II. "On the Tonicity of the Heart and Arteries." By W. H. GASKELL, M.D., Trinity College, Cambridge. Communicated by Dr. MICHAEL FOSTER, Prelector of Physiology in Trinity College, Cambridge. Received March 1, 1880.

The author has made a lengthened series of observations on the heart of the frog and tortoise, both on the entire ventricle and on the apex, supplied, by the help of Roy's* tonometer, with saline solutions or with diluted blood (of rabbit, sheep, or bullock).

That the artificial blood solutions differ in their action on the apex from the frog's own blood in degree only and not in kind, and that consequently Bernstein† is wrong in regarding these fluids as specific stimuli giving rise to rhythmic action, is shown by the following facts.

1. The apex of the frog's heart brought to quiescence after Bernstein's method, will beat spontaneously when the pressure in its cavity is increased by clamping the aortic arches.

2. If while the heart still remains in its natural position within the body, the frog's own blood be replaced by the artificial blood solution, and the ventricle be then nipped by fine forceps, the apex will remain quiescent for an indefinite length of time. As soon, however, as the pressure in the cavity is increased, the apex commences to contract, and beats as long as the heart is distended by the increased pressure.

The conclusions to which the author has been led by his experiments are as follows:—

1. The heart possesses, like the arteries, what may be called tonicity, and the variations in this tonicity play an important part in determining the features of the cardiac beat.

The apex, when first tied on to the cannula, the pressure of the blood solution being kept constant at 10 cm. or less, remains quiescent for some time in the position of greatest relaxation. As, however, the blood solution continues to pass through, the lever of the tonometer rises often very appreciably even before the apex begins to beat. This rise, unless otherwise explained, would seem to show that the first effect of the blood solution has been to bring the apex into a condition which is no longer that of greatest relaxation for that particular pressure.

Further, in correspondence with this raising of tone of the cardiac muscle by the artificial blood solution, is the alteration in the character of the beat.

The first beats, whether natural or artificially produced, which occur while the ventricle is still in a somewhat relaxed or atonic condition in

* "Journ. of Physiology," vol. i, p. 452.

† "Centralblatt f. d. Med. Wissenschaften," 1876, p. 385.

consequence of the operation of being tied on the cannula, are less in height and more pointed in appearance, *i.e.*, remain a shorter time at the height of contraction than those which are obtained after the blood has been passing some time.

2. The tonic condition is in all probability partly due to the alkalinity of the blood.

a. After the ventricle or apex beating with artificial blood solution has been brought to standstill by replacing the blood with "normal" salt solution, then an alkaline salt solution (1 sodium hydrate to 20,000 normal salt solution) causes beats to reappear, and again the ventricle stops beating, but no longer in the position of diastole, the standstill that now occurs is always a systolic not a diastolic standstill.

b. When the ventricle or apex is beating under the influence of an artificial blood solution and the alkaline solution be sent through, then the resulting curve shows how the alkaline standstill is brought about, every contraction is as powerful as with the blood solution, the cavity being closed each time, but every relaxation is less perfect, and of shorter duration than the previous relaxation, while the period of full contraction in each beat is progessively lengthened, the rate of rhythm not being much altered; at last each relaxation becomes invisible, and the lever traces a straight line at the level of the height of full contraction.

c. When the apex is not beating, but is motionless in the position of complete relaxation, as is frequently the case when salt solution alone is sent through, then the alkaline solution brings it very gradually from the position of extreme relaxation to that of extreme contraction without the necessary production of a single beat.

Further, if during this tonic action of the alkaline solution, artificial beats be produced, then, as in the case just mentioned, the time of full contraction in each beat is lengthened as the tonicity rises.

3. Dilute acid solutions, such as lactic acid (1 lactic acid to 20,000 normal saline solution), lower the tonicity of the cardiac muscle.

a. When the lactic acid solution is sent through a beating ventricle or apex, then a curve is produced nearly the exact converse of the curve obtained from alkaline solutions; the separate beats progressively diminish in force, present a pointed appearance, owing to the extreme shortness of the time of full contraction, and very quickly the ventricle or apex remains still in the position of extreme relaxation.

b. When by means of the acid solution the beats have been much lowered in force, then the alkaline solution can bring them back to their original force and character, and then produce its own characteristic effect, and if the acid solution be again sent through, it gradually overpowers the action of the alkali, and the apex or ventricle slowly falls from a condition of extreme contraction to one of extreme relaxation.

c. If the acid solution has brought about a condition of nearly absolute relaxed or atonic standstill, then removal of the acid by salt solution does not improve the beats, and does not raise the tonicity, but immediately the alkaline solution is sent through, the tonicity begins to rise, and the beats are strengthened until the ventricle passes into the condition of systolic or tonic standstill.

d. The reverse case is also true; although salt solution sent through after the alkaline solution will very gradually bring the ventricle from the contracted to the dilated condition, yet the lactic acid solution produces the same effect with much greater rapidity.

e. These very dilute alkali and acid solutions do not produce their effects by permanently injuring the cardiac muscle, for in either case it is possible to restore the beats to their original strength and character by sending the artificial blood solution through.

4. Certain alkaloids act in this respect in the same manner as alkalies, others as acids.

a. Digitalin or antiarin in artificial blood solution or in normal salt solution produce exactly the same effect upon both the beating ventricle and the non-beating apex as the alkaline salt solution.

b. Blood solutions containing muscarin and pilocarpin gradually diminish the force of the beat without necessarily slowing the rate of rhythm until the ventricle stops beating in a condition of relaxation, as in the case of lactic acid solutions; at the same time the beats show all the characters of the atonic beat.

c. Atropin acts in the same direction as alkalies, but only raises the tonicity to a slight extent, at least with the dilute solutions hitherto employed.

5. The tonicity of the muscles of the smaller arteries is increased by alkalies and lowered by acid solutions. This is concluded from the action of the alkaline and lactic acid solutions upon the vessels of the mylohyoid muscle, upon the rate of flow from the abdominal vein when the solutions are sent through the legs alone and upon the mesenteric vessels.

In all cases with the alkali solution the arteries contract, the rate of flow diminishes or ceases altogether, and as long as the alkali solution is passing through the contraction remains; with the lactic acid solution, on the other hand, the arteries dilate to their full extent, the rate of flow is markedly increased, and no constriction takes place unless the alkaline solution be again sent through.

The author reserves for another occasion a fuller description of his results, as well as a discussion of their bearings.