Spalteholz technique.[2] Illustrations are stereoscopic photographs made as described by Long.[3]

The aortic arches exhibit the greatest development and remodeling during this interval, while the head vessels undergo extensive rearrangements. The major features of Tandler's[4] work is confirmed and extended to later stages. A summary of the development of the vessels to the limb buds and visceral organs is included.

The need for a standard and consistent nomenclature which takes into account both embryonic structures and their adult derivatives is discussed.

This is a preliminary note on an extensive study now in preparation for the press.

MARY SANFORD LEITCH

DEPARTMENT OF ZOOLOGY
UNIVERSITY OF CALIFORNIA

THE REMOVAL OF FLUORIDES FROM WATER BY SAND FILTRATION

SINCE it has been established that the dental disease in man known as "mottled enamel" is due to the drinking of water containing fluorine, the removal of fluorides by filtration has become an important problem.

I have found that a contact filter 15 cm high, made of river sand passing a screen 60 to the inch, to which has been added 2 per cent. by weight of powdered aluminium, will remove the fluoride from a solution containing 30 parts per million of sodium fluoride. The absence of fluoride in the filtrate was determined by the zirconium-alizarin colorimetric method.

S. P. KRAMER

FT. THOMAS, KY.

SPECIAL ARTICLES

RARE GASES NOT ESSENTIAL TO LIFE[1]

HERSHEY[2] reported that small animals such as rats could not survive more than a week approximately in an atmosphere of 21 per cent. oxygen and 79 per cent. nitrogen in which the rare gases were left out. He concluded that helium, argon, neon, krypton and carbon dioxide were vital to normal respiration and life. Fidlar,[3] accepting the results reported by Hershey, conceived of the rare gases playing a rôle in the atmosphere similar to the vitamins in foods. Previously, Ramsay[4] considered these gases inert biologically.

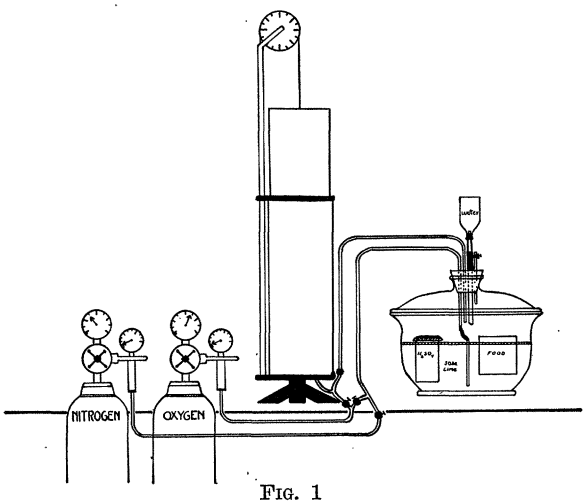

FIG. 1

Through the assistance of the engineering staff of the Linde Air Products Company, oxygen and nitrogen were especially prepared in order to exclude the rare gases. Oxygen was made from electrolytic dissociation of water. The nitrogen was produced by cracking ammonia and removing the hydrogen by control combustion with electrolytic oxygen. Both gases were prepared for the following purpose only, and every precaution exerted to secure pure oxygen and nitrogen. After the work was commenced, it was found that the nitrogen employed by Hershey was not free from rare gases. Nevertheless, it was thought desirable to determine whether these so-called inert gases had any detectable biological activity in the animal organism.

The problem presented the additional possibility of throwing a light on the cause of death in animals continuously exposed to from 80 to 100 per cent. oxygen for two to five days. Lorrain Smith[5] was the first to point out that fatal pulmonary lesions characterized by edema and finally consolidation took place when animals lived for periods exceeding two to three days in these high oxygen atmospheres. Although Hershey submitted no autopsy protocols of the animals who died presumably in the absence of rare gases, the hypothesis was apparent that perhaps the high oxygen atmospheres achieved a relative exclusion of rare gases. Smith's work was confirmed and amplified by many others[6-9] without affording

[2] F. Reagan, *Univ. Calif. Publ. Zool.*, 28: No. 18, 1926.
[3] J. A. Long, SCIENCE, this issue.
[4] J. Tandler, *Morph. Jahrb.*, 30: 275–373, 1902.
[1] From the Department of Medicine, College of Physicians and Surgeons, Columbia University, and the Presbyterian Hospital, New York City.
[2] J. Willard Hershey, *Trans. Kansas Academy of Science*, 32: 51, 1929; *ibid.*, 33: 133, 1930; *ibid.*, 34: 240, 1931; *ibid.*, 35: 141, 1932. SCIENCE, 71: 394, 1930.
[3] Edward Fidlar, SCIENCE, 72: 296, 1930.
[4] Ramsay, "The Gases of the Atmosphere."
[5] Lorrain Smith, *Jour. Physiol.*, 24: 19, 1899.
[6] L. Hill and J. J. R. Macleod, *Jour. Physiol.*, 29: 492, 1903.
[7] H. T. Karsner, *Jour. Exper. Med.*, 23: 149, 1917.

any explanation of the death of animals exposed to high oxygen except that the lungs reacted as if to an irritant. In the author's investigations of the subject,[8] it was shown that animals (rabbits) were alive and well at the end of three months' residence in 60 per cent. oxygen. There were no demonstrable effects except a decline of approximately 15 per cent. in hemoglobin and red blood cells. However, it was not possible, even after long exposure to this oxygen concentration, to build up a tolerance to 80 to 100 per cent. oxygen. Between 70 and 80 per cent. oxygen, some animals in one to two weeks show edema of scattered alveoli, whereas the lungs of others appear normal. Below 70 per cent. continuous residence in high oxygen atmospheres appears safe and above 80 per cent. uniformly harmful. Whether the rare gases were diluted to an extent that made pure oxygen irritating was considered a hypothesis that was clarified by the experiments which follow.

METHODS

A glass jar of eight liter capacity was employed to house two white mice. Bran, mash and oats were provided as food. Water was administered by an inverted bottle, as shown in the diagram. Water vapor was removed by the presence in the glass jar of 250 cubic centimeters of sulfuric acid. Carbon dioxide was absorbed by soda-lime, four pounds being installed at a time. After the mice were admitted, the jar was sealed with lubriseal. The air within the jar was washed out by running in pure electrolytic oxygen for one and a half hours, at a rate of six liters per minute. Pure nitrogen was then added to make an atmosphere of 21 per cent. oxygen and 79 per cent. nitrogen. Special precautions were carried out in testing the atmosphere to guard against any air contamination. Twice a week the air was changed by the same process without removing the lid of the glass chamber. Once a week the food was replaced and the chamber cleaned, which occupied about fifteen minutes. Daily tests of oxygen and carbon dioxide demonstrated the absence of accumulation of carbon dioxide and the absence of leaks. The oxygen concentration remained constant. The inlet of oxygen was furnished from a spirometer which was in a water and oil seal. Measurements of the total oxygen consumption for twenty-four hours were made on the experimental and on control animals.

RESULTS

In early experiments, the mice died within six or seven days, the glass chamber atmosphere at the time of their death showing a remarkable decrease in its oxygen content. When the animals were found dead in the morning, an apparent oxygen consumption of twice normal was accompanied by a decrease in the oxygen concentration of the atmosphere to about four to six per cent. It was discovered that water had come in contact with the bran mash and that a fermentative process had developed with the production of 30 per cent. carbon dioxide. This accounted for the loss of oxygen and the consequent death of the mice.

In the experiments which were made following this experience, the water was separated from the mash, which was reduced in amount. The fermentative process was thus avoided.

In the first experiment, one mouse was alive on the seventeenth day and one died, the cause of death not discovered. The second mouse was then killed and autopsied.

A second experiment was conducted for thirty-two days, both mice being then apparently well. They were autopsied. A third experiment was carried out, four mice being treated in two separate chambers. All four were living and apparently well at the end of forty days.

The weight of all the animals kept in the chamber showed a gradual gain comparable to control mice in the animal room.

The oxygen consumption which varied for two mice between 3,500 and 4,500 cubic centimeters per 24 hours was not significantly altered before or during the inhalation of the atmosphere in the chamber.

Pathological sections of the lungs, heart, liver and in two animals the spleen, showed no deviation from those of normal mice.

CONCLUSIONS

Oxygen and nitrogen were especially prepared free from the rare gases of the atmosphere to test the hypothesis that rare gases are vital to life. Mice were employed as the experimental subjects. A chamber designed to exclude any air contamination was used to house two mice at a time in an atmosphere containing 21 per cent. pure oxygen and 79 per cent. pure nitrogen. Mice were living and apparently well at the end of forty days. No change was observed in their rate of weight gain, oxygen consumption over 24 hour periods or in the sections of their lungs, liver and heart. No evidence was secured to suggest that the rare gases were necessary to the biological activities of the animal organism.

The cause of death in oxygen poisoning is probably without relation to any dilution of rare gases that might take place in a high oxygen atmosphere.

The author acknowledges the technical assistance of Morris Eckman.

ALVAN L. BARACH

[8] A. L. Barach, *Am. Rev. Tuber.*, 13: 293, 1926.

[9] C. A. L. Binger, J. M. Faulkner and R. L. Moore, *Jour. Exper. Med.*, 45: 849, 1927.