the basis of note-book records. There can be no doubt that these two American investigations were in progress simultaneously with our own, that they led to the isolation of the same substance independently and that the fact of its crystallization was, in each case, briefly announced at a date not distant from that on which we first described its properties and named it. Our concern is to ensure that the further literature in an important field should not be complicated and confused by a multiplicity of names for the same substance. Our paper, in which the name "Ergometrine" was given to the pure alkaloid, had, in fact, already been published before that by Davis *et al.* came into our hands; but, even if we had seen this paper earlier, we could hardly have felt entitled to consider the scientific adoption, for our alkaloid, of the name Ergotocin, which was there mentioned only as the trade name of an impure and supposedly non-alkaloidal preparation. We hope that, in suggesting to our American colleagues the propriety of adopting "Ergometrine" as the proper, scientific name for the pure alkaloid, we shall not be misunderstood as depreciating the contributions of those who have been working in the same field.

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THE PROTECTION OF WHALES FROM THE DANGER OF CAISSON DISEASE

THE interesting account by Laurie[1] of respiration in the large and active whales of the Antarctic has stimulated discussion of the problems presented by the necessarily peculiar respiratory activity of these animals during prolonged submersion at great depths. As to the limits of their dives there may be some question, but there is no doubt that whales descend to the depth of 100 meters and thereby encounter hydrostatic pressure of about 10 atmospheres. A terrestrial mammal which has been breathing air in a caisson at a pressure greater than 2.4 atmospheres encounters the danger of effervescence of the dissolved nitrogen in the tissues if by ascending rapidly the pressure is reduced more quickly than the blood can transport the released nitrogen to the lungs. The resulting bubbles of gas obstruct circulation and cause caisson disease. Whales do not apparently suffer from caisson disease, and yet their respiratory system is, as far as we can see, typical for mammals.

The whale does not, however, enter a caisson and rebreathe air under pressure. It submerges with one lung volume of air. An estimate of lung volume at 10 per cent. of the body volume can not be far wrong and would start the diving whale with about 8 per cent. of its body volume as nitrogen. Human divers do not suffer from caisson disease until they have been exposed to 2.4 atmospheres absolute pressure,[2] so that the human body can evidently rapidly eliminate the amount of nitrogen contained after saturation at the 1.4 atmospheres extra pressure. In 100 cc of blood and other tissues about 1 cc of nitrogen is dissolved per atmosphere of pressure, and in fat about five times as much.[3] Applying these figures to a whale with 25 per cent. fat[4] at 2.4 atmospheres absolute pressure indicates the ability to eliminate rapidly and with safety 1.4 $(0.75 \times 1 + 0.25 \times 5) = 2.8$ per cent. of its body volume of nitrogen. About one third of the nitrogen in a whale's lungs could be safely dissolved in the tissues and rapidly eliminated.

To introduce one third of the nitrogen of the lungs into the tissues would reduce the amount of gas in the lungs by one quarter, would require an increase in pressure of 2.4 times and would consequently diminish the lung volume to $\frac{1}{2.4} \times \frac{3}{4} = 0.28$ of the normal volume at atmospheric conditions.

The next question is, whether the lungs could be compressed by hydrostatic pressure to the extent of much less than one quarter of their capacity. The lungs of diving animals are not freely open to the exterior as in man. The nasal orifices can be tightly closed, and the bronchioles (in the porpoise) are supplied with contractile tissue which can likewise effectively hold air in the lungs.[5] The thoracic cross section is nearly circular and the intercostal and abdominal musculature is strong. These structures could support great pressure, particularly if there were no movement of the supporting respiratory muscles. But, if the intrathoracic pressure remained low, while the external hydrostatic pressure increased, there would only arise another problem of how to prevent the injection of viscera, blood and lymph into the thorax. It seems likely that the pressure in the lungs would be close to the external hydrostatic pressure, and that most of the nitrogen in the lungs would be forced into solution in the blood and tissues.

The whale's nitrogen capacity has been calculated at about 2 per cent. of the animal's volume per atmosphere pressure. Four atmospheres extra pressure would then cause the solution of all lung gases (provided that total collapse of the lungs occurs) and would still dissolve in the tissues only three times as much nitrogen as the human diver can rapidly eliminate. The human safety

1 Alec H. Laurie, Discovery Reports, vii, 365, 1933.

2 L. Hill, "Caisson Sickness and the Physiology of Work in Compressed Air," p. 75. London, 1912.

3 *Ibid.*, p. 171.

4 Alec H. Laurie, *loc. cit.*

5 G. B. Wislocki, *Am. Jour. Anat.*, xliv: 47, 1929.

limit is set as the critical pressure below which caisson disease does not occur, but many men have worked safely and endured rapid decompression at much higher pressures.

It is simple to suggest that the average whale is as capable in this respect as even the exceptional human diver. However, it is perhaps worth completing an argument which has been so often the cause of confusion. The danger of caisson disease specifically occurs when nitrogen diffuses so rapidly from the tissues that the critical pressure for bubble formation is reached in the blood vessels. To protect a man, the rate of diffusion is kept small by slow decompression, which reduces the gradient of nitrogen pressure from tissue to lung. The same result might be accomplished in the whale if the structure or composition of its tissues retards the rapidity with which nitrogen diffuses. For example, it is often suggested that the layer of blubber, with its large nitrogen solubility and meager vascularization, would provide for a slow escape of the nitrogen dissolved at high pressure. Corpulent human divers, however, are especially susceptible to caisson disease.

On the other hand, it is quite reasonable to point out Haldane's view that increasing the rate of the circulation removes the blood from proximity with the source of nitrogen before the critical pressure for bubble formation is attained. It is significant that the whale emerges from a deep dive with an oxygen debt and must maintain an active circulation of blood during the period of recovery. The human diver emerges with no oxygen debt and yet sufficiently fatigued to desire the rest which will further slow his circulation. The whale with an oxygen debt possesses likewise the essential conditions necessary for the specific stimulation of blood flow through the central nervous system,[6] and therefore with the precise conditions which are favorable to the avoidance of nitrogen embolisms in the susceptible central nervous tissue.

In reconsidering the situation in the diving whale, it is apparent that all the nitrogen contained in the lungs will be dissolved at about 4 atmospheres hydrostatic pressure, and that further submersion involves no greater physiological problem. Even to dissolve this amount of nitrogen requires the total collapse of lungs and thorax, a difficult process to reverse. But if it is possible and all the nitrogen is forced into solution, the amount present is still only three times as great as any human diver can safely eliminate. During decompression, the circulation in the whale is bound to be accelerated by the stimulus of its large oxygen debt. I believe that it is a conservative estimate that the whale's circulation would be three times as effective as the human diver's at the time of emergence from a deep dive.

In view of the limited supply of nitrogen and the favorable conditions of the circulation there is no reason why a whale with ordinary mammalian respiratory and cardio-vascular systems should be in danger of caisson disease. Any special characteristics of the whale, such as peculiar amount and distribution of the fat and the retina miriabilia, had better be kept in reserve for the solution of other problems of cetacean physiology.

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[6] W. G. Lennox and E. L. Gibbs, *Jour. Clin. Invest.*, 11: 1155, 1932.

THE HELMHOLTZ-KOENIG CONTROVERSY

IN 1870 Helmholtz published results showing that when two notes are sounded on a siren there are waves set up which will produce resonance in tuned Helmholtz resonators. Koenig repeated the experiment, using tuning forks, and failed to produce vibrations in a third tuning fork which was tuned to the difference tone. It is a well-known fact that when two notes are sounded we hear beats whose pitch is the difference between the two original notes.

The controversy which was argued pro and con for twenty-five or thirty years was: Are these tones which one hears due to a vibration or wave in the air or are they subjective tones? If there are waves in the air which produce vibrations in tuned resonators, strings or forks they are called combinational tones. If these waves do not exist in the air the effects in the ear are called beat notes. It seems that both sides of the controversy agreed as to the above distinction between combinational tones and beat notes. There was no quibbling or haziness about definitions. Present-day writers often use the terms beat notes and combinational tones interchangeably. Others seem to make a distinction between the two terms, but the distinction is a matter of pitch. If the pitch is less than 16 or 30, perhaps, the term beat note is applied. If more than 16 or 30 they are called combinational tones.[1]

All experimenters who used sirens and kindred apparatus were thoroughly convinced that combinational tones were a reality. All those who used tuning forks or piano wires as sources were convinced that there were no waves or combinational tones and that the effects were beat notes. Helmholtz and his followers said Koenig and his followers were wrong. Koenig and his group said that Helmholtz was wrong.

Rucker and Edser,[2] using a siren as sources and a tuning fork as a detector, found combinational tones, but when their sources were tuning forks they say they did not find combinational tones. However, they do

[1] Sutton, SCIENCE, March 8, 1935, p. 255.
[2] *Phil. Mag.*, 39: 341, 1895.