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Aviation medicine : a general survey

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AVIATION MEDICINE

A General Survey

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INTRODUCTION

"One of the newest specialties in medicine is that known as aviation medicine. It is a little different from other specialties in that it, to a large extent, comprises portions of other specialties all applied to aeronautics. It includes a certain amount of ophthalmology, otology, internal medicine, neuropsychiatry, psychology, and physiology. The whole purpose of the subject is largely preventive in nature. It involves the selection and care of the pilot, and his protection against the physical forces acting upon him in the air, all with a view to preventing accidents from a physical cause." (37)

The above quotation discloses the scope of aviation medicine as it is today. The work that has been done in this field in recent years is tremendous, and to cover each branch of aviation medicine completely would necessitate a great deal more time than is now available. For this reason, the scope of this thesis will be limited to the subjects listed in the table of contents; however, it is hoped that the thesis will serve as a basis for later and more extensive work in the field of aviation medicine.

The purpose of the thesis is to review some of the literature concerning several of the existing problems of aviation today. All of the literature on these problems has not been reviewed, either because it was inaccessible or in foreign languages, but the more practical and enlightening articles have been reported. Some of the statements are based on personal experience, and others are based on personal opinion, but nearly all the facts will be referable to the authors or articles listed in the bibliography.

THE HISTORY OF AVIATION MEDICINE

"The history of aviation medicine is necessarily so closely linked to that of aviation itself that it is impossible to tell the story of one without giving at least a brief outline of the other." (21)

Man's desire to fly is not new, but it is probably as old as man himself. It is not unreasonable to believe that the earliest man appreciated the fact that birds in flight were able to come and go with much greater ease and speed than he could accomplish by foot. Greek mythology tells us of characters who were able to fly by one means or another. Roger Bacon had visions of man flying, and has apparently made several successful predictions concerning aviation. It is recorded that Leonardo da Vinci was famous for his work on model helicopters, and he is credited with designing types of planes similar to early aircraft seen in the first days of flying. (21)

A Frenchman, Besnier, made the first successful glide, from a housetop to the ground, using a pair of home-made wings. (21)

On June 5, 1783, the Montgalfier brothers, at Annonay, France, launched a large linen bag, paper lined, filled with hot air. This flight lasted ten minutes and covered one and one half miles. In September, of the same year, a repeat flight was made for the royal court, and the first air passengers were a chicken, a duck, and a sheep. (43)

Pilatre de Rozier and the Marquis d'Arlendes made the first human balloon flight on October 15, 1783, when they ascended in a basket suspended from a large smoke filled bag. It is also interesting to note that balloons were used in France, Italy, and Africa during wars. It is also recorded that balloons were used by the Army of the Potomac. (43)

In 1785, Dr. John Jeffreys of Boston, and Jean Pierre Francois Blanchard flew from Dover, England, to Calais, France, in a balloon filled with hydrogen. (21)

As it had been demonstrated that man was now able to fly, it was inevitable that the scientific minds of that day would become interested in the effects on man of venture into this new and mysterious atmosphere above. Glaisher and Coxwell ascended to nearly 30,000 feet in 1862. During this ascent Glaisher noticed his visual acuity was lessened as was his hearing. He also noted paralysis of extremities which was soon followed by unconsciousness.

Coxwell, feeling the same effects, tried to pull the valve rope, but was unable to do so as his arms were also paralyzed. Fortunately, he was able, with his teeth, to pull the release rope, and both men landed safely. (21)

The published accounts of this flight so affected Paul Bert, a French physiologist, that he began to study barometric pressures and their effect on the body when increased or decreased. One of Bert's co-workers was Tissandier, a meteorologist. Tissandier, Crocè and Sivel made a high altitude balloon flight in 1875, and the following quotation is a description of the flight as written by Tissandier:

"I now come to the fateful moments when we were overcome by the terrible action of reduced pressure. At 22,900 feet....torpor had seized me. I wrote never-the-less....though I have no clear recollection of writing. We are rising. Croce is panting. Sivel shuts his eyes. Croce also shuts his eyes....at 24,600 feet the condition of torpor that overcomes one is extraordinary. Body and mind become feebler ....there is no suffering. On the contrary, one feels an inward joy. There is no thought of the dangerous position; one rises and is glad to be rising.

I soon felt myself so weak that I could not even turn my head to look at my companions....I wished to call out that we were now at 26,000 feet, but my tongue was paralyzed. All at once I shut my eyes and fell down powerless and lost all further memory." (21)

The balloon continued upward to 28,820 feet before it descended. Tissandier was the sole survivor of the flight.

This incident stimulated Bert's work, and in 1878 he published his "La Pression Barometrique" dealing with the effects of increased and decreased barometric pressure. He proved that the decrease in partial pressures of oxygen was responsible for the effects of high altitude, and he investigated the blood and respiratory gases for their composition and changes under the condition of high altitude. Armstrong states that one cannot feel that he is an authority in aviation medicine until he reads and digests this publication. It has been said that Paul Bert should be the father, or grandfather, of aviation medicine, and he should receive the honor of being the first flight surgeon. (21)

The previous discussion and report has been concerned primarily with motorless flight and balloon ascensions as they occurred before the twentieth century.

In 1902, at Kitty Hawk, N. C., the Wright brothers, Orville and Wilbur, began gliding tests which enlightened them as to what structural characteristics in gliders gave the best flight performance. This experience also taught them how to steer and to balance a glider. Shortly after, December 17, 1903, Orville Wright made the first airplane flight in history at Kitty Hawk, N. C. The flight covered 120 feet over a 12 second period at an altitude of 10 feet. History reveals that Wilbur ran along side the wing tip to steady it. (15)

There has been some question as to whether the Wright brothers made the first flight or not; there is a record of the attempts of Prof. Samuel Langley to fly one week before the Wright brothers; however, it is also recorded that Langley's ship, "Aerodrome", crashed on the take off, and that it did not actually fly until 1914 when a new engine was installed. (15)

In 1907, the Wright brothers offered their ship to the government, but the offer was refused. Experimentation continued, and only one year later the first aircraft with wheels was successful in tests.

In 1908, September 9, Orville Wright, with Lieutenant Frank P. Lahm as a passenger, tested the first Army aircraft. This ship was the typical Wright model with the fragile longerons, landing skid, bilateral pusher propellers, and elevating surfaces in front. This ship was able to fly 42 m.p.h. with a passenger and pilot for a duration of over an hour. The price paid for this ship was $30,000. Unfortunately, in 1908, Lt. Selfridge, flying the plane just tested by Orville, crashed to his death at Fort Meyer, Va. This accident slowed the growth of military aviation for nearly a year until July, 1909, when the second Wright craft was accepted by the Army. (15)

Flying progressed to the extent that in 1908 and 1909 there were air shows, and, in France, Curtiss outflew Bleriot to win the Gordon Bennett international speed cup. The Army rapidly accepted aircraft as a weapon of war, and as early as 1911, several of our present day Air Corps leaders were trained by the Wright brothers near Dayton, Ohio. In 1911, the first Army bomb was dropped from a Wright pusher. By 1914 a bomb sight had been rigged up, and fifty pound bombs were being dropped. In 1911, a machine gun was being carried into the air for aerial gunnery. In

1912, the first wireless in flying was adapted to the fragile Army plane. (15)

With the establishment of military aviation, doctors and fliers alike realized that some men were not fitted for aviation, and as early as 1912, special examinations were considered necessary. It was apparently necessary to form the Air Medical Service, and men were sent to Europe to study foreign methods and to compare findings.

The appearance of modern aviation was delayed until September, 1914, when the first aero-squadron was organized at San Diego, California, consisting of 16 officers, 77 enlisted men, and 8 planes. Previously, July of 1914, the Aviation Section of the Army Signal Corps had been established, and Colonel Samuel Reber was placed at its head. (43) Later in 1914, Major T. C. Lyster realized that pilots needed higher abilities than other officers. (106) Reber set up standards for military aviators by using a copy of "Physiology" from the Surgeon General's Office. After four to six weeks, Col. Reber appeared again at the Surgeon General's Office and stated that the standards were so high that no one had been able to pass. He recommended lowering of the standards so that pilot material would be available. (107)

The lowering of standards was the key to the lock opening the door to the field of Aviation. It was not at all unreasonable that Reber couldn't get men to fit the physiological standards that were set up. But now, men were available, and progress continued.

The first aircraft in an American war was seen in Mexico in 1916 when Captain Foulois led the first Aero-Squadron in an invasion. The planes employed were useless and were crashed in a matter of five weeks. (15) Earlier than this, the foreign powers in World War I were using aircraft for observation. It was soon discovered that planes were very good to attack from, and soon the pilots and observers carried bricks, stones, iron pipes, etc. for ammunition against enemy pilots. It was quite a feat if one was able to throw something into the enemy propeller. So was the origin of the first aerial combat. Eventually, machine guns made their way into the aircraft, and aerial warfare was on in earnest.

As early as 1910, Germany had secretly, or at least quietly, been investigating the characteristics most necessary in a military pilot, and in 1910 they had organized minimum standards for pilots. By 1915, the Germans had an actively functioning aero-medical board in action. Thus was Germany ahead of the Allied Forces in military tactics, and that this happens again, in connection with World War II, will be shown later. (21)

In 1916, the British organized standards for the "Care of the Flyer" in an attempt to lower the mortality rate among their airmen. They reported that nearly 90% of accidents, fatal, were due to pilot failure, 8% were due to aircraft structural failure, and 2% were due to enemy bullets. (106) It was also shown that about 50% of air corps candidates suffered from neuroses while in training. (21)

In 1917, Lyster and Wilmer made changes in the Army aviation physical requirements, but in May, war was declared in June of 1917, Lyster and Jones drew up a new examination schedule. Sixty-seven examining units were set up over the country, and about 100,000 applicants were examined. (107) (21) Other reports say that there were thousands of men ready for the air corps before war was even declared. (8) As many of these men were sent to England and France there were Air Service medical officers transfered with them, but these early flight surgeons were picked at random and had no special training of any sort. (8)

In September of 1917, a "Medical Research Board" was appointed by the Adjutant General's Office to, (a) investigate conditions affecting the pilot's physical efficiency, (b) to carry on experiments at fields and schools to determine a pilot's ability to fly at high altitudes, (c) to develop a suitable oxygen unit for high altitude flying, and (d) to act as a standing medical board to consider matters concerned with the fitness of the flying personnel. This board consisted of four officers and one civilian, Dr. Y. Henderson, Major Watson, Major Lewis, Major Wilmer, and Major Seibert. The first act of this group was to establish a laboratory at Hazelhurst Field, Mineola, Long Island. The laboratory was opened in January, 1918, and by June, 1918, the floor space was increased three times, and the personnel was proportionally increased. (107) (21)

It was decided that there would be departments in physiology, cardiology, psychology, otology and ophthalmology. The main concerns of this organization were with oxygen want at high altitudes; an altitude tolerance test; aerial equilibration and orientation; and reaction time tests. (107) (21)

Unfortunately the Air Service Medical Research Laboratory was abandoned after the World War, in about 1920. (21) Why the government did not foresee the great opportunities available no one will ever know, but such an unprogressive move should be guarded against in the future. Even today we are years behind the German investigators.

About the time of the establishment of the Hazelhurst laboratories, Schneider and others were working on the problem of high altitudes, and the changes incident to life at high elevations. The startling results caused medical men to wonder about the effects on a pilot, as pilots often went to heights three times greater than Schneider did. (43)

In France, with the American forces, the conditions were somewhat different as concerns research work and pilot care. American fliers were piloting the French S. P. A. D. chasse fighter, the Nieuport 28, the Nieuport 17, and various other fighting craft. When one inspects photographs of these ships, one marvels as to how they held together at the amazing speeds of 135 miles per hour--and faster in dives. It is no wonder that 50% of the men showed neuroses when we realize the conditions under which they were operating.

A group of assigned men were attached to the 3rd Aviation Instruction Center in France where they found 575 students, out of 3,000 American fliers in France, that were a rather miserable lot. These young men were a "good lot", but they had a low morale and a fatalistic attitude. Many men were being killed in crashes, and it is said there is nothing more horrible than the mangled bodies that one finds in smashed aircraft. Small wonder that a fatalistic attitude should exist. These men were getting no exercise except infrequent limbering-up calisthentics in the early morning. It was noted that with the low morale and fatalistic attitude there was no venereal disease. These men were "stale", or, in modern terms, they were suffering from aviator's sickness or aeroneurosis. They had been given only a rotation test to decide their fitness for the air service. As stale as these men were they could get only two days leave at any one time. (8)

It was found that the poor physical condition of these men was mostly responsible for their crashes. At once, measures for physical exercise and recreation were instituted. Better environment, food, training, and examining were planned. (8) It is here that we see the power and importance of good psychology in aviation. That these measures were successful is proven in a report which tells us that 1,869.44 extra flying hours were obtained--despite the shortening days and inclement weather. It was also announced on October 15, 1918, that the record of 4,436.46 flying hours without a death had been established. (21)

Reports to medical men assigned to the 3rd Aviation Instruction Center indicated that some change was necessary. One pilot tells of his taking bromides and aspirin to relieve headaches from gas fumes. He was improperly fitted with goggles and was suffering from eye strain as well. This man had been on day bombing for six straight months. Then, there was the pilot who, being very stale and next to useless for efficient tasks, was given a compound cathartic rather than leave and told to get back to his work. (8)

The British forces had said, "It is very fortunate that the air forces of the United States are profiting by the mistakes of our flying service in recognizing at the beginning that the medical problem of aviation is a very special problem, and cannot possibly be conducted except by an organized body of experts." (43)

It is obvious that the situation just had to be changed. At that time, flight surgeons lived apart from the men, and they were not well received by the flying personnel. The medical problems then, as now, are mainly two: (a) the selection of the pilot and (b) the care of the flyer. Adjustments were gradual, very gradual, and even though some reports indicated success, it was easily seen that aviation medicine had much to accomplish. (43)

In November of 1919, the "School for Flight Surgeons", a branch of the Air Service Medical Research Laboratory, was located at Mitchell Field, L. I. In 1921 this became a permanent institution, and it was recognized as a Special Service School. A fire destroyed the school, and in 1922, December, the "School of Aviation Medicine" was born. Brooks Field, Texas, was the new location in 1926, but in 1931, the organization was moved to Randolph Field, Texas. The functions of the school were (a) instruction and training; (b) investigation and research; (c) extension study. Many valuable experiments have led to new aides in the care and protection of pilots. (21)

Following the war, interest in flying appeared to slacken, and aviation received very little help of powers outside of this field. In 1926, the Air Commerce Act was passed, and the Bureau of Air Commerce of the Department of Commerce was organized to foster and to guide civil aviation. Then, in 1927, Lindbergh made his epic trans-oceanic flight, and aviation was reborn. (27) (21)

This new group, the Bureau of Air Commerce, adjusted the physical standards as they were indicated. Whereas, at first, we were concerned with finding a plane to keep up with the man, it was now found that we must find men to keep up with the planes. The physical requirements are essentially the same now as they were organized by the Bureau of Air Commerce. (27)

Air passenger travel began in earnest, and airmail was something new and exciting, but it was Lindbergh that reawakened America to aviation. Back in 1921, Mitchell had tried to establish the importance of air power--something which later led to his unfortunate dismissal from the Army in 1925. In 1924, four Douglas planes started on a round-the-world flight, but only one made the trip successfully. (15)

Aircraft grew in size and power, airlines were being formed and speeds of 375 m.p.h. were developed; annual air races all over the country were held. (21)

June 13, 1938, the control of civilian flying was given to a new group--the Civil Aeronautics Authority, better known as the C. A. A. Today, the C. P. T., Civilian Pilot Training program, has overshadowed the C. A. A. (21)

With all this growth of aviation fever, it was to be expected that the field of aviation medicine would be flooded with papers and publications. In 1926, Major D. A. Meyers clarified the physiology of blind flying--a brilliant contribution to aviation. Periodicals increased in number, and Bauer published his textbook on aviation medicine. In 1929, a flight surgeons' association was formed, and the "Journal of Aviation Medicine" was started by them, in 1930. In 1937, the publication, "Flight Surgeon Topics" was presented, and several European countries also offered journals. (21)

By 1938 aero research laboratories were being established all over the country. In America, Lt. Col. M. C. Grow realized that facilities were needed, and, as a result of authority later given him, a new laboratory at Wright Field was established. In 1938, also, a second research laboratory was organized and located in Kansas City, Mo. (21)

The Mayo Clinic was ready to accept the importance of Aviation Medicine, and as a result they approached the problem from a practical angle. Ten Mayo men were selected to take the Civilian Pilot Training program. These men included an otolaryngologist, ophthalmologist, cardiologist, neuro-psychiatrist, dentist, surgeon, and an internist. These men passed the course, and are now better able to appreciate the problems of aviation medicine. They now examine C. P. T. students, and follow their students in an attempt to check individual progress against the examiner's impression. The ideal form for which they are seeking is to estimate by examination those persons who have an inherent ability to fly. (72)

Armstrong says, concerning the increased interest in aviation medicine, "This trend makes one feel safe in predicting that the Science of Aviation Medicine will have a growth and importance in the immediate future far greater than anything conceived by its founders." (21)

THE FLIGHT SURGEON: DOCTORS IN AVIATION MEDICINE
and
THE GENERAL HEALTH OF FLIGHT PERSONNEL

With the realization that aviation and medicine were so closely interwoven that medical men, in this field, needed special training, it was felt that an official designation was indicated for this group of doctors. As a consequence, the term "flight surgeon" was "coined" in March, 1918. Today, this term applies to anyone engaged in the practice of aviation medicine, civil or military. (21)

It has been said that aviation is probably the only modern means of transportation that needs medicine to make it more safe. (109) That this statement is well grounded can be accepted when one recalls the British statistics concerning the percentage of fatal crashes of military aircraft due to pilot error. (107)

As aviation medicine is a decided specialty, it is essential that the potential flight surgeon have a good general medical knowledge. Armstrong believes that a "well rounded many-sided man is much to be preferred." (21) The school of aviation medicine has outlined a program which illustrates the great amount of special, or post-graduate, study needed. The duration of the course has been changed by the present war, but previously the basic course covered four months with an average of thirty houss of instruction weekly. The method of instruction is along the same lines as is employed in any medical college. This includes lectures, quizzes, demonstrations, laboratory work, and practical medical aviation experience. (21)

The flight surgeon must have education and professional qualifications of a high order. He must have a pleasing type of personality, and he must know how to handle men of all natures. The doctor in aviation has to exert especial effort to maintain the confidence of the men for whom he is responsible. As was previously stated, the early flight surgeons were viewed as enemies by the flying personnel, for every pilot realized that these medical men could terminate his career. It has been a long struggle for the flight surgeon to establish himself as a useful and necessary individual, for he not only had to persuade the air crewmen that he was working for them and not against them but also he has had, even until recently, the difficult job of proving his worth to the government. Frothingham reports that the early flight surgeon was not well received, and he was told that he must work out his own salvation. (48)

Several "don'ts" were presented to the early flight surgeons, and at Selfridge Field it was gossiped that the flight surgeon came to disqualify rather than to help, and it was only after much hard work that mutual confidence was established between doctor and flier. (48)

Even though we appreciate the importance of the flight surgeon, facilities are none too adequate to train the numbers of flight surgeons that are necessary for the air arm of today. (100) Certainly after this war, with aviation the coming field, there will be multitudes of opportunities for training in the field of aviation medicine.

An annonymous article says that unless flight surgeons are developed to the same extent as has been the speeding up of aircraft production we will be wasting time. It is realized that the mass training of flight surgeons is difficult, but we must have properly qualified men that are familiar with the problems of aviation. We should familiarize ourselves with these problems even though we are civilians. (14)

Just what are the duties of a flight surgeon? First, the flight surgeon must remember that he is a doctor. Second, he must have a good working knowledge of his field as he is expected to select aviation cadets that will justify the government's spending of thousands of dollars on their training. Third, the flight surgeon must care for the flyer in a prophylactic manner. Fourth, the mysteries of aviation physiology and the connective possibilities of these effects must be worked out. (21)

The flight surgeon preserves the mental and physical state of the flying personnel, and, to do this, he must have what may be known as prophylactic knowledge. (100) Prophylactic treatment is the answer to the success of the flight surgeon. He must be able to look ahead and to anticipate situations; he must fly with his men to understand their problems, and he must learn to evaluate each man and his reactions in any type of situation. Flight surgeons are cheap insurance when one realizes that they have the power, by benefit of their training, to temporarily ground a man before he causes irreparable damage to himself, his crew, and his aircraft. (100) To be a success he must be "one of the fellows", and must know his men by their first names. He must always be a keen, observing, student of human nature. (109)

The question of a non-flyer's ability to appreciate the flyer's problems has always been a question involving much dispute. Sheep records that after a doctor becomes a flight surgeon he is encouraged to become a pilot so that he may better appreciate the problems that a flyer meets. Also, this common bond brings the two groups closer together. In 1930, of forty flight surgeons, twenty-nine were on flying status either as passengers or pilots, and of the twenty-nine, seven were pilots. Five more of this group were in pilot training at the time. At that date, flight surgeons were required to fly at least ten hours every month. (95)

In answer to the above suggestion, Neuberger, in 1932, says that the Army gives their flight surgeons flight training while the Navy provides no such experience. This author is against a doctor receiving flying training, as he believes a man can't do both jobs well enough. Also, the pilot-flight surgeon soon arrives at the stage where, because of his own experiences, can no longer see the true effects of flying in other men. (81)

A recent article, 1939, by Adams, outlines the latest policy in the training of Naval Flight Surgeons.

For those men who are interested in aviation medicine, and can meet certain qualifications, there is the opportunity to enter the School of Aviation Medicine at Randolph Field, Texas. After successfully completing this course the qualifyers are designated as Naval Flight Surgeons. There now follows a second phase of training at Pensacola, Florida, lasting three months. This phase consists of special flight and ground school instruction. This work enables the doctor in aviation to realize just what an aviation cadet is up against, and, consequently, the problems of these students are more intimately appreciated. The men receive flight instruction in many types of aircraft, and this is supplemented by 130 hours of classroom work with twenty hours of collateral reading. This author believes such training is a step forward and that after such experience the flight surgeon will probably be more the type of man that "we" think he should be. (1)

Personally, I am inclined to agree with those men who feel that a flight surgeon should receive some flight training. It is impossible that one can evaluate the problems of an individual in any line of work unless he actually participates in that man's work. Of course, by merely riding as a passenger one is able to appreciate the stresses and strains of flying, but this is not enough. Can it be that by merely watching a pilot, flying at a high altitude without oxygen, that the observer is able to feel and to know what effort is needed to concentrate on the exact touch and skill involved in flying under such conditions? Can it be that by merely watching a pilot land a ship that the observer can know what is demanded of that man? I do not believe this to be possible. Personal experience enables me to say that, in several flights, I could never see that landing a plane was such a difficult problem. In fact, landing looked very easy until I tried it. Not until that time did I appreciate how much skill, care, and nervous tension must necessarily be involved in any landing. It is true that men who have had many hours in ~~this~~ THE AIR apparently are able to land and fly without effort or evident concentration. Also, it is true that even air cadets soon learn to fly in a subconscious manner, but it is hard for me to believe that this is ever true of aircraft landings. In flight, it is more easy to relax and to fly subconsciously as there is nothing about the plane to interfere with the pilot's safety.

The landing of an aircraft entails a different situation entirely. Here is the ground rushing up to meet the descending plane; the slightest miscalculation may result fatally. It would be impractical to believe that merely watching would enable us to project ourselves into the pilot so that we could know what stresses and strains are working within him.

I cannot agree with Neuberger (81) who says that the aviation medical officer cannot fly and practice medicine at the same time. It is true that if all the flight surgeon had to do was to steer himself around the sky at the government's expense that in time he would become the same as the rest of the flying personnel, but, the flight surgeon has other duties that entail the selection and care of flying men, and, if he is qualified, he should enter the field of research. Armstrong feels that "there is no flight surgeon today worthy of the name who could not, if he would, contribute something new and worthwhile to the literature of aviation medicine." (21) Is there any better means for the flight surgeon to appreciate the flyer's problems than to gain personal experience under the same conditions and circumstances? I do not think so. I do not believe that the flight surgeon should be allowed to take the complete course of training given to members of the Air Forces, but he could be given basic training, possibly advanced flight training to a limited extent, with some ground school instruction. Is it reasonable that a man with the designation of flight surgeon should be left uninformed of, or untrained in, the very field in which he is trying to help perfect? Such a thing is comparable to saying that one is working with tropical diseases, but yet this one has never been to the tropics. This question is worthy of more consideration.

The flight surgeon is responsible for organizing the medical organization of his post. When accidents occur he must investigate the cause with the view of preventing repitition of such occurrences. (81)

Just the mere association with your men enables you often to hear and to see things that may be of value in preventing future, or imminent, tragedies. (81) I do not believe that this author intends any suggestion of "eaves-dropping", but rather, he realizes that, even though a pilot will confide more in the flight surgeon than in his commanding officer, he will not disclose all pertinent facts, either through error or through intention; therefore, it behooves the flight surgeon to gather as much information, pro or con, as is possible before he passes judgment on such cases.

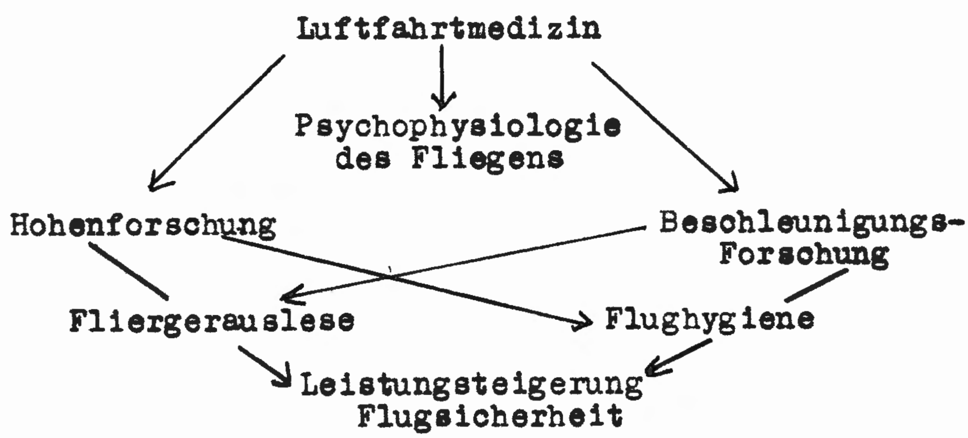
It is apparent that the whole body is strained by the act of flying. Therefore, we must be ever on the alert to detect those little deviations which may, if not now perceived and corrected, lead to tragic results in the future. The three main sources of troublesome defects are the ear, the eye, and the heart. There are well known methods of testing the ear and the eye, but the detection of early heart lesions is a difficult problem in any branch of medicine. It has been suggested that by using the rebreather we can detect early heart lesions. This would be of value in general medicine as well as in aviation. By giving the subject tests to perform while he is being tested we can detect the time of performance change, and, by using standard results, we can classify the patient as to the extent of the lesion. Some of the tests have included the response to a light by pressing a contact point, changing the speed of a motor, and the regulation of a voltmeter to certain values. Of course, the rebreather is primarily intended for investigation concerning a man's altitude tolerance, and his performance test give us an idea of his future reactions, any tendency to mental instability, and a good idea of his ceiling. (31) In investigating blood pressure levels associated with the above work, it is interesting to note that four examiners take the examinees pressure, and the lowest reading stands. The above discussion does not mean to imply that this is all there is to the job of a flight surgeon, but rather that there are often little "tricks" or shortcuts to early interception of potentially dangerous disturbances.

It is essential that the flight surgeon be a tactful man, for there will be times when he is forced to ground men, permanently or temporarily, and of course the grounded man will probably not see any reason why such a thing should happen to him. In times like this it is essential that the flight surgeon practice such a brand of psychology that will enable the pilot to see that all is being done for his benefit and for the benefit of his associates. The importance of psychology in aviation will be discussed later.

Sheep says the flight surgeon has come to stay.

(95) Taylor completed the correspondence course in aviation medicine after two years. The subjects he covered to become a civilian flight surgeon included ophthalmology, otology, cardiology, aviation physiology, psychology, psychiatry, and aviation administration. He advises taking this course as its value is immeasurable, and his associations with the faculty were invaluable. (101) In the same article he gives Greene's viewpoint concerning flight surgeons; he says the optimum time to be trained as a flight surgeon is after three years service while he is still under forty-five years of age. The flight surgeon should necessarily have moral character of a high nature, good self control, initiative, resourcefulness, originality and foresight. (101)

The intricate relation between medicine and aviation is described by the Germans by using the following diagram. (92)



Let us review again the duties of the flight surgeon. He must act as an advisor to the commanding officer of the field group to which he is attached whenever any of the personnel is in questionable health. Secondly, he must evaluate the efficiency or fitness of aviation cadets. Third, he must preside over sick call and the general care of flight personnel. Fourth, he should attempt to contribute as much as possible to the field of aviation medicine. (95) He must be a student of human nature, and, most important of all, I think, he must be an exceptionally good psychologist.

Armstrong warns us that all too frequently some flight surgeons act as though they were walking psychoanalysts. He says these men are poorly trained in the field of psychology with just enough information to become a nuisance.

Of course, in the consideration of the flight surgeon, we must also be concerned directly with the general health of flight personnel, for it is with this consideration that every flight surgeon is directly and constantly concerned.

Probably the first duty of the flight surgeon is to initially select men that are in excellent physical and mental condition. What standards are we to use to select pilots? How can we be sure that our methods of selection are going to give us men who are going to be good investments? As for answers to these questions, we can refer to Armstrong's textbook for physical standards that are used, and for this reason these requirements will not be discussed here. As for an answer to the second question, well--we just don't know that these men will turn out to be good pilots and crewmen. It was earlier stated that Germany had moved ahead of the United States in many ways. Today we are seeing the end results of a great experiment in a practical method of pilot selection as performed in Germany and Russia. As we all recall, the Treaty of Versailles prevented the Germans from using powered aircraft to train military pilots. Unfortunately, no restrictions were placed on glider training, and thousands of German youths were introduced into aviation through means of the glider. This training was combined with a physical improvement program, and as a result every qualified German boy knew how to fly, for the principle of powered flight and glider flight are the same. Records were kept on all these young glider pilots so that when they were ready to enter the military service their abilities and weaknesses were known. These extensive records made the selection of military pilots a comparatively easy job because the German flight surgeons had only to check their physical qualifications--it had already been proved they could fly successfully. By the time these candidates reached military age, all the weak and inefficient had been cast out of flying. The German people grew up with aviation, but unfortunately America fell behind. As a result we now, again, must have rapid selection of pilot material with no assurrance that the men we select are blessed with the inherent ability to fly. The discovery of this ability cannot occur with any test except that examination which demands that the student be able to fly before he comes to the military service. "As in any highly skilled occupation, a person's capabilities are best observed when he is given the opportunity to do what he is being tested for." (103) Of course, the Civil Aeronautics Association made it possible for many young men to fly, but the actual value of the C. A. A. can be measured in a matter of a few short years while the German plan has probably been in effect for close to twenty-five years. Also, just because a man can fly our light planes, this is no indication that he can become a military pilot. The Germans even went so far as to suggest lowering of the physical standards. It would be well to remember also that it has been found that psychomotor tests are dangerous at times "as the human psyche can't be guaged by these tests." (103)

It is realized that the selection of Naval Aviation Cadets is a complex task which needs clarification regarding "the interrelationship between, and the relative importance of, selection and maintenance; the realization of the multiplicity of essential qualifications for service in Naval Aviation; appreciation of the importance of recognizing balanced broad ability rather than seeking isolated desirable traits in extraordinary degree; the conception of selection as a continuous process and as one which should include classification for specialized training and duties as well as the prediction of general aviation aptitude." (68)

The ideal candidate should have many abilities, with the most important including a high tolerance for prolonged flights at high altitude under conditions of reduced atmospheric pressure, low partial pressure of oxygen, and rapid alternating atmospheric changes. He must be resistant to the effects of low temperature, high speeds, and fatigue. The ideal candidate should have high emotional stability, but, at the present, our means of singling out this particular qualification are inadequate. Even with our methods, twenty-five per cent of apparently acceptable candidates are washed out because of some defect associated with personality derrangement. (68) The question of how we are to elicit these weaknesses before both time and money are invested in a flying candidate naturally arises. As was stated, psychomotor tests are often dangerous; so, we must not depend entirely on the results of such tests when we evaluate personal qualifications. Benjamin suggests the use of low pressure chambers to bring out any tendency toward mental or personality unbalance. (31) I have found no statistics concerning the results of using this means of "psyche" determination, but it appears that if the candidate has an inherent personality or mental weakness, the exposure to low oxygen pressures is sufficient to make them manifest. We will see later that even in the "normal" type of person there are personality and mental changes under the influence of lowered oxygen partial pressures.

Previous to 1930, the Boeing Aircraft Company foresaw the importance of the general health of flight personnel. The company so firmly believed in this factor that two flight surgeons were hired to give the company pilots extra examinations in addition to those given by the Department of Commerce. The duties of these men were to keep the fliers in the air in the best possible physical condition and to look for the smallest ailments and minor defects which might later become major problems even before the victim himself realized it. (2) It is believed that one of the most important conditions that the flight surgeon has to combat is neurocirculatory asthenia--the importance of this will be taken up later. Fatigue, related to neurocirculatory conditions, was the most common etiologic factor. This condition may be called air-staleness which, according to Ahrens, is neurocirculatory asthenia. (2)

The Boeing Company has used the Schneider Index to evaluate a candidate's flying condition. But what is the Schneider Index and how is it used? It is a cardiovascular performance test which uses the prone and standing pulse and systolic blood pressure under conditions of rest and activity, assigning such values to each recorded finding so that when the accumulative score is compared to standard performance tests we have an insight into the pilot's general condition. You will recall that we have said that fatigue first shows itself in the cardiovascular system. The exact technic of performing this test can be obtained from Armstrong's textbook on page 117. (21) This author also gives several precautions which must be taken into consideration when the test results are evaluated. It is here stated that, unless there are other cardiovascular findings, a Schneider Index of less than eight should not be considered disqualifying.

If a Boeing pilot showed an index below 10 he was sent home for rest and exercise. From experimentation it was found that after four hours of flying a pilot was less efficient, so, trips or flights were limited to four hours with every pilot receiving a day of rest every two to three days. It was also found by these experiments that a man operated at a higher efficiency at a low, but safe, altitude. Boeing pilots were closely watched as concerns their eyes, ears, nose, throat, and cardiovascular system. (2).

In 1928 it was found that about 60% of plane accidents were, and are, "due to the pilot, not because of some physical defect, but rather as a result of fault somewhere along his higher levels." (70) This is a much better record than the 90% value of pilot error found in World War I. We are still troubled with the selection of pilots for even with the latest safety devices the military flyer must rely upon his experience and skill in emergencies. We are making forward progress in the detection of unsuited pilot material, for we have set up standards of age and intelligence, and we have developed psychological means of gaining insight into the personality of the flying candidate. It is interesting to note that the elimination of flying cadets is started by themselves even before they are called up for examination. It was found that over a five year period the following figures were obtained: 13,325 men were examined for the air service; of these, only 2,686 were qualified for training; 2,049 were eventually ordered to training centers, but only 642 of the original 13,325 were graduated as military pilots. The great discrepancy in the number of examinees as compared to the number of successful candidates is explained on the basis thatmany of the original group did not really want to fly as badly as they thought. Then too, others lacked the necessary physical, mental, and mechanical factors so essential to military pilots. This author arrives at a very interesting conclusion. He believes that the best pilots are found in men over 30 years old as these early years are used in reaching a maturity. (70)

It is important to realize that there are intuitive and mechanical types of flyers. Those pilots who fall into the latter group must necessarily be watched more closely as they are potentially dangerous.

In reference to the care of transport pilots, Tillisch and Lovelace give five outstanding reasons for the maintenance of the health of flying personnel; these are: (a) for the pilot's sake; (b) because of the economic importance of the pilot's health; (c) because of the physical and emotional strain that is constant; (d) because of the increasing age of transport pilots; and (e) because of the pilots and airlines responsibility to the passenger. (103) These men carried on a series of personnel tests in which they used the family and personal history, the physical examination, laboratory studies, X-rays, basal metabolic determinations, decompression chamber tests and blood groupings. In their results they found that

53 of 103 pilots examined had foci of infection, 41 had some slight impairment of hearing, and 71 had physical defects of one sort or another. (103)

In the process of determining a candidate's mechanical ability we have several instruments for use. In America we use the Ruggles Orientator, and the British use the Reid Reaction apparatus. These are instruments which are fitted with plane controls that the subject manipulates in order to simulate level flight, and to elicite a flight reaction while he is still on the ground. The purpose of both of these is to investigate the coordinating skill and the type of reaction that the candidate will give in actual flight. The Reid Reaction apparatus consists of manipulating the controls so that level flight will be held. Level flight is indicated by a white light on the dashboard in front of the pilot. If the white light becomes red or green the pilot must manipulate the controls until the white light again appears. The colored lights indicate a loss of level flight either to the right or to the left. The reaction times are measured on each individual. Comparison of these results with the records of the examinees in actual flight indicate that these tests are of value. Possibly this conclusion came as a result of testing men who had had some previous flight experience. If this is true, we must carefully evaluate the results obtained on such a test unless we can expect that new and untrained men are inherently bestowed with the proper type of coordination when they need it. Possibly we are expecting too much from these newcomers when we expect them to sit down at a strange mechanism which they are expected to control well right from the start. Still the true test of a man's flying ability isn't seen until he takes to the air in actual flight. (70)

All of this entails a great deal of work on the part of the flight surgeon, but with new arrangements and adjustments and pre-selection examination one may be able to ease up the strain on the flight surgeon somewhat. Kafka believes that the family physician holds the answer to this problem. The family doctor can aid the preparedness program by careful examination of the sons of his private patients if those boys are considering aviation cadet training.

He is in a position to save these young men much time and grief if he will but examine them closely and critically. By doing this the boy is eliminated early before he gets to the selection board examining group.

It has been found that many candidates are rejected for reasons which could have been cured or adjusted before they leave home. These physicians should check the eye, the ear, nose, teeth, throat, chest, skin, cardiovascular system as well as personal and family history. In other words, give the boy a complete medical workup with an idea in mind to find any possible deviations from the normal. In this work, a practical point, one may use the following plan as a guide for height and weight: "allow 104 pounds for 5 feet of height, and add 5 pounds for each inch over five feet." (63)

The flying candidate must have a normally functioning body including the heart, respiratory system, vestibular system, kidneys and eyes. In addition we expect to find a constitution strong enough to resist the rigors of military flying. As severe as these requirements seem, the military services are looking only for the average or average plus type of man. (70) It was previously believed that only the college trained athlete was the type of man needed for the air service, but this idea has so been changed by adjustments in our selection systems that anyone who can meet the present requirements is now eligible for flight training.

As concerns the eye in personnel selection and care, we expect the candidate to have good central and peripheral vision, good ocular balance, good depth perception, and good accommadative power. No correction is allowed for military pilots in this country except in cases of men with much service. In Canada, and in Germany, military pilots are permitted so much correction which is ground into their goggles. (70) It is interesting to note that many of the pilots who made up the various American groups of men flying for Canada and England were unable to enter the American Air Forces because of physical disabilities. But, these men accumulated so much glory and so many victories that they have proved that pilots with minor disabilities can fly and fight as well as men with completely normal bodies. This fact also bears more discussion; every day English men who would be unable to pass our Air Force requirements are doing every bit as good a job as men who are physically perfect. However, it has been shown that in proportion to its degree, physical defect increases the inability to fly. (70)

Longacre has reported that the "accident-peak" is reached somewhere between the first 400 and 600 flying hours, and that as the hours of flight increase the ratio of accidents decreases. Each military pilot has about 250 flying hours when he graduates, so it is evident that during the next two years, while he is in this class of 400-600 hour pilots, he must be watched more closely than ever. The author indicates that with the present methods of careful pilot selection there will not be a reduction in crashes due to pilot error. He goes on to say that in the two years following graduation he should have additional training so that he may master his profession. (70)

In the Navy we are often up against other problems not actually related to physical condition. In this branch, the flight surgeon on a carrier must supervise the hygiene of a great many pilots in a restricted amount of space. We must consider the effects of sun glare, especially in the tropics, for it is here that sun glare is so often a single cause of general physical unfitness. The pilots should play handball and volley ball which are games demanding alertness and allowing mental relaxation. In such cramped quarters, variety is necessary for often this exercise becomes a daily task, and a severer state of staleness exists. Frequent eye examinations using the phorometer to maintain ocular balance are helpful. Often, we will find that hyperphoria is the cause of bad carrier landings. (112)

Yanquell mentions three pressing problems of aviation medicine today: "(a) further inquiry into the mechanism of the physical collapse of the flyer following sudden changes of direction in recovery from dive bombing with tests to eliminate those susceptible; (b) the design of an all purpose air goggle to eliminate injurious glare without changing the color of the terrain; and (c) further work on carbon monoxide poisoning from exhaust and to develop tests which expose a pilot's idiosyncrasy to this gas." (112)

A good general consideration to keep in mind is that when a pilot complains of a disturbance in equilibration one must investigate the whole proprioceptive mechanism, and none of the component proprioceptive factors must be excluded or emphasized more than the other. Lately it has been generally agreed upon that the eye is one of the more important factors in disturbances of equilibrium. (70)

There usually comes in every pilot's life that time when his eyes become weaker. Naturally, he feels that he will be grounded if this weakness is discovered; so, he endeavors to find ways whereby he is able to improve his vision without glasses. All of us have heard of eye exercises to correct eye defects. To those individuals, pilots or not, who believe this is possible, A. S. Philps has an answer. He writes an article for the purpose of explaining what exercises can and cannot do. He tells us that no exercise replaces glasses that are genuinely needed, but exercises can help a convergence insufficiency or a heteraphoria. It was found that in some pilots this latent squint, or heteraphoria, upset vision to the extent that they were unable to land their aircraft. These men demonstrated normal visual acuity, but further examination disclosed the existence of this heteraphoria where fatigue had weakened the ocular muscles. Philps also believes that if a man looses an eye early enough, he can reeducate himself to see well enough to be a safe civil pilot even though he is of no military value. (86)

In flying today, the most important consideration is the human machine which has not kept abreast of the latest mechanical developments. Smith says that the human machine may not be as good as it was twenty years ago. Planes, instruments, and clothing have been greatly improved so that the pilot no longer "flies by the seat of his pants", but, rather, he must depend upon an alert and stable nervous system. The English have proved that all these modern advancements are of little value if the human being using them can't adjust himself to their use. (96)

Today's problems are concerned with the mechanical developments in aircraft structure versus the human body. Smith says that we may liken this to expecting a Model T Ford to keep up with the present streamlined auto, wherein the Model T finds the load rather heavy. Mechanical development is held back by the physical-mental shortcomings of the pilots. (96)

Let us briefly review some of the features involved in the general care of flight personnel. Originally, the flight surgeon was concerned with the pilot alone, but today the doctor in aviation has united with the engineering departments in the attempt to construct planes that will help us overcome the effects of the elements and the stratosphere. Then too, today, the pilot is subjected to more strains and stresses than previously due to improvement in basic designs of aircraft. Today there are many more people on board military craft than before. The effects of flight are just as important where these passengers are concerned; all of which increases the personnel to be guarded.

In caring for the pilot we must maintain certain approaches that give the flight surgeon in military circles advantages that the civil flight surgeon cannot claim. The military doctor can, and must, keep in constant and close contact with his men. He must appreciate and evaluate their complaints and their problems. He must be tactful and ever willing to give the flying personnel the best advice and care that is possible. He must truly be a student of human nature. He must be the type of psychologist who can obtain the information he desires without the examinee realizing what is occurring. He must not let the pilot and crewmen feel that they are subjects of some mysterious investigation that he is carrying on. Recall previously that it was mentioned that some men act as walking psychoanalysts when actually they have only enough knowledge to be potentially dangerous. Remember too, and remember well, the old adage that "you can lead a horse to water, but you can't make him drink." No man ever gets the maximum efficiency and cooperation from his associates or employees if they feel that he is ever ready to pounce on the slightest error or "symptom" that they may show.

The flight surgeon must constantly keep his mind active along the lines of his selected work. He must investigate vague problems with the honest intention of helping the flying man with all of his endowed and acquired abilities. He must be able to correct their physical deviations if it is at all possible, and, most important of all, he must not think that he is the all-knowing power who can terminate the career of a flying man at any moment. He must realize that to these men of the air flying is life itself, and, if there is some question as to whether a man should be grounded, he should seek the advice of other impartial flight surgeons so that the flyer is given every benefit of investigation before his livelihood and spark of existence is cut out.

The doctor in aviation should so firmly implant himself into the existence of the flying personnel that they come to believe in him, come to know that he is working for them, and that he will do everything in his power to help them correct their deviations if it is at all possible. All of these suggestions are to be enforced just as strongly for enlisted personnel as they are for the commissioned group. It is the duty of every physician, flight surgeon or not, to direct his efforts toward improving the conditions of life in the air, on the ground, or under the sea.

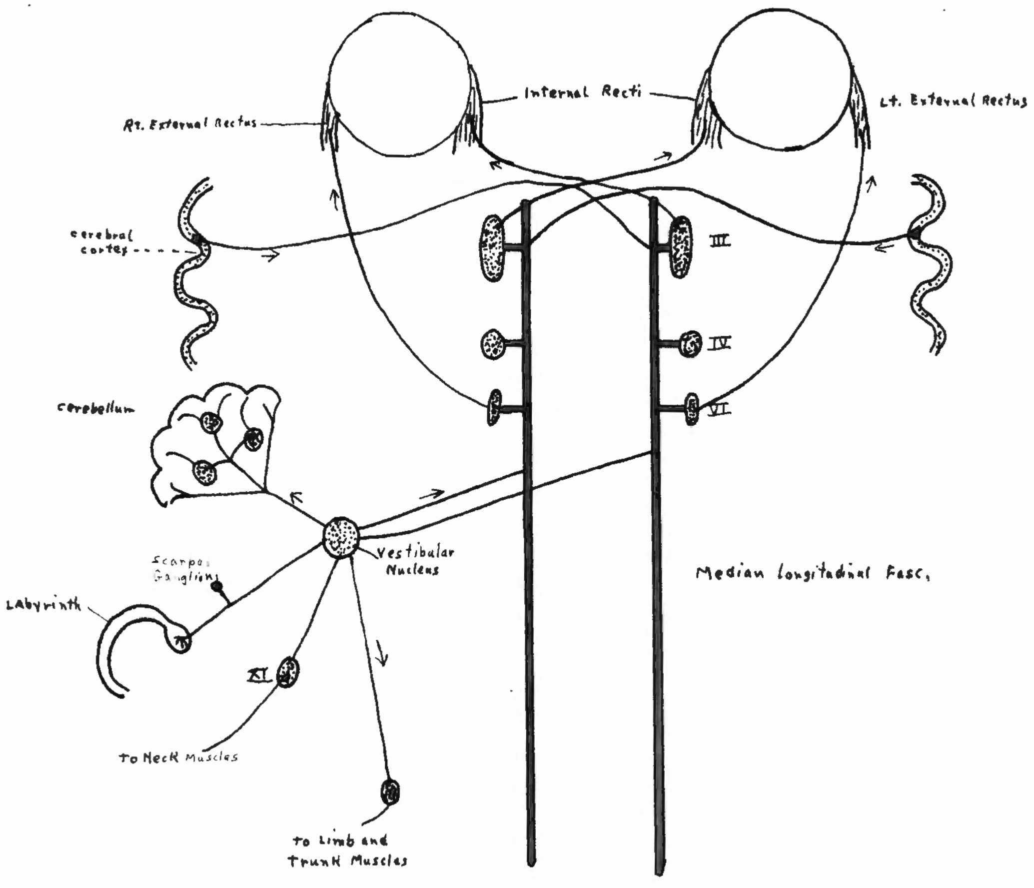
The future of aviation medicine, even aviation itself, depends solely on the capabilities and earnest desires of the man who will call himself a "Flight Surgeon."

AIRSICKNESS

Airsickness is a physicomental state associated with unusual types of motion or accelerations occurring in aircraft flight, probably due to labyrinthine stimulation, and being characterized by nausea, vomiting, apprehension, fear, pallor, diaphoresis, and, often, physical collapse. This type of sickness is to be differentiated from aviator's sickness and altitude sickness, both of which will be considered later. Bauer believes that this type of flying sickness should be called "motion sickness". (26) (29)

Yanquell believes "airsickness" is a term loosely applied to a syndrome wherein the victim becomes pallid, nauseated, vomits, and sweats profusely during the course of aircraft flight. (111)

The physiology behind this condition demands mention of the factors involved in "motion-sickness". Equilibrium is not the function of one isolated part of the body, but, rather, it is the sum total effect of various influences. It is now felt that vision is probably more important in disturbances of equilibrium than even the labyrinth, for true labyrinthine disease is not as common as formerly believed. The vestibular apparatus is also very important, but there are so many factors involved in the vestibular system that it is essential to reproduce the following diagram of the vestibular pathways as suggested by Best and Taylor. (32)



This diagram shows the intimate relationship of the vestibular pathways with the eye, the cerebral cortex, the cerebellum, and the body muscles, principly of the neck. In addition to the above mentioned component parts, we must also consider the whole proprioceptive system of the body. (26)

The vestibular apparatus is a double organ with a saccule, utricle, and three semicircular canals on each side in the temporal bone. In the semicircular canals is a fluid substance known as endolymph which stimulates small hair cells located in the utricle which communicates with semicircular canals and the saccule. Changes in the endolymph causes the afore mentioned stimulation to give a sense of motion that is often just the opposite to the true direction of movement. If we are turned rapidly to the right we may first feel that we are turning left. (26) According to Best, if we are rotated in one direction we develop a sense of counter rotation which is in a direction opposite to the flow of endolymph, and opposite to the slow or vestibular component of a post rotary nystagmus. (32) However, there are three types of nystagmus to consider so, what is true for one type may need slight adjustment or modification to be true for the others. Too, vertigo arises from causes other than rotation. It may occur with alcoholic intoxication, sea sickness, car sickness, cardiovascular phenomenon, renal states, toxic conditions, gastrointestinal or neurological states; however, according to Best, regardless of the associated condition the immediate cause lies in the excitation of the semicircular canals or of their higher or central connections. (32)

Bauer reports that the proprioceptive sensations "apparently play no part in air-sickness, but in the intimate relationship of all proprioceptive function with the vestibular system it is difficult to believe that this is true. (26) If such a statement was true, then there would be little value in our possessing stato-tonic or attitudinal reflexes. It is my impression that our proprioceptive system unites with the vestibular system to maintain our equilibrium and upright posture. Any changes in position from the upright are received and evaluated by both systems.

The etiological considerations are essentially on a physiological basis, for, as Armstrong points out, there is not one "comprehensive treatise" on this condition to indicate any other basis. (31) This author also points out that two facts indicate this to be due principally to motion. The first fact is that the frequency and severity of airsickness "is in direct proportion to the amount and duration of the accelerations encountered in flight." The second fact is "that persons with dead labyrinths seldom if ever become airsick." (31) Of course, the second fact suggests, as Bauer has said, that the labyrinth alone is entirely at fault, but, Armstrong says "seldom if ever" do these types become sick. This in itself propagates the possibility that other factors are involved. Winfield lists three causative considerations: physiological, pathological, and psychological, with combinations of these three being possible etiological factors. (108) This, leaving no other field to be considered, leads us now into some actual considerations as to the location of the disturbance. Armstrong believes that his second fact, given afore, confirms the theory that this condition is due to the involvement of the internal ear wherein it becomes a particular type of vertigo--"provided the meaning of the term vertigo is clearly understood." (31)

Under Winfield's physiological factors we are concerned mainly with effects of the first flight on the labyrinth wherein this organ is subjected to a new form of stimulus. (108) It is true that the labyrinth has been subjected to other changes in position, often at fair speeds, in most of us before we are out of childhood, but the newness of this stimulus is explained by Armstrong when he tells us that the mechanism of vertigo in flight depends upon the fact that the aircraft is in the same position as the body during this acceleration and that "this is contrary to our normal experience and gives rise to conflicting sensory impressions in consciousness." (21) It is reasonable to expect that in due time, with greater experience and exposure that we may become adapted to this stimulus. However, it has been found that even the most experienced pilot may become airsick when he travels as a passenger. (21) Included in the physiological considerations by Winfield are weather conditions, type of aircraft, noise and vibration, ventilation, comfort, diet, ocular stimuli, cold, anoxia, and even boredom. (108) Under this same consideration, Yanquell suggests vestibular hyperstimulation as the most likely etiological factor.

The mechanisms producing the physiological causative factors may be either artificial or natural. That is, the artificial are the result of planned maneuvers while the natural refers to the changes in position or plane of flight as a result of changes in the weather or atmosphere. This condition may result from such maneuvers as tight spirals, (either upward or downward), from spins, or from snap rolls. The latter is one of the most common causes of airsickness. The snap roll is a violent 360 degree rotation of the ship about its horizontal axis while in level flight. (111) (26) (21) Yanquell found that after the snap roll came the Immelmann turn which is a half roll and 180 degree rotation at the summit of a loop. (111) The natural mechanisms responsible involve the effect of "air-pockets" on the level flight of the ship. This results in the same situations as acrobatic flying, and is most common on windy days or when there are abrupt weather changes. The drop caused by an air pocket results in stimulation of the endolymph which is followed by the usual symptomatology of this condition. This brings out Armstrong's idea that the "really important acceleration of aircraft either in acrobatics or in turbulent air, is in a linear vertical direction", wherein "this acceleration may be as high as 32 feet per minute and of sufficient duration to cause an airplane to rise or fall a distance of 100 to 1000 feet in a few seconds." (21) All of which is to make us realize that there are other types of motion than rotation which can cause vertigo.

It is interesting to note that 100% of a year's group of Naval Aviation cadets have admitted to having some disturbance of this nature at one time or another, and these men are superior physically to the rest of the Navy as determined by examination. Also, many people who refuse to admit any disturbance of this type probably have had mild attacks which they refuse to identify. Because of this we consider that such a reaction is more likely a normal than an abnormal or pathological response. (111)

Winfield had included pathological etiological factors wherein he states that organic disease increases the susceptibility to this state. Also, that such local conditions as sinusitis or otitis media may result in hypersusceptibility to this condition, at least for the duration of the condition. (108) Other than this interpretation there is very little concern with pathologic etiology in recent articles.

That psychological factors are heavily involved is evident when we review some of the selected literature. Bauer says that this condition is probably largely on a psychological basis, and that some persons are more sensitive than others. (26) He brings out that vision apparently increases the susceptibility to this condition "for if the slightly ill passenger watches the horizon, he will become more acutely ill. If he fixes his eyes on some definite point in the cabin of the ship, he will be less apt to be sick." (29) This, he says, brings in the psychological factor as it is the mere movement of the ground and horizon that apparently brings on these attacks. Then too, the nervous and high strung type of individual is always more susceptible to these effects. (29)

Armstrong writes that "the vomiting of airsickness is nothing more or less than the natural reaction of the body to a state of fear whereby it rids itself of all unnecessary impediments in preparation for fight or flight." (21) Conflict, he believes, occurs in a psychogenic state where fear of death, and desire of self preservation are accentuated according to the situation. In his textbook he records Conn's findings wherein there were personality changes in twenty-five children who became car sick in relation to the apparently normal personality integration of twenty-five children who never became car sick. (21)

Yanquell tells us that in Naval Air cadets, when they had been forewarned of a particular maneuver, that there was very little effect evidenced as compared to sudden maneuvers performed without warning. He also brings out that, even with warning, neurotic individuals were not helped, and there was no sympathetic inhibition. (111) Armstrong furthers the importance of psychology when he reports that often the train of symptoms characteristic of this state may persist for hours or days after the flight is over. This duration couldn't be due to prolonged physiological effect; so, it must be explained on a psychological basis. (21)

Winfield states that airsickness may recur as a psychological escape mechanism if the individual can't adapt. (108)

The incidence of air sickness, in its more severe forms is negligible, as it has been shown that the frequency is no higher than 5% among passengers. (29) Previously, it was stated that 100% of a year's group of Naval Air Cadets reported that they had had episodes of distress. Due to the low incidence, this condition does not appear to be serious, but with so little information on the subject we cannot know just how important it is. Never the less, this problem needs more investigation even with its low incidence.

The symptomatology is apparently agreed upon by the few men who have investigated this problem. As was stated in the definition, the main symptoms are nausea, vomiting, apprehension, fear, pallor, profuse sweating and collapse. (21) Additional symptoms given by Bauer include headache, and increased salivation. (26) Armstrong describes the subjective symptoms as having their origin in the gastro-intestinal tract with slight nausea increased to the point that projectile vomiting may occur. Temporary relief may follow but soon there is a session of retching. The skin becomes cold and clammy after the onset of nausea; then, as the symptoms progress there is a sensation of nervous and muscular tension followed by lightheadedness, muscular weakness, and collapse. He says the best description of the symptomatology is in the words "sick all over". There may be mental depression with a sense of impending disaster due to the abnormal physiological and psychological processes occurring. There may be no distinct vertigo, but dreamy states may occur. (21)

Armstrong gives such a valuable description of the objective symptoms that it may well be quoted here: "The first objective signs in airsickness to be observed are pallor of the skin, beads of cold perspiration on the forehead, and a drawn anxious expression of the face. When nausea is severe or vomiting occurs the face becomes yellowish or greenish gray in color and the patient has the appearance of being acutely ill. The pulse rate and blood pressure both increase during the early part of the illness, but may finally drop below normal.

"In the early stages there is evidence of muscular tenseness followed in the later stages by muscular weakness and tremor, and the gait becomes staggering. There is rarely any objective evidence of vertigo, and nystagmus is seldom observed. In severe cases there is evidence of great physical prostration and mental depression." (21)

Yanquell says that it is essential that the flight surgeon be able to differentiate the normal reaction from the pathological reaction of the neurotic. (111)

He also states that if airsickness persists we should search for carbon monoxide gas poisoning; also eye muscle unbalance and the effort syndrome may mimic the symptoms of airsickness. (111)

In any discussion of treatment we must necessarily be concerned with prophylaxis. Armstrong describes two methods that will render one immune to airsickness, but also he states that these are not practical. We could destroy the labyrinths or we might destroy the vestibular portion of the eighth nerve. The other alternative consists of daily turnings in the Barany chair over a long period of time. Neither is worth the risk or effort involved however. (21) It is necessary that patients who may be more severly injured by the effects of this condition should never be allowed to fly.

A great deal of prophylactic treatment is dependent upon the steward or stewardess who can usually detect these nervous individuals early enough so that she may watch them a little more closely. If she sees the people THAT ARE SUSCEPTIBLE she will know how to distract their nervous attention so that they suddenly realize that their fears of flying were groundless, and that they have no fear of being ill. Other suggestions come from Bauer who says that the new passenger should be instructed as to the use of the safety belt. He should also be given cotton for the ears if the cabin is not soundproof. Chewing gum is a valuable aid for releasing the pressure in the eustachian tube. The prospective passenger should eat something light before flying, as heavy and rich foods increase the susceptibility to this state. The cabin,of course,should be ventilated properly to avoid noxious gases, and the color scheme should be such that it does not upset the nauseated passenger any more so. (26) The air of the cabin should be fresh and not odorous. It is essential, if possible, that the vomiting passenger perform his act in the washroom away from the sight of the other passengers. (21) (26) Iced gingerale has been found useful in many cases. (111) The passenger should be instructed to fix the eye on some point in the cabin as it is the movement of the ground and the horizon that causes this upset. Yanquell suggests the passenger fix the gaze on some distant landscape, but I feel that this is less efficient than fixing the gaze on some point in the cabin. (111)

As additional prophylaxis Bauer suggests giving the patient a map on which the stewardess will describe the route; reading matter may be used. This may be impractical as often the mere effort of trying to read or to concentrate when one is nauseated is enough to precipitate a more serious condition. (26)

Lilly suggests a light diet before the journey, and advises a laxative with seconal sedation, 3/4 to 1 1/2 gr., the night before. It is best to avoid watching moving objects. Frequent small meals easily digested may help. (17)

The methods of actual treatment are few, but they may be very effectively combined with the prophylactic treatments. Winfield warns against the use of drugs that will further depress cortical function. (108) Armstrong supports this view. (21)

Bauer suggests that the passenger be given an effervescent drink along with 1-2 grains of amytal, Wright's suggestion, which may cause the patient to sleep long enough to awaken in a relaxed and refreshed condition. (29) In another article, Bauer suggests an alkaline effervescent drink. (26)

It has been found that if airline passengers, who are susceptible to this disorder, will drink 1 or 2 glasses of acidophilus milk with meals for 2-3 days that they may avoid any occurrence of airsickness. (111) Yanquell suggests the use of antispasmodics and sedatives, and he feels that 3 grains of sod. amytal just before the takeoff is very useful in the apprehensive passenger. This author also suggests a course of calcium lactate averaging 15 grains tid for a week. He also advises the use of tincture of belladonna at a dose of 5 minims. Armstrong reports that Ross and Olsen found that strychnine reduced vestibular reaction by at least 20% as measured by decreased post rotary nystagmus. (21)

In the military flying man we must have other suggestions and treatments as flying is his profession and he cannot well evade air travel. Yanquell advises in the student pilot, graduated doses of acrobatic training with especial hygienic care, wherein the flight surgeon and instructor assure him that he is not abnormal, and that he can overcome this effect. His personal habits such as smoking, eating, and bowel habits should be checked and regulated. Any indulgence in alcoholics should be avoided as this increases one's susceptibility. No drugs can be used on the military pilot as he must always be on the alert. (111) The other important considerations are that the pilot or crewman must be in good condition, must be well fed, and he must have suitable clothing for his protection. It is well to avoid noise and noxious gases, and the flyer must be comfortable in the plane.

Lilly's book suggests placing the vomiting patient in a horizontal position and giving him 1 1/2 to 3 grains of seconal or 3 grains of sodium amytal. Atropine and scopolamine, 1/200 gr. for both drugs, may be valuable in lessening reflex stimulation from the labyrinth. Codeine sulfate in 1/8-1 grain doses may be useful in controlling the vomiting. (17)

The prognosis is usually very good, as more experience will allow adaptation to the causative factors. If the complaints persist the man and his aircraft should both be examined closely so that any possible benefit might be derived.

AVIATOR'S SICKNESS

Aviator's sickness is a not well explored entity characterized by a train of complex symptoms appearing in those who fly, and leading on to a state of physical and mental strain. (7) It is obvious that this definition lacks much; however, in 1936, H. G. Armstrong published an article titled "A Special Form of Functional Psychoneurosis Appearing in Airplane Pilots", (18) and I feel that this work should be discussed here rather than later under the heading of psychological care. Armstrong's definition of this entity is: "aeroneurosis is a chronic functional nervous disorder occurring in aviators, characterized by gastric distress, nervous irritability, fatigue of the higher voluntary mental centers, insomnia, emotional instability, and increased motor activity". (18) It is well that the following synonyms be given now: (a) chronic fatigue, (b) staleness, (c) aviator's stomach, (d) flying stress, (e) aeroasthenia, (f) flying sickness, (g) aviator's neurosthenia, (h) fatigue.

The material for Armstrong's study included 163 unselected pilots, aged from 22-50 years, having from

1-18 years experience, and from 400-5,680 flying hours. The observations made on these men were accomplished by close personal contact, for a period of six months to three years, including information gained from physical examinations, and from personal or professional attendance. (18)

It is imperative, I believe, that we include some discussion of neurocirculatory asthenia as it occurs in relation to aviation. Cecil's definition is: "neurocirculatory asthenia is a condition characterized by instability of the nervous and vasomotor systems, with clinical manifestations of fatigue, dyspnea, palpitation, and precordial pain."

You will recall that we said earlier that nearly 50% of the student pilots in World War I were suffering from neuroses, or at least from functional nervous disorders. Studies by H. Graeme Anderson of England in 1919 disclosed that these men were suffering from the same disorders that one sees in private practice, but because the cases he observed occurred in flying men, he coined the term "Aeroneurosis". Armstrong believes it is the most suitable term for this problem, and I believe that "aeroneurosis" is synonymous with "aviator's sickness". (18) I also feel that the topic of "neurocirculatory asthenia" should be included here.

Munroe feels that this might better be called "flying Strain", and he states that this is the same as "staleness". (80)

The etiological factors involved are many, but Armstrong divides them up into the predisposing causes and the exerting factors. (18) Under the predisposing factors aeroneurosis appeared in males most commonly at the ages of 35-40 years in those men who had the greatest inherent instability. The personalities of these men were predominantly extravertive although they were well integrated. 83% of the men were married and had had children. There was no particular significance attached to physical build as most of the men were of similar type. It is assumed that if females had been obtainable for examination that, being more unstable, they would be affected to a greater extent than the males studied in this series. (18)

The exerting etiological factors include debilitating states other than those caused by alcohol and tobacco which, in this condition, are apparently of little importance. (18) Physical agents, however, are very significant and the author presented the following chart to demonstrate the most important physical agents and their primary and secondary effects: (18)

Harmful Physical Agents and Their Effects

Physical Agent	Primary Effect	Secondary Effect
CO poisoning	Anoxemia	Nerve tissue destruction
Anoxia	Anoxemia	Nerve tissue destruction
Pure Oxygen inhalation	Irritation, congestion, and lung edema	Anoxemia and nerve tissue degeneration
Head Trauma	Concussion, laceration, edema, and brain hemorrhage	Nerve tissue destruction
Centrifugal and centripital forces	Pressure, congestive edema and brain hemorrhage	Nerve tissue destruction
Speed	Unknown at present	Unknown
Barometric pressure changes	Unknown at present	Unknown

Armstrong believes this condition is probably organic as well as functional.

Emotional factors play an important etiological role. Biological changes, as always, are a constant source of trouble to the emotional mechanism. Physiological and physical changes which make the flyer concerned about his chances of passing the next physical examination result in worry and fear of failure. Also, in days gone by the aircraft pilot was a great hero and everyone looked up to him; but, now, there is no hero worship, and the pilot's ego is deflated. Such factors as this, insignificant as they may seem, probably result in the pilot's questioning the advisability of his continuing in this hazardous field at the risk of losing his life. (18)

Economic and social factors are very much in evidence for each time the flyer is grounded he loses pay and he must accordingly lower his standard of living if this continues. The fear of this results in worry and constant mental unrest.

The psychic trauma involved in seeing his friends crack-up is a severe problem for if he is to continue in his chosen profession he must forget these things. But even the strongest man is wont to let these unpleasant memories steal out. This is especially true when he has had a crash or near accident himself. This calls forth the instinct of self preservation including fear of loud noises, fear of falling, and the realization of the everyday hazards of his occupation. These things are important, and, if they come out often enough, the man with an inherent psychic weakness is bound to suffer from their effects.

Fatigue of the high brain centers is known to play a very important part in this condition for it is said that in flying that the concentration required is greater than in any other field of endeavor. In general we must consider thwarted ambitions; distortion of the biological pattern; disqualifying physiological, physical, nervous, and mental conditions; ego deflation; economic and social insecurity; psychic trauma; and the desire of self-preservation. (18)

An anonymous article states that, because the body attempts to compensate its cardiovascular system to changing circumstances, this system becomes rapidly fatigued. Recall that previously we stated that the cardiovascular system shows the first effect of fatigue. (9)

Other considerations in the etiology of this condition are presented in an anonymous article in the Lancet. (7) Here it is suggested that the cause is principally due to anoxemia in high flights, leading to breakdown characterized by fatigue and asthenia. However, this article is more concerned with the effects of high altitude and changes in pressure.

Another article, anonymous, discusses aviator's sickness, but this author refers to symptoms which occur after ascending or descending in aircraft. (12) These articles serve to show the confusion that has surrounded this subject. Munroe says that the symptoms are due to fatigue in most cases, and that the results are comparable to the combined effects of high altitude flying and fatigue. (80) But again, this author is somewhat indefinite as to just what aviator's sickness is.

The etiologic factors usually concerned in neurocirculatory asthenia include its incidence in young adults, 20-40 years of age, who are under a strain, due to fatigue or toxic effects. Heredity plays an important part in individual susceptibility. (52)

The symptomatology is not complete, and, as remedial diseases are never allowed to go to completion, we must depend upon the early signs. (18) Aeroneurosis commonly appears after the patient has spent many consistent hours in the air. There is usually a gradual and insidious onset which, according to Armstrong, may be related to visceral disturbance. The disorder is essentially subjective with few objective symptoms. The victims of this disease usually have complaints indicating a fatigue of the higher cortical and brain centers along with increased motor activity and irritability. (18)

There are several subjective symptoms which are referable to the cerebrospinal nervous system. Subjectively the patient is restless, irritable, and refuses to believe that he is not well. If he is persuaded that he is ill, he says it is due only to overwork and not to any malfunction of his body. He is troubled with occupational dreams and nightmares that usually contain visions of disastrous flying accidents. He complains that he can't sleep, or, if he does sleep, he sleeps light and does not feel rested upon arising. Everyone seems to irritate him, and he finds that he is not only apprehensive for the future, but also he is miserable in his profession and surroundings. He finds that when he arises he is extremely depressed and is filled with dread and apprehension. This state improves during the day while it is worse in the morning and in the evening. These patients arouse the suspicion that they are mild paranoid types of personality as they show distaste for any duty assigned to them, and they complain that their superiors are discriminating against them--making their duties the most difficult and dangerous. (18)

Other subjective symptoms involve the eye and include fatigue, irritation, blurring of vision, blepharitis, and dryness of the eyeballs. The ear, or rather vestibular symptoms, shows increased unsteadiness with past pointing and increased nystagmus time. Of course, as we have shown, the eye is very important in the symptom of unsteadiness and vertigo. Some men in this series displayed distaste for food, and they all displayed ceaseless muscular activity. These latter symptoms suggest that condition so often seen in overtrained athletes--staleness.

The physical changes are few, but it has been shown that the mental state in this condition is very similar to that which appears in pneumonia as a result of anoxemia. (18) This is a very important observation as it was said above that early articles on aviator's sickness were somewhat different from recent works in that the earlier authors were firmly convinced that this condition resulted from changes in the partial pressure of oxygen that men encountered in flight. Seibert states that, depending on the individual, all pilots show breakdown at various times of their lives as flyers, but, whereas this condition was formerly believed to occur from stress and strain, it was now thought to be due to a decreased amount of oxygen going into the blood. (93) Bancroft suggest that the mentally overworked person who eventually seeks medical or psychiatric advice is possibly suffering from chronic oxygen want. (74) Another article associates this state with the effects of overstraining both the physical and intellectual powers as a result of exposing the body to conditions which it is not primarily adjusted to. (12) An anonymous article in the Lancet discusses "descent sickness" in respect to aviation sickness where it reports that "with descent sickness, pilots may be seized with emotional disturbances from which even the strongest may not be exempt; there is a feeling of emptiness, with thoughts and visions of death conjured up by the rapidity of the fall." The author suggests that this is probably a personal experience that indicates unsuitable personnel. (7)

Armstrong reports that the subjective mental state is "more apparent than real" because the patient could carry on his duties successfully if it was absolutely essential. The physical changes in the eye, although this organ is absolutely normal, show a weakness of the extrinsic muscles, indicating the involvement of projection pathways. It is often useful to have the patient close his eyes lightly so that the examiner can detect a nervous twitching or coarse tremor of the closed lids. These patients also often show exaggerated tendon reflexes which would be in keeping with their increased muscular activity. It has been noticed that often there is a nystagmus with the eye in the lateral position. (18) The constant state of stress causes breakdown of normal functions without organic destruction. (18) That this is the result of nervous or emotional strain can be appreciated by most observers, and that such a nervous or emotional condition provokes a sympathetic response has been proved for years by the physiologists. Too, we know that even a short period of sympathetic activity tends to drain one's reserve strength; so, it is not at all unreasonable that pilots or flying crewmen should be continually asthenic and irritable if they once weaken to the ravages of the stress and strain of flying.

Armstrong found in his study that there is usually a latent period, often amounting to several years, before the onset of this condition. Also he states that most cases occur between the ages of 25-40 years. (18) As was reported earlier, Longacre stated that the accident peak in military aviators was reached somewhere between the first 400 to 600 hours of flying, or somewhere in the two to three years following graduation. (70) It is not impossible that these two facts may be more closely related than is now apparent. Possibly the situation is this: by the time a young military pilot has accumulated 300 or so flying hours, he has probably realized that military aviation is an exacting profession and is not a new and novel game to be played. He suddenly realizes that a great deal is demanded of him, and, as a result, he either tries too hard or he becomes too much of a mechanical flier in his attempts to produce exact results. He may begin to worry about his apparent lag in progress with the result that the more he flies the more mentally upset he becomes. He is exhausting his energy reserves as a result of his increased tension and concentration. This in turn may result in aeroneurosis, which, because of its insidious onset, may result in his death before its existence is determined. The present indications of validity of this conjecture are few, but the possibility of the interrelation of these two facts may bear further investigation.

It is my impression also that the relationship of neurocirculatory asthenia to the problem of aviator's sickness should be more deeply investigated. The similarity in the definitions and eiological factors have been previously made apparent. N. C. A., or nuero-circulatory asthenia, presents palpitation, precordial pain, dysnea, frequent sighing, dizziness, faintness, tremor, and nervousness as its main symptoms. (52) It was noted earlier that fatigue first betrays its presence in the cardio-vascular system; also, Munroe states that the stress of "staleness" affects first the cardiovascular, then nervous, and finally the muscular systems. (80) Then too, Ahrens states that the most common case of this sort of pilot fatigue is undoubtedly neurocirculatory asthenia. (2) Now, as the main exciting factor of aeroneurosis from one cause or another, is fatigue, it is relatively easy to grasp the relationship of N. C. A. to staleness. It was appreciated years ago that many cases who presented the above symptoms of N. C. A. were not suffering from true cardiac lesions, but rather from the effects of fatigue on the cardiovascular system. Most of us at one time or another, being fatigued from study or physical work, have felt that we were short of breath, and we noticed that regularly our respirations frequently interrupted by a sighing type of breathing. At the same time we noticed faintness, tremor, nervousness and a tendency to increased muscular activity. This is important in the prophylactic medical care of flying personnel, and, as Gaede says, if the condition is potentially present in any of the men under a flight surgeons care, he must "nip it in the bud" before serious incapacitation results. (52)

As the term fatigue has been used somewhat freely, it would be well to evaluate the meaning of this word. Schneider suggests that "fatigue is a progressive flagging of efficiency together with subjective sensations of a loss of control." This refers to a related group of phenomena associated with a loss of efficiency, and it may be that minor disabilities become more evident during fatigue. (74) I feel that most of us will agree that this last statement is true. McFarland says that to place the locus of fatigue is difficult as the nerve fiber has been shown to be almost indefatigable. (74) This is confirmed by Best & Taylor who say that while reflex conductions will fatigue, "nerve trunks are almost indefatigable". (32) Psychologists believe that the locus may be found in higher cortical centers as evidenced by their interpretation of mental blocking. (74)

Bauer reports that according to Miller the basic characteristics of fatigue are decreased central nervous system conduction, reduced or lost muscle tone, circulatory changes, cellular changes in body parenchyma, and changes in the "adaptive metabolism" shown by a decreased alkaline reserve, increased pH, and a lowered blood sugar. (29)

Fatigue is associated with an exhaustion of the energy reserves, especially in pilots as they do very little muscular work; however, the muscular tonus, increased unconsciously in pilots, is directly associated with fatigue resulting from increased mental concentration. In connection with exhausting of energy reserves, it was found by Benedict that the number of calories in half of a peanut would fulfill caloric requirements demanded by sustained mental effort over a period of several hours. (74) Diet is often an important factor in fatigue, and it has been shown that alcohol hastens the loss of function and impairs efficiency. Tobacco, with effects being due to the nicotine alkaloids, causes an increase in pulse, a rise and then a fall in blood pressure, impairment in vision, and breathlessness on exertion. It has been demonstrated that smoking progressively lowers a pilot's ceiling. McFarland believes that if a pilot must smoke he should abstain before breakfast, and he should avoid excessive inhalation at all times. (74) This is not in agreement with all other authors. (18)

There are definite subjective symptoms associated with this condition. The gastro-intestinal tract is involved to the extent that there is often a history of gastric distress one to four years earlier which often recurs after periods of hard flying. This distress is likened to the hunger pains of ulcers, but there are no other symptoms existent. (18) There is often hypermotility with gurgling and a mild, watery diarrhea. In N. C. A. there are not these definite findings, but when we consider the cardiovascular system we see the similarity of these two conditions coupled with the fatigue factor. Gaede says that in N. C. A. the heart beat and rate increase. Here is also a lowered diastolic and systolic blood pressure as well as a lowered exercise tolerance "with a tendency to neurocirculatory asthenia." (18)

No involvement of the respiratory system is reported by Armstrong, but there is at least the effect of fatigue on the rhythm and type of respiration. It was found that pilots suffering from this condition had some polyuria with urine of a low specific gravity. Also, it was found that these men showed an increase in sexual functions. (18)

In the diagnosis of "Aeroneurosis", Armstrong states that a tentative diagnosis is based on "the occurrence of a functional gastric disorder in pilots of several years experience combined with a general irritability and increased motor activity with subjective complaints of insomnia and mental fatigue." To make a positive diagnosis he reports that we must rule out other organic disease and other functional nervous diseases. To assist in the differential diagnosis he describes hysteria "as an inborn instability with short explosive outbursts and a tendency to self seeking satisfaction based on a complacent observation of the disability". Neurasthenia displays symptomatology just the opposite to the increased motor function of "staleness". Psychasthenia, he says, "concentrates its symptoms on the psychic side and develops in an altogether different personality". (18)

The course of this ailment is variable, and is best included under the prognosis. The prognosis of this condition is good as concerns the length of life, unless the disease results in a fatal crash before its existence is uncovered. In N. C. A. we can, according to Cecil, expect complete recovery in 15%, and improvement in 17%, while the rest will either not change or else they will gradually become worse. Armstrong believes that by early grounding the prognosis is very good. (18)

In the treatment of this condition we are confronted with a real situation. Actually, there is very little active treatment that will answer our problem. This naturally leaves prophylactic treatment as the best means of combating this condition. We must gain the patient's confidence and remove any fear he has of heart disease or other organic trouble. It is best to eliminate any exciting factors such as tea, coffee, alcohol, or tobacco. (53)

Further, in prophylaxis we should definitely limit flying hours with a plan to insert frequent days of rest from flying. A co-pilot should be present on all long flights. (29)

The selection of aviation cadets should be strict enough to eliminate all potential cases of aeroneurosis.

I believe this can be accomplished by eliminating all candidates that show a tendency toward N. C. A. or general vasomotor and emotional instability. However, it is said that these types often make the best pilots. Armstrong says that careful selection often "deprives aviation of those who will be the highest type of pilot." (18)

Good psychological care, as well as physical methods, should be employed in treating these cases. (29) In the final disposition of the case we should decide just how harmful the continuation of flying, or non-flying, will be on the patients and the "flying public's" welfare. It may be that, under a flight surgeon's care, these men will be perfectly good risks, but this must rest with the individual case.

I have, intentionally, postponed the discussion of the pathology and pathogenesis of "aeroneurosis" until this time, as I believe Armstrong's report gives vast insight into the problem; it may be well to leave this subject with his explanation in mind.

There is no pathologic picture associated with this condition, but the pathogenesis is very important. The following states according to Armstrong, may be discarded: focal infections, wasting diseases, debilitating states, exhaustive fevers, toxins, intoxication, inferiority constitutional states, hereditary taints, defective mentality, and emotional instability. (18) This, he says, leaves only the "psychogenis theory" of pathogenesis which is as follows.

"When an individual enters on his career as a pilot he is essentially physically perfect, with a high degree of intelligence, filled with ambition, possessed of great natural courage, fired with enthusiasm, and devoted to duty. The irresponsibility of youth, the pride of accomplishment, the zest of living and the ignorance of inexperience carry him blithely through the first few years. Gradually, however, as time passes, physical perfection is replaced by physical defect and physiologic change, ambition by apprehension, reckless courage by cool judgment, irresponsibility by responsibility, youth by age, inexperience by experience, and pride by ego deflation. In other words there has been created a situation in which instinctive desires conflict absolutely with social regulation." (18)

"The pathogenesis consists of profound emotional stresses, long continued, producing a physiological hyperactivity and depletion of the higher nervous centers." (18)

AVIATOR'S DEAFNESS

Before a discussion of flying deafness it is indicated that the anatomy of that portion involved should be discussed as it is described by Armstrong. (21) (22) In this condition we are primarily interested in the eustachian tube and its physiology.

The eustachian tube extends from the nasopharynx to the middle ear cavity, ordinarily closed, and being made up partly of cartilage, and partly of bone and connecting tissue. The cartilaginous portion extends from the slit-like orifice of the nasopharyngeal part for a distance of about one inch, after which it is of bony structure. At the lower end the tube is supported by a triangular section of cartilage with the base downward. This forms a prominence known as the torus tubarious. The upper part of the cartilage is in the shape "of a hook on cross section, open below and laterally." The tube in this part consists also of a fibrous connective tissue support. The bony portion extends from the junction with the cartilage to the middle ear which covers a distance of about one and a half inches. (21) (22)

The eustachian tube is actually only a potential tube with its greatest diameter at the nasopharyngeal outlet. It's least diameter lies at the junction of the bony and cartilaginous portions. The mucous membrane is ciliated columnar like the nasopharynx, and it extends up the tube to line the middle ear cavity, being thick in the cartilaginous portion and thin in the bone part. (21) (22)

The muscles involved with the actions of the eustachian tube are the levator veli palatini, tensor veli palatini, and the salpingopharyngeus. (22)

The function of the eustachian tube is to drain and to ventilate the middle ear. The cilia beat toward nasopharynx and, with the help of the numerous goblet cells present, help to keep this pathway clear from ascending foreign substances. As was said, the tube is normally closed, and it opens as a result of muscular action, swallowing, and changes in air pressure. We are especially interested in the physiology of this structure as it plays the main role in aviator's deafness. This is understood when we realize that in flying there are expected changes in atmospheric pressure as a result of ascent and descent. In flying upward there are equal changes of pressure involving increasing intervals of altitude. (22)

Pressure changes are important as the ear is an air filled cavity wherein the eustachian tube must open if this pressure is to be equalized.

Armstrong and Heim carried out a series of studies in which they gradually decreased oxygen pressure at definite intervals starting at sea level and moving upward. The first evidence of the effects of pressure change came from 110-180 feet when the pressure had changed from three to five millimeters of mercury. The subjects detected a fullness of the ear, and a slight bulging of the tympanic membrane was noted. These sensations were increased up until the pressure change reached 15 millimeters of mercury when there was an "annoying click". This apparently relieved the pressure, for subjects were relieved and the drum came back to a normal position. The investigators concluded that this indicated that 15 millimeters of mercury of excess pressure is needed, at sea level, to force the tube open. It remains open until the pressure is again resting at 3.6 millimeters of mercury when it closes. This amount of mercury is equivalent to about 110-130 feet of altitude. (21) (22)

It was found that as the atmospheric pressure increased, there was a "flutter-valve" action of the tube, and it remained closed with all pressure increases in all their subjects but one. This subject suffered a ruptured drum. (22) The examinees discovered that, unless the pressure reached a negative eighty to ninety mm. of mercury, swallowing helped to reduce the pain. When a negative pressure of this degree exists the eustachian tube will not open, and a severe train of symptoms results.

One form of aviator's deafness, especially the type referred to by Armstrong and Heim, is that known as aero-otitis media. "Aero-otitis media is an acute or chronic, traumatic inflammation of the middle ear caused by a pressure difference between the air in the tympanic cavity and that of the surrounding atmosphere, commonly occurring during changes of altitude in airplane flights, and characterized by inflammation, discomfort, pain, tinnitus, and deafness." (21) (22) Lamport gives essentially the same definition, but says that it occurs especially in susceptible persons. (64)

It is true that there are other forms of aviator's deafness due to other conditions, but at this time we are particularly concerned with the deafness resulting from malfunctions of the eustachian tube due to pressure changes. The placing of emphasis on this particular type is justified by Guild who says that with the enclosed cabins of modern planes that even under combat conditions the dangers of acoustic trauma are secondary to the dangers of acute tubal occlusion. (55)

The etiological factors are dependent upon the normal physiological functioning of the eustachian tube in acting as the ventilator of the middle ear when there are changes in the atmospheric pressure. This usually results in trauma of the tympanic cavity if the pressure is not adjusted. Armstrong says that failure of the tube to ventilate is due to two factors: (a) failure to open the tube may be due to ignorance, but sleep, analgesia, and anesthesia may be responsible; (b) the inability to open the tube may result from infection, obstruction, sinusitis, paralysis, or malposition of the jaw. (22) Willhelmy discusses six of his cases which were selected from a group of pilots showing the similar symptomatology-constant ear pain and vertigo with sudden losses of altitude. These six selected cases showed malocclusion of the jaw, and each responded to repositioning of the mandible by increasing the vertical dimensions of the jaw to relieve pressure on the eustachian tube. (105)

Lewis reports that the etiology is due to the expansion of gases in the ear region, and says that occasionally the irritation and congestion resulting from rapid changes of altitude have caused an acute otitis media. (67)

The symptomatology is divided by Armstrong and Heim into the acute and chronic types. The acute subjective symptoms are referable to the results of experimentation previously described, wherein, at a pressure change, lowering, of 3-5 millimeters of mercury, the ear feels full. At a change of 10-15 mm. of Hg the sensation is annoying, and a 15-30 mm. change results in tinnitus of a hissing, crackling, roaring, or snapping nature. As changes rise above 30 mm. of pressure, the pain, tinnitis, and vertigo become unbearable. As was mentioned, usually a 15 mm. change in pressure will suffice to open the eustachian tube with a click that provides relief. After ascending, the pressure in the middle ear has been balanced with that of the outside air, and in descent the air pressure in the ear becomes negative. The physiological discussion mentioned the "flutter-valve" like action of the tube ostium when pressures outside were increased. This action prevents the proper ear ventilation resulting in the establishment of a negative pressure. When these negative pressures reach around -80 to -90 millimeters of mercury the eustachian tube is unable to ventilate as the muscles opening the tube refuse to function (64) This explains the difficulty encountered in rapid descents. When this pressure reaches a value of -60 mm. of Hg. pressure there is a severe otitis media--like pain. As the negative pressure reaches 80 mm. there is severe pain in the ear and paratoid region and the victim has deafness, vertigo and tinnitus. When the pressure reaches from -100 to -500 mm. the ear drum almost always ruptures. It is said that the "patient feels as though hit along side of the head with a plank." There is a loud explosion, a sharp piercing pain on the affected side with symptoms of nausea and collapse or shock. In cases of severe trauma there is pain, deafness, and vertigo which may last from 4-48 hours. The effects of moderate trauma last from 1-12 hours. (22) The deafness that results is of the conduction type. (21) (22) (38)

Willhelmy describes ear symptoms as being characterized by impaired hearing, stuffiness in ear, tinnitus, and dizziness. There are also symptoms of sinus involvement, and headaches are severe and constant over the vertex and the occiput. (105)

The flyer affected by the described pressure changes often complains of a loss of auditory acuity which we find in examination to be along the lower tone levels. Paul Campbell, in a personal experiment with Hargreaves, ascended to 12,000 feet and began a descent at the rate of 1000 feet per minute, trying not to swallow during this time. At 7,500 feet the excruciating pain in his ears forced swallowing in an attempt to equalize the pressure. It appeared that the pressure on the left side was relieved, but that on the right side persisted. This resulted in an acute aero otitis media characterized by severe pain in the temporomandibular joint and the parotid gland. His Rinne test was negative while the Weber test, positive, was limited to the affected side. His recovery, without treatment, required seventy-two hours. (38) Campbell also found that if fatigue is present when the pressure changes occur that we see a mixture of conduction and perception deafness as shown by an audiometer curve. The two authors, from their work, concluded that, with frequent swallowings, descents of 300 feet per minute are bearable, but descents of

1000 feet per minute are unbearable. (38)

The objective symptoms of acute aero-otitis media include the bulging of the ear drum with a loss of the light reflex when the pressure is increased. When a negative middle ear pressure exists the drum is retracted and there is a decrease in the size and brilliance of the light reflex. The handle of the malleus is more prominent and appears to be "foreshortened". (22)

With severe trauma the drum shows inflammation, varying from a pink to an "angry red", along the flood vessels, handle of the malleus, and the periphery of the drum. Armstrong believes that, by inspection alone, this state cannot be differentiated from an acute infectious otitis media. Frothingham reports that even the normal ear drum is congested after rapid descent, and this may, although it causes no permanent damage, last for 24-48 hours. (48)

Traumatic ruptures are usually linear, extensive, and may occur in any portion of the drum. The margins of the fresh rupture are red and the drum is hyperemic. There may be blood in the canal, and the labyrinth wall shows edema, inflammation and tenderness. (22)

The audiometer test shows varying diminutions of hearing. Armstrong believes that deafness isn't so common if the normal audiometer range is from plus twenty to minus twenty decibells. However, Witting and Hughes report that the audiograms of persons hard of hearing show an inherent error of less than five decibells, and that normal ear audiograms are slightly more accurate. They dispute the belief, or suggestion, that from plus twenty to minus twenty is the normal range. (34)

The subjective symptoms of chronic aero-otitis media are that, again, the ear feels stuffy and full, and the patient has difficulty in clearing his ears. He may show a partial loss of hearing that often varies from day to day, and this may occur bilaterally although it is most common in one ear. The patient may be bothered with head noises, but there is usually no pain or vertigo. The condition becomes worse with continued flying and fatigue or debilitation or with upper respiratory infection. (32)

The objective symptoms are the result of repeated insults wherein we see a retracted drum, prominence of the short process of the malleus with a rotation of the handle of this ossicle. The drum appears dull, thickened, and shows alterations in the cone of light.

Some cases occasionally develop fluid in middle ear which often leads to perforation. (38) Armstrong reports that the drum is most commonly retracted although it may bulge. The ear membrane is dull, lusterless, and slightly thickened. The light reflex is diminished or absent, and there is either bilateral or unilateral diminution of auditory function. As before, the deafness is of the conduction type with a negative Rinne, a positive Weber, and with prolonged bone conduction type. (22)

Campbell and Hargreaves report that a purulent otitis media may result, and the tube may become stenotic as a result of mucous membrane overgrowth. This latter results in a unilateral deafness for low tones, and is referred to as chronic catarrhal otitis media characterized by a negative Rinne test. (38)

It is important to remember in the diagnosis that overclosure of the mandible may result in this condition. If the patient lacks molar teeth or has a poor fitting plate combined with a mild catarrhal deafness, vertigo, and a tenderness of the temporomandibular joint which eases with the interposition of a flat object between the jaws, we should suspect an aero otitis media due to overclosure of the mandible. (105)

Aero otitis media is diagnosed mainly by the history of exposure to rapid changes in altitude or pressure with the additional findings of the available hearing tests. A short description of the most important of these tests is desirable.

The transmission of air conducted, but not bone conducted, sounds, is affected by middle ear disturbances. On this basis, there are two important tests which are used to differentiate perceptive and conductive deafness. The Rinne test is performed by placing a vibrating tuning fork on the mastoid process after the opposite ear has been plugged up with the examiner's finger. When the patient no longer hears or feels any vibration, the still active fork is placed by the external meatus of the ear being tested. The normal case with no middle ear involvement shows the ability to hear the sound after vibrations are no longer felt. In cases with middle ear involvement the sound is not heard after the vibrations stop, and these cases are said to be Rinne negative while the person who does hear the sound is said to be Rinne positive. (32)

The Weber test is performed by placing a vibrating tuning fork on the patient's forehead in the mid-line.

The normal person hears the sound through both ears or the tone is located in the midline, but a person with unilateral middle ear deafness locates the sound in the affected ear. The sound is referred to the normal ear if the patient has inner ear deafness. (32)

Auditory acuity is determined with the audiometer or the new Western Electric Phonograph audiometer. The usual audiometer is an elaborate arrangement whereby certain tones are transmitted to the listeners ear through an ear piece. The tone is varied as is the pitch, and by plotting the resulting values from the points where specific tones were last heard we have what is called the audiogram. However, the new W. E. Phonograph audiometer is apparently more successful. This also referred to as the 4A audiometer where there are numbers recorded on a phonograph disc, being heard by the examinee through an ear piece receiver. The intensity of the stimulus numbers are reduced in steps of three decibels each, and the results are recorded and graphed as described above. (34)

A practical method of auditory testing with the whispered voice is as follows. The candidate, with back turned toward the examiner, should be twenty feet away. After as complete an exhalation as possible, the examiner calls the numbers 18, 23 and 66 as the test numbers. He should interject other numbers, but the results are based on these three numbers. If the candidate is unable to hear, keep moving closer until he can. The whispered voice should be audible at no less than eight feet. (34)

The pathology of this condition is very limited, and consists only of either a passive hyperemia or an anemia, depending upon whether the cause was negative pressure, or positive pressure. Both the middle ear and eustachian tube show this effect. When the pressure is relieved there is an active hyperemia, the eustachian tube is blocked by congestion, and the ear closes. (21) (22)

The treatment is divided into prophylactic and active forms. The prophylactic treatment can be summed up by two words--avoid exposure, but this is not often practical, as military pilots must do the impossible at times, and, also, there are airline passengers who display a low threshold of resistance to even gradual pressure changes. Of course, in military aviation it would be wise to test the patency of the eustachian tube of potential altitude flyers by using the Politzer bag. The latter is a soft bag of rubber for inflating the middle ear. The flyer should be cognizant of this trouble, and it is the duty of the flight surgeon to see that he realizes the problem. (22)

It has been found that as most people swallow every 60-75 seconds that only high rates of ascent or descent such as 4000 feet a minute may cause difficulty. If high rates of altitude and pressure change are unavoidable the flying personnel should chew gum, inhale oxygen, or swallow. Airline passengers can do this and more. They can eat or drink during the changes. To facilitate pressure adjustments in babies and children the airline stewardess usually gives them a drink or something to eat. To aid in prevention, airlines have limited the rate of climb to 2-300 feet per minute. Military and civil authorities have also suggested staying at altitudes under 2000 feet if there is temporary or permanent eustachian stenosis. The flyer or passenger with an upper respiratory infection should gargle with hot salt solutions, use a detergent spray in the throat and nose, and should take along atropine, benzedrine, or ephedrine inhalent compounds. (22)

The active treatment for the relief of pain should consist of inflating the tympanum with a Politzer bag if the drum shows the existence of pressure. Pain is also relieved by heat, either wet or dry, but the best method is to flood the external canal with large amounts of water at 110-115 degrees of Fahrenheit and to follow this with dry heat applications. Often the pain will be so severe that analgesia is needed. We should use hot gargles and astringents if the eustachian ostium is blocked. (22)

If the tympanic membrane is ruptured it should be treated expectantly. Chronic cases should have treatment directed at the cause, but gentle tubal inflation may help shorten the course. The patient should avoid flying while this condition exists. (22)

Willhelmy suggests treating those cases caused by mandibular malocclusion by taking X-rays to detect a loss of alignment. A good impression should be taken, and all questionable teeth should be removed. The pressure on the eustachian tube, resulting from mandibular malocclusion is usually relieved by repositioning the mandible and increasing the vertical dimensions of the jaw by properly inserted supports. He reports that after three years, the cases be treated in this way have had no recurrence of their distress. (105)

Lamport reports that Armstrong believes the only cure or method of eliminating this painful condition is to fly back up to a high enough altitude so that voluntary ventilation will become possible. (64)

Lovelace, Mayo and Boothby have used helium for rapid reductions of tympanic vacuums, but this is too expensive and therefore impractical. A more practical method, reports Lamport, is to use the combined Mueller and reverse Politzer technic wherein the patient takes a maximum inhalation, holds the lips and nose shut, and tries to produce as much nasal suction as is possible. At the peak of this effort the ear supposedly ventilates and the symptoms are relieved. (64)

Armstrong suggests after-treatment of dry heat with inhalations or nasopharyngeal astringents every four hours. Plugging the ear with cotton often helps during cold weather. If the condition does not subside within twenty-four hours we should suspect an acute infectious disease. (22)

. . . .

It was previously stated that there are other factors which often produce deafness in aviators, and a general discussion of the most important causes will now be given.

The auditory acuity of the aviator as determined by the audiogram demonstrates somewhat the effects on hearing of six factors: (a) the inherited hearing apparatus--a hereditary investigation of family history may disclose important information; (b) age--each decade naturally results in a certain diminution of receptivity for higher tones; (c) noise--irritating and traumatizing noises from the propellor, engine, and air speed are known to have an important effect on the auditory acuity; it is interesting to note here that noises of low frequency involve the high tone areas because the important 4,096 area of the cochlea lies in the basal turn of the organ which gives it the greatest exposure to sound energy regardless of its transmission; also, this area is known to have a poor blood supply which makes it logically more susceptible to practically any influence; (d) barometric pressure changes as previously discussed; (e) disease, acquired or congenital; (f) anoxia--especially important as is realized when we say that the 4,096 basal turn area of the cochlea has a poor blood supply. (37)

Lewis says that altitude, or changes in barometric pressure as above, has no effect until a height is reached where there is functional impairment of the whole group of higher cerebral sensory and psychic centers. This, he reports, is signalized by the onset of semiconsciousness or unconsciousness. (67)

It was found by measurement that the noise intensity developed by multi-motored aircraft exceeded the intensity of noises developed in a boiler maker's occupation. Analysis of airplane deafness shows a loss of acuity at the upper end of the scale as a result of the effects of the high intensity vibrations at the lower end of the scale. I presume this refers to the effects of the vibrations on the 4,096 area of the cochlea in the basal area. At any rate this loss at the upper end causes the inability to recognize consonants. It will be mentioned later, that often pilots are unaware of any progressive deafness until they find that they have difficulty understanding ordinary conversation. (6) Guild reports that acoustic trauma probably causes more impairment of hearing for high tones than for low tones. (55) Walter believes that there is a temporary loss of ear function after every flight which occurs coincidently with a gradual progressive loss of function in older pilots. (34)

Pilots are not all effected by noise to the same degree, but probably all are equally susceptible as it appears that any tissue under severe and constant stimulation or irritation will respond by malfunction sooner or later. Hearing losses are most frequently associated with loud noises which affect C-4 (2048 double vibrations) and C-5 (4096 C. V.); this usually involves low tone perception also. This author states that no complaints may be registered until spoken words are not well understood, and it has been shown that pilots will have difficulty in understanding radio instruction from the ground if their acuity for tones near C-3 (1024 D. V.) is diminished. (34) Dickson, Ewing and Littler also say that those affected usually complain first of speech infrequencies. (44) Dickson reports that using a 6A Western Electric Audiometer the first evidence of acoustic trauma is localized at 4,096 cycles per second and is characterized by a dip in the audiogram at this level. (45)

Campbell and Hargreaves present the following classification of aviator's deafness:

A. Acute fatigue of the end organ of hearing and associated structures.

B. Chronic accumulative fatigue of the end organ and associated structures.

C. Conduction deafness due to changes in pressure of the middle ear.

D. Chronic conductive deafness due to alterations in the tissue resulting from faulty ventilation of the middle ear.

There may be combinations of these types with one superimposed upon the other as a result of fatigue or injury. (38)

We have already discussed the types of aviator's deafness included under C. and D. in the classification of Campbell and Hargreaves.

Fatigue according to Howell is a "more or less complete loss of irritability brought about by functional activity." (59) An earlier discussion of fatigue was given under aviator's sickness. The physiological conception of fatigue is that the result should be in proportion to the time and intensity of the stimulus. (38) Campbell flew 50 hours in various planes under varying conditions to conduct his experiments. For six months, previous to the flying tests, monthly audiograms were taken, and these showed a variation of only 2-3 decibels. Then, five to ten minutes after each flight, audiograms were taken.

These records demonstrated that the time needed for complete recovery approached the square of the time the fatigue force was applied. (38)

As to the force of the fatiguing elements, Armstrong says that "if several noises arrive at the same points with equal intensity, the combined noise level will be only a few decibels above that of any one component." (21)

Campbell and Hargreaves give the following sources of noises as being important in aviation: (a) engine, (b) propellor hum, (c) noise of the wings and the slipstream, and (d) sounds from moving parts. As vibration energies they give: (a) preaudible positive and negative pressure changes from the propellor, and (b) suprasonic vibratory frequencies and their overtones from speedily moving objects. (38)

In chronic accumulative fatigue inherent tendencies determine resistance to the effects of constant stimulation, but, if this condition occurs, the cochlear area 4,096 shows the first effect which, as was previously noted, may spread to involve the conversational areas of this organ. This type is a pure perceptual high tone deafness with a positive Rinne and no conduction deafness. (38)

Campbell and Hargreaves concluded that of the four types the first two were due to a decrease in actuity in the 4,096 area which is weak due to a deficient blood supply. The last two types are due to a decrease in acuity for lower frequencies resulting in a conduction deafness. (38)

This discussion makes it evident that in noise deafness we have a real problem which, regardless of our efforts, sooner or later affects all pilots. I am inclined to feel that, for the most part, there is a great deal of natural physiology involved in this problem because most individuals eventually lose their auditory acuity for certain tones. I do not deny that the constant effects of noise irritation produce an occupational deafness, but I do feel that there is more involved in this problem than simple noise effects. Never the less, we must do something to ward off this condition as long as possible.

In the Royal Air Force pilots are protected from noise deafness by close fitting flying helmets with attached ear phones and additional protection is instituted by means of ear plugs. (45)

Dickson, Ewing and Littler offer the following means for protection: (a) flying helmets strapped so that the attached ear phones are blocking the passage of external sounds into the ear; (b) ear defenders; (c) finger tips in ears--practical only for crew members; (d) ear plugs of cotton wool saturated with vaseline; (e) ear plugs of liquid paraffin and cotton gauze saturated with vaseline; and (g) packing the meatus with plasticine--a new plastic substance. (44)

An annotation in the Lancet reports that ear plugs have been unsuccessful, but that suitable helmets are the best protection. (6)

Guild reports that cotton, wet or dry, doesn't stop intense denotation waves, but this author suggests the use of ear plugs of wax, paraffin, fingers, or solid obturators. A British firm has manufactured the "Tommy" which is a soft hollow spherical rubber bulb with an opening on one side. The short necked opening is surrounded by a soft rubber flange. This fits the ear easily, and it is cheap to manufacture. Users can hear soft voices, but the article takes the "sting" away from intense denotations.

In conclusion, we may say that the preceding discussion indicates there is much work to be performed in giving our pilots some protection against the debilitating effects of loud noises.

THE EFFECTS OF HIGH ALTITUDE

Man has realized for at least one hundred and fifty-nine years that when he ascended to a high place he was less efficient and his body reacted strangely. The first report of the effects of high altitude in aviation appeared in 1783, when Pilatre de Rozier ascended in a balloon to 10,500 feet; upon descent, he complained of ear aches. (37) This was a pressure or conduction problem such as was discussed in the last section, and is not necessarily the result of high altitudes, but rather the effects of too rapid descent or an unbalanced eustachian mechanism.

In 1862, Glaisher and Coxwell ascended to 29,000 feet where they noticed a train of symptoms characterized by a loss of visual and auditory acuity, paralysis of the extremities, and coma. This was discussed under the history of aviation medicine as was the flight of Tissandier and his associates. As a result of the latter flight Paul Bert, in 1865, published his "La Pression Barometrique" which deals with the effects of increased and decreased barometric pressures. Bert was the first man to show that the effects of high altitude were due to a decreased partial pressure of oxygen. (23)

Very little investigational work was performed until the World War I when Schneider, working at the Army Air Service Medical Research Laboratory at Mineola, Long Island, studied the effects of altitude flying. After this period, 1920 to 1935, there were few reports by American authors on the effects of altitude flying. Some improvements were noted as airlines placed the upper limit of commercial flying at 18,000 feet. What studies were performed came as a result of necessarily making some investigations to keep up with the type of aircraft being built then. (23) It was not until the onset of World War II that medical men in aviation, except for the Germans, began to study current problems in order to increase ceilings of pilots so as to give the flyer every possible advantage over his enemies.

America is far behind the other great powers in the problem of producing planes that will reach the altitudes that English and German aircraft are capable of. Our Boeing Flying Fortress, B-17, has an effective fighting altitude of around 30,000 feet, but our Bell Airaeobra P-39 and our Curtiss P-40 pursuits have an effective fighting altitude of under 16,000 feet. The German Messerschmidt, the British Hurricane, and the British Spitfire are effective at altitudes of 30,000 feet, making our pursuit ships of little value against the enemy Messerschmidt. It is probable that if engineers would continue to develop planes capable of high altitudes, such as the new Republic P-47 pursuit, the field of aviation, and necessarily of aviation medicine, in America would completely surpass the efforts of any other country. (94)

Although Picard attained an altitude of 53,000 feet, it is impossible that man can go over 45,000 feet without the special equipment of the Picard gondola. This sphere was sealed tight and the atmospheric pressure was maintained at a level compatible with life. (28)

The relation of barometric pressures and oxygen tension to elevation is shown in the following chart: (93)

Feet	Barometer	Oxygen Tension
0 (sea level)	760 mm.	101.32
10,570	530	51.09
13,200	490	44.81
14,000	460	38.53
15,300	440	34.34
16,500	420	30.16
17,900	400	25.97
18.600	390	23.88
20,050	370	19169
21,000	---	17.30

It will appear shortly that the values of oxygen tensions given here are not in accord with the next chart, but, I believe this author, Seibert, is referring to the oxygen tensions, or partial pressures, of the lung gases and not of the atmospheric gases.

Humans are adapted to breathing air which is 20% oxygen at a pressure of 14.7 pounds per square inch, but Marshall reports that, if no physical work is done, it is possible to exist at an altitude where the atmospheric pressure is one half this value. Translated from the chart, by reducing the barometric reading one half we find the value of 380 millimeters of mercury pressure, which in column one gives us an altitude of about 18,000 feet. At 50,000 feet the pressure of the atmosphere is about one fourth its sea level value. (77)

The atmosphere is a mixture of gases of which oxygen comprises 20.93%, nitrogen--79.04%, CO_2--.03%, with the remainder consisting of the rarer elements of neon, argon, xenon, and helium. These percentages are standard at any altitude, and only the partial pressures of the gases change. (28)

Altitude	Barometer	Oxygen %	Partial Pressure of Oxygen
Sea level	760	20.93	159 mm.
10,300	506	20.93	106 "
18,000	380	20.93	80 mm.
28,000	253	20.93	53 mm.
40,000	148	20.93	32 mm.

To determine the partial pressure of any gas in the atmosphere we multiply the total barometric pressure and the per cent of any gas in the mixture we are using. The following is the method of determining the partial pressure of oxygen at sea level and 760 mm. of mercury:

760 x 20.93 = 158.840 or, essentially
15 x mm. of mercury. ? (28)
cm ?

To provoke gaseous diffusion we recall from physical chemistry that there must be a difference between the pressures of the gases involved. If the partial pressures of oxygen in the lung were the same as those of the blood there would be no diffusion exchange, but venous blood coming to the lungs has less than fifty per cent of its original load of oxygen and a correspondingly higher percentage of carbon dioxide. These large differences between the gas tensions of carbon dioxide and oxygen in the venous blood and alveolar air makes possible the diffusion rate. (32)

When oxygen is inspired it absorbs water vapor amounting to about 47 millimeters of pressure. This must be deducted from the total atmospheric pressure as this amount of oxygen, 47 mm., is essentially lost to the body. We now have an atmospheric pressure value of 713 mm. of partial pressure for all the gases and water vapor in the alveolar air. We must also deduct the partial pressure of carbon dioxide, and, as a result, the percent of oxygen is reduced to about one third of its original amount before it reaches the alveoli. Recall that there is approximately 20.93 % oxygen in the atmosphere; one third of this value leaves about 14.2 % available oxygen, and to find the partial pressure of any gas we multiply the barometric pressure by the per cent of that gas present. Therefore, we would find 14.2 % of 713, the barometric pressure, to determine the oxygen tension in the alveolar air. This is 713 x .142 = 101.246 millimeters of mercury partial pressure, and so we clarify the values of Seibert's chart giving oxygen tensions. (27) (32)

It was proposed that the blood oxygen was diminished one half when the barometric pressure was lowered two thirds, but this was not substantiated until 1905. It was found that we were not so much concerned with the amount of oxygen as with the partial pressure. This has been since verified by removing one third of an animal's total blood before exposing it to low oxygen partial pressures. These animals reacted in the same way as the normal subjects at the same levels. (58)

To a certain altitude the human organism is able to adapt itself to atmospheric variations. At this point the amount of oxygen absorbed falls below the body needs. The critical zone varies with individual cases and the body reacts to produce more red blood cells and to increase the pulmonary ventilation. This is not enough above, say 18,000 feet, and the body suffers from a relative anoxemia produced by the low tension of oxygen and not as a result of an actual deficiency. The increased pulmonary ventilation tends to lower the partial pressure of the carbonic anhydrase in the alveoli. To maintain ionic equilibrium there is a consensual lowering of the blood bicarbonate and this tends to increase with altitude. The natural result of increased pulmonary ventilation, objectively, is to reduce the pulmonary amplitude or excursion as we often see in cases of alkalosis. This is due to a disturbance of the acid-base blood balance resulting from the excess loss of pulmonary and circulatory carbon dioxide. (33) Bauer confirms the appearance of an alkalosis which results from carbonic acid-bicarbonate unbalañce due to increased respiratory movements at high altitudes. (28)

Our main problems in high altitude flying are concerned with the development of suitable oxygen supplying apparatus, and the development of means to combat the effects of lowered temperatures that exist at high levels. Carson gives three existing problems of today: (a) the difficulty of maintaining an adequate oxygen supply to the body under the very low barometric pressures of altitudes above 35,000 feet; (b) the damaging effects of nitrogen elimination from blood and tissues as air emboli--causing aero-embolism; (c) the coincidental effect of extremely low temperatures which tend to exaggerate the first two problems. (41)

Three questions are presented in connection with the development of pressure cabins for stratosphere flying: (a) at what altitude should we start supercharging the cabin; (b) what is the flow of air required per unit passenger; (c) is humidity control desireable? (47) I can give no exact reference to the answers of these questions, but I believe that these problems have at least partially ~~be~~ been worked out on the new Boeing "307" "Stratoclippers".

According to Armstrong, the temperature decreases two degrees centigrade for each thousand feet of elevation up to 35,000 feet, after which the temperature is fairly constant at -55 degrees centigrade. Pilots often feel the effects of temperature of -10° C. even with flying clothes. (23)

Armstrong presents four problems in high altitude flying: the first three are concerned with the desire to fly as high as possible with comfort safety, and health without oxygen; the fourth consideration is the desire to fly at the highest altitude compatible with safety, health and comfort while using oxygen. (19)

To keep pilot and crew at a sea level environment as far as oxygen is concerned, or to keep the partial pressure of the oxygen to 159 mm. of mercury, we must have a certain percentage of added oxygen to the air inhaled. These values, given later should actually be doubled because of waste, leakage, and the fact that inspiration is only half of the respiratory cycle. (28)

The critical zone of individual adaptability will vary with the case. (28) This is supported by Seibert who investigated thirty five pilots who were troubled with the effects of altitude; eight cases were reported (93):

A. Pilot of 28 hours became giddy above 4,000 feet.

B. Pilot with 10.5 hours troubled with giddiness and blurred vision at 6,000 feet.

C. Man with 140 hours fainted twice above 8,000 feet.

D. Pilot with 300 hours; since a crash, fainted at 8 and 10,000 feet.

E. Flyer with 50 hours had headaches and sensations of compression above 3,000 feet.

F. Pilot with 400 hours was at first normal, but then fainted three times at 7,000 feet.

G. Pilot with daily flights over fourteen months usually was fit up to 12,000 feet, but now he becomes giddy at 5,000 feet.

H. The last pilot, hours unknown was well at 6,000 feet, but he became progressively apprehensive and uneasy.

The effects of flying at high altitudes include the effects of anoxia, the effects of cold, and the effects of lowered pressures.

The effects of anoxia, or oxygen want, are well described in an article that reports the story of a weather pilot who was flying a ship in which the altimeter registered only one foot for each two feet of actual ascent. It was the duty of the weather pilot to take off before dawn, and, in progressive steps of

1,500 feet, to fly to an altitude of 16,000 feet. Each time that this pilot reached what he believed to be only 10 or 12,000 feet his plane would fall off into a spin. Actually, he was unknowingly flying at around 20 to 24,000 feet. The pilot was not especially concerned with this defeat, and he became more determined to reach his 16,000 foot level. After many futile attempts he tried to use the phone to contact the field to ask for advice. Unfortunately, he dropped the piece and was unable to find it--later it was found in his lap where it had originally fallen. He lost all sense of fear and time, and he began to cry because of his failure. His vision became so limited that he could not see beyond the nose of the plane. He began flying semi-automatically without realization. After repeated attempts, all failures, he suddenly lost consciousness, and, fortunately, he regained his senses at eight thousand feet when he discovered that he was in a full throttle power dive. He recovered from the dive to find that he was nearly out of gas, and he automatically switched on the emergency tank which held enough gas for only fifteen minutes flying time. He was so confused that he again attempted to reach his required altitude, but during the ascent he suddenly realized that something was wrong. The plane was ninety miles east of its home base when the emergency tank of gas was exhausted. He made a forced landing at an emergency field in semi-darkness. His vision began to improve and he suddenly recalled all that had happened. His flight had lasted two to three times as long as usual. Following this flight his subjective symptoms were anoxia, fatigue, tremor, and a subjective loss of confidence, but after twenty-four hours of rest he apparently recovered. This pilot had always been normal, but the effects of anoxia had caused a loss of good judgment, a loss of emotional control, and a profound narrowing of his visual ability. (65)

At 20,000 feet, Ruffo of the Italian air forces, says there is a heaviness of the head, a somnolence, and a mental and physical torpor that prevents the pilot from being alert. The author of the anonymous article that reports this case says that this is a syndrome of nervous depression due purely to rarefied air, and that we see this state occurring in pneumatic cabins. (10)

The circulatory system attempts to compensate for low oxygen pressures by increasing the pulse rate and the pulse pressure. It is important that perfect circulation be maintained as the heart is especially susceptible to the effedts of lowered oxygen supply. With heart involvement at low oxygen pressures the onset is insidious and collapse is unheralded. (104)

Another investigator showed that the lack of oxygen was responsible for the effects of altitude on the heart. The electrocardiogram of anoxia often shows a lowering or inversion of the Twave with a depression of the R-T interval and an occasional Q. R. S. deformity. (23)

Occular function is somewhat effected by anoxemia, but it appears that if one's eyes are normal that there is probably not much effect evident except in the narrowing of visual fields and a weakness of convergence and slight decrease of accomodation. Depth perception, reaction time, color vision, field of binocular fixation and muscle balance were affected to a small percentage except when previous derivations or weaknesses were present. (106)

In another series of the effects of anoxia on occular movements it was found that there were increases in reading time at 15-18,000 feet, and a reduction of precision in the general qualitative characteristics of the occular movements occurred. There was evidence of nystagmus, general unsteadiness and accentuation of abnormalities. A general decrease in the comprehension of the reading of test literature was noted as were impairment of perception or memory for immediate recall. It was felt that this decrease in occular efficiency may have been due to not only the lack of oxygen delivered to the cortical area, but also the effects of anoxemia on the subcortical areas. (73)

Schneider reports that the power of the external occular muscles decreases after 15,000 feet as does visual acuity and light perception. Some vision persists up to the time of unconsciousness.

Complex mental functions are effected to the extent that, of four examinees, only one was not effected by oxygen deprivation. These men were given slide rule problems to work out during four hour stay at a simulated altitude of 12,000 feet. Four men, all but one in good health, and all 25 years old were used. A sudden and maintained anoxemia results in psychological changes which appear in the most insidious manner. In oxygen deprivation there is an initial period of euphoria as in alcoholic intoxication, but this is followed by mental dullness. Persons with excessive emotional or sympathetic unbalance are more disposed to the effects of oxygen deprivation. (25)

Other studies on the effects of lowered oxygen tensions or mental functions disclosed that at altitudes of 12,000 feet there was impairment of reason, memory, and judgment. After staying at a simulated altitude of 12,400 feet, oxygen tension of about 44 millimeters, for three hours, a group of seventeen medical students showed impairment of emotional control which was preceded by elation and overconfidence. Also, there were complaints of headaches and lethargy, dizzy spells, yawning, oppression, joint pains, and epigastric discomfort. It was noted that these subjects mispronounced several words, and their performance tests were poor. It was also noted that neurotic individuals tended to collapse first. (24)

In the early days of flying, when an ascent to 9,000 feet could be accomplished in the amazing time of thirty to forty minutes, it was written that one became short of breath, had an increased pulse, was troubled with malaise, had a buzzing in the ears without being dizzy, would complain of frontal headaches, and would, because of the cold, have a strong desire to urinate. On landing there would be an intense feeling of warmth, the face would be flushed, the eyes would sting, and the pilot would desire to sleep. It was felt that this symptom complex resembled Caisson's disease somewhat. (12) Too, it was reported that if one went too high too rapidly there would be hypotension and cardiovascular fatigue. These would result in cerebral anemia and collapse. (9)

Altitude sickness, very much the same as mountain sickness, occurs as a result of anoxia from decreases in the total and partial pressures of air which caused a decrease in alveolar oxygen tension. This in turn resulted in a tissue anoxia from decreased saturation of the blood with oxygen. The symptoms of this condition appeared as an increase in the frequency of respiration after appearing as low as 4,000 feet, but hardly ever does respiration increase to more than five additional breaths per minute. (23)

It has been demonstrated that there are two types of individuals as concerns altitude flying: (a) fainters--46.7% and (b) non-fainters--53.3%. The non-fainters have, as a result of anoxia, a paralysis of their psychic centers before involvement of their lower functional centers, but just the opposite is true of fainters. During ascent the pulse increased, starting low as 4,000 feet, until a limit of endurance was reached. In the non-fainters this occurred with an increase of twenty-eight beats as compared to a maximum increase of twenty-six beats in the fainting group. The blood pressure changes usually began about the same altitude, and the non-fainters showed a gradual rise of systolic pressure from 8-12,000 feet, but beyond this there was a slow fall with an increased pulse pressure. The fainters showed a sudden terminal diastolic drop. At 16,000 feet there was often a tendency for the blood pressure to return to normal values.

The onset of the effects of anoxia are often so insidious that coma may occur before realization of what is happening. At 12,000 feet there is first euphoria and then depression. The sensory effects of high altitude leave on dropping to a lowered altitude, but the general effects persist for longer periods. An exposure of from 10--20,000 feet for a period of two hours is followed by a dull headache and a persistent sense of fatigue. Exposure of from 15,000 to 18,000 feet for two to six hours may be followed by a severe intractible headache, nausea, vomiting, vertigo, and mental confusion, muscular asthenia, and complete prostration. As the length of flights at these altitudes continues, the after effects increase in proportion both in intensity and duration. (23)

The victim is unaware of the onset of symptoms and thinks he is quite alert, but perception is more affected than sensation. Some other signs of anoxia are panting, lack of concentration, headache, fatigue after landing, vertigo, vomiting, noises, and ear aches. Prime physical fitness is not a guarantee of freedom from this condition. A possible cause may be that the relative anoxia allows stagnation of toxic metabolic products that cause collapse. (93)

There are cumulative effects of aviation anoxia. There is a gradual lowering of the pilot's ceiling, and examination, strangely enough, disclosed in these chronic cases that the blood non-protein nitrogen was lowered. This was explained as the result of the attempts of the adrenal cortex to aid in promoting tissue respiration. Animal experimentation bears out this conclusion. (19)

It was found in 1939 that at pressures corresponding to 8-9,010 meters there were increased tendon reflexes--normal to 2500 meters, decreased to 5,000 meters, and again increased as altitude increased. Other signs were cyanosis, amaurosis, cloudy mentality, and disturbances in hand writing. Altitudes of 8-9,000 meters can be maintained only for a few seconds without serious nervous symptoms. (98) The most resistant animals deteriorate when overexposed to periods of oxygen pressures of about 10%. (35)

Various metabolic changes occur when the amount of oxygen falls below 6-7% of an atmosphere. The respiratory quotient increases, lactic and oxalic acid appears in the urine, nitrogen output increases, and there is fatty degeneration of the body organs. Death occurs if the amount of oxygen falls below 3-4% of an atmosphere. (58)

Armstrong believes there are five pathologic states associated with decreased atmospheric pressure. Three of these are due to the expansion of body gases in the middle ear, the sinuses, and the gastrointestinal tract. The fourth state is aeroembolism. According to the laws governing the expansion of gases we know that intestinal gases will naturally expand as pressure is reduced. Too, all of us are conscious of the uncomfortable feelings associated with intestinal bloating. The fourth state, aeroembolism, is a condition related to the "bends" or Caisson disease of deep sea divers and pressure workers. Whenever the atmospheric pressure is diminished, the internal pressure of nitrogen in the body exceeds the pressure of the nitrogen entering the body. This results in tissue saturation with this gas. The body then attempts to cast off this nitrogen into the lungs by means of the blood stream, and the tissues pour the gas into the circulation. Remember that the present discussion is concerned with the fact that this nitrogen is in solution in the body fluids. If, the concentration of nitrogen, more than doubles its saturation value, as occurs in rapid ascents, it comes out of solution and forms bubbles in the blood. Nitrogen is eliminated in the blood, but the blood, body tissues, and fatty tissues have difficulty in excreting the excess. When this gas becomes bubbles in the blood it provokes symptoms of joint pains, paralysis, paresis, hyperesthesia, embolism, pulmonary edema, and often a neurodermatitis or pruritis. (23)

Pilots can probably ascend at a rate of 3,000 feet per minute without danger, but any greater speed of climb may produce aeroembolism. The pilot at 34,800 feet is subjected to the same relative decompression as a diver in 100 feet of water which equals four atmospheres of pressure. (51)

We have seen that the upper level of safety without extra oxygen is at 18,000 feet where the barometric pressure is 380 millimeters of mercury, and we know that the cause of the effects of aviation anoxia is due to a lowered partial pressure of oxygen rather than being due to a lesser amount of the gas. Several investigators have demonstrated how insidiously the effects of anoxia begin to progressively disturb the normal functioning of the body. The victim is unaware of such a condition for he, at first, feels wonderful and believes that nothing can stop his progress. He will go to nearly any extreme to accomplish a mission, whereas, if he was functioning under normal levels of altitude he would never take the risks that he does. He may recover sufficiently to prevent accidents, but then again, if he is susceptible to anoxia, he may be unable to recover in time to save his life.

We have seen, also, that there are few systems of the body which remain free of the effects of anoxia. The heart, eye, lung, body gases, and brain are all effected to the extent that the pilot is essentially inhibited wherein he is not only dangerous, but also he is not capable of carrying out the duties demanded of high altitude pilots.

Investigators have correlated the similar pathology and symptoms between Caisson's disease and a like condition that occurs in high altitude pilots when great levels are reached too rapidly.

Over a period of exposure the high altitude pilot gradually becomes less useful, and cannot carry out his missions. Too, if he is an interceptor fighter he must be cautious to not climb too rapidly less he develop aeroembolism. It is true that the pilot may show compensatory body changes in response to the continued stimulation of low barometric pressures, but he cannot resist deterioration for long. The problem is what can we do to protect the airman from these destructive processes.

To protect the pilot from aeroembolism we can denitrogenate him by several hours of breathing oxygen. Pure oxygen must be inhaled for five hours before 95% of the body's nitrogens is eliminated. This is not practical as we cannot expect an interceptor pilot to spend his life in a room filled with oxygen. (51) Also, a patchy pneumonia will result if 100% oxygen is inhaled over any length of time, and its use at all may very often be detrimental. (58) Behnke reports that the airman's bends occur at 35-38,000 feet without preoxygenation; occurs at 30,000 feet with 45 minutes of preoxygenation; occurs at 34,000 feet with ninety minutes of preoxygenation; occurs at 37,000 feet with three hours of preoxygenation; and it occurs at 40,000 feet with five hours of preoxygenation. The effects of nitrogen displacement last about two hours without symptoms. This is obviously not practical. Helium, mixed with oxygen, is apparently better, but as yet it has not been used sufficiently. Also, preselection of pilots for high altitude work is important. (51)

Oxygen eliminates symptoms up to a certain point by increasing the gas pressure. Up to 32,000 feet the need varies, but above this 100% oxygen is needed; but, gradually again, there is a falling available oxygen pressure with an inadequate hemoglobin saturation. At 44,000 feet the hemoglobin is 65% saturated; at 47,000 feet the barometric pressure falls to 100 millimeters pressure, which leaves 53 millimeters pressure of available oxygen. It is important that oxygen be used above 10,000 feet, but at 15,000 feet it is absolutely essential that we have oxygen for efficiency. Without oxygen one fallsunconscious above 25,000 feet, and even with 100% oxygen at 35,000 feet pilots are inefficient. Death occurs above 47,000 feet, and aeroembolism may appear. Above 40,000 feet the only sure means of safety lies in the use of a pressure suit or cabin. (27)

Oxygen inhalation may be beneficial in restoring the oxygen tension to a normal level in the lung alveoli and it may suppress hyperventilation, but it cannot prevent a fall in the carbon dioxide tension in the pulmonary alveoli and the blood. (33) The importance of this is signified in the previous pages. This author suggests using oxygen combined with 8% carbon dioxide, and he states that about 350 liters per hour at 10,000 meters should be used. (33) Armstrong says that by breathing pure oxygen before we reach critical levels may prevent anoxia. (19)

Another investigator in 1918 inhaled 67% oxygen and 12.2% of carbon dioxide in a rarefaction equivalent to 6,000 meters with good results, and, by using eleven liters of this mixture at twenty-two respirations per minute, he was able to stay at 13,000 meters for eighteen minutes. He was able to reach a simulated altitude of 50,000 feet. He believes that this confirms Mosso's explanation of altitude sickness as being the result of anoxemia plus acapnia, and he says that special masks for breathing are to be developed. (10)

Zunty of Berlin states that at altitudes of 4-8,000 meters that we need no precautions if the partial pressure of lung oxygen is raised. Unfortunately he neglects to say how this can be done. (11)

Future trends to the prevention of the effects of high altitudes are apparently directed toward pressure cabins or pressure suits in which the atmospheric pressure can be regulated. (23) However, in these ~~cabins~~ suits we must not use such a high degree of relative pressure that the pilot is unable to move. (77)

To maintain the partial pressure of oxygen in the inspired air at 159 millimeters the percentage that must be present in the air is as follows:

Altitude	Barometric Pressure	% oxygen needed
Sea level	760	21.0
10,000	530	30.2
15,000	440	36.4
20,000	375	42.7
25,000	315	50.8
30,000	260	61.6
35,000	220	72.8

As was stated, these values should be doubled to overcome the effects of leakage and waste. This is also true as inspiration is only one half of the respiratory cycle. (28)

The time to start using oxygen should be automatic at a set altitude to prevent the insidious onset of anoxia. (28) It is my impression that it would be much more advisable to begin oxygen at a level of from 8-9,000 feet if high altitudes are eventually to be reached. At least by 10,000 feet all of the crew must have oxygen in use. This should be a standard rule in as much as one seldom realizes that he is anoxic until his efficiency has been disturbed. It is better to use prophylactic oxygen than to wait until anoxia begins to appear.

Pressure cabins are the real answer to this problem, but it remains the task of the engineers, with medical assistance, to construct a practical cabin. Unfortunately, in military use the advantage of these cabins would be destroyed by bullet punctures which would of course destroy the value of the cabin--not to mention the effects on the crew.

A British article reports that at heights above 43,000 feet it is necessary to be able to artificially increase the pressures in the lungs, as merely supplying oxygen through a face mask is not enough. To accomplish this purpose a high altitude suit is inflated to a pressure that will sustain life at any level. Simulated altitudes of 80,000 feet have been reached without undue discomfort. Low altitude tests have proved that the suit does not interfere with ~~his~~ the pilot's vision or his control. The gas pressure is maintained by an oxygen jet which forces gaseous circulation. A cannister purifies the air. The suit is made of a rubberized fabric with a curved double window for vision. (4) It is generally believed that this suit may be the answer to the problems of acceleration as well as the problems of high altitide flying.

Pressure suits also show real promise for even if the suit was pierced by a bullet the wearer would be hit and the release of pressure would be immaterial. A complete suit with metal joints and a plastic head piece would not only preserve vision but also it would probably aid in the movement of the limbs.

Future work will answer this problem of high altitudes, but until this menace can be destroyed, the future of aviation will be inhibited.

THE EFFECTS OF ACCELERATION

"Acceleration may be defined as change of velocity, or the rate of such change, either as regards rate or direction, or both. There are three general types of acceleration--linear, centrifugal, and angular. The two former affect the body principally by inducing stress, the latter principally by induc*ing vertigo." (21)

A view of the early history of this subject discloses that in 1917, a Frenchman, Garsaux, applied high centrifugal forces on dogs strapped to a horizontal wheel. The pathological changes that occurred after a positive acceleration, head to seat, demonstrated cerebral trauma and anemia, and a congestion of the visceral organs below the heart. (20)

In 1926 Bauer discussed the effects of acceleration and stated that it was a question among medical men as to whether the results found in Garsaux's dogs was due to centrifugal force or to vasomotor relaxation. Straight ahead acceleration, or transverse acceleration are not as dangerous as the stresses coming from a high speed turn. It is not believed that we will be able to turn safely at speeds over 300 miles per hour. (29)

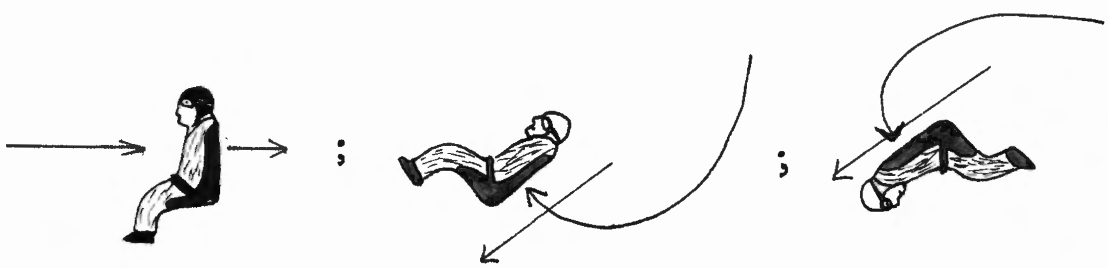
Williams in 1929 reported on negative accelerations and described the vision changes, red vision or "seeing red" which occurred at 3 G. The after effect in this case lasted from seven to nine seconds. (30)

In 1933, von Diringshofen made pneumotachograph measurements on subjects during gradually increasing positive accelerations occurring in spiral dives where a maximum speed of 4 G was reached. He found that as acceleration increased so did the respiratory rate increase proportionally, and the inhalation-exhalation ratio increased as did the velocity of breathing. Blood pressure and pulse increased according to the duration of the exposure.

Jungblood and Noyons exposed rabbits to a constant low acceleration applied to the long axis of the body. They were able to demonstrate a narrowing of the vascular bed of the splanchnic area, and stated that they explained this as the result of a reflex arising from a lowered carotid sinus pressure. The heart rate goes down. At accelerations of from 3-5 G value the heart filled deficiently, and it was noticed that the minute volume fell regardless of the increased rate. (30)

Stainforth reported that tensing the abdominal muscles increases tolerance, but Orlebar advises against holding the breath as this increases thoracic pressure and prevents the complete filling of veins. In 1939, Armstrong published a textbook in which many pages were devoted to acceleration. (20)

Angular accelerations usually occur as a result of head movements during flight, but the vestibular system is involved here. A positive acceleration occurs when one pulls out of a power dive where the forces act from head to seat, and a negative acceleration occurs when one does an outside loop and the force is applied from seat to head. Transverse accelerations are best seen in the Navy where planes are launched from a catapault and planes are stopped by an arresting gear on a carrier. The force here is directed from the front to the back of the body. The following diagram will present the direction of these forces on the pilot.



TRANSVERSE Accel. Positive Accel Negative Accel.

The unit of measure for accelerations is G which actually stands for gravity because gravity is the important factor in the problem of accelerations. Reference to a dive of 7 G, means a dive involving a force 7 times the effect or pull of gravity. By linear accelerations we mean that the body inertia must be overcome by forces, and centrifugal accelerations cause a body to move in a curved path. (21)

The physiological effect of acceleration is to produce an acute cerebral anoxia resulting in collapse after a power dive with the ultimate effect depending upon the magnitude, duration, direction of accelerations, and the pilot's physiological condition. Investigators have demonstrated that a healthy young adult can withstand 4.5 G for 5 seconds before blacking out. (50) Armstrong reports that blackout occurs at 3-4 G as blood drains from the head, and that as the acceleration increases the time of blackout,or amaurosis fugax,is lessened. At 5-9 G unconsciousness results, but vision and consciousness return after a few minutes of level flight. The duration is important as the effects are in direct proportion to the time of exposure. Tolerance to the effects of acceleration vary from day to day according to the subject's physical condition. (20)

We have mentioned "blackout" or"amaurosis fugax" in connection with the effects of accelerations. Using an example, if a ship is at an altitude of 35,000 feet when it starts a power dive it may develop a speed of 6-700 miles per hours. This amounts to 12-13 G, which is 12-13 times the normal acceleration of gravity alone. In this dive the pilot is horizontal and the force is applied transversely, but as he pulls out of the dive he moves to a vertical position and the force is applied from the head to the seat. The centrifugal effect of changes in the lines of force in respect to the body axis pulls the blood downward in the body, as well as the viscera, in a direction from the head to the seat. This, as previously mentioned, lowers the carotid sinus pressure and produces a narrowing of the vascular bed of the splanchnic vessels in an attempt to maintain blood pressure. This relative anemia results in the pilot's "blacking out", which means he has become unconscious. The unconsciousness appears after an initial loss of vision in the eye is noted, and it is because of this that the term amaurosis fugax is used. Dorland defines a condition, amaurosis partialis fugax, as a condition of sudden transitory blindness with scotomas, and to a certain degree this describes the visual effects of "blackout". It is said that the average pilot can't be sure of pulling out of a dive of over 5 G intensity, and Army regulations do not permit power dives to exceed this value. (49)

Certain structural parts of modern aircraft have been reinforced to strengthen weak areas, but thus far man has been unable to keep up with mechanical progress. It is known that living tissue cannot stand the strain of turns of over 660 miles per hours, as it is the rapid change in motion that causes the effects of acceleration. This author says we do not feel any effects of a ride in a high speed express elevator which gains altitude. I question this statement as I have felt a strange lightness, a quickened pulse, and trembling knees after a short ride in this type of elevator. He says that the centrifugal or centripetal forces, as the case may be, pulls the body organs to one side or another along with the body fluids causing a loss of function from anemia which in turn would cause tissue hemorrhage. Also, regardless of actual tissue trauma, cerebral anemia is to be first considered. (110)

An interesting observation of Wurdeman's work in

1935 discloses that he feels there is a limit to human tissue resistance, and especially would this resistance be noticed if takeoffs and landings at 100 miles per hour existed. Today, speeds of 150 miles per hour are not uncommon with landings and takeoffs. (110)

Livingston describes blackout as a condition that results when an aircraft is maneuvered so that a member of the crew is affected by a loss of vision which may vary from a haze to a temporary complete blindness. He actually placed himself under the conditions existent for air crewmen so that he would know better just what the flyer is up against. He also concluded that there was a relationship between the amount and duration of G produced and the susceptibility of the subject to "blackout". (69) Sheard and Phillips have found that with acceleration in a curved flight, the force exerted is expressed by the equation $F = MV2/r$, where F represents the force, M the mass, V the velocity and r the radius. The force is greater in direct proportion to the square of the centrifugal velocity, and it is inversely proportional to the radius. (85)

As an explanation of the amaurosis, Marshall reports that at 6½ G he found the heart and liver had dropped four inches, and the aorta was empty. This resulted in a lowering of the blood pressure in the retinal arteries to a point where it was less than the normal intraocular pressure of twenty millimeters. This, due to retinal ischemia, causes amaurosis. (76) Livingston suggests that the amaurosis is due to alterations, type not mentioned, in the region of the external geniculate bodies and the area striata, but the anonymous author maintains that cerebral anemia is the real cause of amaurosis fugax. (3) In his original article Livingston reports that the blood supply to the brain is being centrifuged away, and the blackout is probably due to a retardation of the blood flow rather than an actual anemia. Actually, the whole visual pathway is involved. (69)

This naturally leads to a discussion of what we mean by anemia. I believe that those men who say the eye becomes anemic because the blood is centrifuged away are just as correct as those that maintain there is a retardation of flow behind the amaurosis. It would be rather hard to believe that with all the centrifugal forces existent that some blood would not be naturally centrifuged away, but the impression derived suggests a picture of empty vessels. Recall that Marshall found the aorta, I presume he means the arch, empty. I am inclined to agree with the men who maintain that due to the acceleration change in pulling out of dives that there is merely a retardation of the flow of blood. This suggests that the blood is present, but the available head of pressure needed to force it into the tissues is overshadowed by the greater effect of the downward force of gravity. Both of these effects will, in reducing blood flow, result in an anemia.

It was announced that at 4 G, positive acceleration, the carotid pressure is zero. (85) Rook and Dawson, using hypotensive pilots, concluded that the ability of this type to withstand "blackout" depends solely on the ability of the cardiovascular system to respond to stress and strain regardless of blood pressure. (85) In the same article it was noted that in 1920, Flack had demonstrated that pilots, under the stress and strain of war, showed a high pulse pressure and a lowered diastolic pressure. He believed this resulted from repeated sudden dilatations in the capillary and arteriolar beds following dives and other maneuvers high in G. From these reports, according to Phillips, it appears that centrifugal force is the most important factor. Von Diringshofen announced in

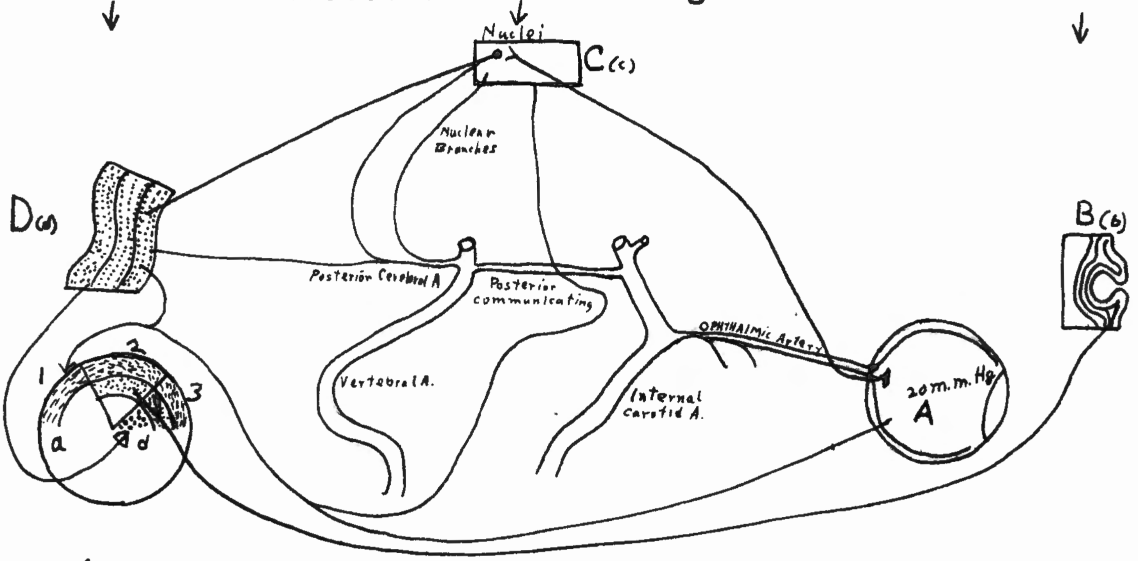
1934 that "blackout" resulted after blood drainage from the head and upper body. This is apparently accepted. (85) I do not suggest that this is incorrect, but it is evident that we should combine the importance of cardiovascular adaptability with the effects of centrifugal force. Otherwise, how are we to explain that some men are more suited than others for the job of test-piloting new ships through greuling tests at high accelerations. There must be an individual factor inherent in these particular men.

An interesting statement is that at 6.9 G the blood becomes as heavy as molten iron. The great weight of the blood would naturally resist the efforts of the cardiovascular system to maintain blood pressure. (51)

The optic "blackout" is not due to pressure on the eye vessels nor to a loss of blood from the organ, but rather it is due to a retardation of the existing flow to the whole optic tract, especially about the external geniculate body, the calcarine fissure and the association tracts. (85)

Livingston presents the following chart as explanatory of the areas involved and effects produced.

Direction of Centrifugal Force



Areas:

A. Eye with its blood supply.

B. Cortical area, representing conscious mental processes and initiating effector response.

C. Area of lower visual centers, external geniculate, pulvinar, upper quadrigeminal body with end arteries, fulfilling the duty of intermediate relay stations.

D. Corticovisual area.

Effects:

a. Visual simple blackout produced through mild action at the three points a, c, and d.

b. Blackout with loss of power or thought or emotional states produced by more pronounced actions on a, b, c, and d.

c. Blackout from profound effects upon a, b, c, and d. With emphasis on the psychovisual cortex d, embodied in dream states. Beyond this condition lies fainting and collapse.

In pulling out of a power dive the onset of amaurosis is not coincidental with leveling or pulling up. There is a short period wherein the acceleration changes before the blood pressure; it is due to the inertia of the blood and partly because of the attempts of the cardiovascular system to prevent the effects of rapid deceleration. It is probable that this lag phase accounts for the variations in individual susceptibility, and, it explains why we are able to tolerate a great acceleration of a short duration better than a small acceleration over a long period of time. (85) This means that when a pilot blacks-out he is in nearly level flight or in a slight climb. The adjacent diagram will demonstrate this fact. (85) That blacking out does not occur in this position at all levels will be shown later.

An interesting experiment was conducted by an investigator who injected a radio-opaque dye into the circulation of monkeys before exposing them to the effects of accelerations. The results of this work showed it was possible to empty the heart of blood in sixty seconds with 3.3 G; also, the heart could be emptied in eight seconds at 4.4 G. Too, Fischer showed that when the forces are vertical there is an increase in the diameter of the aorta and vena cava. (85)

In 1938 the results of experimentation with human subjects was reported. (20) Armstrong and his workers constructed a human centrifuge with speeds of 1-20 G. To create high speed effects the machine was fitted with a chain that could be moved into various positions. The purpose was to study the effects of high linear accelerations of short duration giving as high as 16 G and over as short a period as .5 of a second. It should be recalled that G refers to the pull of gravity; so, there is the effect of 1 G on all humans in any position. The results of positive accelerations on the human subjects were:

a. 1 G: normal effect of gravity in the upright position.

b. 2 G: with the subject in the sitting position there was a sense of increased pressure.

c. 3-4 G: there was an exaggerated sense of heaviness in the limbs.

d. 5 G: the body is beyond muscle control, and there are dragging sensations in the thorax; the legs are congested, and inspiration is difficult.

e. 5-9 G: vision was suddenly lost, and coma occurred at 6 G.

The effect on respiration and the pulse is usually influenced by psychic factors, and true readings are difficult to obtain. Up to 4 G the respiration and the inhalation--exhalation ratio are slightly increased, but from 4-5 G two things may occur: (a) we may see irregular breathing with long slow labored inspirations and rapid forced expiration, or, (b) the breathing is stopped at mid-inspiration to prevent downward traction on the diaphragm. We also see an increase in the pulse in proportion to the extent of the acceleration. Armstrong shows that the pulse increases in proportion to the duration of acceleration until it becomes stable at a level where after it maintains a constant rate. (20) (21)

There are several reports concerned with the clinical features of the subjective effects of high accelerations, but I think that Livingston's is the best. "The first impression derived from the terrific impact of the aircraft against the resistance of the air at the point of turn, is one of intense bodily strain, producing what may be called a concertina sensation. The cranium feels as though it were a solid ball of great weight resting upon a feebly compressible spinal column. The skin of the forehead, cheeks, and eyelids produces a feeling of numbness that can be likened to the tactile sensation or an urticarial wheal. Then, according to the gravity factor produced by the maneuver, and the natural susceptibility of the experimenter, the visual disturbances make their appearance usually in the form of a prodromal blurring, or blue haze, followed rapidly by a sensation of intense blackness. At the same time there may arise a feeling of weakness in the limbs, amounting perhaps to an inability to move arms or legs. In my own case the blindness came with such suddenness that warning signs were almost absent. Likewise, the return to visual appreciation came about in similar fashion, and the wall of blackness snapped away as does a camera shutter on its release. "Black-out" endures for from 1 or 2 seconds up to 12 or 20 seconds. If it lasts longer actual fainting tends to set in. With the longer periods there seems to come a state in which voluntary action is checked and thought is stilled, but collapse, with its characteristic features is not reached. My own "black-out" lasted, according to Flight Lieutenant Lee, quite 12 seconds, and probably 15 seconds. I could recall the first turn in the first experiment, and a short period prior to flattening out, but nothing in between. Yet, from this wholly negative period into which, as a susceptible type, I slipped, I came back to the full and instantaneous realization of the situation to find myself sitting normally, still holding the speaking tube without displacement. The three loops out of the dive produced only discomfort with just a suspicion of visual uncertainty at 200 miles per hour. The final dive and turn, made purposely under less intense conditions, resulted in dimness of perception of the ground 5,000 feet below. It was though one had overtaxed the accommodation by bringing print too near the eyes. Recovery should follow immediately unless fainting occurs." (69)

Flight Lieutenant Waghorn said, after the Schneider Cup Races in 1932, "During the turns (at about 350-400 m.p.h.) I would sometimes lose all control of my machine; my head felt congested, and I had the impression that my eyes were bathed in blood." The late

Jimmy Collins says, "My eyes felt as if someone had taken them out of their sockets and played with them, and then put them back in my head." He made this statement after a 9 G dive from 18,000 feet down to 7,000 feet. (85)

It is evident from the above reports that the effects of acceleration are very dramatic. Each investigator has reported similar symptomatology characterized by a progressive increase in loss of muscular function accompanied with the sensation of being pushed into the seat of the aircraft. As the plane pulls out of the dive the subject becomes blind and may often lose consciousness. Recovery is imminent in the short period of anywhere from one to twenty seconds unless fainting occurs. The body feels as though it is being compressed vertically as a result of general muscular tension, and the head is held up with difficulty in the pull out. (21) No particular after effects have been found, but it is possible that over a long period of time there would be traumatic brain damage; the only evidence of the effects of acceleration are seen in animals, and we cannot uncompromisingly accept these findings as similar to the effects in man.

The blood pressure above the level of the heart is decreased while that pressure below the heart is increased, and the blood pressure changes are inversely proportional to the intensity of G. Armstrong has stated that, due to his findings which showed a carotid blood pressure of 18 millimeters at 8.3 positive G's, this proves the "theory" that amaurosis fugax is due to cerebral and optic anemia. His blood pressure charts also demonstrate the lag phase showing the earlier drop in acceleration as compared to the delayed blood pressure changes. This lag also exists in recovery, and it explains why many pilots do not complain of symptoms until after they have pulled out of a dive. (21)

Examination of Armstrong's charts (21) discloses that the usual duration of the effects of acceleration lasted about 5-12 or 15 seconds, but it is seldom that in flying that airmen are subjected to the G's for so long a period of time. Also, pilots in the armed forces are restricted to the limit of 5 G in a power dive. Armstrong has said, however, that where the exposure was for five seconds there was a drop in blood pressure of nearly 50 millimeters of mercury, but where the duration was only 1/5 second the blood pressure fell only 10 millimeters. (21)

Thus far we have been concerned only with positive accelerations, but there are also transverse and negative forces to be considered. The usual transverse accelerations are not usually troublesome if the body is supported, as these forces hardly ever exceed 2-4 G's. (20) Transverse accelerations are at right angles to the long plane of the body as occurs in level flight, but these forces may act from behind forward or on the lateral aspects of the body. (21) Both positive and negative accelerations are essentially the same here. (20) Up to 6 G there is no demonstrable effect except the sensation of pressure. This is because the pressure is distributed over a large surface of the body whereas, in the centrifugal accelerations the force is concentrated from the head to the seat. Respiration becomes more difficult at 6-8 G as the pressure is compressing the abdomen and the thorax, and it is observed that to combat this effect "the breath is usually held with the thorax in the mid-inspiratory position." (21) Humans have withstood transverse accelerations up to 12 G's without deleterious effects if their bodies are well supported. The greatest effect results when the acceleration is directed from back to front as there is little anterior support to the body. Forces acting laterally are, due to anatomical reasons, withstood. (21)

Pulse changes increase in proportion to the amount of force exerted, but seldom do the rates go above 100 per minute. The blood pressure tracings in this type of acceleration show indirectly the characteristic respiratory changes. The pressure rises in steps to the point where it maintains a constant level, and this is due to abdominal and thoracic compression which forces abdominal blood into circulation. The irregular rise is due to respiratory movements which both aids and prevents circulation to the heart. (21) Transverse accelerations are not usually debilitating.

Negative accelerations are not encountered except in combat flying where acrobatics are necessary. The maneuvers that result in negative accelerations are outside loops and spins, inverted spins, and inverted flight. Armstrong also conducted experiments concerned with negative forces at the same time that he used his human centrifuge to solve the effects of positive accelerations. His results were as follows:

a. 1 G: there is merely a sense of hanging with head down; actually, this force is a .2 G change from the normal 1 G effect of gravity.

b. -2 to -3 G: there are sensations of throbbing and severe pain and congestion of the head.

c. -3 to -5 G: there is intense congestion and pain. The tears flow and the skull seems about to burst. The skin and conjunctiva show hemorrhages and injections that persist for days. Above 3 G the breath is held, and there is confusion and slight mental shock that persists for days, no coma occurs.

It has been found in these experiments that -5 G is the upper limit of blood vessel pressure safety in the brain. Too, at -4 to -5 G the stomach contents gush from the mouth. The skin congestion is relieved in 10-15 minutes. (20)

The blood pressure is very high as there is very little resistance to overcome, and a high intracranial pressure results in the inexpansible skull. This causes the distress and mental confusion that was observed. A negative acceleration of 2 G causes a rise of 65 millimeters of pressure while a positive 2 G force lowers the pressure only 30 millimeters. There is a similar lag between the blood pressure and the acceleration, but in this type of force the lag period lasts only about 1 second. (21)

The pathology of positive accelerations is not marked even after long exposures according to one investigator. (20) Other reports tell of visceral dislocation, and many have been incapacitated from brain and visceral hemorrhages; some pilots have even become blind. Dogs have displayed brain injury after being revolved at 4-6 turns per second. Autopsy showed cerebral anemia with engorgement of visceral vessels. Death can result from injury to the brain stem by herniation into the foramen magnum or from pressure. Even without death there are occasionally permanent injury. (110)

As was stated, the pathology of transverse accelerations is negligible, but in negative accelerations there are several important changes existant. There is hemorrhage in the circle of Willis, most commonly occurring in one of the posterior communicating branches. There is an anemia of the viscera. Hemorrhage from the nose is also common. Other pathological changes have been previously given. Armstrong presents a more comprehensive pathological picture in his textbook. (20) (21)

It will be apparent from our discussion of acceleration that we have a problem that will ever appear as long as there is military flying, but the possibility of an eventual ceasing of air acrobatics is very unlikely. Then too, we must look ahead in anticipation of the greater accelerations that will occur as a result of better aircraft designs. We must not dismiss the possibility of rocket flights too lightly as "stranger things have happened." We now have many unsolved problems in the field of amaurosis fugax; so, there will be no dearth of material on which to work.

Hill and Barnard in 1897 organized an experiment with the following purposes; (57), to prove that, (a) by the support of the abdominal wall the distention of the veins under the hydrostatic stress of gravity is largely prevented, (b) by expiratory contractions of the abdominal muscles the veins can be compressed, and (c) so long as vasomotor tone is present, the splanchnic area is resistant and gravity is of little importance, (d) when vasomotor tone is absent the whole of blood tends to collect in the abdominal vessels, and, (e) the respiratory center is excited by anemia to increased activity.

The results of these experiments led to three conclusions which were, (a) with an atonic abdomen and a deficient vasomotor tone or a patulous abdomen we must expect a deficient circulation and cerebrial anemia when this type of person stands erect; (b) by abdominal compression the compensation for the hydrostatic effect of gravity is easily supplied even when the natural compensatory mechanisms are abolished; and (c) the healthy heart cannot be thrown into a paralytic dilatation by the most forcible compression of the abdominal veins. (57)

It is remarkable that as far back as 1897 people were concerned with the physiological effects of gravity. Of course they were not concerned with flight problems of today, but, regardless, and as will be seen, these investigators have given us a valuable group of suggestions. This record proves that the idea of a pneumatic belt as support about the abdomen is not a recent innovation. Too, they substantiate my belief that factors other than gravity are very necessary to overcome if we are to overcome acceleration effects.

German suggestions for helping the pilot exposed to these forces are many. (51) They believe that all pilots who are to be exposed to the effects of acceleration should have a full stomach so that, with the physiological gastric hyperemia of digestion, there will be no room for more blood. Incidentally, it has been suggested that it is because the air force eats so well that all Germans are desirous of air service. Rook and Dawson, however, state that pilots who have eaten heavy meals a few hours before flying will blackout quicker than if their stomachs were empty. (85)

Another German suggestion was to inhale 5-6% carbon dioxide which, by increasing the cerebral circulation increases tolerance or resistance to acceleration by 1-2 G's. As to the success of this I do not know, but I am inclined to believe that this is of no avail when the effects of acceleration are existant as we have shown that the symptomatology is due to a low head of available pressure to force the blood to the tissues. Vasoconstrictor drugs are used with the same principle in mind, and the Germans report that any drug which improves capillary tone will improve the ceiling. The answer to this is essentially the same as that for the use of carbon dioxide. (51)

Some of the simpler means of prevention used by test pilots, especially, are binding the abdomen tightly. The legs are also bound tightly. When the pilot is ready to pull out he may bend over, or he may simply scream. The purpose of these actions is to impede the backward flow of blood as much as possible, and the screaming tends to equalize the intrathoracic pressure. This also aids in regulating the pressures in the middle ear. By leaning forward the pilot transfers the plane of force to a more vertical direction. Other postural suggestions have been advanced and it is suggested that the pilot and crew lie with their bodies parallel to the long axis of the plane. Also, the body should be sharply bent forward at the moment of turn. (69) The Germans also advocate this position. Unfortunately, it is somewhat of a problem to adjust the pilot's vision when he is in this position. Then, too, the mechanical problem in arranging controls on such a small lever basis is an engineering problem that yet needs answering.

It is suggested that because pulmonary ventilation per 100 c.c. of oxygen consumed is greater in the erect than the reclining position, this hyperventilation can be corrected by the fall of absolute cardiac output that occurs in prone position. (75) If one attempts to reduce the effects of acceleration by moving back farther toward the tail of the plane he finds that the farther back he goes the more severe the blackout and coma are. (85)

We now have the mechanical possibilities to consider. By using an adjustable oleo seat we may spread out the forces that are encountered. This same author believes that body belts are not yet practical as they are unable to give both upward as well as backward pressure. (69)

Armstrong and Heim advise the use of an inflatable pressure belt which is to be inflated as the power dive begins. This belt is claimed to give the wearer resistance against 1.5 G more pressure than could generally be tolerated. (85) The Germans report that pneumatic belts will increase acceleration tolerance only 1-1.5 G. They have also suggested the use of water pressure suits, but as these may be very cumbersome and vulnerable to bullets it is not practical. (51)

An annotation in the Lancet (3) states that such things as belts, water jackets, and yelling are all useful as they all tend to prevent visceral flooding by pressure at the expense of the cranial blood supply.

Armstrong reports that the essential features of such a pneumatic belt as we have described are that it must be inflatable over that area of the abdomen which is not protected by bone. This includes the area of both flanks and the entire abdominal wall from the costal margin to the inguinal ligaments. To assure inward pressure the belt is to be covered with an inelastic fabric to prevent curling of the edges. The inflatable portion must be strongly constructed and supported. Each belt should be individually fitted to the wearer.

The belt must maintain a pressure between 50 and 100 millimeters of mercury, but this is so uncomfortable that the wearer must be able to inflate and to deflate the bag at will or upon occasion.

A. L. Bennett of the department of physiology and pharmacology at the University of Nebraska Medical College has suggested the use of a pressure suit that covers that portion of the body below the heart. This suit has very useful possibilities and only time will show its usefulness. Doctor Bennett also believes that a pressure suit and anti-blackout suit may be developed so that the flyer can approach his objective at a high altitude before diving to release bombs. I believe that this combination is very practical and well worth trying.

Future experiments and advanced developments may result in new flying possibilities if we are able to overcome the effects of acceleration.

THE PSYCHOLOGY OF AVIATION

The term psychology implies a study of the reactions of an individual in response to the demands of his environment. As the flying environment is constantly changing, due to either human or natural efforts, the science of psychology is obviously an important field in aviation medicine. The psychology of aviation attempts to explain the processes whereby airmen become aware of and respond to their surroundings, and the term implies a necessary relation between mind and body. This is suggested because all perception involves two separate and distinct processes, the physiological wants and the conscious experiences. These two must be intimately linked if the term psychology is to fulfill its meaning. (99)

Body and mind are closely interwoven, but what is the uniting medium of mind and body? Sutherland presents these two theories as a possible explanation: (a) interaction between the two, or (b) parallelism between the purposes of each. (99) Dunlap reports his conception to be that the psychological processes are integrative, or dependent upon the working together of the central nervous system as a whole. (46) According to

Carlson, the correlation between achievements and intelligence is high. (40) It is apparent that the individual with a good mind and body can accomplish nearly any task that confronts him, but if he is troubled in one manner or another, his efficiency drops off. People must have "drives" that act as stimuli for the engaging of the problems of every day life, and if these drives are not existent, the body cannot function correctly or efficiently. L. Carlson, in 1939, gave the following important facts which correlate the demands of aviation with the field of medicine and psychology: (a) intelligence; this is the capacity to deal effectively with new situations, and a normal amount of intelligence is absolutely essential in flying; (b) learning and memory; it is essential that there be a normal rate of learning and habit formation; (c) attention; this factor must be well balanced and there must be no deviation to increased or decreased ability to maintain attention; (d) nervous stability is absolutely essential; (e) emotions; must be stable above average level; (f) reaction time and age; the reaction time should be better than average, and the flyer should be young. (39) Dunlap states that discriminative judgment shows no falling off in rapidity or accuracy except as impaired motor control and attention produces it. (46) This statement, I believe, indicates the very important interrelationship between body and mind as related not only to aviation but also to every day life.

When an aviation cadet is called upon for a physical examination, one of the things he must undergo involves a somewhat ineffective psychiatric examination. I say somewhat ineffective because, today, there are reportedly few private examinations conducted. To save time two or three candidates are examined at once, but it is impractical to believe that in the presence of other cadets, and over such a short period of time, that any real insight into the flying cadets personality may be accomplished. The examiner of a candidate must arrive at a fair interpretation of the subjects neuro-psychiatric qualifications (54) but it seems impossible that such a short examination can answer our questions concerning emotional patterns. Greene states that personality study does not consume much time, and it should be applied from the moment the examinee is first seen. (54) Of course it is possible to receive an early impression concerning ones personality type, but I have always been of the opinion that, in psychiatric studies especially, there is too great a tendency to lead the patient into a personality grouping, whether right or wrong, based on the examiners first impression. I am not implying that my suspicion is absolute correct, but I do feel that such a thing occurs at least frequently. It is true that personality study is not a great time consumer as the important pieces of a jig-saw puzzle, representing the true personality, are gathered at varying intervals and under varying conditions, but Greene's statement above should not suggest that personality study is complete in a short time. To accurately determine one's pattern it is essential that we maintain close, but unsuspected, relationships. To be successful the examiner must never for a moment allow the subject to feel that the psychologist is using their friendship and associations as subject material for investigations that may later result in the interruption of the flyer's career. Too, recall that Armstrong, as previously stated, warns against the man who considers himself a walking psychoanalyst, for this character has just enough psychological knowledge to be a danger and a nuisance. (20) (21)

Porter believes that in a personality study we must consider (a) the biographical outline, (b) physical confirmation of physiological functions, (c) psychobiological processes and functions, and (d) psychobiological integration. (91) Surely this will stand in opposition to Greene's statement concerning how little time a personality study requires. (54)

There have been established lists of desirable and undesirable traits or qualities. If a flyer develops these undesirable traits he must be eliminated from training or from flying as he is a constant source of danger. These bad traits inhibit normal progress, and retrogression may set in. Porter says these traits may act to or against the pilot's best advantage. I will explain this by saying that we often find many of the commoner undesirable traits in the best military pilots. (91)

A large number of pilot-candidate failures is attributable to the flight surgeon's inability to determine the candidate's psychological flying equipment. (56) Porter believes we should analyze the student carefully before allowing him to fly as we may often detect undesirable qualifications before some unfortunate experience occurs. (91) From a military standpoint we must select stable personalities that will withstand the stresses and strains of military aviation with the added mental effects of war flying. In 1935, Jensen stated that it was not known which type of personality is most desirable, and there are no mechanical devices that will indicate one's potential success or failure; however, we do have our psychiatric findings to assist in detecting unsuitable candidates. We must delve into the individuals inner life to find if there are hidden fears or characteristics of psychopathic types. Cadets, who have unreported epileptoid equivalents, have been involved in many training crashes whose causes have been undetermined due to the cadet's masking of his weakness. Often the existance of epileptoid equivalents is accidentally discovered when an attack occurs in the presence of fellow cadets. These states represent an unstable nervous system. (62)

The following signs are included in the epileptoid equivalents: (a) enuresis, (b) pavor nocturnus; nightmares, (c) dizziness, (d) fainting, (e) nail biting, (f) stammering or stuttering, (g) headaches, (h) amnesia periods, and (i) migraine. (62)

When a student is learning to fly he must move through two phases of the learning process. At first his trial and error methods are on a mechanical basis, but inherently he must have an impressionable autonomic action reserve that is capable of responding to impressions as to how the plane should be controlled. Soon the student realizes that he is no longer mechanical, but rather he is concerned with conscious decisions as to how he wants the plane to fly. He has passed from the mechanical phase to the autonomic or fore-conscious control period. Soon the autonomic control is replaced by discrimination control, and the student flies in an unconscious manner. Porter says this is proved when a pilot is questioned as to the control movements in a certain maneuver; we discover that he cannot answer the question because his conscious mind does not know the answer. (91) It is especially important that, in aviation cadets, the mind becomes trained so that in emergencies they will relax completely and thus avoid "freezing" into paralysis. Control of the mind activity in this manner, for the given purpose, is accomplished by placing the student in the particular situation that is troublesome, and, as problems arise, the instructor adjusts the student's reaction. Of course, it is essential that the student know about the nervous phenomenon so often associated with early flying. (54) In other words, we are using prophylactic treatment in the prevention of flying accidents.

The previous discussion indicates the two or three main stages through which the mind passes while receiving flight instruction. We must appreciate these stages when we are considering the psychological reactions of the student pilot. Of course, when the problem of undifferentiation of the stages occurs, the case is no longer a medical one. It is the duty of the flying board at the field to decide on this man's future worth in the air forces.

We must consider the applicant's inherent qualities as well as the modification of these qualities by his acquired characteristics. We must give great consideration to his temperament, and all individuals involved in this study should be considered as tendengy toward the affective or cognitive side. This means that the persons involved become better aware of things by an increased ability to understand and to reason out problems. So that a student may learn rapidly, we must seek fundamental inherent characteristics that are mirrored by the individual's artistic trend. Too, we must consider the personality within the limits of extroversion and introversion. The flight surgeon examiner should delve into childhood and early school history to establish the inherent type of personality;

from this point we modify our expectations or demands according to the initial character of the flyer. The author states that the flight surgeon's ability to determine aeronautical efficiency, as well as to detect abnormal inhibition, is based on his appreciation and recognition, in a standardized examination, of the requisite psychological characteristics. It is essential that the examiner maintain close contact with flying personnel so that he may better be able to determine an accurate norm with which he is able to evaluate his findings. (56)

"From birth, an individual's intelligence moulds his activity and attitude toward his environment. At any given time of his life the degree to which he has compensated his temperamental and personality trends to serve best his interests, can be taken as a measure of the degree of intelligence with which he has been endowed inherently." (56)

Haselton presents four inherent types of personality as occurring within the limits of extroversion and introversion. These are, (a) the affective introvert, (b) the affective extrovert, (c) the cognitive extrovert, and (d) the cognitive introvert. He also says that mediocre intelligence abrogates all types. (56)

Patient, in 1938, reports that the successful pilot is endowed with special abilities--something extra, but that even with our careful selection nearly 50% of trainees fail in their course; because of this, it is the duty of the flight surgeon to investigate other possible causes of this high loss. The author presents the following classification of personality types as suggested by the given authority:

A. Jung:

1. Extrovert: positive reactions or attitudes.
2. Introvert: abstracting attitude.

B. Kretchmer:

1. Introvert
2. Cycloid: affective type; can be cheerful or sad.
3. Schizoid: a non affective; cool and calculating.

C. Rosenoff:

1. Cycloid
2. Schizoid
3. Antisocial: elicits selfish behavior; lack of moral compensation.
4. Epileptoid: precursor of epilepsy; strong, unreasoning, and impulsive; makes tenacious

personal attachments.

D. Trotter:

1. Stable: a resistant person who tends to remain in early moulds; lack of progress because he feels alone in the advancing world and like to remember the "good old days".
2. Unstable: Mind in constant flux; marked reactiveness to many stimuli.

Patient cautions that here personality means the same as temperament. (33) According to Noyes, "personality is that organization of the constitutional, affective, ideational, and cognitive capacities and tendencies which characterize the individual." Noyes says that "temperament is the fundamental and prevailing splint, life mood, reactive affectivity, and tempo peculiar to the individual personality as shaped generally by the general biochemical structure of the organism, particularly as they are determined by the endocrine glands and the vegetative nervous system." (83)

Porter has described some personality types named by himself. He describes the introspect as being the normal personality type who is an inquiring person, a good student, thinks a lot, reads and digests, and is possessed with a logical and methodical mind. He inquires into his body, and tends to become acutely distressed by minor ills because of their potentiality and not because of their severity. The "introspect" has a perfect family life, is kindly and considerate of others, and he is often imposed upon. His mind is always active and is continually probing and seeking into new things. His existence is tinged with day dreaming, but he has few bad habits. He is a philosopher, a planer, an ingeneous "gadgeteer", but he is often lax in executing his plans. He tends to be quiet, not seclusive, and he enjoys society to the full. The introspect may easily be quickly offended by unkind remarks, but he makes a very dependable officer in military service although he lacks some force. As a pilot he is methodical, calculating, and dependable. He may develop a torpidity of outlook and a mediocrity of thought and his ideas become pointless; however, a change of environment reestablishes his standards. He is, Porter reports, not an introvert or schizoid, but "a common man who needs a little prodding to reach the heights." (90)

The "realist" according to Porter is acutely conscious of the concrete world in which he lives. He accepts things at face value, and material benefits strongly attract him. To provide these benefits he seeks financial security. To achieve a goal he follows a logical, obvious, and difficult course, and we find that flare, native intuition and thoughtful planning are all absent. His success is the result of unstinted effort. He abhors indecision and suspense and he is very curious. He indulges strongly in alcoholics, and he does well as a flier until "his hasty decision is a wrong one"; he tends to minimize hazards, and he takes chances. His past accomplishments are no indication of his future potentialities, and he may miss his main goal as he is often easily sidetracked. (87)

The "chronic boy" is characterized by the adult persistence of undesirable personality traits from childhood and adolescence, but he is normal. This type is frequently found among fliers, and he needs countless little attentions to pacify his ego. Praise is his favorite article, and his rationalization is tinged with sublimation. Emotion excesses are a big problem but he hides their presence well; alcohol is his major problem. Unless his wife understands him, his marriage is complicated for he loves only himself.

His addiction to affairs is not so much from the sex drives as it is from a desire to have his ego satisfied. He makes a better pilot than an officer, for he never fosters a subordinate's idea lest it surpass his own suggestions. He is intelligent, successful, and engaging, but in a position of responsibility he is a blustering official. Porter suggests that he has an emotional fixation somewhere along the lines of his mental development. (89)

To me these descriptions are very interesting as they are practical considerations that demonstrate the ability of Porter to appreciate and to evaluate the importance of all the factors concerned in a personality study. Undoubtedly, men of these types were dismissed as not the proper type of man for air training. Due to a lack of appreciation of the necessity of deep insight into personality studies, the air force has probably lost men that would have developed into top-flight pilots.

Fatigue is an important psychological consideration, and we have discussed it to some extent previously. It is the result of the cumulative ill effects of mental and physical conflicts, on a personal basis, that causes fatigue. Alcohol, tobacco, worry, emotional conflict, lack of exercise, wrong diet, and a lack of oxygen at high altitudes are all contributing factors. This author quotes Armstrong as saying fatigue is important in one's inability to withstand the effects of high altitude, as a chronic emotional stress upsets that system, sympathico-adrenal, so important in high flying. The cumulative effects result in a lowering of pilot efficiency. (79)

The effects of anoxia in producing psychological changes are not usually significant below 9,000 feet, but above this level there is the onset of memory decrease and psychological complaints. At 14,000 feet there are visible disturbances such as changes in mood with fatigue or euphoria. At 18,000 feet there is not only a decrease of sensory perception, neuromuscular control, and field of attention, but also there appear narrow, irrational, or fixed ideas with self criticism and loss of sound judgment. From 20,000 feet upward, the reaction to simple motor and sensory tests is altered. The victim loses neuromuscular control, twitches, and has emotional outbursts. (23)

Paton in 1918, reported that until we know the true effects of low oxygen tensions on the tissues we cannot determine the effects of anoxia on the flying man's personality. The flyer is often unable to adjust in the air and, regardless of his desire to continue, he is aware of the fact that he is not able to carry on. From the mental strain of avoiding this truth he often suffers a loss of nerve and morale which suggests the existence of a psychoneurosis or an anxiety neurosis. Continued exposure to low oxygen pressures increases the mental strain, and his psychological changes become more intense. (84)

Ovington reported that in altitude flying it is important to realize that at the various levels the physiological responses of fliers are similar, but the psychological factors are entirely different. (82)

We have seen how important aviation psychology is in the minds of numerous investigators, but Armstrong in his discussion of the condition of "aeroneurosis" has made us all cognisant of the significance of the relationship of this field to successful military and civil aviation. (20) (21) "Aeroneurosis" was discussed earlier in this paper.

The problem of what to do about the presence and the effects of psychological unbalances is a vast one that will necessitate many changes and new approaches, especially in so far as pilot selection is concerned.

How are we to approach the problem successfully? According to Paton, "A personality study is a great deal more than a mere psychological analysis, and often the correct interpretation of emotional and mental reactions is to be sought in the solution of some complex biological problem." (8) Our first suggestion is to improve flying conditions, especially where the effects of anoxia and acceleration are concerned. Possibly, better protection of the pilot from cold and loneliness will assist in overcoming our problems of psychology.

Is our problem the result of inefficient, or just incomplete, candidate examining? Mashburn says that the traditional selection in the air corps is grossly inefficient. In a large crossection he says it is important to remember that 1/2 the group will be average, 1/4 will be above average, and 1/4 will be below average. The author believes that a pilot's potentiality depends on the quantity rather than the quality of the various desirable traits that he may possess. The quantity is the determining factor between success and failure in aviation. Objective tests for probing the candidate's emotional makeup should be used in conjunction with performance tests that indicate one's traits.

After the candidate has been shown to possess a sufficient quantity of the desirable traits, we should attempt to evaluate and to identify these factors in order to establish a norm that could be used in selecting future aviation cadets. Three factors that indicate one's efficiency are: (a) what are his present skills, (b) how many years of usefulness may one expect in return for the cost of training, and (c) what is the cost of training. It is essential, for the tax payer's benefit, that the usual sixty-five of one hundred cadets that are washed out never be admitted to training in the future; because of the great waste existent we should attempt to organize some psychological standards. (78) It is Patient's impression that the extrovert appears to have the best chance to be a successful pilot, but there is probably no inherent flying difference between the extrovert and the introvert. It is interesting to note that a high percentage of candidates sublimate in reality adjustment. It is probably dangerous to associate any body type with the successful aviator, and Jensen and McIlnay have disproved Kretchmer's suggestion that the asthenic body type with a schizoid personality make the best pilot. Reaction timing devices may give us a clew as to the measurement of temperamental traits.

Carlson, after a series of psychological examinations in order to rate the potential pilots' abilities, concluded that a minimum level of intelligence, as measured by test, is necessary to meet the standards of the flying department. He also concluded that, regardless of the amount of education a man has had, he should be required to make at least a minimum grade on an examination required of all who desire to enter military aviation. (40)

Desirable features in a flyer include cheerfulness: depression is a sign of maladjustment; a stable nervous system; self reliance and aggressiveness; modesty; frankness; satisfaction; punctilliousness--courteous; seriousness and ability to relax; cooperative. (83)

We may frequently see anxiety states or states of fear which demand pilot care. Jensen says that anxiety is usually the first symptom resulting from intense training or strain or precarious situations associated with exhaustion. The symptoms are restlessness, irritability, habit changes, jumpiness, inability to concentrate, insomnia, nightmares, and gastrointestinal complaints. (61) Sutherland gives as the genesis of fear, "Fear is a painful state of consciousness arising from the sudden perception of anything immediately antagonistic to the will to live. A man, rising in the morning with a slight degree of visceral toxemia is moved to anger by events which he disregards when in perfect health. The disability of fear is, that it destroys judgment and so hinders the man from escaping the very thing against which the emotion of fear is a violent protest." (99)

Fear is usually unconsciously suppressed in the normal individual, and so, when the pilot feels fearful he should be grounded and allowed to recuperate on a rest regime as planned by his flight surgeon. The doctor must gain the man's confidence by assuring him that fear is something that will respond to treatment. Before the pilot is sent away on leave he should have a full understanding of what his problem is so that he will cooperate to the utmost. A common sense approach is indicated, and, if possible, try to uncover any shocks in earlier life that may be responsible; find out what he dreams about, and, when you have gained his confidence, investigate every possibility for the etiological factor involved. These pilots must be recognized and treated lest a vicious circle be established, for this may result in a fatal accident or in becoming totally inefficient. (61)

Let the flight surgeon remember that the object of aviation medicine is one of a preventive nature, and let him exert his efforts to the utmost in attempting to clarify the psychological problems of aviation.

CONCLUSION

The realization of the intimate relationship between medicine and aviation is nearly as old as the latter itself. With the development of military aviation, medicine became an inseparable part of flying. As each year passed it became more evident that here was a new field that offered not only excitement and adventure but also unsolved and uninvestigated problems. Then, in the early years after the first World War, the flight surgeon became a definite type of individual who was required to have special training to enable him to assist in the advancement of aviation by not only solving flying problems but also by being able to eliminate individuals lacking in necessary qualities.

Even with acceptance of the flight surgeon, aviation medicine was supported only by a small group of enthusiastic workers who, because of their feverish interest in the medical problems of flying, were able to keep a few investigational laboratories functioning. How much more complete our present knowledge might have been if America, as did Germany, had foreseen the future importance of advancing aviation medicine along with the progress made by aviation engineering.

Armstrong reported in 1939 that about 80% of the four thousand odd references in this field were in foreign languages, and that the remaining 20% were published in so many different journals that reading them all is an enormous task. (21) It is my impression that the same is true of the nearly six thousand articles which have been published up to this date.

Now that the new World War has definitely proved that the flying arm of the military organization is probably the most devastating power we have, it is essential that medical men do all in their power to defeat those problems which now have limited the extent of high altitude flying and dive bombing. With so many physicians now in the armed forces, it becomes the evident duty of Army and Navy officials to assign to aviation medicine those men who have as deep an interest in this field as the investigators who have given us our existing information.

Too, let us not forget that, in the days following World War II, we shall undoubtedly see such feverish enthusiasm in civilian aeronautics that the practicing physician will have to be acquainted with the diseases and conditions resulting from flying if he is satisfy the demands of his many air-travelling patients.

Every flying individual should feel indebted to such men as Armstrong, Heim, Bauer, Livingston, Porter, and countless others, for these unsung heroes, cognisant of the importance of aviation medicine, have spared no effort in their attempts to make the art of flying more safe. It is to be hoped that the work performed by these men will stimulate still more medical research workers to direct their efforts toward furthering the science of aviation medicine.

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