MAN IN THE DEEP

Surgeon Commodore John Rawlins, OBE, MA, RN

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It was a great honour to be invited to Chair a panel of such distinguished and internationally recognised diving physiologists and I accepted without hesitation. The task of Chairman is not an onerous one; it has been likened to that of a procurer, namely to introduce the parties, see to the arrangements and then take no further part in the action. But when I received a programme just recently I saw to my alarm that I was also billed to introduce this session on Man in the Deep with a talk on "The Survival of Man in the Extremes".

Survival conjures up a picture of a man marooned on a desert island, or adrift in a small boat, or lost in the Arctic waste; it is the business of staying alive after the equipment or the organization has failed. But, in deep diving, when there is a failure of either the man, his equipment, or organization, his survival is limited to a matter of minutes at the outside and hardly forms a subject for a 15 minutes presentation. Indeed, the whole business of diving, whether shallow or deep, is of avoiding the survival situation.

As for embracing the presentations of the other speakers: how do you bring together Swallowable Radio Transmitters (a somewhat uneuphonious term) and How to Dive to 2,000 feet and Return Within the Hour? It is impossible. So, in the face of these imponderables I propose to look at some of the stress-producing problems of deep diving; to consider their interactions and their physiological implications, and then to give some thought to the way ahead.

Owing to the success of the Unites States Navy in planning working dives to 1,000 feet, I think we are all confident that in the future we should be able to dive within the whole region of the Continental Shelf; but the problems of deep diving are basically those of the first 50 or 100 feet of pressure, respiratory gases, temperature, visibility, psychological stress.

First of all, let us look at the effects of pressure. We know from observation from deep submersibles that quite complex creatures exist in the very depths of the ocean and this would indicate that pressure does not have too much effect on biological cells, and I doubt very much that the effect on mammalian and human cells differs greatly from that of other biological species. But pressure is important when considering creatures with gas-containing cavities, such as man, diving mammals, and indeed fish with swim bladders, because then you get volume changes and the appearance of pressure differentials and physical changes in gases themselves, which brings me to the subject of respiratory gases.

As you all know, pressure affects the behaviour of the respiratory gases as far as the physiology is concerned, so that oxygen becomes toxic as we get deeper, and nitrogen narcosis may be detected at depths as shallow as 50 feet, and by about 300 feet most of us are rendered incompetent either physically and/or mentally. Carbon dioxide under pressure does not in itself affect us physiologically, but since the significant partial pressure of carbon dioxide remains the same, when one is diving at great depths and using large volumes of gas, the significant proportion of carbon dioxide is very small and therefore extremely difficult to eliminate, which we have often found to our cost. I might add that pressure increases the density of a gas so that at 60 feet a helium/oxygen mixture is four times as dense as air at the surface, and this doubles the airway resistance which, in turn, increases the effort of breathing, increases oxygen consumption and depletes our oxygen reserves.

Visibility at 1,000 feet is usually zero, but then we can get zero visibility in shallow water where there is much suspended matter - for example, in a harbour like Portsmouth, or a flooded coal mine - and visibility contributes very largely to psychological stress. However, the human physiology is a flexible one and is capable of adaptation and acclimatisation, and is responsive to training. For example, one can work very efficiently in conditions of zero visibility, probably the most classic case being that of the diver walker who, over a period of five years, worked in nil visibility beneath the foundations of Winchester Cathedral and to whom that edifice probably owes more than to anyone else.

Temperature at 1,000 feet is pretty constant at between two and four degrees Centigrade, say 35/40 degrees Fahrenheit. The reason I want to talk about temperature is, partly because it is my personal interest, partly because it illustrates very well the interaction between different problems of depth, and partly as an example of the hazards that are superimposed on man at depth because of his diving system - it does not have an effect as such on diving mammals.

As a response to cold, shivering is significant to my talk because it has metabolic cost; it is the primary method of thermogenesis in a human and it costs oxygen, increases carbon dioxide output and increases ventilation. It is significant in the case of the Ama who dives naked throughout the summer to depth of between 60 and 80 feet. She demonstrates remarkable physiological adaptation to cold: she can tolerate a lower skin temperature than you or I without shivering. She can also tolerate a lower deep body temperature: this is very important because if she were to shiver she would lose her vital oxygen supply and so shorten her breath-hold dive. Indeed, in the winter she pays some lip-service to insulation by wearing an all-enveloping cotton garment which, by trapping a layer of water somewhere near the skin, may have some effect, but is not an efficient method of insulation .

However, insulation at its best won’t get us very far . In an attempt to find out whether by insulation alone one can prevent heat loss, a man wore a total of one inch thickness of foam neoprene, and was unable to maintain his deep body temperature in 40°F water. One has to do something more; one has to add heat to replace that which has been lost: either by an electrically heated undersuit, by a closed-circuit warm water circulating suit similar to the cold water cooling suit used by astronauts, or by using the free-flooding warm water suit now largely used by commercial divers, and available off-the-shelf.

However, as you all know, deep diving requires a helium/oxygen atmosphere, and helium has six times the thermal conductivity and six times the heat capacity of air. Thermal conductivity is not affected by pressure, but density is, and hence heat transfer. Now I have already said that at 600 feet the density of a helium/oxygen mixture is four times that of air at the surface; at 1,000 feet or 40°F, the increase in density and the thermal properties of the gases raises the convective conductance from the skin - that is, the way in which the surface loses heat to a gas - to about 20 times that of air at the surface. These facts not only dictate the atmosphere in a submerged habitat, PTC, lockout chamber or submersible, must approximate that of the preferred mean skin temperature of 93°F, it also means that although the diver in water may be wearing an efficient heated suit, he will still lose heat steadily unless his gas supply is also heated. During experiments in the USA one of our subjects breathing 43°F oxy/helium at 860 feet lost 3°F deep body temperature in two hours, and that is very serious. Another subject produced such a copious flow of secretion from his upper respiratory tract that he had to spit out his mouthpiece, and in an actual dive this would of course have proved fatal.

For man to operate at great depth it is essential to heat both the skin and the gas supply, but this necessary equipment adds to the diver's load. How deep is a man going to be able to work effectively as his equipment becomes increasingly complex? Man functions best in an optimum environment, which is why we have centrally heated, pressurised aircraft and, some of us, air-conditioned cars. I believe that in order to exploit the depths, man will need to take his environment with him in the form of sophisticated submersibles with great manoeuverability, navigational efficiency, manipulative skill and strength.

I give you this thought: Man achieves his greatest domination over Nature when he uses his ingenuity to design and build machines. Man has long shown that he has the strength to move mountains - although not always the faith. Bulldozers have proved a great substitute for sweat the of man's brow, and they are a good deal easier to come by than Faith ......

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Brief Profile

Surgeon-Commodore John Rawlins is Director of Health and Research (Naval). In 1955 he was awarded the MBE for his work on protective helmets while with the RAF Institute of Aviation Medicine and in the same year began work on the problem of escape from sinking aircraft.

In 1961 he was awarded the OBE for this work which culminated in the introduction into Royal Navy aircraft of an automatic underwater escape system.

Two years ago he was awarded the Gilbert Blane Medal of the Royal College of Surgeons for his work on the problem of cold in diving.

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