The Effect of the Lability (Resilience) of the Arterial Wall on the Blood Pressure and Pulse Curve.—II.

By Leonard Hill, F.R.S., and Martin Flack.*

(Received March 31,—Read April 10, 1913.)

(From the Physiological Laboratory, London Hospital Medical College, London Hospital Research Fund.)

In a paper published in the 'Proceedings of the Royal Society,' 1913, B, vol. 86, p. 180, Russell Wells and Leonard Hill brought forward evidence to show that the nature of the arterial wall has an important effect in modifying the conduction of the pressure waves from the heart to those arteries where the pulse is usually explored, such, for example, as the radial, where sphygmograms are recorded and readings of arterial pressure taken with the sphygmomanometer. They concluded that the conduction depends on the greater or less "resilience" of the arterial wall, using the term "resilience" to express "the ease with which an elastic tube distends with a rise and recoils with a fall of pressure of the contained fluid"; thus a rubber tube with a wall of 0·2 mm. thick is more "resilient" than one with a wall 0·4 mm. thick, the thinner, more "resilient" tube yields with the rise and recoils with the fall of pressure more than the "harder," thicker-walled tube. A glass tube, in this sense, has no resilience, and the same may be said of rubber pressure tubing. As the arterial wall contains muscle, its "resilience" will be altered by a more or less contracted state, also since the degree of contraction and "resilience" may vary locally it is to be expected that the curve of blood-pressure may likewise vary, *e.g.* in the brachial and in the femoral arteries. We have found this to be the case under certain conditions, namely, in cases of aortic regurgitation.† In such cases the systolic pressure reading for the leg is much higher, 100 mm. or more, than in the arm arteries. Also in normal men a difference in the systolic pressure in the two radial arteries may be observed when the heart is made to beat forcibly by a short period of hard exercise and after one elbow has been placed in hot and the other in cold water. The artery relaxed by heat gives the lower systolic pressure.

Russell Wells constructed a schema by means of which a known rhythmically changing pressure could be passed (1) through rubber tubes of the same calibre, but varying thickness, *e.g.* 0·8, 0·4, 0·2 mm., (2) through various lengths of the

* During tenure of Eliza Ann Alston Research Scholarship.

† L. Hill, with Martin Flack and W. Holtzmann, 'Heart,' 1909, vol. 1, p. 73; L. Hill and R. A. Rowland, 'Heart,' 1912, vol. 3, p. 222.

same tube, (3) through the same tube and same length of tube, but with increasing amplitude. With an entering pressure of 160 mm. systolic and of 40 mm. diastolic, a curve taken with the Hürthle manometer from the 0·8 mm. tube had all the characters of a "low" pressure sphygmogram—great amplitude, sharp rise and fall and very well-marked dicrotic wave; while with exactly the same entering pressure the curve taken from the 0·2 mm. tube took on all the characters of a "high" pressure sphygmogram—slow rise, flat top, slow fall and slightly-marked dicrotism. Using the same tube, it was found that the higher the pressure and the more the "resilience" of the tube was brought into action, the nearer together were the diastolic and systolic pressures at the end of the tube. A length of 30 cm. of 0·2 mm.-thick tube with an entering pressure of 78 mm. Hg diastolic and of 148 mm. Hg systolic gave an almost continuous pressure of 104 mm. diastolic and 107 mm. systolic at its farther end. The same length of 0·8 mm.-thick tube gave a much more discontinuous pressure at its farther end. Lengthening a given tube had a like effect, approximating the diastolic and systolic pressures at its farther end, *e.g.* by increasing the length of a 0·8 mm. tube from 15 to 30 cm. the difference between systolic and diastolic pressures was diminished from 66 to 44 mm.

The use of the word "resilience" in the sense given above is not in accordance with the meaning given to this word by the physicist, and in the discussion which followed the reading of the above paper it was suggested by the President of the Royal Society that the word "lability" might be suitable. We propose to adopt this word and thus free ourselves from the charge of ascribing to "resilience" an equivocal significance. By the "lability" of an artery, then, we mean the ease with which it distends with a rise and recoils with a fall of pressure.

We have investigated the effect of the "lability" of arteries on the pressure curve, (1) by means of a simple schema, (2) by interpolating a length of artery between a Hürthle manometer and the carotid artery when recording the blood-pressure curve in the living animal. The schema consists of a piece of rubber pressure tubing, connected at one end to a Hürthle manometer and branching into two channels at the other end by means of a T-piece. A short length of rubber pressure tubing forms the channel on one side, and an equal length of artery that on the other side. The two channels are connected by another T-piece to a short length of rubber pressure tubing, which is closed at its farther end. This tube is rhythmically pulsed between the thumb and finger, the whole schema being filled with water to a pressure equal to that of the normal arterial pressure. Clamps are arranged so that, in turn, either the rubber pressure tubing or the artery is made to conduct

the pulse to the manometer. We rhythmically pulsed the tube as hard as possible between thumb and finger, so that the pressure curves produced were made of approximately equal amplitude.

Fig. 1 shows the curve obtained—A, when 5 inches of rubber pressure tube conducts the pressure-wave to the manometer; B, when the conduction is by 5 inches of femoral artery (human), all the branches of which have been tied so that there is no leak. The "lability" of this length of artery has a very great effect, as is seen by the diminution of the systolic wave and the absence of "overswing" secondary waves. Fig. 2 shows—A, the curve obtained from the carotid artery of a cat, conducted to the manometer by a 23-cm. length of pressure tubing; B, when the manometer is connected by a 23-cm. length of cat's artery, made up of the aorta together with the part of one carotid and one femoral artery. The arrangement was such that the pulse curve could be transmitted alternately by the rubber pressure tube or by the artery. Fig. 3 shows the effect of transmitting the pressure curve from the carotid of a cat through—A, 8 cm. of rubber pressure tubing; B, through 8 cm. of excised cat's carotid. Fig. 4 shows the effect of transmitting the curves—A, through 6 cm. of rubber pressure tubing; B, through 6 cm. of cat's carotid. Fig. 5 shows that, after hardening the 6-cm. length of carotid artery in alcohol, the same result is obtained as with rubber pressure tubing. Fig. 6 demonstrates the effect of 4·5 cm. of cat's carotid (B) on the conduction of the pressure curve. Even this short length notably alters the curve, particularly in diminishing the dicrotic wave.

Fig. 7 shows the effect of connecting one end of an 8-cm. length of carotid artery, closed at the other end, to the rubber pressure tube through which the pressure curve was being conducted. This brings down the amplitude and approximates the systolic and diastolic pressures just as effectually as if the conduction were wholly through the same length of carotid. Fig. 8—A shows the curve taken from the right and left carotid of a cat. On the right side the cannula was inserted as near the aorta as possible, while on the left side the cannula was inserted as far from the aorta as possible. The dicrotic wave is much less marked in the tracing taken from the longer length of carotid. B shows tracings taken from the right and left carotid, both being as short as possible. There is no noteworthy difference. We give this tracing as a control, to show that the conduction by the length of artery is the factor which makes the difference in A. Fig. 9 shows the pressure curve of the cat taken—A, from the long length of left carotid still embedded in the tissues; B, from the short length of right carotid. In A, the dicrotic wave is less evident, and the curve has a flatter top, but the difference is less than in fig. 8.

Fig. 1.

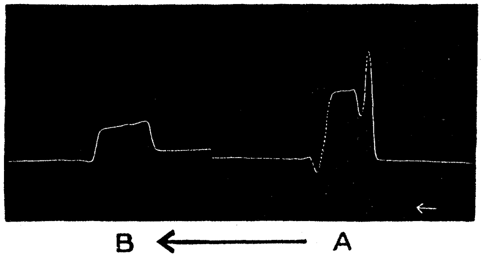

Fig. 2.

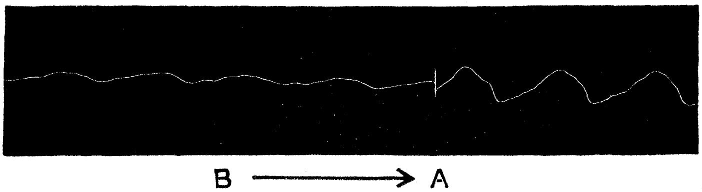

Fig. 3.

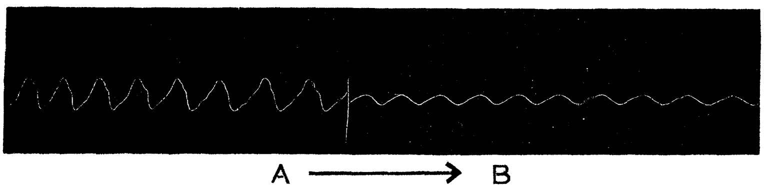

Fig. 4.

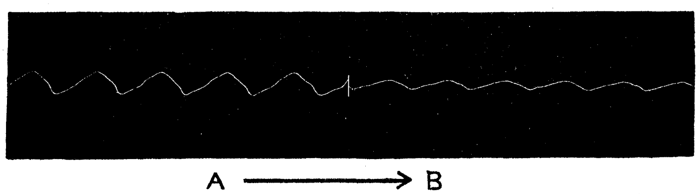

Fig. 5.

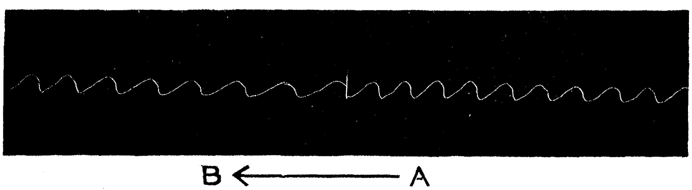

Fig. 6.

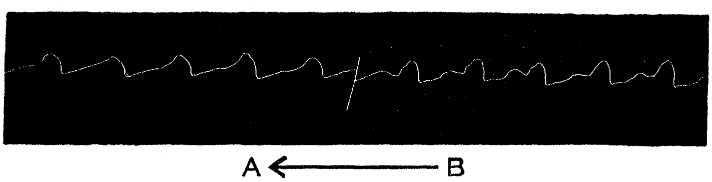

Fig. 7.

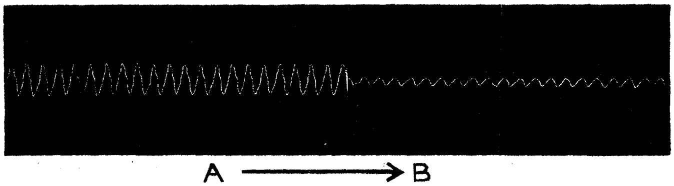

Fig. 8.

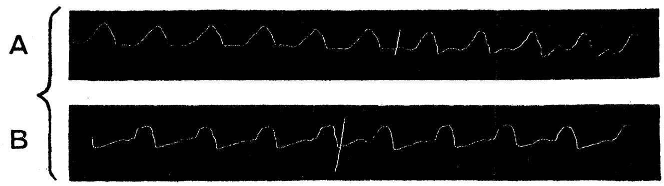

Fig. 9.

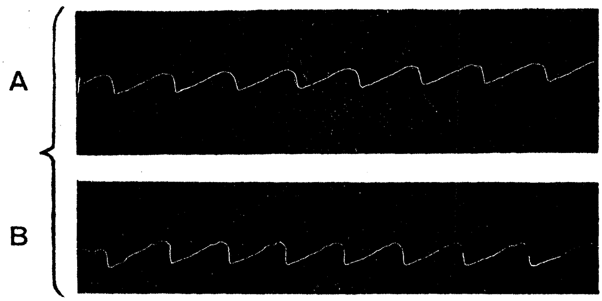

Fig. 10.

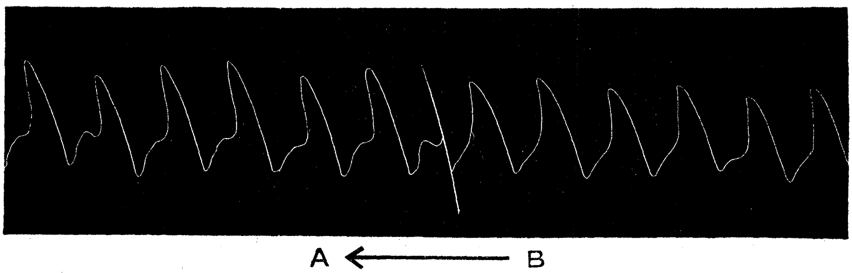

Fig. 10 shows the pressure curve taken from the carotid artery of a dog—A, through the rubber pressure tubing; B, through 5 inches of human femoral artery. The greater approximation of systolic and diastolic pressure and the diminution of the dicrotic wave is evident.

These results confirm our previous conclusion that the nature—"lability"—of the arterial wall notably affects the conduction of the pressure wave, and therefore both the form of the sphygmogram and the readings of pressure

obtained with the sphygmomanometer. Much of the systolic force of the heart is stored as potential energy in the distension of labile large arteries, to be given up again on their recoil during diastole; a part is spent in overcoming their resistance to distension; the greater the lability the less will be the amplitude of the systolic wave which reaches the peripherally placed arteries; the higher also will be the diastolic wave, the closer the approximation of the diastolic and systolic pressures, the less marked the dicrotic wave.

It follows from these considerations that, supposing the force of the heart remains constant, what has been termed a "high" or a "low" pressure form of sphygmogram does not depend only on the resistance in the arterioles, but may be obtained according to the greater or less "lability" of the conducting arteries—*e.g.* aorta—subclavian—brachial—radial. So, too, will the readings of systolic and diastolic pressure vary with the "lability" of the conducting arteries. Observations on cases of aortic regurgitation have shown us that the systolic readings may be 100, even 150, mm. Hg higher in the leg than in the arm arteries. This great difference is entirely due to conduction modified by the "lability" of the arteries. The arm arteries in such cases are more "labile" than the leg arteries—the latter are contracted, "harder," more rigid, and conduct the systolic wave from the aorta with far less diminution of force. This is to ensure a circulation through the capillaries of the leg, to compensate for the great fall of diastolic pressure. By local modification of the contractile state of the arteries either the full hammer-like stroke of the heart may be delivered to the capillary vessels with a wide variation between the systolic and diastolic pressures, or a more uniform pressure be conveyed with the systolic variations of pressure approximated.

In reading the systolic or diastolic pressure by means of the sphygmomanometer we read, not the actual pressure produced by the heart, but this pressure as conducted by the arteries to that artery selected for observation. In the normal young man, placed in the recumbent posture, the arteries so conduct, that approximately the same readings are obtained in the arm and in the leg arteries. The contraction of the muscular coat of the arteries is controlled so as to effect this. In cases of aortic regurgitation the conduction is widely different. A similar difference may also pertain in conditions of functional activity, *e.g.* the leg arteries may be more contracted and give higher readings of systolic pressure after running up a flight of stairs. High readings of systolic pressure do not necessarily indicate any greater systolic force exerted by the heart. They may indicate, and probably often do indicate, less "lability"—arteries held in the contracted state so as to conduct the systolic wave with almost undiminished

force. The character of pulse curves, taken either with a Hürthle or other spring manometer, placed in direct communication with an artery, or by means of the sphygmograph, depends very largely on the "lability" of the conducting arteries. It is arterial "lability," not reflection of waves, which modifies the form of the pulse curve taken in different arteries. While the pressure waves produced by the heart may remain the same, the form of the sphygmogram may be altered, and what has been termed a "high" or a "low" pressure curve may be produced by variation in the "lability" of the conducting arteries. The wall of an artery is supported by the surrounding tissues and skin, the whole being permeated with blood; it will be a matter for further consideration as to how far the lability is affected by the condition of the surrounding tissues. Comparison of figs. 8 and 9 shows how large a part the tissues normally take in supporting the arteries.

On the Probable Value to Bacillus coli *of "Slime" Formation in Soils.*

By Cecil Revis.

(Communicated by Sir J. R. Bradford, K.C.M.G., Sec. R.S. Received April 8,—Read April 24, 1913.)

During the course of an investigation into the causes of variation in the physiological activity of *Bacillus coli*, a number of experiments were started, in which soils, either virgin or mixed with cow dung or human excreta, were inoculated with cultures of *B. coli*, together with cultures of various soil organisms so different from the colon organism that they could not be mistaken for it on plating out. The requisite quantity of soil was placed in a layer about ¾-inch deep in large flat litre-bottles, and the cultures were added in the form of emulsions in physiological salt solution, made from agar slopes. Sufficient water was also added to make the soil visibly moist. The bottles were closed with cotton-wool plugs and kept at ordinary room temperature in the dark. Controls which were inoculated with all the organisms except the *B. coli* were started at the same time. The soils were examined from time to time by withdrawing about 5 grm. by means of a sterile tube, shaking this up with 50 c.c. of sterile water, spreading plates directly on to ordinary agar and incubating at 20° C.

It was found very difficult to isolate the *B. coli* in this way because of the rapid and expansive growth of the other organisms present, and because the