Physiology of Whales

Sir Leonard Hill[1] suggests that whales' blood should not become supersaturated with nitrogen since there is not enough air in the lungs. I have observed that Blue and Fin whales spend the vast majority of their lives submerged—at what depth we may never know—and that their sojourns at the surface are usually momentary. The result is that while the decompressed state of the whale lasts only for a few seconds in every ten to twenty minutes, the compressed state predominates. Therefore there is a constant passage of nitrogen into the blood and very little opportunity for it to return into the lungs. Supersaturation is bound to occur if the whale's dive is sufficiently deep.

May I be allowed to advance an *a posteriori* reason for believing that the whale dives deep enough to produce supersaturation of the blood with nitrogen? It lies in the phenomenon of nitrogen removal which occurs in whale blood and to which I have already directed attention[2]. The blood of Blue and Fin whales is capable of so absorbing atmospheric nitrogen that it is not to be regained by evacuation of the blood[3]. It is a most interesting fact that one of the few mammals which might run the risk of caisson sickness is just the one to have a mechanism for avoiding it.

Prof. Krogh has objected[4] that the rate of nitrogen removal shown in my experiments is too low to clear the blood of excess nitrogen quickly enough. The scope of my experiments sufficed only to establish the fact of nitrogen removal and not the rate, which may easily prove to be higher in the blood of living whales or when estimated by a more efficient technique than I was able to use.

In this connexion, I originally suggested that bacteria in the blood were the cause of the nitrogen removal. Further work on whale blood at the London School of Hygiene and Tropical Medicine has failed to support this. The nature of the reaction is not known, except that oxygen is apparently required.

With reference to Dr. Argyll Campbell's suggestion[5] that whales avoid caisson sickness by filling their lungs with water before a dive, I think it may safely be said that this is unlikely since the blast of exhalation is composed only of gases and water vapour. I have just returned from a whale-marking cruise, during which I frequently passed through the column of vapour left by a whale. On one occasion while I was standing in the bows of the whaler, a large Blue whale, about ninety feet long, came up directly beneath the bows and blew in my face. The blast was tremendous and seemed curiously cold, little warmer than the surrounding atmosphere, 5°–6° C. This chilliness is, I imagine, a result of the decompression of air in the whale's lungs. When the whale dives, the air is compressed and produces heat, which is absorbed gradually by the tissues of the lung. During the ascent to the surface the air expands and absorbs heat. The air in its chilly state is discharged before it has time to absorb heat from the lungs and, being saturated with water vapour, appears as a thin mist. This explains why the blast of whales is visible in the tropics where the breath of other mammals is invisible. But only the blasts from whales which have come up from a deep dive will be visible. No decompression cooling will occur in the lungs of whales which did not dive deep and come up again fairly rapidly.

Dr. J. S. Haldane tells me that the same phenomenon occurs in the air lock of caissons, where on decompression the air becomes very cold and supersaturated with moisture. Difficulty is experienced in getting the workers to stay long enough in the lock on account of the chilly discomfort.

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[1] Hill, L., Nature, **135**, 657, April 27, 1935.
[2] Laurie, A. H., Nature, **132**, 135, July 22, 1933.
[3] Laurie, A. H., "Some Aspects of Respiration in Blue and Fin Whales", *Discovery Reports*, **7**, 363–406; 1933.
[4] Krogh, A., "Physiology of the Blue Whale", Nature, **133**, 635; 1934.
[5] Campbell, J. Argyll, Nature, **134**, 629, Oct. 20, 1934.

Osmotic Pressure of Fixing Solutions

It has long been the custom in many laboratories to make up certain fixatives in saline solutions, but the value of this practice has recently been questioned[1] on the ground that the osmotic pressure of most fixatives, as determined by the freezing point, is already greater than that of the tissues. However, since the particles of the fixative are presumably able to pass more or less freely across the surface membranes of the cells, it seems likely that they do not produce any effective osmotic pressure. If this is so, then the freezing point of a fixing solution is no guide to its 'physiological' osmotic pressure. Further, it is possible that the addition of salts to fixatives is necessary to prevent the distortion which would result from the fact that the particles of fixative differ from those of the tissue fluids in mobility and electrostatic charge.

Since very few critical data exist about the effects produced by fixatives made up in salt solutions[2], it was decided to test the question carefully, using a marine invertebrate in which osmotic effects should be especially conspicuous on account of the high internal concentration of salts. A number of fixatives, both single substances and fixing mixtures, were made up in distilled water and in sea-water, and were then tested as to their effects on the stellate ganglia of *Sepia officinalis*, in which the saline concentration of the blood is close to that of sea water. Each ganglion was cut into two pieces, one of which was fixed in the solution in sea-water, the other in that made up in distilled water. After fixation, the two pieces were transferred to a single receptacle and treated together in all subsequent processes, embedded side by side in paraffin and sectioned in the same block.

It was found that the presence of salts in the fixative is *essential* for good fixation, especially with fixatives which penetrate slowly[3] such as those composed of potassium bichromate, formaldehyde, chromic acid, picric acid or osmium tetroxide. For example, ganglia fixed in 1 per cent chromic acid or 4 per cent formaldehyde in distilled water showed very great distortion, due apparently to swelling and bursting of the cells (Figs. 1 and 2). Similarly, when such fixatives as Champy, Regaud or Flemming without acetic acid were made up in distilled water, they were found to cause bursting of the cells, especially at the centre of the piece, such effects being absent when the same solutions were made up in sea water (Figs. 3 and 4).