THE LUMLEIAN LECTURES ON THE MUSCULAR ARTERIOLES:

THEIR STRUCTURE AND FUNCTION IN HEALTH
AND IN CERTAIN MORBID STATES.

Delivered at the Royal College of Physicians of London.

By GEORGE JOHNSON, M.D., F.R.S.,

Fellow of the Royal College of Physicians; Professor of Clinical Medicine and Senior Physician to King's College Hospital; etc.

LECTURE II.—*Concluded.*

The Relation between Renal Disease and Hypertrophy of the Heart.—Various Hypotheses.—Hypertrophy of the Muscular Arterioles: its Relation to Renal Disease and to Cardiac Hypertrophy.—Results of Arterial Tension in Bright's Disease. 1. Degeneration of Arterial Walls. 2. Cerebral Hemorrhage. 3. Reduplication of the First Sound of the Heart: its Cause and its Practical Significance.

I HAVE already referred to the hypertrophy of the left ventricle as an intelligible physiological result of the more forcible muscular effort required to propel the blood through the resisting arterioles. During the progress of the cardio-vascular changes, it happens not unfrequently that the walls of the large arteries undergo more or less of structural change. They become thickened and indurated, and, as a result of these textural changes, their elasticity is more or less impaired. These structural changes in the walls of the larger arteries may be partly caused by the excessive strain to which they are subjected under the influence of the high tension resulting from the antagonism between the resisting arterioles and the hypertrophied ventricle. It is a matter of common observation, that the walls of the arch of the aorta not unfrequently have their texture injured and their elasticity impaired by the forcible distension to which they are subjected when, in consequence of incompetence of the aortic valves, the left ventricle has become much dilated and hypertrophied.

In part, perhaps, the arterial degeneration in cases of Bright's disease may be excited by the morbid quality of the blood which they are continually transmitting—the same morbid quality of blood as that which not uncommonly sets up inflammatory changes in the lining or the investing membrane of the heart itself. Whatever may be the determining cause of the structural changes in the larger arteries, it is certain that, since the elasticity of the large arteries is a force which aids the heart in propelling the blood onwards, the loss or impairment of that elasticity must add to the work of the heart, and thus tend to increase the hypertrophy of the left ventricle. Hence the resistance to the blood-current resulting from the excessive contraction of the muscular arterioles is still further increased by the not infrequent complication of degeneration of the walls of the large arteries.

Dr. Galabin, in the pamphlet before referred to, has shown, from a comparison of the *post mortem* records at Guy's Hospital, that hypertrophy of the left ventricle is more frequently associated with granular kidney and healthy large arteries than with atheromatous arteries and healthy kidneys. He also shows that the hypertrophy of the ventricle, which results from degeneration of the arteries alone, is less in amount than that which is often associated with disease of the kidney while the large arteries are healthy. This result might have been inferred from the experiments on apnoea referred to in my last lecture. For, since it has been proved that the combined force of contraction in the muscular arterioles is greater than that of the ventricle, it is evident that the contracting arterioles would impede the circulation, and so add to the work of the ventricle in a greater degree than the degeneration and impaired elasticity of the large arteries.

In the advanced stages of renal degeneration, some of the muscular arterioles may undergo degenerative changes, partly perhaps due to the impure blood which they transmit, and partly to the excessive strain to which they are subjected by the forcible contraction of the hypertrophied heart. In the so-called lardaceous form of renal disease, the muscular arterioles very early undergo this degenerative change, and, their contractile power being thus impaired, they are unable to regulate or to impede the circulation. Hence it happens that hypertrophy of the heart is rarely associated with this lardaceous form of disease.

Amongst the accidental injuries which result from the high arterial tension associated with renal disease, one of the most frequent and most serious is the occurrence of *rupture of one or more intracranial arteries*, and consequent hæmorrhage into the substance or on the surface of the brain. It has been a debated question with some writers on cerebral hæmorrhage, whether the occurrence of that accident is favoured by hypertrophy of the left ventricle. When hypertrophy of the heart is a result of disease of the aortic valves, or of degeneration with impaired elasticity of the walls of the large arteries, it is generally no more than sufficient to overcome the impediment thus offered to the circulation. The strength of the left ventricle, therefore, in such cases is not a true measure of the force with which the blood is sent into the distal arteries. On the contrary, it is a measure of the difficulty with which the blood is transmitted through the primary branches, and, therefore, through the entire system of arteries. When hypertrophy, thus originating, is associated, as it sometimes is, with cerebral hæmorrhage, the reason is that the hypertrophy and the hæmorrhage are joint results of one common cause, namely, degeneration pervading more or less extensively the arterial tree. The hypertrophy of the left ventricle is a consequence of degeneration of the aorta and its primary branches. The cerebral hæmorrhage is a consequence of a similar degeneration of the arteries of the brain.

The state of the circulation is very different when the left ventricle has become hypertrophied, in consequence of the impediment resulting from contraction of the hypertrophied muscular arterioles in connection with degeneration of the kidney. In this state of things, while the arterial stopcocks are resisting the passage of the morbid blood, the strong left ventricle is forcibly driving it onwards. There is thus an excessive strain upon the whole length of the arterial pipes, between the stopcocks and the cardiac forcing-pump. One of the bits of arterial tubing being overstretched, becomes brittle, and breaks; then the powerful ventricle forces the blood through the ruptured artery into the yielding tissue of the brain, and a rapidly fatal sanguineous apoplexy is the result. It is a well known fact that some of the most formidable cases of cerebral hæmorrhage are those which are associated with granular contraction of the kidney.

Here it may be convenient to discuss the phenomena called *reduplication or doubling of the first sound of the heart*, which many observers have noted as being one of the most frequent results of the high arterial tension associated with various forms and stages of Bright's disease. Dr. Sibson devoted much time and labour to the investigation of this physical sign of arterial tension, and he discussed it at length in his Lumleian lectures. He explains the reduplication of the first sound by stating that the left ventricle, owing to the resistance offered by the tight arteries to the expulsion of its contents, continues its contraction later than the right, which has expelled its blood into the pulmonary artery with comparative ease. The shock of the first sound is heard at the end of the contraction of the ventricle. Hence, in consequence of the left ventricle contracting more tardily than the right, there is a doubling of the first sound.

Dr. Sibson admits that there is a difficulty in reconciling this explanation of doubling of the first sound with the absence of doubling of the second sound in the same cases. If the left ventricle contract more slowly than the right, so that the sound of the two ventricles is separated by an appreciable interval, it would seem that the aortic valves must close later than the pulmonary, and there should be a double second as well as a double first sound. Dr. Sibson endeavoured to meet this difficulty by the following argument. "In these cases, the systemic arteries are always in a state of great tension. When the blood ceases to be sent into the tight aorta, the instant contraction of the walls of the arteries sends the blood back upon the aortic walls and valve. The pulmonary arteries, at the commencement of the systole, are comparatively flaccid, but become tense at the end of it. The walls of the pulmonary artery begin to contract and send back a return wave again upon the trunk of the artery; but, as these walls are not always in a state of tension, they take a longer time to contract than those of the aorta and its branches. Owing, therefore, to the slowness of the pulmonary and the quickness of the aortic contraction, the latter, which is already heavily handicapped, makes up in speed what it loses in time, and the two systems of arteries deliver their back-stroke at the same instant."

Now, it seems to me that this explanation, while it apparently removes one difficulty, raises another of a very formidable character. If the greater tension of the aorta, in the cases of renal disease under consideration, enable it to overtake the earlier but less rapidly and forcibly contracting pulmonary artery, it seems obvious that, in the normal condition, when the aorta and the pulmonary artery commence their elastic contractions at the same instant, the much greater tension of the aorta, with its thicker and stronger walls, should react

upon and close its valves before those of the more feebly contracting pulmonary artery are closed, and the result would be reduplication of the second sound as a constant and normal condition. During the last two years, since my attention has been particularly directed to this subject, I have met with numerous instances of an analogous doubling of the first sound in cases of general emphysema of the lungs, with impeded pulmonary circulation and resulting fulness and hypertrophy on the right side of the heart. In these cases, the increased tension of the pulmonary artery consequent on the obstruction in the lungs can never equal the normal tension of the aorta. However great may be the hypertrophy of the right ventricle in cases of emphysema, the thickness of its wall is never equal to that of the left ventricle. If, then, in accordance with Dr. Sibson's theory of asynchronous ventricular contraction, the right ventricle, in consequence of increased tension in the pulmonary artery, complete its contraction later than the left, and thus cause the doubling of the first sound, the closing of the pulmonary valves must inevitably be effected later than that of the aortic, and the second sound must also be doubled. The reverse, however, is the case. The second sound is single in these cases of emphysema, while the first is distinctly reduplicated.

There are anatomical difficulties in the way of accepting the theory of an asynchronous contraction of the ventricles in explanation of doubling of the first sound. The muscular fibres of the two ventricles pass from one side to the other and interlace in such a manner as appears to render the synchronous contraction of the ventricles a physical necessity. And, in watching the exposed heart of a living animal in the different stages of apnoea—first, in the stage of systemic obstruction, with distension of the left cavities, and later, during the period of pulmonary obstruction, with great distension of the right cavities and comparative emptiness of the left—I have particularly observed the uninterrupted exact synchronism of the contractions on the two sides.

A consideration of the difficulties which present themselves in relation to Dr. Sibson's theory of reduplication of the first sound in connection with Bright's disease led me to seek for another explanation of the phenomena;* and last year I ventured publicly to suggest that the true explanation is to be found in the fact that *the contraction of a dilated, and especially of an hypertrophied auricle becomes audible, and thus the first division of the double first sound in the cases under consideration is the result of the auricular systole*. I believe that this explanation of reduplication of the first sound will be found consistent with all the ascertained facts. I was led up to this explanation by observing that the rhythm of the heart's sounds in cases of reduplication is precisely the same as that of the triple pericardial friction-sound which may often be heard in cases of pericarditis, the first element of the triple friction-sound being caused by the systole of one or both auricles roughened by lymph.

This triple pericardial friction-sound may require here a few words of explanation. For some years past, when describing the friction-sound of pericarditis, I have been in the habit of speaking of it as not merely double—to-and-fro—but, in a large proportion of cases, as triple, a third sound often intervening somewhere between the other two. I said "somewhere", because until recently I could not tell at what period of the heart's revolution the third sound occurred. I got the first hint towards the solution of the problem from a very interesting clinical lecture published by the late Dr. Hyde Salter (*Lancet*, July 29th, 1871, p. 151). In that lecture, Dr. Salter described a case of rheumatic pericarditis, in which a friction-sound double over the mid-sternum became triple over the right third intercostal space, close to the sternum; and, as this triple character of the friction-sound was most marked when the stethoscope was placed directly over the right auricle, Dr. Salter said: "I feel no doubt that the third element of the sound, on passing from the surface of the ventricle to that of the auricle, is due to auricular pericardial friction." This patient recovered.

In a second case of renal pericarditis related by Dr. Salter, a single pericardial friction-sound of distinctly presystolic—that is, auricular systolic—rhythm was heard over the third costal cartilage, about an inch to the left of the sternum; and, the patient dying a few days afterwards, the left auricle was found covered and roughened by lymph. "The roughening was confined to the surface of the auricle, and, therefore", Dr. Salter remarks, "the friction-sound coincided with the movements of the auricle."

Not long after the publication of Dr. Salter's lecture, a man was admitted under my care with granular kidney in an advanced stage. A few days after his admission, I noted a presystolic friction-sound, most distinct between the left nipple and the sternum; and, as the

sound was evidently synchronous with the auricular systole, I stated at the bedside that it was probably caused by recent lymph on the surface of one auricle. Three days later, in addition to the presystolic friction before noted, there was a systolic friction-sound heard most distinctly over the apex of the heart, just to the left of the mammary line, the heart being enlarged. I then expressed my belief that, besides the roughening of the auricle by lymph, there was a patch of lymph near the apex of the ventricle. In the course of about a month, first the presystolic friction ceased to be heard, and then the systolic friction ceased and was replaced by a systolic blowing murmur at the apex. The patient died after being rather more than two months in the hospital; and, at the inspection, we found, as we had expected, that the right auricle and the apex of the right and left ventricles were covered by lymph, the smoothing down of the surface of which by friction accounted for the cessation of the friction-sounds which were distinctly audible when the surfaces were roughened by recent exudation. The margins of the mitral valve were thickened by lymph, and thus the regurgitant mitral murmur was explained.

And now, having learned from the study of Dr. Salter's recorded cases, and from the observation of this one case under my own care, that an auricle covered by lymph may cause a friction-sound of presystolic rhythm, I saw that in this sonorous influence of the contracting auricle was to be found the interpretation of the triple friction-sound of pericarditis with which I had long been familiar as a clinical fact, although I had not heretofore been able to explain it.

When the general surface of the heart, including both auricles and ventricles, is covered by recent lymph, the friction-sound is distinctly triple, *rub-rub-rub*, reminding one, as Dr. Salter says, of the triple sound of a canter. The first two divisions of the triple sound occur in quick succession, the third after a longer interval; then follows a pause, and again the *rub-rub-rub* occurs. Now, if, while we are listening to this triple sound, we place our finger over the heart's apex, or over one carotid artery, and at the same time bear in mind what we have seen of the rhythmical contractions of the exposed heart of a living or a recently dead animal, we can readily perceive that the first element of the triple sound is auricular systolic, the second ventricular systolic, and the third ventricular diastolic; while the silent interval which follows coincides in time with the post-diastolic pause. The relation of the triple friction-sound to the heart's movements may be represented as follows.

Rub	}	Auricular systole.
Rub		Ventricular systole.
Rub		Ventricular diastole.

Rub	}	Auricular systole.
Rub		Ventricular systole.
Rub		Ventricular diastole.

I have thus briefly referred to the triple friction-sound of pericarditis, for the purpose of pointing out that the rhythm of the heart's sounds in a case of reduplication of the first sound is precisely the same as that of the triple friction-sound. The triple friction-sound being represented by *rub-rub-rub*, the triple sounds in a case of reduplication may be expressed by *rat-tat-tat*. The cauterizing character of the sounds may be imitated by bringing down sharply upon the table in quick succession the ends of three flexed fingers, making the two first taps nearer together than the second and third. The friction-sounds are longer and more nearly continuous, but I repeat that the rhythm is precisely the same in the two classes of cases. The relation of the triple sound to the heart's movements may be represented as follows.

Rat	}	Auricular systole.
Tat		Ventricular systole.
Tat		Ventricular diastole.

Rat	}	Auricular systole.
Tat		Ventricular systole.
Tat		Ventricular diastole.

The reduplication of the first sound in cases of Bright's disease is usually heard most distinctly between the mamma and the sternum in the third left intercostal space; that is about the line of junction between the auricle and ventricle. The sound may be single or indistinctly double at the apex, while it is decidedly double at the third in-

* A Clinical Lecture on Triple Pericardial Friction-Sound, and on Reduplication of the First Sound of the Heart (*Lancet*, May 13th, 1876).

terspace and again single over the aorta. This statement of the position in which the reduplication is best heard accords with Dr. Sibson's account; but our explanations differ essentially. He states that, in this position, the asynchronous contraction of the two ventricles is best heard, while I maintain that the contraction of the tense, dilated, and often hypertrophied auricle is there heard immediately before the sound of the ventricular systole.

The question then arises, Does the contraction of the auricle afford a satisfactory explanation of the first division of the reduplicate sound? I believe that it does. It is of course admitted that in the normal state the contraction of the auricle, contrary to Laennec's original theory of the heart's sounds, is inaudible; but we have positive evidence of sound resulting from the auricular systole in two distinct morbid states. First, as a result of constriction of the mitral orifice, we have the now well-known presystolic—or, as Dr. Gairdner happily designates it—the auricular systolic mitral murmur. In these cases, the impediment resulting from mitral constriction causes a slow but forcible auricular systole with a resulting presystolic, that is, preventricular systolic murmur, followed by a short first sound, the result of rapid contraction of the partially filled left ventricle. Second, when the surface of an auricle is roughened by lymph, there occurs the presystolic, or rather the auricular systolic friction-sound. Third, as a result of obstruction in the systemic arteries, and consequent distension of the left auricle, either with or without hypertrophy of its walls, we have, as I believe, an audible auricular systole, constituting the first division of the reduplicate first sound in cases of Bright's disease. The rhythm of this auricular systolic sound—its place in the heart's revolution—is precisely the same as that of the auricular systolic mitral murmur, and of the auricular systolic pericardial friction-sound; and this identity of rhythm in the three classes of cases affords one of the strongest proofs that the sound in each case is caused by the auricular systole. The triple friction-sound of pericarditis, and the triple sound associated with doubling of the first sound, are alike suggestive of a canter.

I have before stated that the reduplication of the first sound occurs not only in connection with Bright's disease, but it is very commonly associated with the impeded pulmonary circulation resulting from advanced general emphysema of the lung. I have observed it frequently in elderly persons with degeneration and rigidity of the arterial walls; also very distinctly above and to the right of the left nipple in some cases of mitral regurgitation. There is one feature which is common to all these cases, and that is an impeded circulation either pulmonary or systemic, and the obstruction acting backwards causes distension, and by degrees hypertrophy of one or both auricles. It is obvious that an impediment commencing in the systemic arteries, or on the left side of the heart, may by a retrograde influence extend through the lungs to the right cavities of the heart.

In some cases of coexisting emphysema of the lungs and chronic Bright's disease, both sides of the heart become simultaneously hypertrophied, and the reduplication of the first sound is distinctly heard over an extensive surface. During the last year I have seen several examples of this complication. It is obvious that the theory of asynchronous ventricular contraction entirely fails to explain the reduplication which results from a simultaneous—equal or nearly equal—impediment in the systemic and in the pulmonary vessels. An equal retardation of the two ventricles would not throw one behind the other. But the auricular theory completely explains the phenomena. That a distended and especially an hypertrophied auricle should produce sound by its contraction, is quite consistent with what we know of the causation of the normal sounds of the heart. While the first sound is caused by the tension of the ventricular walls and the auriculo-ventricular valves during the systole of the ventricle, the second sound results from the sudden tension and vibration of the arterial valves and walls during the diastole of the ventricle. In like manner, it is maintained that when, in consequence of excessive arterial pressure, there is great distension of the heart's cavities, the tense auricle contracts audibly and causes the earlier division of the double first sound, the double sound being the result of the auriculo-ventricular systole.

That the contraction of the terminal muscular arterioles, excited by blood-contamination, the result of renal disease, should act backwards through the systemic arteries and the left ventricle and auricle, so as to cause an appreciable modification of the heart's sounds, and ultimately hypertrophy of the muscular tissue of the propelling heart and of the resisting and regulating arterioles, is an interesting illustration of the correlation of physiological forces and of the intimate relation between physiology and pathology.

In confirmation of the explanation which I have given of the so-called reduplication of the first sound, I may mention that, after I had written the lecture in which I first publicly propounded this theory, my

attention was directed to a recently published thesis by Dr. Exchaquet of Paris, entitled *D'un Phénomène Stéthoscopique propre à certaines Formes d'Hypertrophie du Cœur*, in which I found that my explanation of the phenomena had been anticipated.

The author of the thesis gives the results of numerous observations made by his teacher M. Potain on that modification of the heart's sounds which Dr. Sibson called reduplication, but which the French observers designate *bruit-de-galop*. Dr. Exchaquet quotes Dr. Sibson's Lumleian Lecture, raises various strong objections to his theory of asynchronous ventricular contraction, and maintains that the pre-systolic element of the double first sound is caused by an *abnormally energetic and forcible contraction of the left auricle*. I was much interested to find that my explanation, arrived at quite independently, had thus been anticipated and confirmed by M. Potain, who points out that, when the chest is not thickly covered by fat, the pre-systolic contraction of the auricle may be seen and felt in the third left intercostal space, where, in the same cases, the *bruit-de-galop* is also most distinctly heard.

I find, however, that M. Potain looks upon this modification of the heart-sounds as being almost invariably associated with certain forms of albuminuria. As an exaggeration of a normal phenomenon, he has observed it to a very slight degree, and as a transient condition in persons free from organic disease and from functional disorder of any kind; but when the *bruit-de-galop* is pronounced and permanent, he believes it to be invariably associated with albuminuria and resulting distension of the left auricle; and, in fact, he looks upon this acoustic sign as diagnostic of certain forms of albuminuria. The author makes no reference to the very frequent association of the *bruit-de-galop* or doubling of the first sound with emphysema, and other conditions, resulting in an impeded circulation through the lungs, and consequent distension of the right auricle, but often unassociated with albuminuria: a class of cases of very common occurrence to which I have directed attention in this lecture.

The reduplication of the first sound, upon the interpretation of which I have dwelt so long, is not without its practical prognostic significance and value, in so far as it affords undoubted physical evidence that the impediment to the circulation, whether in the pulmonary or in the systemic vessels, is acting backward through the ventricle upon its associated auricle, and is causing some degree of auricular dilatation and hypertrophy; and, on the other hand, the cessation of the reduplication, as, for instance, in some cases of acute and transient Bright's disease, is evidence of returning freedom of the circulation, and is thus far of favourable omen.

Again, it is obviously important to observe and study this peculiar modification of the heart-sounds with sufficient care to distinguish it from any form of valvular murmur. I do not doubt that a modification of reduplication, by which the two first elements of the triple sound are blended together, so as to give the first sound of the heart a prolonged character, has often been mistaken for the murmur of mitral regurgitation; and this error of observation has been made the basis of an alarming, but wrong, prognosis. I scarcely need add that our interest and our duty alike prompt us to avoid so serious a mistake.

AN ANOMALOUS CUTANEOUS ERUPTION IN VARIOLA.

I WISH to call attention to two cases of variola lately under my care, in which the first appearance of any eruption was a symmetrical erythema of the flanks and loins. In one of the cases, which was confluent and very severe, the true papular eruption seemed to commence just above the erythematous patches and spread upwards, and, contrary to the usual rule, appeared on the face last. The most curious point, however, about this case was, that the erythematous patches, after becoming more livid, gradually returned to the normal colour of the skin, which they attained on the eighth day of the disease, and remained from first to last perfectly free from the specific eruption. In another case, just as the papules were appearing on the face, I noticed a patch of erythema along the anterior border of each axilla; the subsequent condition of these patches, however, I am unable to state, as the patient was sent into hospital. A friend of mine also had two cases with patches of erythema in the flanks; and Trousseau refers to the subject in his *Lecture on Modified Small-Pox* (vol. ii, p. 81), under which category my cases would come, having all been vaccinated in infancy. A common point of interest in these cases is that the patches of erythema appeared at or about the juncture of the trunk with the extremities.

JOHN CROSS, M.D.Camb., Stanhope Terrace, Regent's Park.