The Physiological Effects of Flying.[1]

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THE first observations upon the effects of flying seem to have been made in 1783, when some sheep and fowls were sent up in a balloon to a height of several hundred feet. Apparently, upon its descent, the observers were delighted to find that the aerial flight had induced no ill-effects. In December of this year, however, after an ascent to about 10,000 feet, a human observer is reported to have experienced considerable discomfort from the effects of cold as well as pain in the right ear.

The stimulating effects of low altitudes are recorded in a handbook on aeronautics published in 1786. "The spirits are raised by the purity of the air and rest in a cheerful composure." The author noted that all worries seemed to disappear as if by magic, so that ballooning came to be regarded as having a therapeutic value. This stimulating effect of altitudes up to 10,000 feet is still well known, many pilots stating that they experience a great desire to sing.

Between 1783 and 1903—the date of the first flight of the Wright brothers—the study of the effects of altitude was the chief point of physiological interest in aeronautics; but with the coming of the aeroplane many other problems have come into existence. Of first importance are those connected with the ability of man safely to fly a machine, of which he himself represents at present the controlling and co-ordinating mechanism. In addition, however, we have the question of the effects of flying from the point of view of the ordinary passenger.

As a general rule, passenger flying consists in what is known as 'straight flying,' no 'stunts' or aerial acrobatics being indulged in. The machine takes off, rises to a thousand feet or so, and proceeds direct to its destination. To many, the idea of aerial progress in a state of unstable equilibrium appears fraught with peril compared to usual forms of motion upon the earth's surface. Yet, with the increasing safety of machines, aviation must now be considered little if any more dangerous than motoring, especially in these days of speed and congested traffic. All machines for public transport are most carefully tested and inspected, and designers and constructors of aeroplanes are constantly seeking ways and means of making flying more and more safe.

An opinion as to the security of flying must not be formed from the number of accidents which occur in military flying. Such flying is totally different from civilian flying, involving considerably greater risks. The comparative safety of civilian flying is in part attributable to the careful medical selection of pilots. Pilots are not permitted to carry passengers or goods without the most searching medical examination, and are not passed for service until they have received a certificate of airworthiness in exactly the same manner as the aeroplane itself. The British company, Imperial Airways, Ltd., has recently carried more than 60,000 passengers and flown more than 3 million miles without serious accident. This point is emphasised, because the enjoyment of flying as passenger depends largely as to whether or not the passenger enjoys a feeling of security.

The other chief factor is the state of the atmosphere. If the weather is 'bumpy,' a passenger may become 'air-sick,' more especially when travelling in an enclosed cabin. As with sea-sickness, many people anticipate being 'air-sick,' and in this frame of mind the malady is prone to occur. Save in exceptionally bad weather, there is no reason why the average person should be 'air-sick,' the number of individuals liable to air-sickness being considerably less than those liable to sea-sickness. The best guide as to whether one is liable to air-sickness is previous experience in regard to swings, trains, and scenic railways. Only those who are liable to discomfort nausea on these are likely to suffer from air-sickness. There is no direct connexion between air-sickness and sea-sickness save perhaps that the person who becomes severely and intractably sea-sick is possibly likely to suffer from air-sickness. The subject who is just ordinarily sea-sick will not necessarily be 'air-sick.' The liability to air-sickness among the general population is considerably over-rated. Nor, it must be emphasised, is there any connexion between 'giddiness' when looking down from a height and a liability to 'air-sickness.'

At the heights of average aerial travel, that is, up to five or ten thousand feet, there are no effects from altitude upon the average passenger, nothing beyond a slight deepening of breathing being noticed, frequently attended, as already noted, by an exhilaration which often manifests itself in a desire to sing. Civilian passenger machines do not ascend high enough to induce anything akin to 'mountain sickness,' neither are the average altitudes reached sufficient to induce harm in people who are suffering from lung or heart ailments of such a degree as to enable them to pursue an average everyday life on the ground.

With regard to flying as pilot, various points must be taken into consideration, since it is upon him that the safety of the aeroplane rests.

Simple flying calls for certain co-ordinated limb movements which are initiated as the result of sensory impressions. Of such impressions those of vision are the most important, since without good visual judgment accurate flying is not possible. In fog and cloud flying, a pilot has to rely upon the information obtained from instruments by the use of his eyes. The same is true in a large measure of night flying, although here a certain amount of visual information is generally also available from external sources (horizon, stars, etc.). In all

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stages of flying experience, therefore, a pilot is dependent upon visual information, gathered either from objects outside or from instruments within the machine. In particular this is true during the stage of training, when all co-ordinated movements are initiated consciously. With growth of experience the pilot derives an increasing amount of information from the nerves of 'deep' sensation, namely, the 'feel' of the control column, rudder bar, and seat, and, as a result, comes in time more or less automatically to initiate the appropriate co-ordinated movements necessary for the accurate control of his machine.

Information is also derived from the 'feel' of the wind and varying air currents upon the face. Auditory sensations, however, do not play a great part in flying, although good hearing is necessary for the correct appreciation of the 'note' of the engine, as well as for the reception of wireless and so forth.

Besides the faculty of correct perception, a pilot must be capable of accurate co-ordinated performance with his limbs as the result of his perception. Delicately co-ordinated movements of arm and leg are necessary for the accurate control of an aeroplane. Some individuals are incapable of achieving this delicacy and are consequently heavy handed or heavy footed, or both. Other individuals are incapable of combining arm and leg movements with sufficient accuracy owing to an inability to perform successfully two relatively simple movements at the same time. The examination of the responses by means of a special apparatus—the Reid apparatus for testing flying aptitude—for the purpose is of great value in ascertaining a pilot's powers of performance.

Lack of aptitude for flying, therefore, may be due either to defective afferent impressions—chiefly from the eyes and the muscles, or to defective co-ordinated movements.

Further, to be a safe pilot, an individual must possess accuracy of judgment and coolness in emergency, also great powers of physical endurance to enable him to withstand high altitudes or long hours, as well as the effects of quick rotary movements in aerobatics and the effects of gravity after diving quickly or when rapidly turning at full speed at a sharp angle.

The effects of altitude call for especial consideration from the point of view of the pilot. In addition to the effects of diminution of oxygen supply, the effects of extreme cold and the actual diminution of the air pressure have to be considered.

The main effects of diminution of pressure in itself are due to the expansion of the air enclosed within the middle ear. This tends to expand as the pressure is reduced, but the pressure of such air is, generally speaking, automatically adjusted by swallowing. Therefore, only subjects suffering from catarrh of the Eustachian tubes leading from the throat to the middle ear are likely to suffer any inconvenience from this cause. The same is true when atmospheric pressure is again increased on coming down from average heights (1000-2000 feet). The movement of swallowing again automatically adjusts the pressure. When descending from greater heights, the increased pressure on the ear drum through the outer ear may be counterbalanced within the middle ear by gently blowing up the ear drums, while holding the nose, by the movements of forced expiration, a device well known to all pilots. Where Eustachian obstruction exists, however, a pilot may suffer considerable inconvenience during descents, especially if undertaken too rapidly. Diminution of pressure also causes any gas within the intestines to expand. Although in some cases this may affect breathing by hampering the action of the diaphragm, generally speaking, as the amount of this gas is not normally large and its expansion induces peristalsis of the bowels, it is soon voided from the body and inconvenience from this cause is rare. The idea that at great heights there is a danger of trouble arising in the body from the release of gases into the blood owing to the diminution of pressure, such as takes place in the diver or compressed air worker, is erroneous. In the case of airmen the diminution of pressure at present is not sufficiently great or rapid to bring about any liberation of gases held in solution in the blood plasma.

Since 1878 it has been known that the chief cause of 'mountain sickness' or 'altitude sickness' is lack of proper oxygenation (anoxæmia) of the body owing to the rarefaction of oxygen in the air breathed. Experiments conducted in rarefaction chambers, as well as at high altitudes, such as Pike's Peak and Monte Rosa and the Andes, have fully proved this point. In respect of life at high altitudes, however, a certain degree of bodily acclimatisation takes place after the first few days, which is not the case in respect of flying. In an aeroplane, the length of stay at high altitudes is not sufficient to induce any acclimatisation, beyond possibly a transitory concentration of the blood plasma. This will be appreciated when it is realised that a man who flies 240 hours yearly in reality only passes 10 days out of 365 reaching and returning from his maximum heights.

In high flying the cause of trouble is the demand by the body for a normal supply of oxygen under conditions where the head of pressure of the 'pressure feed' is failing. At 19,000 feet, although the percentage composition of the air is unaltered, the total atmospheric pressure is only half normal; that is, the pressure which drives the oxygen into the blood is only half the normal, and accordingly the body will receive only half the amount to which it is accustomed—actually less, since here no allowance is made for the pressure of water vapour. The gradual failing of the pressure feed of oxygen to the body with increasing height necessitates deeper and deeper breathing to get in the required amount of oxygen and a proportionately quicker rate of heart beat to keep up the circulation of the blood, which carries the oxygen to the seats of combustion. For this work alone, more and more oxygen is required in an atmosphere in which oxygen is progressively diminishing. This throws a certain strain upon the muscular mechanism of respiration and upon the circulation; a strain which is increased owing to the relatively immobile position of the pilot. Unless, however, such strain is unduly severe or prolonged, it is readily tolerated by the body up to heights of 18,000 or 19,000 feet, provided that the respiratory and circulatory mechanisms are properly tuned up.

If the embarrassment of the respiration and circulation were the only effects of altitude, then until this became really excessive, the administration of oxygen to pilots, although an advantage as conserving the normal action of the lungs and heart, would not be altogether a necessity. A more subtle, and therefore often a less appreciated, danger exists which renders the administration of oxygen necessary, namely, a dulling of perception and judgment in addition to a gradually increasing general muscular weakness.

This dulling of perception and judgment begins lower, in most people after 12,000 to 15,000 feet. The pilot himself may not be, and usually is not, aware of it, and even possibly has an extra feeling of confidence. This may be exemplified by an observer who, during the War, returned from high flying reconnaissance, thoroughly pleased with himself, only to find later that he had taken 18 photographs on the same plate; and by a pilot, who, meeting enemy aircraft at 19,000 feet, in spite of the protests of his observer, cheerfully waved his hand to them but took no further action. Nearly all pilots notice the tendency to somnolence at high altitudes; many have difficulty in finding their way, being able to see the ground but not to read their maps. As a rule, scout pilots are less affected by altitude than high reconnaissance pilots, since they do not maintain high altitudes for the same length of time. At great heights it takes longer to see, to hear, and to act. The lessening of muscular power is more obvious; most pilots are aware of the difficulty of swinging a gun or even drawing the shutter of the camera at very high altitudes.

With aircraft going possibly to 30,000 feet or more, the danger to the pilot is greatly increased, and the use of oxygen is absolutely necessary. The effects of altitudes of 25,000-28,000 feet have been long known. Glaisher in 1862 noticed that at 26,000 feet, although he could see his instruments, he could not read them. Shortly afterwards he became paralysed in his hands, as did his assistant, who, however, managed to pull the valve rope with his teeth. In 1875 three Frenchmen, Croce, Spinelli, and Tissandier, made their famous ascent, only Tissandier surviving. Although warned of the necessity of using oxygen, they were all paralysed before they realised the necessity of taking it. Tissandier gave a graphic account of his experience, from which the following is quoted: "At 26,000 feet the condition of torpor which comes over one is extraordinary. Body and mind become feebler little by little, gradually and insensibly. 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." The balloon ascended to 28,820 feet, and then descended.

Recently, in November 1927, Capt. Gray, of the United States Army Aviation Service, after ascending to 42,470 feet, lost his life during the descent at about 29,000 feet owing to his oxygen running out, probably owing to a miscalculation in the time of climbing and descent.

Oxygen abolishes the troubles of altitude which are due to oxygen want. The man with oxygen perceives and acts far more quickly and accurately than does the man without oxygen. It is for this reason that during the War all long-distance bombers and high photographic aircraft, both enemy and British, were eventually equipped with oxygen apparatus. On such aircraft the use of oxygen is an absolute necessity if really efficient service is to be rendered.

When oxygen is carried it should be used throughout the flight, beginning before the aircraft leaves the ground. It should not be reserved until the individual feels he wants it, since the effects of want of oxygen which matter most are apt to be unnoticed by the individual.

The best method of taking oxygen is by means of a mask. This is more satisfactory than by a pipe, because it ensures a larger amount of the oxygen delivered reaching the lungs; moreover, there is not the same danger of the tube being blocked by frozen condensation, water, or saliva. Further, a mask also protects the face from frostbite. Instead of the usual mask some prefer a combination of mask and pipe, since it can be discarded more quickly should this be necessary.

The advantages derived from the use of oxygen at high altitudes may be summarised as follows:

1. It keeps a man alert and in a condition in which quickness of perception, accuracy of judgment and action are preserved to the full.
2. It gives a man more power to control aircraft, and gives the tactical advantages of height without its disadvantages.
3. It abolishes the disagreeable symptoms—headache, lassitude, etc.—which are so frequently experienced during and after flights at high altitudes.
4. It keeps the heart and respiration efficient for a much longer period and prevents their overstrain.
5. It helps to keep the body warm.

In addition to the effects of oxygen want, the effects of the cold of altitudes must also be borne in mind, since these in themselves tend to throw added strain upon the respiratory and circulatory mechanisms as well as inducing numbness and sensations of fatigue.

For success in flying, therefore, nervous stability, respiratory and circulatory efficiency are essential. It must be recognised that flying, especially military flying, imposes a very definite stress upon the body, especially when flights are made without the aid of oxygen for long periods at relatively high altitudes. When to this is added the stress of offensive and defensive warfare in the air, it is obvious that bodily strain or breakdown as the result of stress is likely to ensue if too prolonged.