In Table I are shown data from experiments in 2 dogs. These are typical of all our results. There was a decrease in cardiac output after the administration of digitalis with a return toward normal in 5 days. There were also decreases in the size of the heart. These changes in the size of the heart paralleled the changes in cardiac output, that is to say, with decrease in output there was decrease in size. This result is the same as that found by Harrison and Leonard so far as cardiac output is concerned. We injected digifolin in one of our experiments in order to make our results comparable with theirs. The decrease in cardiac output and size of heart was always present 2 hours after the administration of digitalis and occurred irrespective of the heart rate which was sometimes increased and sometimes decreased.

The per cent decreases in cardiac output are greater than the per cent decreases in heart area. This is, of course, expected for the output is a cubic while the area is a square measurement.

We conclude that there is close correlation between volume output and cardiac size in the same dog. When the output decreases this results from the effect of digitalis on the dimensions of the heart, in this case the dimension in the frontal plane. In patients with heart failure a similar comparison between size and output should be instituted; but in this case the relation of length of cardiac muscle fiber to optimum length must no doubt be taken into consideration.

[1] Harrison, T. R., and Leonard, B. W., *J. Clin. Invest.*, 1926, iii, 1.

[2] Fick, A., *Verhandl. physik.-med. Ges. Würzburg.* 1870.

[3] Stewart, H. J., *J. Biol. Chem.*, 1925, lxii, 641.

[4] Robinson, G. C., and Wilson, F. N., *J. Pharmacol. and Exp. Therap.*, 1918, x, 491.

[5] Cohn, A. E., unpublished experiments.

3828

Physiological Action of Cyanide on Protoplasm.

FLOYD J. BRINLEY.* (Introduced by J. H. Bodine.)

From the Zoological Laboratory, University of Pennsylvania.

Since it is known that hydrogen cyanide passes through living membranes very rapidly,[1] it was thought desirable to ascertain whether the toxicity of cyanide is due to its action on the internal

* National Research Fellow in Biological Sciences.

protoplasm or to its effect on the cell membrane. In this study a small species of amoeba of the proteus group was used. Some individuals were immersed in aqueous solutions of hydrogen cyanide or potassium cyanide and others were injected with the same solutions by means of the Chamber's micro-manipulator. The concentrations of cyanide ranged from N/100 to N/3000 and the pH values used were 6.8 and 7.4. The animals were studied under direct-illuminated and dark-field microscopes and the rate of Brownian movement was used as an index of viscosity of the protoplasm.

By means of a micro-pipette, aqueous solutions of HCN and KCN were injected into the amoeba in amounts equal to nearly one half the volume of the animal; the cyanide quickly diffused throughout the protoplasm, producing a decrease in viscosity, as was evident by an increase in the rate of Brownian movement. The organisms recovered and no toxic effect was noticeable. The action of injected cyanide on the protoplasm is not greatly different from that of injected distilled water.

When amoeba are immersed in aqueous solutions of HCN or KCN, the viscosity of the protoplasm is decreased and the animal gradually swells, assuming a spherical form, and Brownian movement within the internal protoplasm is greatly accelerated, indicating a liquefaction. Finally, the cell membrane ruptures and disintegration of the cell occurs. HCN is much more powerful in its action than KCN, even when the solutions are of the same pH value. It is suggested that the swelling of the organism in cyanide is due to an increase in permeability of the cell membrane to water and a simultaneous decrease in viscosity of the protoplasm.

If amoeba are immersed in aqueous solutions of HCN or KCN and the cell membrane torn with micro-dissection needles, the protoplasm flows from the torn surface and a new membrane is formed around the extruded globule of protoplasm, indicating that the internal protoplasm is not injured. The reaction of these individuals is similar to the reaction of those placed or immersed in HCN or KCN. The membrane seems to be stronger and firmer after the animals are immersed in KCN than when they are placed in HCN.

These experiments seem to indicate that cyanides have little, if any, toxic effect on the interior protoplasm of amoeba but are decidedly toxic to the membrane when applied to the surface of the cell.

[1] Brinley, F. J., *Biol. Bull.*, 1927, liii, 5.