At an environmental temperature of 30°C, no loss of RR occurred with mice in mixtures of oxygen and helium at pressures less than 125 atm. At 110 atm and 20°C, five animals lost their RR, but this was restored when the pressure vessel was warmed to 30°C. However, at pressures above about 100 atm distinct tremors were observed in the animals and respiration appeared very labored. Attempts to reach higher pressures showed that these pressures were lethal, although they were only slightly higher (in the range 135 to 145 atm). Within 5 minutes of reaching the higher pressures, animals passed rapidly through a phase of prostration and respiratory difficulty to death, in a way unlike that induced by anesthetics.

A test was made for a subliminal anesthetic effect of very high pressures of helium by combining these with subanesthetic pressures of nitrous oxide ($ED_{50} \sim$ 1.5 atm; see *6*). These experiments were generally unsuccessful, since the mice died on compression. This may have been due to a secondary effect of the gas—the abrupt rise in pressure with helium causing a compression of nitrous oxide in the animals' pulmonary air spaces and producing a transient lethal nitrous oxide tension. In one case, however, the animal survived and showed no signs of anesthesia in an atmosphere of nitrous oxide (1.2 atm) and helium (125 atm); thus 125 atm of helium failed to contribute 20 to 30 percent of an anesthetic dose.

In one experiment with neon, a mouse showed no loss of RR at 110 atm and an environmental temperature of 30°C. As with helium, the mouse died when the pressure was raised to 135 atm.

Further studies were performed on Italian great newts. The use of these animals avoided some of the technical difficulties experienced with mice and made it possible to study not only the effect of high gas pressure, but also that of hydrostatic pressure alone. For the latter studies the chamber and its inlet valve were completely filled with water, and pressure was applied through the gas supply line. The anesthetic pressure of nitrogen for these animals was found to be 40 ± 8 atm (standard deviation) at 30°C (*7*), compared with 34 ± 5 atm (S.D.) for mice (*6*). We found that the RR was lost between 165 and 245 atm, irrespective of whether the pressure was applied with the use of helium (3 experiments) or neon (4 experiments), or hydrostatically (4 experiments). The animals exposed to these pressures lost all spontaneous movement and frequently took up contorted postures. After exposures to hydrostatic pressures for 15 to 30 minutes, spontaneous movement was restored when the pressures were reduced. These animals were kept for 12 hours and no ill effects were observed. (No attempts were made to investigate survival of animals exposed to high gas pressures, since profuse bubble formation occurred on decompression.)

The conclusion suggested by these preliminary experiments is that the loss of activity in all cases resulted from the effects of high pressure alone. If helium and neon are capable of anesthetic action [and according to the clathrate theory (*8, 9*) they should not be], then their anesthetic pressures must be greater for mice and newts than the limiting mechanical pressure which the tissues of these animals can tolerate. This view is supported by Carpenter's studies of the anticonvulsant action of helium in mice. He estimated, by extrapolation, an ED_{50} of 163 atm, and comparison of anticonvulsant end-points with end-points such as loss of righting reflex (*6*) suggests that the partial pressure of helium required to remove RR would be above, possibly substantially above, 250 atm. This is in keeping with the single experiment with nitrous oxide and helium, where 125 atm of helium did not contribute the fraction of an anesthetic dose required to reach the end-point. More detailed experiments will be required to assess the nature of the sickness produced in these animals by high pressure.

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22 March 1967

Radar Observations of Locust Swarms

In the recent report (*1*) of the first radar tracking of single insects in free flight, it was suggested that the entomologist will soon be using radar as a tool. Some entomological applications of radar have in fact already been illustrated by observations made on swarms of desert locusts (*Schistocerca gregaria* Forsk.). Thus, the first such observation (*2*), over the Persian Gulf in 1954, demonstrated a night-flying swarm over the sea, covering an area at least 50 km across and detected by a naval radar set at ranges up to 100 km. More recently, a series of 3.2-cm radar photographs of very large flying swarms was secured and analyzed by the Rain and Cloud Physics Research Centre at the Indian National Physical Laboratory. These analyses not only recorded flying locusts around Delhi, over areas totaling 900 km^2 on 27 July 1962 and 1400 km^2 the following day, at heights up to 1500 m above the ground, but also provided approximate estimates of spacing or density, by volume, of flying locusts, recorded as 0.07 and 0.13 locust per cubic meter on 26 and 27 July, respectively (*3*). The orders of magnitude of the densities, by volume and area, so indicated were consistent with those previously found for swarms in eastern Africa, by photographic methods and corpse-counts after spraying. Moreover, the Indian radar observations made it possible to arrive at an order-of-magnitude estimate of some 10^{11} locusts within 100 km of Delhi on these dates (*4*), and to make a detailed study of the meteorological factors involved in this impressive manifestation of insect behavior (*5*).

Mention should perhaps also be made of earlier sightings, in Arizona, of individual unidentified insects in a vertically directed searchlight beam, which were found to coincide with the appearance of "angel" reflections on an adjacent vertical-incidence radar operating at wavelengths of 3.2 and 1.25 cm (*6*). When these observations were recorded it was suggested that such a radar might provide useful data on variations in the density of flying insects.

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23 May 1967

Seal Ears

Graham (*1*) expresses the need for a physiological investigation of the middle ear of true seals (Phocidae), similar to that on sea lions (Otariidae) (*2*). Odend'hal and Poulter (*2*) describe cavernous tissue covering the linings of the middle-ear cavity in two species of sea lions and put forward the hypothesis that these tissues serve to equilibrate the air pressure of the middle ear with the external pressure of the water, which varies with depth of diving. Graham accepts this hypothesis, and, on the basis of comparisons of the bulla region of phocids and otariids, proposes that, if true seals do have similar cavernous tissues, they should be able to dive deeper than eared seals, because the volume of air available for compression in the bulla is larger in true seals.

In the course of some studies for a cochlear microphonic experiment, I have opened the bulla of several freshly killed harbor seals (*Phoca vitulina*) and can state that the middle-ear cavities in this species of Phocidae are covered with cavernous tissue, much in the same way those of sea lions are (*2*). However, this appears not to be a new observation, as Tandler has already described this tissue (*3*). Tandler suggests the same function of equilibration as proposed by Odend'hal and Poulter for the sea lion, but he states that importance should be attached only to the morphological findings, not to the speculation about function.

The assumption of Graham, concerning the existence of cavernous tissue in the tympanic cavity of true seals, is thus substantiated, but it should be noted that the hypotheses offered are both based on the supposition that the Eustachian tubes in diving seals are blocked, and the evidence in support of this is not very conclusive.

Another aspect is that the essential point of equilibration is that of keeping the same pressure on each side of the tympanic membrane, while in the first approximation the pressure of the tympanic cavity relative to the external pressure is of minor importance. As a seal closes the orifice of its auditory meatus when diving, the air in the long, cartilage- and bone-supported meatus is trapped, and, consequently, hypotheses on equilibration of the middle ear in these animals should take into account equilibration of the meatus as well. I have made some transverse sections of the auditory meatus of a grey seal (*Halichoerus grypus*) and have found that the space between the lumen and the cartilage actually is occupied with cavernous tissue (Fig. 1). Distention of the cavernous tissue will cause a decrease in the size of the lumen of the meatus; assuming a regulation mechanism for the meatus similar to that proposed for the middle ear by Tandler and Odend'hal and Poulter, we can imagine how the pressure of the two cavities separated by the tympanic membrane may be equilibrated, but other possibilities cannot be excluded, and experiments seem necessary to establish the role of the cavernous tissue in pinniped hearing.

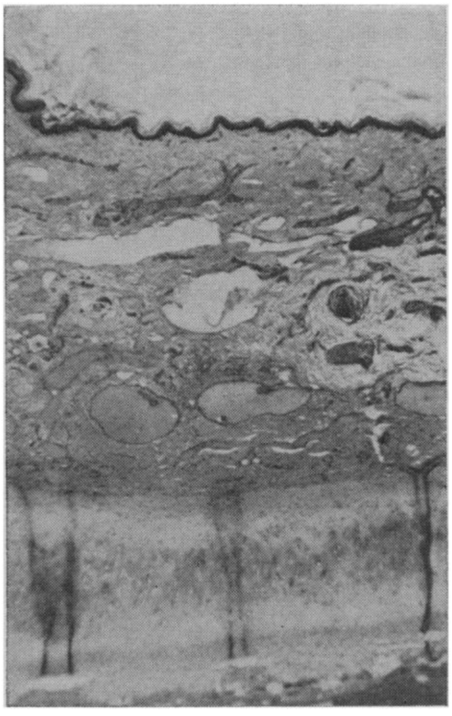

Fig. 1. Transverse section of the auditory meatus of a grey seal, showing cavernous tissue, partly filled with blood, between the lumen (top) and the cartilage (bottom). Black lines in cartilage represent artifacts (× 31).

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6 April 1967

Pollution in the Great Lakes

In the report on pollution in the Great Lakes by R. H. Rainey [*Science* **155**, 1242 (1967)] a plus sign has been omitted from Eq. 1, which should read:

$$C_2 = C_2^0 \exp(-RT/V) + [C_1 + (Q/R)][1 - \exp(-RT/V)]. \quad (1)$$

The neglected effects of the natural forces of purification may be significant when the equation is applied to organic matter, particularly the effects of sedimentation and attendant anaerobic decomposition of organic matter in the deposited sludge and also the decomposition of organic matter by oxidation—the oxygen coming from photosynthesis and from surface aeration as in an "oxidation pond." By introducing a term for these effects, $-K_1VC_2dT$, into the differential equation on which Eq. 1 is based, one obtains the equation:

$$C_2 = C_2^0 \exp[-(R/V + K_1)T] + \{(C_1 + Q/R)/(1 + VK_1/R)\}\{1 - \exp[-(R/V + K_1)T]\} \quad (2)$$

However, it must be admitted that the estimation of the value of K_1 in this equation would be difficult, particularly because of the seasonal growth of algae and the attendant creation of organic matter which at night or in cloudy weather has the same kind of effect on depletion of oxygen in the lake as does decomposing sewage.

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