That same inquiry turned up yet another previously unexpected phenomenon, namely the existence of numerous other effects of hydrostatic pressures which fall altogether outside the pattern of antagonism discussed so far. Here hydrostatic pressure effects either were not antagonized but even potentiated in the presence of pharmacologically active inert gas components. Here again the order of potentiation in producing effects often bore no recognizable relation to the order of potencies characteristic of the excitable tissue phenomena we have discussed so far. Phenomena in this category include such things as cell death, development of cell pathology, and changes in cell replication. I think it is probably not terribly surprising that a group of effects of this type should exist which may well reflect some of the many changes in cell functioning that can be brought about by high hydrostatic pressures without involving excitable cell membranes, or for that matter cell membranes at all as a primary target.

From a practical point of view, the existence of this group of pressure effects suggests the possibility that when we use addition of narcotically active gases to diving mixtures to minimize some of the manifestations of HPNS, in addition to the complexities of modification of the clinical picture by uneven action of these agents, we may be producing additional problems. By creating such conditions we may succeed in exposing our subjects to quite high hydrostatic pressures by suppressing the acute manifestations of HPNS while significant other pressure effects may be exerted upon our subjects which may not be relieved to the same extent, or which may even be exaggerated, by these modifications of our diving atmospheres. This, then, could confront us with the possibility of pressure-induced injury that might not become manifest until sometime after the dive is completed. Since we are dealing with human beings at risk, I think it is appropriate to recognize this possibility, and in future studies directed toward medical problems of extremely deep diving, we must include work designed to probe for, and if possible to dissipate, any such residual injury problems at the level of animal experiments rather than risking possibly painful surprises from the ultimate effects of what must be termed human experiments.

I hasten to add to this that at the present time such dangers constitute no more than a purely theoretical possibility. I would be inclined to question the validity of suggestions that some of the behaviour changes that have been reported in subjects undergoing very deep dives can be interpreted as valid evidence for residual changes of any kind resulting from such dives, although surely they do not allow us to discount that possibility. At the level of animal experiments, we have conducted experiments which involve repeated exposures of animals and which, in the obliging way nature has with such things, yielded equivocal data that would be equally compatible with an affirmative and a negative conclusion in this matter. We have currently underway what we hope will be more sensitive experiments utilizing behavioural criteria and quantifiable memory performance, but the results of those experiments will not be in for another year, and even then I would suspect that they can hardly furnish more than suggestive evidence tending to sway us one way or another.

I have tried to give you some feeling for the lines of investigation of high pressure effects on the central nervous system which have engaged our attention over the last several years. I hope I have conveyed to you three ideas.

The fact that these phenomena are real, and that coping with them is one of the prerequisites for further development of deep diving.

Some sense of the types of real and probable hazards these phenomena impose, and some concept of kinds of working hypotheses we currently entertain as to the biophysical mechanisms underlying them.

Finally, a sense of the fact that in addition to their immediate bearing on problems of deep diving these phenomena are characteristic of many problems in underwater physiology in that they bear upon and provide opportunities for studies of a wide range of problems in basic physiology and in particular in basic adaptive biology.

I have tried to give you some feeling for the lines of investigation of high pressure effects on the central nervous system which have engaged our attention over the last several years. I hope I have conveyed to you three ideas.

Professor Ralph W Brauer is director of the Institute of Marine Biomedical Research, and Professor of Biology at the University of North Carolina at Wilmington, 7205 Wrightsville Avenue, Wilmington, North Carolina, 28403, USA.

COLD ADAPTATION IN HUMANS
A LESSON FROM KOREAN WOMEN DIVERS

Suk Ki Hong

I would like to express my thanks to the RAN for inviting me and giving me this opportunity to present some of the experimental results I have obtained over the past 20 years from studies on Korean women divers.

Professor Brauer has described very interesting effects of pressure which is an important environmental variable to diving individuals. There is another very important aspect of diving, body heat exchange in water. To dive, you have to go into water, stay there and pressurize.

I started my research on the physiology of Korean women divers exactly 24 years ago. At the beginning we were concerned with the respiratory physiology of breathhold diving, particularly the effects of pressure. However, it soon became apparent to us that the real problem with Korean women divers was not respiratory physiology but thermal physiology. This is because the water temperature is about 22°C in the middle of summer, which is relatively warm but still cool. In the middle of winter, the water temperature decreases to 10°C.

In that water temperature range these women are exposed to a severe cold stress. To overcome that they should dress very heavily. However we observed that they wore just a thin cotton suit, which does not give much protection against cold water stress. Therefore we undertook an extensive series of studies. In fact, we spent the next 10 years documenting the quantitative pattern of heat exchange as well as the nature of cold adaptation.

To begin with we simply measured the rectal temperature during one work shift (45 min) in summer, when the water temperature is about 22°C. We found that the rectal temperature dropped slowly over a 45 minute period to about 35°C, at which time they quit diving because they could no longer tolerate the cold stress. At the same time, the skin temperature decreased to 27°C. Thus the mean body temperature decreased by about 5°C over the 45 minute period. In winter, when the water temperature is down to 10°C, the rectal temperature had dropped to about 35°C in about 30 minutes, at which time they again quit diving. In other words there is a critical rectal temperature (approximately 35°C) below which human beings cannot voluntarily tolerate the cold stress.

We then estimate the amount of body heat lost to the sea water during one shift. In summer, the cumulative heat production, determined from the increment in oxygen consumption, was about 94 Kcal, while the magnitude of heat lost from storage was about 293 Kcal. Thus, the total heat loss amounted to 387 Kcal in 45 minutes. Since they did about 3 shifts a day in summer about 1000 Kcal of body heat were lost daily. In Winter they lost about 575 Kcal in one shift, again with a daily heat loss of about 1000 Kcal.

The question arises whether, if they keep losing that much heat every day all year round, they adapt to cold? As of 1962 or so, there were debates among human physiologists whether human beings did indeed develop adaptations to cold. To be sure, adaptations to cold in other animals have been proven beyond any doubt, but many physiologists doubted that this was the case in human beings. We felt that we had a golden opportunity to study whether humans did indeed adapt to cold. So we started a series of studies to find out if there were any adaptations.

To make a long story short, I will briefly summarize the results of ten years of work. We found four major adaptive changes to cold in these women.

1. They had a reversible increase in basal metabolism during the cold season by about 3O%.

2. They had a greater body tissue insulation, by about 10%, compared to normal subjects.

3. The cold-induced constriction of the finger blood vessel during immersion of one hand in 6°C water was much greater in divers than in non-divers. Greater vasoconstriction means less blood flow so less heat loss. Blood flow was 30% lower in divers than in non-divers.

4. The critical water temperature (the water temperature which a subject can tolerate for three hours without shivering) was also about 10% lower in divers, indicating the higher shivering threshold in divers.

There are a few other adaptive phenomena, but these major adaptive changes are very similar to those found in animals. In other words Homo Sap*iens is no differ*ent from other animals.

When we published these results another question was raised, “How do you know that these changes are due to cold?” I had no real answer to this question because I did not have the data to show that these changes can be reversed by eliminating cold water stress.

Fortunately, when I visited Korea in 1977, I found that the diving women who used to be very lightly dressed now all wear wet-suits. They told me that they wore them to keep warm. So, I felt that if I had a chance to get back to these women divers again and demonstrate the absence of cold water stress accompanied by disappearance of all the adaptive changes I had observed before, this would enable me to reinforce the earlier conclusions. So we went back to these women divers about four years ago and repeated everything we did in the olden days. I am greatly indebted to both Drs DW Rennie (State University of New York at Buffalo) and YS Park (Kosin Medical College in Korea) who collaborated with me in this study.

What are the effects of wearing wet-suits on body heat loss during diving work in the sea? In summer (water temperature 22.5°C), the heat loss in the 60’s was 380 Kcal in one shift of 45 minutes. Contemporary wet-suited divers do one shift lasting 2 hours, during which they lost about 300 Kcal. Similarly, in winter (10°C water) the heat loss in the olden days was 580 Kcal in one 30 minute shift. Contemporary divers can stay in the water for 2 hours during which they lost only about 400 Kcal. This means that indeed, by wearing wet-suits, they have eliminated a tremendous cold water stress to which they had been subjected daily prior to wearing wet-suits.

When we measured their basal metabolism in 1960 and 1961, we found that there was no difference between divers and non-divers in summer. However, in the middle of winter, the divers’ basal metabolism went up by 30% over the summer level in a reversible manner. When we repeated the same measurements in 1980 and 1981, there was no difference between divers and non-divers whatever the season. This means that a metabolic adaptation (ie. the reversible increase in basal metabolism) to cold no longer exists in divers using wet suits. If we had measured the basal metabolism in 1978 or 1979, we might have observed a partial disappearance of this type of adaptation. However, it took three years to write up the grant application and get the funds. By then the metabolic adaptation had disappeared completely.

Critical water temperature is a function of the skin fat thickness, which provides a barrier for heat loss. In 1961, we found that non-divers with fat thickness of 3-4 mm had a critical water temperature of around 32°C. However divers who had a similar skin fat thickness had a critical water temperature of only about 28°C. In other words, there was a marked difference in shivering threshold or critical water temperature in the olden days. When we went back to them in 1980, we found that they were all fatter. The skin fatness had increased in both divers and non-divers. We compared the critical water temperature as a function of the skin fat thickness in these subjects. Overall there was an inverse relationship between the two variables as expected. However, we observed that the critical water temperature for a given subcutaneous fat thickness was lower in divers than in non-divers by about 2°C in 1980 and about 1°C in 1981, but the same in 1982. There had been a progressive, gradual loss of this adaptation over a period of three years.

The maximum tissue insulation (for a given subcutaneous fat thickness) in the olden days was consistently higher in divers than in non-divers. However, in 1980, we found that they were identical in both groups. In fact, in all three years we found no difference between the two groups, indicating that the insulative adaptation had already disappeared after wearing wet-suits for three years.

The finger blood flow response to immersion of one hand in 6°C water was then investigated. The finger blood flow before immersion was about 45 ml per minute per 100 ml of finger volume. When we immersed one hand in 6°C water, the flow dropped immediately and then increased (cold-induced vasodilation), followed by the so-called "hunting phenomenon". In the 1960's, we found that the women divers showed a greater vasoconstriction and a reduced hunting phenomenon than non-divers. When we repeated this test in 1980, we found that this peripheral vascular adaptation was already partially lost. By 1981, this adaptation had disappeared completely.

Our findings may be summarized as follows. Our early studies (conducted from 1960 through 1970) indicated at least four types of cold adaptation in women divers, a reversible increase (30%) in basal metabolism in winter, a 10% increase in tissue insulation, a 30% reduction in the finger blood flow response to immersion of one hand in 6°C water, and a 10% reduction in the critical water temperature. When we repeated the same studies in 1980 after the divers had been wearing wet-suits for three years, the basal metabolism and insulation returned to normal while the peripheral vascular response and the critical water temperature partially returned to the non-divers' level. In 1981, after wearing wet-suits for four years, we found that the finger blood flow response was back to normal, but the critical water temperature still remained lower for divers than for non-divers. It took five years to lose all the cold adaptation changes they had acquired when diving without wet-suits.

These studies have shown that it is quite certain that these women divers were indeed acclimatized to cold at one stage. In other words, our studies lend strong support to the notion that Homo sapiens can indeed develop adaptation to cold.

Question:
What about age? The divers would be getting older every year.

Dr SK Hong
I did not make it clear. We did not use the same subjects in every study. But our non-divers were all age matched to the divers and the results obtained from them were much the same in the old and new series.

Question:
The end point for the traditional diver was a rectal temperature of 35°C. The divers in the wet-suits have a longer diving time. Is their endpoint also the same as in cotton suited divers?

Dr SK Hong
This is a very important point. They stay in the water much longer, but their rectal temperature at the end of two hours in the water has hardly changed. There is a 0.2-0.3°C drop in the rectal temperature over a two hour period. The question then comes up, why do they not stay longer? They do not wear gloves and the hands get awfully cold. Also they get physically tired.

Question:
Do they wear hoods?

Dr SK Hong
Some people do, others do not. About half of them wear them.

Question:
Any difference between the ones that do and the ones that do not?

Dr SK Hong
We did not find any difference.

Question:
The original Ama divers, did they come from specific tribes or specific areas or families?

Dr SK Hong
No. Usually, they dive if their mothers do. When there are many women divers in a community, the young kids, at the age of about 11 or 12, just jump into the water and start practicing shallow dives. After 4 or 5 years of training they become professional divers. It really takes many years of training to become an independent diver.

Question:
It is almost similar to what John Pennefather mentioned earlier that it is natural selection.

Dr SK Hong
It is dependent on training and ability. There is nothing to indicate that there are other factors involved.

Question:
Are they still breathhold diving, or do they use compressed air?

Dr SK Hong
They are still breathhold divers. The union specifically prohibits scuba diving, because it would wipe out the resource.

Question:
Present day Ama are fatter than their mothers. This would increase their insulation.

Dr SK Hong
So we had to make comparisons for a given skin fat thickness. They were very skinny in 1960's. I think this reflected, to some extent, the poor economy.

Question:
The Ama divers are female. Is that because they adapt better, or because they are pushed into it?

Dr SK Hong
My theory is that they are there because they can tolerate cold water better than males. Because, if you look at history, both male and female divers were once involved but gradually male divers disappeared from the scene. However, in Japan, where they dive only during the warm season, you find both male and female divers. So there is nothing magic about the absence of male divers in Korea where they do dive all year round, they have to tolerate the cold stress and have to compete with women, and there is no way that they can win.

Question:
Why are present day Ama fatter?

Dr SK Hong
Nutrition accounts for the increase in the amount of body fat in contemporary divers. But remember, our data are based on a given skin fat thickness, so we have ruled out skin fat as a variable.

Question:
Did the effect of the wet-suit increase their breathhold capacity?

Dr SK Hong
We do not know. Breathhold time is longer in divers than in non-divers, but not much. Breathholding time is not an issue, because usually they do not breathhold for long. They hold their breath for a diving time of about 30 to 40 seconds, and we have reasons why they do that. To get the maximum bottom time and to increase the fraction of time they spend on the bottom, shorter and shallow dives are better.

Question:
When you say that breathholding is a matter of training, is it partly a personal thing, or is it endless practice that makes them able to breathhold just that bit longer? Do they go down on a shot line and get there quickly, or do they have to swim down?

Dr SK Hong
I think it does require skill. They have to learn to swim and to dive from shallow to deeper and deeper depths, and they have to learn all the tricks.

Dr Suk Ki Hong is a professor in the Department of Physiology, State University of New York at Buffalo, Buffalo, New York, 14214, USA.

IMAGINARY CONSULTATION

"MY STUPID EARS"

Noel Roydhouse

In a letter recently published in an Underwater Association newsletter a reader asked for their Medical Adviser's advice on solving his problem. It was a problem which troubles many divers, "Ears". I have set down the *thoughts* which would have occurred to me had he **told his tale** during a consultation concerning his problem to draw attention to the problem of misdirection of attention if the patient's diagnosis is uncritically accepted.

"I have a diving problem, my ears. I have a history of sinus problems." *Prior to 1920 this would have been "nasal catarrh" but owing to a world wide tendency for ENT Surgeons to operate on normal, non-infected sinuses in the 1920's, folk medicine changed this to "sinus trouble", as the patients underwent thousands of operations upon their normal sinuses. The reason they improved temporarily is well documented by the Immunologists but basically the shock of the operation gave three to six month cure, after which they relapsed and their catarrh was often worse. By the 1940's such operations were given up but folk medicine "sinus" problems have incorrectly and mistakenly persisted.* "At the age of thirteen I had my tonsils removed." *Probably unnecessarily so, as in my 34 years of taking out children's tonsils the age group of ten to fifteen years rarely need tonsillectomy.* "And ever since then I have been plagued by sinus." *Nasal catarrh really, and it is stuffiness or blockage of the nose with or without a mucous or thin discharge from the nose, sometimes with a "pressure" in the nose or under the eyes.*

"I noticed when snorkelling that I was unable to equalise pressure as readily as before the tonsillectomy." *No wonder. "Sinus" is often stress induced and the unnecessary operation of tonsillectomy would be enough to bring on nasal catarrh.* **"Over the years the problem has got steadily worse."** *I would guess four to five years - see later.* "Now I've only got my stupid ears." *He is getting emotionally involved with his problem and this adds to the stress and makes him worse again.* "Wet in the bath, and I've got earache." *I have published several papers on this[1,2] and he fits the typical case described. Appendix 1 is an abstract of Reference 2.*

"I have all but completed the divers' course necessary to get a certificate but was unable to pass the medical due to blocked Eustachian tubes." *Named after Bartolomea Eustachi, an Italian Anatomist (1520-1574) who first described this tube which is also known as the Internal Auditory tube.* "After a half hour dive to about 30 feet." *Diving to 30 feet meant that he had cleared his ears or he would have ruptured his ear drums. Diving, in itself, does not cause any permanent blockage of the Eustachian tube. If one does not clear one's ears on descent the water pressure compresses the inner soft tissue end of the Eustachian tube and at two metres unless equalisation has occurred the Eustachian tube is locked. This means that the chest muscles cannot produce enough pressure to open the Eustachian tubes as they cannot raise the pressure*