal, resting type of observations.

The choice of tests which will provide the type of data sought must be arbitrary at the outset, since data permitting definite selection are not currently available. The situation requires, therefore, that a rather wide spectrum of tests be investigated from which final selection of a suitable test battery can be made. Literature review and experience suggests that each of the following parameters warrants consideration:

1. *Static Lung Volumes*.—Vital Capacity, Residual Volume, Total Lung Capacity. Data exist indicating that there is a definite relationship between chronologic age and the vital capacity (VC) and residual volume (RV). The VC decreases and the RV increases with age.

2. *Dynamic Lung Volumes*.—Maximum Breathing Capacity, Timed Vital Capacity, Mid-expiratory Flow Rates, etc. Prior studies have indicated there is a definite age-related decline in these measures of expiratory flow rate.

3. *"Diffusion Capacity"*.—The studies of Bates and others have indicated that the diffusing capacity for oxygen and carbon monoxide (DO_2 and Dco) both decline with age.

4. *Distribution of Inspired Air*.—With the known age-related alterations in the thoracic cage and pulmonary structure it is likely that an age-related distribution abnormality exists—the same can be said of measurements of the *mechanics of breathing*; i.e., that the total work of breathing and its subdivisions will increase with age.

5. *The Respiratory Responsiveness to Alterations CO_2 , O_2 and pH, and to Exercise*.—There is little information as to the relationship between age and the respiratory response to various stimuli. This is a complex relationship, of course, in which the central nervous system is intimately involved. Since the speed and adequacy with which the respiratory apparatus responds to various stimuli is of considerable importance in aerospace problems particularly, this is an area which deserves further exploration. Data of this type is not obtained by "routine" pulmonary function testing; yet, it may be a critical determinant of functional integrity under certain circumstances (e.g., the sudden loss of pressurization at high altitudes).

6. *The Arterial Blood Gases at Rest and During Exercise*.—As mentioned above, arterial O_2 and CO_2 tension and pH ultimately are altered by pulmonary functional impairment. Often, blood gas abnormalities are absent or minimal at rest and can be disclosed only by an exercise test. Occasionally, study of arterial blood gases, particularly during exercise, will detect an abnormality which is not disclosed—or only suggested by—the other pulmonary function studies (e.g., some forms of diffusion insufficiency).

7. *Pulmonary Hemodynamic Alterations*.—Alteration of pulmonary function frequently leads to deviation in pulmonary hemodynamic behavior. In some instances, hemodynamic abnormalities may precede abnormalities in pulmonary function detectable by other means (e.g., in primary pulmonary hypertension). Furthermore, alterations in pulmonary hemodynamic behavior may well correlate with age. In particular, the capacity of the pulmonary vascular bed and the ability to lower pulmonary vascular resistance in response to an increase in pulmonary blood flow may diminish with age.

8. *Oxyhemoglobin Dissociation Curve*.—It is known that the hemoglobin oxygen dissociation curve is altered in a variety of patients with variant types (other than A) hemoglobin. It is not known whether hemoglobin maintains its biochemical integrity throughout the life span. Interest attaches to the possibility that the O_2 dissociation curve may alter with age and to the possibility that hemoglobinopathies which

alter the O₂ dissociation curve may occur in the "normal" population with some degree of frequency. Since alterations in the O₂ dissociation curve may be of significance in determining tissue oxygen delivery on exposure to low atmospheric O₂ tensions, this area warrants consideration.

A series of patients free from detectable cardiopulmonary disease and ranging in age from 20 years upward will be studied. Each study will include one or more of the following measurements:

1. Static lung volumes.
2. Dynamic lung volumes.
3. Helium mixing time.
4. Minute ventilation, oxygen uptake and CO₂ output.
5. "Single breath" nitrogen test.
6. Nitrogen clearance curve.
7. "Single breath" carbon monoxide diffusing capacity.
8. "Steady state" carbon monoxide diffusing capacity.
9. "End-tidal" carbon dioxide tension.
10. O₂ dissociation curve.
11. Oxygen cost of respiration during various maneuvers.
12. Ventilatory response to exercise, CO₂-rich and oxygen-poor gas mixtures.

The above battery obviously cannot be carried out in the required 30-60-minute time period. It is planned, therefore, to study small "pilot groups" of approximately 100 subjects with one or more components of the above battery to ascertain which measurements are providing first, the most reproducible data (in terms of the lack of first vs. second test variation on the same day) and second, the most promising data in terms of age-related trends. As such information becomes available, certain tests will be chosen for inclusion in the eventual standard protocol for establishing a PAR with regard to pulmonary function, while others will be dropped from the study schedule. Thus, in stepwise fashion an ultimate standard protocol will be derived. This standard protocol will then be applied in a large series of subjects (300-500), and the results of individual tests will be correlated with one another and with the

data obtained in other sections of the clinical research institute.

The high-altitude, high-speed nature of modern aircraft offers a number of actual and potential situations wherein acute or chronic alterations in pulmonary function may have a bearing upon pilot performance and passenger safety. Certain alterations in respiration may produce undesirable physiologic changes in patients with normal pulmonary function, changes which may be exaggerated in subjects with underlying pulmonary or cardiovascular disease. Other respiratory alterations may be important only in persons with significant pre-existing pulmonary disease.

Hyperventilation is a frequent accompaniment of high-altitude flying and of a variety of anxiety-producing situations which may occur in flight. Some data exist indicating that hyperventilation is associated with:

- a. Electrolyte alterations in blood and tissue.
- b. Bronchospasm due to low alveolar CO₂ concentration.
- c. Cardiac arrhythmias.
- d. Central nervous system aberrations.

Since pilots, passengers and any personnel involved in anxiety-producing situations may hyperventilate, it would seem important to determine the response of a series of subjects to this event, with special attention devoted to the possible exaggeration of cardiac or central nervous system abnormalities with advancing age, or pre-existing cardiac or pulmonary disease.

Exposure to High Inspired Oxygen Tensions may well occur in pilots of advanced-type aircraft and in instances where pure oxygen inhalation is called for by loss of pressurization. The effects of exposure to high oxygen tensions upon body metabolic processes are poorly understood. However, some data indicate that such exposure can significantly decrease mental and physical performance. More data are required to define the influence of high oxygen tensions and the critical level of tension at which decrements in performance may occur.

Exposure to Low Inspired Oxygen Tension may also occur in aircraft. Such exposure is likely to have especially severe consequences in patients with pre-existing pulmonary disease,

even though such disease might be subclinical under most circumstances.

The individual with normal pulmonary function utilizes a certain amount of oxygen in carrying out respiratory work. As respiratory work increases (due to increased ventilation), the oxygen utilized increases. In patients with respiratory disease, the oxygen requirement per unit of respiratory work is in excess of normal. Measurement of the oxygen utilized/unit respiratory work increase may detect early derangements of pulmonary function and indicate patients in whom sudden demands for increased respiratory work will be poorly tolerated.

VISUAL AND AUDITORY LABORATORY

Evaluation of the visual system includes fundus photography, the resultant colored slides of which yield information regarding the minute as well as the gross changes of the eye grounds. Such information relates to the occurrence of vascular changes in aging. Use of a photometer in conjunction with the Fundus Camera has been used to investigate retinal metabolism. With an electronic pupillograph, the dynamic measurement of the pupils, separately and consensually, is recorded on a strip chart record. Concurrently, the latency period of light stimulus to iris response is recorded on a memory oscilloscope. These pupillary reactions activated by both light and sound stimuli and directed by the autonomic nervous system, are indicative of physiological aging processes.

Refractive measurements include visual acuity findings (with both Landolt Rings and conventional letter symbols), keratometric readings, retinoscopy, stereopsis, phorias and ductions, and amplitudes of accommodation and convergence. The tests are performed at 20 feet, intermediate, and near distances.

Visual fields are tested using the multiple pattern screening method, the perimeter and the tangent screen.

Intra-ocular pressures are taken by means of the manual and electronic tonometers.

In addition, critical flicker fusion, dark adaptation, brightness contrast sensitivity, color discrimination and span of recognition (tachistoscopia) evaluations are made and recorded.

Where indicated, Slit-Lamp study and other procedures are followed.

Hearing tests include both pulsed and constant pure-tone threshold tests using a Bekey audiometer and/or other audiometric equipment together with a sound chamber. Facilities are available for studies with and without background noise, monaurally and binaurally.

PHARMACOLOGY AND BIOCHEMISTRY LABORATORY

Certain physiological and pathological changes occurring in the older age groups are reflected by changes in body chemistry. The Pharmacology and Biochemistry Laboratory is interested in making biochemical determinations of such changes which can be correlated with clinical and physiological measurements. Several areas in such a broad field may be fruitful, but in this laboratory attention is focused on blood lipids and cholesterol, and on the endocrine products. The development of coronary disease is thought to be closely related to the blood lipid and cholesterol levels. These biochemical methods are being developed.

Conventional chemical procedures for measuring plasma lipid fractions are difficult, time-consuming, and not very reproducible. Also, these methods require large amounts of starting material. The gas chromatograph is a relatively new instrument which offers the qualities of high sensitivity with a high degree of accuracy, and precision of measurement. The work, primarily of Sweeley, Horning, and others, indicates that this instrument is particularly adaptable to the analysis of cholesterol, triglycerides, fatty acids, and phospholipids. Therefore, one might expect to be able to do adequate analytical work with minimal amounts of blood.

Many investigators have reported that an increase in cholesterol and other lipid fractions is seen in atherosclerotic patients. Probably because lipid measurements are so difficult to do, not much data is recorded correlating lipid fraction with objective measures of cardiovascular function. If the gas chromatographic measurements prove to be satisfactory it will be possible for us to attempt such a correlation using the wave-forms of the ballistocardiogram and EKG measurements.

In the endocrine field, methodology in some areas is more satisfactorily developed. This laboratory is primarily interested in the outflow from the adrenal cortex and in the gonadal hormones.

Since the target organs of the endocrine system are under the direct control of the trophic hormones from the anterior lobe of the pituitary gland, it may be interesting to study changes in the ratio of peripheral blood concentration of various endocrine hormones with age. It is known that gonadal function changes with age; and it is to be expected that the stress mediating mechanisms become less efficient with age. Whether these differences in function are due to peripheral changes, changes in the pituitary-adrenal axis or changes in the neural integrating mechanism is not known.

The second major interest of this laboratory is to study stress factors in the field of aviation.

It has been established for a number of years that stressor agents cause hyperplasia of the adrenal cortex in animals. It is known also that a hyperplastic adrenal cortex is under the influence of the ACTH secreted from the anterior lobe of the pituitary gland. Further, research has established the fact that the enlargement of the adrenal cortex in response to stressor agents can be prevented by the administration of glucocorticosteroids to the test animal prior to exposing the animal to the stressor agent. Biochemically, the response to stressor agents is seen as an increase in the peripheral blood levels of 17-hydroxycorticosteroids (17-OH Cs).

In view of these findings it seems reasonable to expect that the adrenal cortex of a person under stress should be hyperplastic if the work situation acts as a stressor agent. In such a case the kinetic response of the adrenal cortex to a test dose of ACTH should be different from that of a normal.

In many pathological states the biochemical systems of the body undergo changes that may be objectively measured. Often these biochemical measurements prove valuable as a primary criterion of disturbed body function, as in the case of blood sugar measurements on a diabetic individual. In this study selected biochemical determinations are being performed on subjects being evaluated under other projects of this re-

search area. Orientation will be toward clarifying other clinical data by biochemical determinations and toward identifying certain determinations with the greatest value in predicting performance capabilities.

COAGULATION LABORATORY

The development of intravascular blood clots can lead to acute disability, as can the appearance of a bleeding tendency. The delicate balance which maintains blood in its normal fluid state is known to be altered by a variety of factors. For example, "stress" has been said to accelerate clot formation—but also is known to enhance fibrinolytic activity. Little is known regarding the effect of hypercapnic acidosis, hypocapnic alkalosis, hyperoxemia and hypoxemia upon the status of the blood clotting mechanism. If these conditions do affect coagulation, they may have important bearing upon thrombotic risk in patients breathing oxygen or subjected to conditions producing hyperventilation or hypoventilation.

Multiple studies have suggested that patients with atherosclerosis differ from normals with respect to the speed of coagulation, the degree of clot-dissolving activity and the level of certain coagulation factors in the blood. Little is known regarding the age-relation of such changes in coagulation. There also have been studies indicating that the likelihood of clot formation may be predicted by the finding of coagulation changes suggesting the presence of "hypercoagulability." If these studies can be validated, they may offer a new approach to the detection of subjects with atherosclerosis and, more critically, those in whom the risk of thrombosis may be particularly high.

BEHAVIORAL SCIENCES LABORATORY

Recent behavioral studies indicate substantial decrements in certain aspects of mental and behavioral functions with age, not only in old age, but from youth to middle age. The functions most affected involve such factors as speed of computation and skilled movements, speed of perception and goodness of short-term memory, particularly in complex or distracting situations. Unfortunately, all of this work has

been piecemeal in that behavioral test findings have not been related to each other or to physiological and clinical findings in a global fashion. The intercorrelation with a broad variety of carefully chosen behavioral task scores with elaborate and precise clinical data, should yield valuable insights into the processes of aging, as well as the behavioral implications of certain physiological findings. Behavioral test proficiency scores will be especially carefully interrelated with tests of goodness of visual and auditory sensory functioning, so as to separate peripheral from the more central kinds of deficits.

The tests now in use include:

1. Perceptual motor speed tests:
 - a. Serial, choice reaction-times.
 - b. Serial stimulus matching reaction-times.
2. The Wechsler Digit symbol substitution test and the Reitan Trails Making Test, two brief, well-standardized speed tests which are good discriminators of age and brain dysfunction, respectively.
3. Running short-term memory test.
4. Speech intelligibility test for digits, using unfavorable signal-noise ratios and two degrees of frequency-band limitation, designed to discriminate between sensory and perceptual disability.
5. The Halstead Tactual Performance Test and Wechsler Block Design Tests, both good indices of organic brain impairment.
6. The Halstead Categories Test, an excellent index of organic brain impairment.
7. Visual flicker-fusion thresholds (CFF) are measured by the Visual and Auditory Laboratory.
8. The Cattell 16PF Personality Inventory is given on the second or later visits.

Groups of older people are almost invariably slower on the average than groups of younger people, at almost any psychological test, and frequently are somewhat poorer also. Much of this so-called "age decrement" in performance may be due to cardiovascular disease which produces cerebrocirculatory insufficiency. If true, this fact would be of the first importance in establishing policy in regard to age, health, and flying.

Results from behavioral tests have already demonstrated that cardiovascular disease is statistically associated with some impairment of mental efficiency. Further statistical correlations will be obtained on a continuing basis, and special types of cardiovascular cases will be recruited and tested. It is particularly important to find sizable numbers of cases of parallel age range and ranges of severity of disease of several types, who are on different medical regimens.

An attempt will be made to assess the nature of this impairment by comparing test profiles of cardiovascular disease cases with cases suffering known kinds of organic brain impairment.

From the longitudinal studies of various physiological and behavioral characteristics, masses of data will be obtained. In order to extract and identify these elements of diagnostic or prognostic significance, these data must be subjected to sophisticated statistical analyses. In addition, electronic computer techniques must be utilized in analysis and interpretation of continuous wave-form data generated by medical techniques, such as electrocardiography and electroencephalography.

BIOPHYSICS AND ELECTRONICS LABORATORY

Since the solution to current and anticipated problems in aeromedical research can only be solved by using a team approach, the Biophysics and Electronics Laboratory plays an integral part in the multidisciplinary activities of the Institute. In the development of new techniques and procedures for clinical evaluation of the functional status of aviation personnel, experiments are becoming more complex, and more variables must be accounted for or controlled. In order to delineate physiological parameters more precisely between individuals, increased accuracies in measurements are required. The development of integrated data handling systems has contributed greatly to the growing sophistication of research instrumentation in medicine. As a consequence, the use of computers has become a necessity, both on-line and off-line, to analyze measurement results and

to search for useful correlations not obviously discernible.

The demand on this laboratory's creative capability is demonstrated in an all electronic measuring and magnetic tape recording system in the Cardiovascular Laboratory and a new analog computer for the reduction of pulmonary function data.

The range of activities of this laboratory includes the design and development of transducers for measuring physiological function, data conditioning systems, data acquisition systems, on-line and off-line data reduction systems and the application of the latest state-of-the-art in biophysics and electronics to problems in civil aviation medicine.

Computer demands and statistical guidance for the appropriate analysis in such a program are evident, so that the inclusion of epidemiological supervision for our staff is mandatory. Eventually, a verification of laboratory studies is planned in an airborne environment.

In conclusion we may say that we can hope, with several years of consecutive studies on individuals, to:

1. Develop from the foregoing procedures a significant set of techniques by which the physiological aging rating for that individual may be ascertained.
2. Develop a profile of physiological capabilities which insures performance demand.
3. Develop more refined techniques of evaluating the significance of pathological states, as well as their detection at the earliest possible age, so that some alleviation may be effected to preclude the ultimate development of incapacitating decrements.
4. Aid in the formulation of physical standards determined by physiological rather than chronological age, thus lengthening the productive period in the life of qualified aviation personnel.