*PHYSIOLOGICAL PROBLEMS AT HIGH PRESSURE

By

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A simple review of some of the problems which beset us at high pressures may be of value to you. Men are exposed to high pressures both under water and in "Caissons" in which there is air at high pressure in order to keep the water out. Now, you might ask "Why need men be exposed to changes of pressures?." The Air Force have pressurised cabins so that when we go up the pressure need not fall, and we also have pressure suits so that a man may be enclosed in air at a pressure greater than that outside him at great heights. "Why can't you do that for your under water work?" The answer is quite interesting.

There is certainly an equivalent of the pressurised cabin, a more or less spherical vessel which is let down into the sea and in which the pressure is not raised. But let us see what it has to withstand. One atmosphere's pressure is equivalent to one kgm. per square centimetre; and 10 metres of sea water give you another atmosphere's pressure. Hence, for example, at a hundred metres you are under a total pressure of 11 atmospheres. If you go down one kilometre you are at a pressure of a hundred atmospheres, and if you go down 10 kilometres, about a thousand atmospheres, or one ton pressure on every square centimetre of your sphere; and it is quite clear that that is a pretty tough engineering job. It is a very much tougher job than making a pressurised cabin; even though pressurised cabins, as you know, have burst. In fact you need a steel sphere, but it has to have a glass or quartz window, and if it is to be of any use it must have an apparatus outside, worked by some kind of remote control, for picking up objects or boring holes or whatever it may be. That is by no means a simple engineering problem. It is not so simple to put wire with insulation through a wall when there is a pressure of one ton per square centimetre on that wall. That is only one point. In fact, at 100 metres, which is about the practical limit for work by divers in dresses, these problems are not at all difficult. The main trouble is that a man in a steel cabin lowered to 100 metres cannot get into a sunken ship, and he has to be extremely expert if he is going to use a remote control apparatus; in fact some fatal accidents have occurred with explosives, simply because of the difficulty of doing things by remote control.

What about an armoured suit? Why shouldn't a diver go down in a metal suit with air at one atmosphere inside and water at 10 atmospheres outside? Plenty of armoured suits have been designed, and they work beautifully in shallow water down to about one atmosphere; but, it is obvious enough that they would not work at any great

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depth such as one kilometre. They would just cave in unless they were quite fantastically thick. But still they might work at a hundred metres where there is only 10 atmospheres extra pressure, until you start thinking about it. Consider the shoulder joint of such an apparatus. We might be able to reduce its area to about 500 square centimetres, though perhaps that would be rather a tight fit, but if we did that, there would be a pressure of about 5 tons at a hundred metres; and even if you had super ball-bearings with a co-efficient of friction of only 1%, you would need a force of about 30 kgms to move your shoulder. The thing just does not work.

So, for many purposes, the only thing is for men to go down in a flexible dress and breathing air at a pressure equal to the water outside. There are several types of diving dress. The simplest one is just a bag which you wear on your chest or elsewhere connected to a mouth-piece; you have a cylinder containing compressed air or compressed oxygen which feeds it; and you may have some means of removing the carbon dioxide from the air, if you want to economize. That is the simplest type, and it would be amply sufficient for a great deal of work in India because the water here is relatively warm. In European waters you must be dry to keep warm, so you must have a dress which covers the whole of you. There are several types of dress. There are self-contained dresses where you take your own compressed air or oxygen with you, and there are dresses in which the air or other gas is sent down to you through a pipe from the surface either by means of pumps or from a bank of cylinders.

For experimental purposes my colleagues and I from 1939 to 1944 certainly did some real diving in water, but we also had two forms of "fake" diving. First of all, we had some cylinders, very much like ordinary boilers, in which the air pressure could be rapidly raised. One in which we did most of our work was about 8 ft. long and 4 ft. in diameter; it was lying on its side, so that we could get three people sitting there, not very comfortably, and two side by side very comfortably; and within that small volume we could get the pressure up very rapidly.

But there was an intermediate form of "fake". We had another chamber, in which there was about 7 ft. of water; above that water there was an air space in which a man could sit, so that he could pull a comrade out of the water if he or she lost consciousness. The air pressure above the water could be raised, so that we could get a man in a diving suit under water, at a pressure equivalent to 100 metres of sea water. And it was found that the results which we obtained in that water under pressure were directly applicable to diving in the sea. It was a pretty good fake, whereas what we discovered in compressed air in the dry was not necessarily correct under water. So we always did our final experiments under water with compressed air above it before we went on to do them in the sea. It is easier to pull a person out of 7 ft of water, then out of 70 ft or 300 ft.!

Now, I want to give you a rough classification of the dangers to which men are exposed. There are the physical effects of the pressure as such, and there are the effects of sudden changes of pressure. But the most important ones are the effects, both immediate and remote, of breathing various gases at high pressures, because when you breathe a gas at high pressure it goes into solution in your blood, and later in your other tissues; and the effects of that may be serious.

We also have to consider secondary effects, e.g. the effect of cold, to which divers and others may be exposed, and we have to consider psychological effects, which are quite important.

My colleagues and I were specially concerned with preparations for the attack on the "TIRPITZ" under which some divers finally managed to stick bombs. That was in Norway; the water was extremely cold; they had to swim for a considerable distance; and it was not an entirely safe job: not all of them got back. But it would have been very much less safe if they had carried with them a supply of compressed air. If you have cylinders of compressed air then you can only take, according to the depth you are at, half or perhaps a little more of the oxygen out of it, so nitrogen has to come up to the surface in bubbles, which the enemy may detect. Whereas if you have oxygen in your cylinders and something to absorb the carbon dioxide you can pretty well avoid making bubbles at all. You have to be rather clever and you have to have a good deal of practice to avoid doing so; and we had a special gadget to make any bubbles that did come out as small as possible.

With regard to pressure, experiments on fish, frogs, and so on, show that pressure as such only begins to have a serious effect on physiological processes at pressures of the order of 100 atmospheres, corresponding to a depth of a kilometre, and I don't think any man has ever been to a pressure of more than 20 atmospheres. In fact it is a most surprising thing that at these high pressures you do not feel particularly abnormal. Certainly if you are in compressed air you notice the air is pretty thick; to breathe out quickly is quite an effort, but you do not necessarily feel bad. On the other hand you do feel pressure changes.

The most obvious effect is that known to every airman during descent—the pressure on the ear drum. A diver must learn to open his or her eustachian tubes. In an aircraft you can hold your nose and blow, but in a diving suit, if you think of it, you have a glass window between your nose and your fingers, so you have got to learn to open up without using them. This is a trick, and perhaps one person in four never learns to do it and had better not become a diver. Of course if you are compressed too quickly your ear drums may burst. They generally mend again. Since I learned to open my eustachian tubes, my troubles have been first of all with sinuses, and also with stopped teeth. You have had a tooth stopped; behind the stopping there is a cavity with air; when the pressure is increased that tooth may cave in; or air may get into the cavity, and during a rapid decompression the tooth may literally explode. This has happened; I lost two teeth that way.

Now what can a trained man stand up to in the way of pressure changes? My own best record was "in the dry". I ran up from one atmosphere to 7 atmospheres in 90 seconds. That corresponds to diving in water at 40 metres a minute or 2 ft/sec, although the first atmosphere was quicker. Compared with a dive in air, it corresponds to a vertical dive at twice the speed of sound or 2 Mach. It was beginning to be a bit uncomfortable but by no means intolerable; but you cannot do very much better than that. I do not think any airman is likely to dive at twice the speed of sound in an open aircraft, so I do not think that question is going to arise for you.

These dangers are mechanical. And they are simply due to the fact that the air pressure is different on two sides of a membrane, whether it is the ear membrane or the rather tougher membrane which may form between your nose and sinus. There are much more serious dangers.

If a man is going down in the water and the air pressure is not supplied quickly enough the first thing that will happen will be that he will feel his legs pinched. He may get considerable pain, his testicles being squeezed by the water as the air is gradually driven up into the upper part of his dress; and if he still does not get enough air he will have pulmonary haemorrhage which may kill him. Similarly if, in coming up, he can not get rid of air quick enough, he may burst his lungs; and that is particularly so in a type of dress with a mouth-piece. We divers had a word for getting rid of air at the edge of your mouth-piece; it is called "guffing", and it was one of the things that one had to learn to do in a self-contained dress. Nevertheless even if you are careful, you may burst your lungs, particularly if you have what is called a congenital bulla, which of course is a hazard in airmen. They too occasionally burst one.

But it is the kind of thing which may very well happen if you are breathing air through a mouth-piece and if you have not got the automatic habit of getting rid of unwanted air. You must remember that you have got to train your men to make all kinds of physiological adjustments automatically, e.g. opening their eustachian tubes, bubbling air out of their dresses, and controlling various valves. They have got to have done these things hundreds of times because they may have to do them under circumstances of combat when they have two minutes to spare getting away from a bomb they have just started off, or something of that kind. They have to do these things without thinking, as a cyclist, let us say, balances without thinking.

I have occasionally noticed people who appear to lose consciousness during a very rapid compression, say going up from one to 10 atmospheres in five minutes or so. I have never done it and none of my physiological colleagues did. I suspect it may be a mere psychological effect.

Now I come on to the important dangers. The arterial blood is very nearly in equilibrium with the alveolar air, and the amount of gas which is dissolved in it is proportional to the partial pressure of that gas in the alveolar air. For example, if I am breathing air at one atmosphere I shall have a partial pressure of 80%, of an atmosphere of nitrogen. If I am breathing air at 10 atmospheres I shall have a partial pressure of 8 atmospheres of nitrogen, and each c.c. of my blood will carry approximately ten times as much nitrogen to my brain and other tissues. And that is the main source of danger. The only exception is that most of the oxygen in the arterial blood is in combination with haemoglobin, so that the total amount carried in it is only about 16% greater than normal if you are breathing pure oxygen or if you are breathing air at 5 atmospheres.

Now I am going to deal, in turn, with the effect of excessive nitrogen, oxygen, carbon dioxide, and other gases. There are two main effects of the nitrogen which you inevitably take up into your blood and into your other tissues when you breathe air under high pressures. The first is what I believe is now generally called aeroembolism. Nitrogen dissolves in all the tissues of the body; and unlike oxygen it is a great deal more soluble in lipoids than in water. Hence it dissolves in your adipose tissues and in your central nervous system. Now supposing we have a bit of extra gas dissolved and we suddenly take the pressure off, what happens? It is somewhat like the formation of carbon dioxide bubbles which occurs when we open a bottle of soda water. But the bubbles of nitrogen which are formed are very much smaller because nitrogen is very much less soluble than carbon dioxide. You can indeed get carbon dioxide bubbles in the intestine, but they are not very dangerous although they may be a real cause of inefficiency in fliers.

Supposing you breathe air under water at a depth of 10 metres or less i.e. air at two atmospheres' pressure or less, you can be decompressed instantly even after 24 hours; though I would recommend a short pause, say at a depth of three metres. But after being at a pressure anything higher than that, there are several kinds of symptoms if you decompress too quickly. With very rapid decompression you get pulmonary embolism. What happens sometimes is this: a diver on the bottom fails to use the screw which is at the back of the helmet adequately, in order to let the air out, his dress gets inflated and he just falls upwards. You have some weights on your dress and on your boots, and you normally adjust this valve so that your net weight is about 10 pounds, and you can move about comfortably. But occasionally a diver is blown up to the surface. If he is blown up from even 20 metres, he is very likely to get his lung capillaries blocked with bubbles; he is black in the face and unconscious. The only thing to do is to screw his face-piece up and drop him down again. Many lives have been saved in that way. By all means send another man down after him as quickly as you can, but meanwhile get those bubbles recompressed at all costs. Of course, in many operations they have a compressed air chamber available for recompression, but it may be quicker to drop the man overboard.

The commonest symptom, when one is near the border-line of serious bubble formation, is itching in the skin which is supposed to be due to bubbles in the skin capillaries. They have been seen with a capillary microscope, I am told. At a later stage you get pains in the joints. Those are undoubtedly due to the formation of bubbles in the synovial fluid, and they are not really very bad. Mine have usually been either at the base of the thumb, in the shoulder, or in the hip. They are called "bends", but I do not regard them as serious pain, using the simple criterion that they never made me sweat. And I think there is a good deal of psychology in the objection which people have to bends Much more serious are the effects of bubbles in the central nervous system. They can lead to permanent paralysis or paraesthesia. My own case is quite instructive. I had on several occasions been at 10 atmospheres' pressure, corresponding to 90 metres depth breathing air, and I decompressed on a certain time table without any harm. I then breathed a mixure of four volumes of helium with one of oxygen, instead of air. On reaching atmospheric pressure I had fairly nasty bends, and pain of the pins and needles type. I did not worry to be recompressed as I wanted my lunch. But I probably ought to have been, because I was left with a permanent area of paraesthesia over the area supplied by my 4th and 5th sacral roots. Those who know some anatomy will congratulate me that my third was not involved! Helium has certain advantages of which I shall speak later. But in my opinion which is based on very definite experience, it does not make decompression safer, but less safe.

What are the precautions to be taken against bends and the like? First of all, descend as quickly as you can and stay as short a time as you can at the bottom, so as to cut down the time during which you are absorbing nitrogen, and then come up about half way and decompress by stages. My father worked out the methods some 55 years ago; the point being that you should run things fairly fine, so that you should not be breathing in an excess of nitrogen for any longer than is necessary. The trouble is that there are various tissues which take it up and get rid of it at different rates, so calculations had to be made as to the way in which one could go up, without exposing any of the tissues to risks; then of course they had to be checked by practical experiments.

Diving tables are available given in feet, usually at stages of 10 ft apart, but a very important improvement was introduced by Sir Robert Davis. For reasons which will be clear to you in a moment, it is not safe to breathe oxygen at great depths, but when you have got up to about a depth of, let us say, 15 metres it is safe to start breathing oxygen. The usual plan is to let down a "bell" with an assistant in it, and an open bottom. The diver gets into the bell, takes his face piece off, and starts breathing oxygen from a special apparatus. His arterial blood is now almost completely cleared of nitrogen, and will take away nitrogen from the tissues at a very much greater rate than if he were breathing air. Under these circumstances the time needed for decompression can be cut to considerably less than half of what it was before. It is obvious that the same principle can be applied to rapid ascents in planes. If the pilot has been breathing oxygen for some little time before, he is very much less likely to get aeroembolism.

Bends have been known for a long time to be due to nitrogen. In about 1935 Capt. Behnke of the U.S. Navy and his colleagues discovered another effect of nitrogen. At about 8 atmospheres' pressure people become silly, and at 10 atmospheres where most of my work was done, some people have sensory symptoms. A typical statement was, "my fingers feel like bananas." Others see a sort of mist around. I don't, but my thoughts wander. I begin to remember episodes from my childhood, nonsense words suddenly seem to be very important to me, and I obviously behave in a stupid manner. Objectively we found that everybody's manual skill was very greatly reduced. Their score on the test which we used was reduced to about a half. But the striking thing was that a very large fraction of them tried to cheat. Their morals were at least as much affected as anything else. It was at first thought to be an effect of pressure. But Behnke made it quite clear that it was due to nitrogen. It disappeared when one breathed a mixture of 4 volumes of helium with one of oxygen. Case and I found that we got just as good effects breathing a hydrogen and oxygen mixture. That made it clear that it was due to nitrogen, and in fact other so called inert gases such as argon have quite a similar effect to nitrogen.

I said that we used hydrogen, and you might ask "Is not a hydrogen and oxygen mixture extremely dangerous and liable to explode"? Well of course, a mixture of 4 volumes of hydrogen and one volume of oxygen is very explosive. So we had cylinders with 98% of hydrogen and 2% of oxygen. That mixture is not explosive, but is of course very dangerous to breathe at ordinary pressure. But at 10 atmospheres it gives a partial pressure of 20% of an atmosphere of oxygen; the mixture supports life perfectly well and is not explosive; and under these circumstances, you behave normally.

It is a curious discovery of Behnke's that nitrogen is a narcotic, because we were always told that physiologically it was an indifferent gas. It is a narcotic for just the same reason as nitrous oxide and many other substances which are not metabolised in the body but get in the way of various chemical reactions. Nitrous oxide is about 40 times as soluble in water as nitrogen. So on this view one would expect that at 10 atmospheres, air which contains 8 atmospheres' partial pressure of nitrogen, would be about as narcotic as 20% of nitrous oxide. In fact is is about as narcotic, I would say, as 40% or 50%. The increased effect is because it is relatively more soluble in lipoids and, therefore, in the central nervous system. A number of gases have been tested in this way, and it appears that the solubility in water and oils determine when they will become narcotic. You can calculate that hydrogen or helium would not become so until one got to 100 atmospheres or so and are, therefore, perfectly safe to use at pressures like 10 or 20 atmospheres.

Now I am going to say something about oxygen. Oxygen, in spite of what you are told, is a virulent poison. It has two main effects. When I breathed oxygen at 40 ft. (which is about a total of 2.3 atmospheres): after breathing it for about 3 hours I developed a nasty cough, and after about 4½ hours I said I had enough and was decompressed; and I had bronchitis for three or four days after that. If I had continued for 6 or 8 hours I should probably have died of bronchopneumonia. You can get bronchopneumonia from breathing pure oxygen at atmospheric pressure for several days on end. That is the effect on tissues which are directly exposed to high pressure oxygen. There is another effect, namely convulsions and other nervous symptoms at higher pressures, say 4 atmospheres. In particularly sensitive people the nervous symptoms will arise before the bronchitis. The most striking of these are epileptiform convulsions with loss of consciousness. If you have an E.E.G. going you find spikes very similar to those of an ordinary epileptic fit. This is commonly preceded by fibrillations of some of the facial muscles, especially the buccinator oris, and you may or may not be able to foresee the fit. Occasionally people see purple lights and other things, and sometimes there is some anxiety, but never confusion or excitement.

People who are very resistant to oxygen poisoning, like my wife, if they are given pure oxygen to breathe, say at 3½ atmospheres, react by intense bradycardia. Her normal pulse rate would be about 70 or so, and on breathing oxygen it dropped to somewhere between 30 and 40, and stayed there for some time. If her vagus let go, as I suppose it did, and the frequency came back to normal, then of course blood with a lot of oxygen in it was coming pretty quickly through the brain, and she would probably have a convulsion within 5 minutes or so. Other people are not so good at slowing down their circulation. If one does not slow it down, then one will have a convulsion a good deal quicker than otherwise. Or one may get jactitation without loss of consciousness—some sort of sub-cortical discharge is going on. Some people usually get that; I have occasionally had it.

At about 3.7 atmospheres, we found that the mean time for the onset of convulsions was about half an hour, but it was lessened during hard work. We were inclined to hope that some narcotics might slow down the onset a little; but certainly the amount of amytal which would be needed to do so was so great that it would have taken the edge off our efficiency in any important operation. We tried all sorts of things like vitamin C and so on; but we did not find anything which would reduce our liability to these fits without very great effects on efficiency otherwise. At 3 or 4 atmospheres you can hold out for about half an hour: at 6 to 10 atmospheres it is about 5 minutes, and the contractions may be rather violent.

In the course of that work I was the first person to notice the taste of oxygen. Oxygen is not a colourless, inodorous and tasteless gas. It has quite a taste, but you need to taste in at about 6 atmospheres, i.e. about 30 times the concentration in air. The taste is a mixture of sweet and sour. We found that the time of onset of these convulsions was extraordinarily variable. My wife had five convulsions. In 17 experiments at 90 feet, she once had a convulsion after only 13 minutes, and once held out for 92 minutes without one, though she had the facial twitching which usually heralded a convulsion. That is a perfectly enormous range, and it means that you cannot predict, as you can with bends.

Finally we come to carbon dioxide. In an apparatus where air is pumped down, the pumps may start leaking at a high pressure, and carbon dioxide may accumulate. There is no danger at all of oxygen want. Supposing a diver is at 5 atmosphres he could reduce the oxygen in the air in his dress to 4% without being any the worse for it, because he would still have a partial pressure of a fifth of an atmosphere. But long before he did that he would be unconscious from the carbon dioxide which he produced. Again men may want to leave a submarine; but to do it, they may have to flood it in order to be able to open the doors. (There are special escape chambers, but they may be inaccessible or damaged by a collision). There might be 2% of carbon dioxide in the air, and this would be completely harmless. But if the submarine were on the bottom at 40 metres, it would be compressed to a partial pressure of 10%, and no one would have the faintest chance of doing anything under such conditions. I found that whereas at one atmosphere, even 12% of carbon dioxide causes a bit of panting and confusion, but you don't lose consciousness, at 10 atmospheres men lost consciousness in five minutes or so in anything from 0.7%

to 0.9%, that is to say a partial pressure of 7% or 9%. It is clear that this was a synergism with nitrogen. One passes out very peacefully and wakes up when the pressure has fallen to about 5 atmospheres. There is nothing very unpleasant about it.

Case and I found that cold (half an hour's immersion in water at freezing point) also increased the effect. Consciousness was lost a good deal more quickly at 10 atmospheres than if one was not so cold. We were interested in this with a view to problems of escape from submarines; what we could reasonally expect people to do in the Arctic or north Atlantic.

Now I want to say a few words on the psychological side. Some people find diving objectionable and others become rather claustrophobic in a steel chamber. Even men who have been trained in diving and have worked in submarines and are not at all claustrophobic may find these convulsions somewhat objectionable. Others find them funny, and these are the chaps you want. Men with a fine record of courage in combat asked to be returned to duty, or they developed symptoms which might be regarded as hysterical; or sometimes they indulged, after convulsions, in criminal behaviour. For example one was making advances to a lady which she repelled, and the evening after having a convulsion he tore up all the rose bushes in the front garden of her house. Whether this was really a cerebral effect or, as I think, much more probably an expression of the fact that he didn't like having convulsions, I don't pretend to know; I leave that to psychologists. It is important to realise that one wants for this kind of work a very specially equipped person with rather peculiar psychological qualifications.

What application was made of this work? To clear under water obstacles, the team concerned was one diver crawling at the bottom in mud in a self-contained dress and one man in a boat above him, with a telephone, and a line to pull him up if necessary. If a mine exploded, only these two were lost. Rapid ascent was needed for two reasons. First of all in the case of air raids when if you are in a boat you are perhaps safer than on land, on the other hand if you are under water a shock wave even 400 metres away may kill you. Secondly if you are under water and hear something ticking which you think is a mine with a timefuse, it is nice to think that you need not spend half an hour coming up! Psychologically that was of some considerable importance, even if it probably did not save very many lives. Now at 10 metres air is good enough, you can come up straight away, and pure oxygen would not be dangerous either. At a greater depth you must steer between the danger of bends and the danger of fits. My wife and I worked with various mixtures of air and oxygen. We were able to recommend slightly different mixtures for different depths. It is clear for example that at 15 metres a mixture of 60% oxygen and of 40% of nitrogen would give no danger of convulsions and would allow of instantaneous ascent; and even if bubbles were formed in the lung capillaries, they would consist largely of oxygen and be quickly absorbed. As an example of the success we attained, I may say that the time for ascent which is recommended after breathing air at a hundred feet depth for an hour used to be 57 minutes. With a mixture, we were able to cut it down to 2 minutes, which is a very considerable reduction. The first naval rating to do it on our programme got mild bends; and it was then recommended that you should take 7 minutes.

But everyone knew that it was safe to come up, not absolutely instantaneously, but in a minute or two.

I think that medical personnel and physiologists should pioneer in taking physiological risks. These are by no means as great as others taken by divers and airmen, but for example, explosive decompression is not entirely devoid of risks. It may be of the utmost importance to be able to show divers that, for example, they have got 5 minutes available if the oxygen supply in their dress suddenly gives out. They don't have to panic if they can get to the surface in 5 minutes. Then they will be O.K. It is your job to demonstrate this to them. The diver may have too little confidence in quantitative physiology to try quite a number of things which a physiologist will try.

I think that diving has one curious application, not to Aviation Medicine but to Space Medicine. The diver, especially in a self-contained apparatus, is under no physical strain when he is upside down. If I hang by my feet in air, the blood runs into my head and I am quite uncomfortable after 5 minutes. That is not so under water, because, of course, the water pressure increases with depth and if I have a soft helmet, as in a self-contained type of dress, I feel absolutely nothing. One of the first things a diver must do is to get accustomed to working upside down. The receptors in one's ears are still working. One knows one is upside down but one is completely indifferent. It seems to me that this would be a psychological preparation for men who are going to work under no gravitation; and it might be worth the Indian Air Force's money to invest in a self-contained diving dress or two and let people flap around in them, simply for two psychological reasons. First of all you get accumstomed to a condition where up and down mean very little, and secondly you get accustomed to living with a mouth-piece between your teeth, which again may be important under certain conditions.

In conclusion I must thank the Aero Medical Society for the patient hearing which they have given me. Much of what I said is quite irrelevant to their work. However, the physiology and psychology of flying and parachute descent are nearer to those of diving than are those of accurate shooting or long-distance marching. And the relation between physiologist and fighting personnel should be similar. Each should show sufficient competence and courage to earn the respect of his, or her, "opposite number". I am only sorry that I am too old to help the Air Force of my adopted country directly. I shall be very happy if, by this lecture, I have done so indirectly.