attended division of the facial artery, in the two cases in which it was wounded,—a circumstance quite peculiar, when contrasted with what occurs after division, by missiles, of arteries in other parts of the body. This, I believe, is owing to the artery being cut, not torn, as in other injuries, and may be owing to its being divided *on* the bone; but it is probably more often owing to the bone being first fractured, and the sharp edge cutting the artery, as with a knife. Certainly the hæmorrhage is most alarming, and in case No. 3 it seemed to have nearly proved fatal, although I saw the patient immediately after the injury, on the spot where he fell.

(*To be continued.*)

ARTICLE IV.—*On the Alteration of Pitch of Cardiac Murmurs by Conduction through the various Media composing the Thoracic Organs and Walls.* By SYDNEY RINGER, late Physician's Assistant at University College Hospital.

IN a paper published in the Proceedings of the Royal Society,¹ I have endeavoured to show that the pitch of sound is altered by conduction. The nature of the alteration varies with the conducting medium. The following is a summary of the conclusions there arrived at by experiment:—

That porous substances, such as wood or bone, lower the pitch in proportion to their porosity. All other solids, such as iron and glass, raise the pitch.

Fluids raise the pitch.

Fluids in motion raise it more than fluids at rest.

Solutions in water raise it more than pure water, and in proportion to the strength of the solution.

Minute particles suspended in water raise it more than either pure water or solutions.

Gases raise the pitch slightly.

The heart's substance lowers the pitch.

Cellular tissue raises it.

All the above altered the pitch in proportion to the amount of the conducting medium listened through.

In the following paper it is intended to explain the alterations in pitch in cardiac murmurs by conduction by the above principles; but as these alterations in pitch have not hitherto been noticed, it is necessary first to state them.

¹ *Proceedings of the Royal Society*, Jan. 26, 1860.

When a murmur, conducted either through the heart's substance or the sternum, is listened to, the pitch is found to be lower than at the point of production. Thus an apex murmur is found to have its pitch lowered when listened to at either the ensiform cartilage or at the base of the heart; whilst a base murmur is found to be lowered in pitch when listened to at the apex or ensiform cartilage.

Should there, however, be effusion into the pericardium, the very reverse takes place of what is stated above; the pitch being then raised, instead of lowered, at the different points named.

Again, a murmur generated at the base, at either orifice, is found to have its pitch raised at the second cartilage to which the vessel in which the murmur is generated runs; whilst, on the other hand, it is notably lowered at second cartilage on the opposite side. Thus, should it be an aortic murmur that is being listened to, the pitch is found to be heightened at the second right, and lowered at the second left cartilage. Should it be a pulmonary murmur, the reverse is the case.

Any murmur heard through the medium of air-containing lung is found to have its pitch heightened by the conduction.

The cause of the lowering of the pitch when heard through the medium of the sternum, or heart's substance, is explained by the property they possess of lowering pitch by conduction, which has been shown to be the case in the paper I have alluded to.

In effusion into the pericardium, it has been said that the pitch is raised, instead of being lowered, as in the above case. This is due to the property fluids have of raising the pitch, and was well illustrated in the following case:—A patient suffered from extensive effusion into the pericardium; also from a loud mitral regurgitant murmur. The pitch of this was found to be higher at the base and at the ensiform cartilage than at the apex. As the fluid became absorbed, as ascertained by percussion dulness, so did the distance to which the pitch was raised, beyond that again falling. Thus, when the fluid reached as high as the second rib, the pitch was found to be raised to that point; but when it fell to the third rib, the pitch was still found to be raised as high up as this; but, on listening higher still, the pitch fell again. After the fluid was considerably absorbed, the only direction in which the pitch was raised was in passing inwards to the ensiform cartilage (the patient being in the erect posture). On placing the patient in the recumbent posture, and depressing the upper part of the chest, at the same time elevating the lower, thus causing the fluid to gravitate away from the apex and ensiform cartilage, the pitch was found to be lowered in passing to the ensiform cartilage. On restoring the patient to her first position, the pitch again became higher at this point than at the apex.

The elevation of the pitch of a basic murmur at the second cartilage, to which the vessel generating it runs, is also due to the fluid in

the vessel. It may be objected that the distance is too short; and also that, as the blood is in motion, the murmur would be carried, and not conducted, by the fluid. The following experiments, however, show that these objections are not valid:—

Into an india-rubber tube, 13 inches long and $\frac{3}{4}$ ths of an inch diameter, a funnel was inserted. Immediately below this a small opening was made, just large enough to admit the end of a tuning-fork. Water was kept constantly running through this, and the stethoscope (covered with a diaphragm) was applied to different parts of the tube. By this method, the pitch was found to be most appreciably raised the further from the fork the stethoscope was applied to the tube. The elevation of pitch was easily recognised at a distance of $2\frac{1}{2}$ inches. Next, an aorta was tied to the mouth of a tap, and an artificial murmur produced by causing a constriction of the vessel by a piece of twine tied round it. The pitch of the murmur so produced was decidedly raised the further it was heard along the vessel from the point where the sound was generated. It was easily appreciated at a distance of $2\frac{1}{2}$ inches.

To set the question quite at rest, a tourniquet was placed over a man's femoral artery, immediately below Poupart's ligament, and an artificial murmur thus produced; this was found to rise in pitch in passing down the course of the vessel. A well-marked difference was noticed at a distance of $2\frac{1}{2}$ inches. The intensity of the murmur quickly diminished in passing to the right or left of the vessel, the pitch being at the same time rapidly raised, which was due to the interposition of the integuments; but this interposition could not be the cause of the rise of the pitch in the course of the vessel, as the murmur could be heard in that direction at a distance of at least 6 inches, whilst it was completely lost at a distance of 2 inches to either side of the vessel. Thus the murmur must have been conducted by the blood; whilst the same thickness of integuments was over the artery at the lower as the upper point listened to, for both points were above the place where the sartorius muscle crosses it. Indeed, in the paper alluded to, I have shown:—

1. Fluids at rest raise the pitch.
2. Fluids in motion still more.
3. Solutions raise it more than water.
4. Fluids holding minute particles in suspension raise it still higher. Now all these conditions are found in the blood.

The reason the pitch is lowered when the murmur is listened to at the second cartilage opposite to that to which the vessel producing the murmur runs, is, that it is conducted through the sternum, which has been shown to lower the pitch.

In passing up to the sternal notch, the pitch of a basic murmur is found to rise. Here, probably, two causes act:—First, the vessel which conducts the sound is nearer this point; and, secondly, lung

to some extent intervenes, which raises the pitch, gases having this tendency.

It has been stated above, that a murmur heard through lung is found to have its pitch raised. This is due to the air it contains. This has been proved elsewhere, but the following experiment also shows it. A patient presented himself with a loud mitral murmur, audible over the entire chest. A point where much lung, and only lung intervened, was chosen, and the stethoscope applied to this point. The patient was directed first to expire deeply, and the pitch ascertained. He was then told to inspire to the utmost, and retain it, whilst the pitch was again ascertained; and under the last condition it was found most appreciably raised. The only altered condition here was an increase in the amount of intervening air.

The following is the diagnostic application of the above facts :—

When a murmur is very intense, it is audible over the entire heart region, often rendering it difficult to decide whether there is but one murmur audible at the other orifices merely by conduction, or whether two original murmurs exist. The point of greatest intensity will decide one; and, if percussion dulness excludes the possibility of fluid in the pericardium, and the pitch of the less intense murmur heard at the other orifices be higher than that of the most intense, this is indubitable proof of the existence of a second murmur.

In cases where tumours simulate in their percussion dulness, fluid in the pericardium, should a murmur exist, the tumour being solid would probably lower the pitch; should it be however fluid, the pitch would be raised by conduction through it. Again, it is often difficult to decide whether a basic murmur be aortic or pulmonary, or both; it being heard with equal intensity at both second cartilages. If aortic only, the pitch will be heightened at the second right cartilage, but lowered at the second left, and *vice versa* in the case of a pulmonary murmur; whilst, should both exist, the pitch will be heightened at both cartilages.

In conclusion, I beg to thank Dr Wylde, the conductor of the Philharmonic Society, for kindly examining and corroborating many of the experiments devised to elucidate this matter; and also Dr Hardie of Leith, who greatly assisted me in conducting the same.